



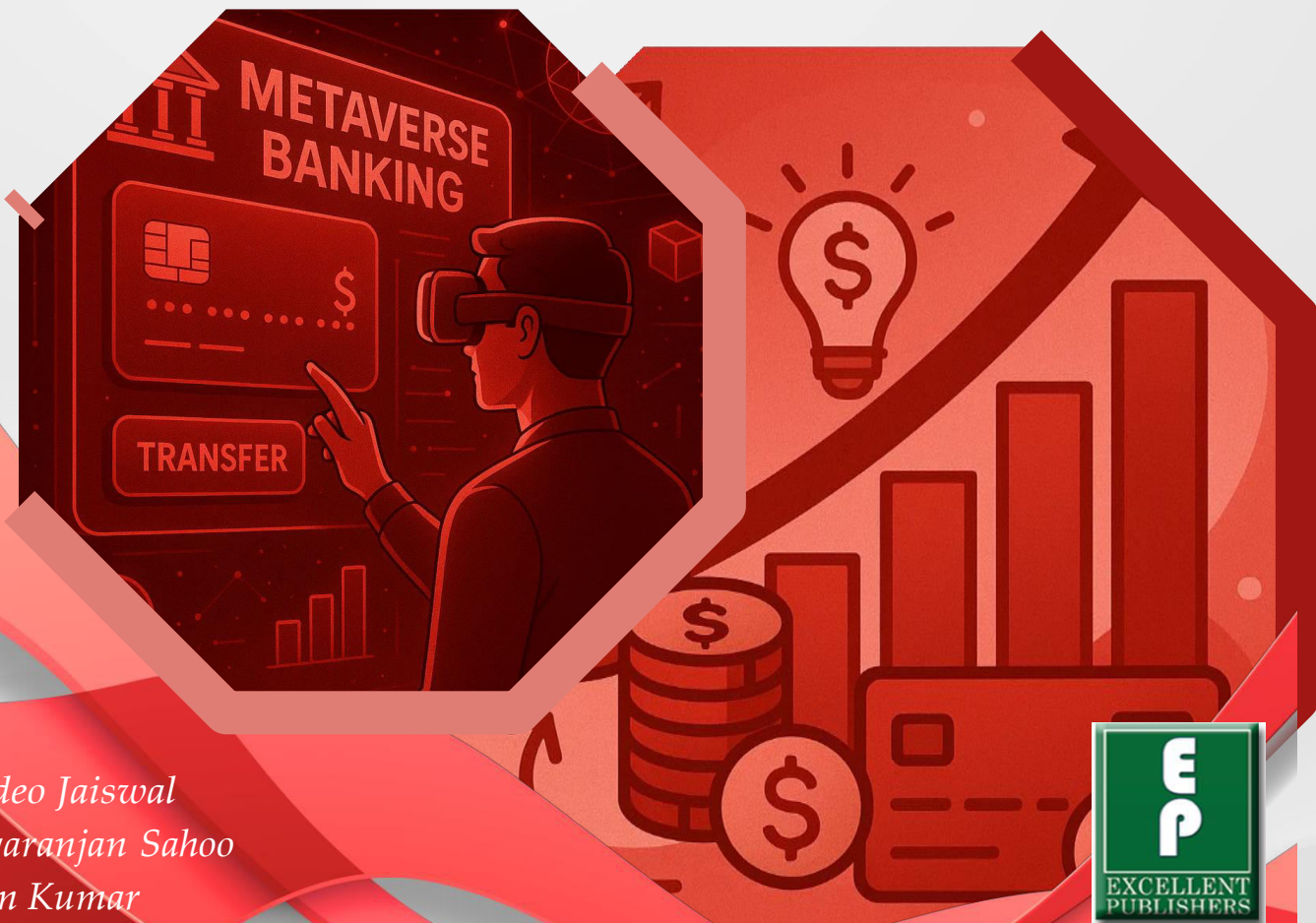
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INTERNATIONAL CONFERENCE ON METAVERSE BANKING AND FINANCIAL TRANSFORMATION

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METAVERSE BANKSCAPE FOR VIKSIT BHARAT @2047
TRENDS, TECH & TRANSFORMATION

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TRACK 1

TRACK 1: METAVERSE BANKING & CUSTOMER EXPERIENCE

INTEGRATING 5G & IOT IN DIGITAL BANKING: CHALLENGES & OPPORTUNITIES

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Abstract

The impact of 5G on banking could be profound as the high speed, low latency, and higher bandwidth will enable banks and financial institutions to provide a superior digital experience but also build high-end user-centric digital engagement. Along with faster data accessibility, 5G has the potential to enhance back-end processes, physical branches, and customer experience, and actively drive fine-tuned connected devices. This paper explores the huge opportunity underlying the revolutionary combination of the prevailing 5G environment with IOT based devices in modern digital banking, evaluate the essential innumerable cost benefits of 5G-IOT devices in bank use, put forth a case for IOT devices in physical branch banking to minimize errors, failures, risks and improve employee customer experiences, etc.

Key words: 5G, IOT, branch banking, logistics

JEL CODES:

Introduction

The wireless environment has undergone a significant revolution with 5G that creates faster communication with open ware access tools. Physical operations of bank branches, ATMs, lockers, safe vaults and stores can undergo massive changes by integrating IOT capabilities supported by 5G tools. The large banks will continue to improve digital applications core banking services via integrated remote wares. With an average performance is 100 times faster than 4G, with higher bandwidth and low latency, the digital banking possibilities are huge.

5G speed tops out at 10 gigabits per second (GBps). More bandwidth to send and receive (much) more data with lower latency, high device density, etc. This means 5G delivers superior performance. 5G improves client

engagement, increases operational efficiency and saves money. Collaborative partnerships with trusted sources are critical for ensuring successful deployments and unlocking new breakthroughs in 5G.

This paper explores the huge opportunity underlying the revolutionary combination of the prevailing 5G environment with IOT based devices in modern digital banking, evaluate the essential innumerable cost benefits of 5G-IOT devices in bank use, put forth a case for IOT devices in physical branch banking to minimize errors, failures, risks and improve employee customer experiences, etc. The EHS (environment, health and safety) staff at the branch are distinct from the IT dept., accounts section and customer service or clearing house team,

etc. The challenge is the lack of central IT hardware staff that are not deployed at branch level to supervise IOT devices unless

the branch manager raises a support call ticket to the area DGM office.

Literature:

Waracle Research (2019) mentioned that the large banks would continue to improve digital applications core banking services via integrated remote wares. IBM (2022) revealed that the cost of losses to companies in the USA in 2021 was a massive US\$4.24bn. The practitioners' literature has highlighted the revolutionary use of portable IOT devices by BFSI and service sector. Currently, branch managers use CCTV and host of roof wall cameras to monitor each part of the branch. Managers must perform banking duties rather than operate as a CONTROL ROOM security officer. Similarly, cameras can lead to breach and intrusion of humane privacy and should be replaced with non-video (photograph) devices such as IOT.

Most 5G applications are industry-specific and have a strong relation to business outcomes.

The industry 4.0 use cases include

- AI robots
- AR/VR
- Autonomous vehicles
- Connected transport
- Digital twins
- Drones
- Massive-scale IoT networks
- Industrial IoT
- Smart factories and manufacturing

Similarly use cases associated with low latency are:

V2X (Vehicle-to-Everything) communication: V2V: (Vehicle-to-

Vehicle), V2I (Vehicle-to-Infrastructure), autonomous, connected cars, etc.

Immersive Virtual Reality, Simultaneous translating, Real-time applications, etc.

5G ultra-low latency use cases will require a combination of 5G networks and edge computing.

The advantages of IoT devices includes;

- IoT encourages the interaction between devices, called as a machine-to-machine interaction.
- It provides good automation and control.
- IoT possesses strong monitoring feature.
- Increased efficiency and time-saving.

The disadvantages of IoT devices includes;

-IOT does not have any international compatibility standard.

-IOT may become highly complex.

The impact of 5G on banking will be profound as the high speed, low latency, and higher bandwidth will enable banks and financial institutions to provide a superior digital experience but also build high-end user-centric digital engagement. Along with faster data accessibility, 5G has the potential to enhance back-end processes, physical branches, and customer experience, and actively drive fine-tuned connected devices. Cloud-based products and services will potentially be more reliable, faster, and efficient.

Blockchain coupled with 5G will further enhance functions like asset tracking, digital identity, and cross-border payments. 5G and edge computing will bring networks closer to user

application. 5G technology will make AI an inherent part of financial services. Portable remote-controlled devices are also suggested for convenience, control and safety.

BRANCH STAFF OPERATIONS

Voice Controller is a smart IoT device which allows the user to enjoy features like media, alarms, lights, thermostats, control the volume and much more functions just by their voice, control speakers, capable of managing timers and alarms. The employee and customer safety needs include thunder detection, lightening detecting alerts, snake alerts, and display LED warning to all persons inside the branch. Rodent avoidance and prevention system, smart Lock in teller cubicles. The smart cabin door locks allow the user to lock cubicle doors from within the branch premises. It prevents unauthorized bank staff entering into cubicles to stop entering into the tam counter table. Display indicators provide status on the door lock or not.

Light Switch helps a user to manage lights using voice connects to Wi-Fi network, Easy on/off, push to toggle, Air quality Monitor, humidity and temperature levels, smoke Alarm,

The smoke detection & switch off provides alerts and enabling a mechanism to switch off mains circuit breakers switch off power supply, blower horns for loud audio sirens and auto start UPS ventilators.

LED Bulbs and Lighting System, personal wireless lighting system that allows the user to reduce illumination at desktop and reduce ambiance lighting during the day. The staff has access to live status on branch amenities.

B. BRANCH CUSTOMER EMPLOYEES' VEHICLE PARKING

The ability to parking with sensors in 5G accurate with minimum gaps between customer vehicles exact parking spots within the limited metropolitan branch space and causing hindrances, obstructions and congestion to favour smooth and happy customers.

The parking visitor's area monitoring includes detecting object movements in parking area, indicators for wrongly aligned vehicles within park spot, metal detection of customer vehicles entering into parking slots via the branch main gate.

IOT ARCHITECTURE:

Figure 1 describes the COMPONENTS OF IOT The major components include power supply to Wi-Fi, battery, sensors, display, alarms, speakers, routers, etc. The key elements in IOT are the high-quality sensors and PLC based controls.

Figure 1: COMPONENTS OF IOT

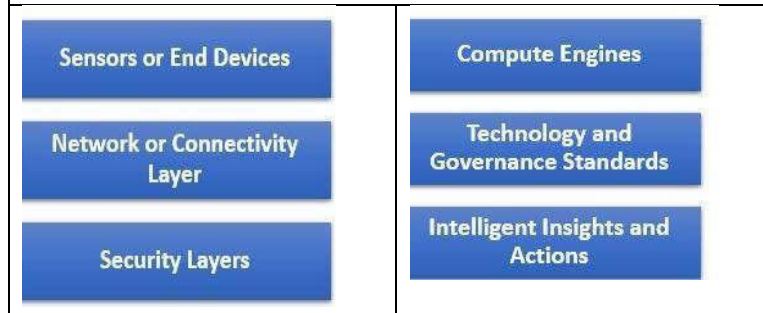
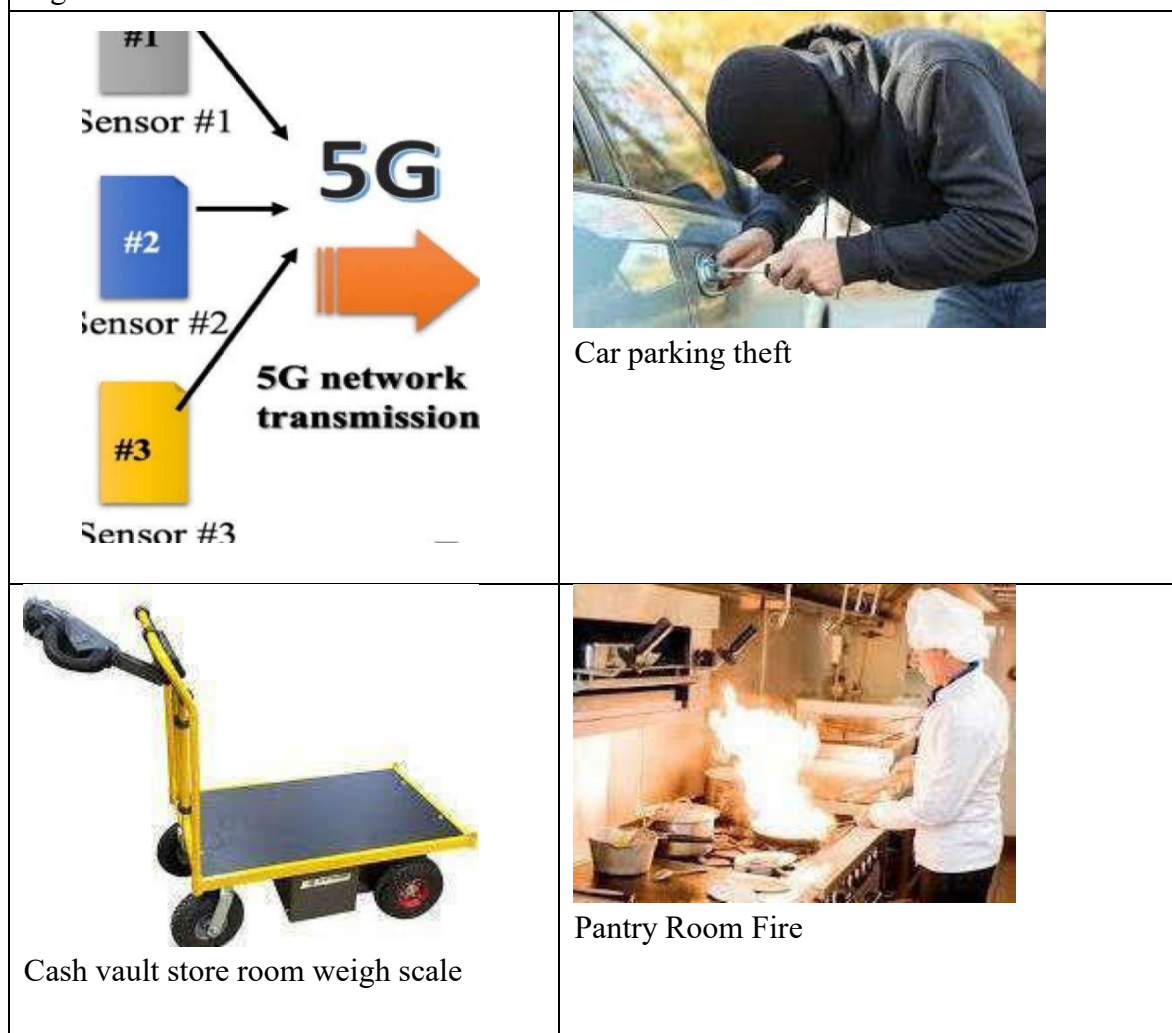


Figure 2 describes threat detection and justification for IOT deployment.

Figure 2 : SOURCE: IOT ARCHITECTURE & MONITORING



 ATM tampering theft	 Lavatory Use TOILET OCCUPIED
 ATM Out of Service	 Teller cubicle theft
SOURCE	Author's review

Research Gaps

Since there are very few studies specifically relevant to indian banks, we attempt to answer the following questions;
 How to make the branch functions and processes within the branch smooth hassle-free and humane less?
 How to minimize external threats to the bank?

Research Objectives

1. Explore the huge opportunity underlying the revolutionary combination of the 5G environment with IOT-based devices in modern digital banking,
2. Evaluate the essential case elements and innumerable benefits of 5G-IOT devices in bank use,

Hypotheses:

The null hypotheses are proposed below;

H1: 5G & IOT can reduce risks to the bank's assets from natural disasters or manmade disasters.

H2: 5G & IOT can reduce TAT (turnaround time) of customer service points.

How to minimize customer visitors and human threats to the bank?

How to protect the physical movable or immovable assets of the bank?

How to conserve energy use, reduce paper, wastage and improve employee accountability?

3. Map IOT devices in physical branch banking to minimize errors, failures, risks and improve staff and customer experiences.

4. Improve the reliability of branch operations and branch's physical assets.

H3: IOT can reduce carbon footprint of the branch.

H4: IOT can reduce energy and water bill of the branch.

H5: IOT can reduce stationeries and consumables bill of the branch.

Methodology

A field survey was planned to collect, the user Experience responses from

- (i) Likely User groups – Branch Officers, Staff, Customers, Non-customers
- (ii) Current and existing IOT Users – manufacturing plants, service sector units already implemented and adopted INDUSTRY 4.0
- (iii) Focus Group study - Technology experts
- (iv) Secondary Research – Research review reports (e.g., Gartner, IDC, Forrester, others)

Research design:

Table gives the Sampling design.

Table 1: Sampling design

Category of Responder	Number of Responders
Focus Group Technology Expert	10
Branch Officers	10
Branch Staff,	10
Customer users,	10
Visiting non – customer users,	10
INDUSTRY 4.0 manufacturing plants	10
INDUSTRY 4.0 service sector units	10
Research review reports	10
source	Author's review

Table 2: Scope of Data collection & USE CASES

LOCATION /AMENITIES	SCENARIOS & DISPLAY
STAFF ERGONOMICS	Air quality Monitor, humidity and temperature Smoke Alarm Personal control desktop ambiance lighting during the day. Personal control AC cooling at desk
STAFF PARKING	Smart parking and tamper prevention
CUSTOMER PARKING	Smart parking and tamper prevention
CUSTOMER PASSBOOK PRINTING	cash counting machine use e-lounge
STAFF AMENITIES	male/female/handicap toilets occupied/vacant STATUS
Staff Entertainment	Coffee machine status live indicators; PANTRY ROOM
BRANCH MANAGER and incharge	SANITIZER STATUS PANTRY SMOKE DETECTOR Electric panel room status Entry gate open status Pass book printer status smart office lighting
INCHARGE	BIO-METRIC ATTENDANCE MACHINE
INCARGE	SCANNERS DOCUMENTERS
CASH VAULT /LOCKER ROOM	Autonomous trolleys weighing scale, packet counting
STATIONERIES STORE ROOM	Autonomous trolleys weighing scale,
TELLER COUNTER	Customer mike & customer speakers
E-LOUNGE RECEPTION	Aqua guard, AC ON/OFF, SANITIZER REFILL STATUS
COURIER OUTWARD SECTION	
STORE ROOM	FORMS STOCK, STATIONERIES STOCK, PREPAID CARDS
Source	Branch Layout & Banking Manual

The survey was launched after a pre-test, through an e-questionnaire propagated by direct e-targeting to responders with a link to the static online page form. The primary

research method of consented video Zoom interviews was conducted by remote experts and staff users.

Conclusion

This study proposed the adoption of IOT based 5g technology and its impact on banking. The benefits were suggested to be profound, high speed, low latency, and higher bandwidth to provide a superior digital experience but also build high-end user-centric digital engagement. Along with faster data accessibility, 5G has the potential to enhance back-end processes, physical branches, and customer experience, and actively drive fine-tuned connected devices.

The findings from this research study can be useful and of particular importance to banks. It will add to satisfied employees and customers. Banks can increase the security of their branch locations. It will reduce physical thefts, loss of cash from teller counters, tampering of ATMs, tampering of customer and staff cars in the parking areas, reducing waiting time staff toilets, personalized ergonomics, etc. It will facilitate inventory control of Forms, stationeries, sanitizer refill stock, reduce carbon footprint, energy bill, water bill and help queue management, etc. The cost added by IT dept. staff deployed at the branch can be recovered from reduction in damages, losses, etc

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Smart Shopping in the Metaverse: AR and AI Shaping Consumer Decisions

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Abstract:

Augmented Reality (AR) in the digital era and Artificial Intelligence (AI) are redefining how consumers engage with products and services, particularly within tech-enabled and virtual banking ecosystems. AR enhances consumer experience by providing immersive, real-time product visualizations, while AI delivers personalized recommendations and real-time customer support, both contributing to more confident and informed purchase decisions. The rise of metaverse banking introduces a 3D, immersive financial environment that integrates shopping and banking experiences through virtual avatars and intelligent interfaces. This paper examines how the convergence of AR, AI, and metaverse technologies shapes consumer behavior by improving engagement, satisfaction, trust, and purchase intention. This study highlights the dual aspects of emerging technologies offering opportunities like enhanced personalization and stronger customer loyalty, while also presenting challenges such as data privacy risks and integration complexities. The findings reveal that AR, AI, and metaverse platforms together create more immersive, user-friendly, and customer-centric digital shopping experiences. The research delivers key insights for businesses and financial institutions aiming to adapt and thrive in the dynamic digital landscape.

Keywords: *Augmented Reality (AR), Artificial Intelligence (AI), Metaverse Banking, Consumer Behavior, Technology-Driven Shopping, Immersive Digital Experiences, Customized Customer Engagement, Buying Intentions, Virtual Commerce, and Digital Innovation.*

Introduction

In today's fast-evolving digital landscape, innovation is reshaping how consumers interact with products, services, and the broader financial ecosystem. Among the most transformative developments are Augmented Reality (AR) and Artificial Intelligence (AI), which are revolutionizing the retail experience. AR enhances engagement by offering real-time product visualizations, helping consumers make more confident, informed decisions. Meanwhile, AI delivers smart personalization through virtual assistants, tailored recommendations, and predictive insights based on individual behaviors and preferences.

Alongside these technologies, metaverse banking is emerging as a groundbreaking advancement in financial services. It offers immersive 3D environments where users can manage their finances, interact with digital assets, and complete

The quick move to digital commerce and banking has changed a lot about how people shop, make decisions, and do business. New technologies like Augmented Reality (AR) and Artificial Intelligence (AI) are changing the way people purchase and reshaping their expectations. AR offers immersive experiences that let users visualize, try out, or use things in their real-life situations environment, helping reduce uncertainty and improve understanding ultimately leading to buying decisions with more confidence. Meanwhile, AI drives intelligent systems that look at a lot of data consumer data to deliver real-time insights, personalized recommendations, and predictive shopping experiences tailored to individual preferences.

transactions all within a virtual space. Together, AR, AI, and metaverse technologies are creating a new era of shopping and banking that is seamless, highly interactive, and centered entirely around the customer experience.

This paper explores how AR and AI are transforming consumer decision-making processes by offering greater transparency, convenience, and personalization. It also examines the role of metaverse banking in creating a seamless interface between financial transactions and digital shopping environments. As businesses and financial institutions shift toward these virtual-first models, understanding the combined impact of AR and AI on consumer behavior becomes critical. The goal of the study is to show how these technologies are changing the future of finance and retail in a world that is becoming more and more digital.

Background of the study

At the same time, metaverse banking is redefining financial services by bringing them into dynamic, 3D virtual environments. In these immersive spaces, users can manage their finances, access services, and even shop using avatars and interactive virtual tools, creating a seamless and highly personalized experience.

As the ecosystem of tech-enabled shopping expands, integrating AR, AI, and metaverse technologies presents both exciting opportunities and significant challenges. While these innovations empower consumers to make smarter, faster, and more confident decisions, they also raise concerns around data privacy, digital accessibility, and the ability of users to adapt to rapidly evolving technology.

This study aims to examine the impact of AR and AI on consumer choices within tech-driven shopping platforms, particularly in the context of metaverse

This study explores the impact of Augmented Reality (AR) and Artificial Intelligence (AI) on consumer behavior within digital shopping environments, with a particular focus on the emerging trend of metaverse banking. It examines how AR enhances consumer engagement by offering interactive, immersive product experiences, and how AI contributes through personalized recommendations, predictive analytics, and virtual assistant support.

The research centers on the use of these technologies within the digital commerce and sectors of financial services, which are increasingly shifting toward immersive, virtual platforms. It aims to understand how the combined use of AR and AI

Review of literature:

The combination of artificial intelligence (AI) and augmented reality (AR) has drastically changed how consumers behave in tech-enabled shopping, especially within the emerging domain of metaverse banking. Bonetti et al. (2018) examined the ways in which immersive technologies like AR and VR in retail environments enhance consumer engagement, satisfaction, and purchase intentions through experiences such as virtual try-ons. Similarly, Hilken et al. (2022) demonstrated that AI-powered AR interfaces enable personalized and interactive service experiences, enriching customer journeys). In the context of digital banking, Mukerjee (2024) found AR to significantly influence consumer

banking. Understanding this interaction is essential for businesses and financial institutions aiming to thrive in a digitally interconnected future.

Scope of the Study

influences consumer trust, behavior, and purchase intentions in virtual retail settings.

The scope of the study is limited to consumer interactions within online and metaverse-based shopping environments, excluding physical retail experiences. It investigates user perceptions of these technologies, patterns of adoption, perceived benefits, and potential risks considering both consumer and business perspectives.

This study is valuable for retailers, financial institutions, technology developers, and researchers who seek to understand the strategic impact of AR and AI in future-ready, digitally connected shopping and banking environments.

engagement and behavioral intention, particularly in e-banking interfaces. Further, Bhattacharya and Bansal (2024), along with Kaur (2024), highlighted how AR/VR technologies influence consumer cognition and emotion in the metaverse, fostering immersive shopping experiences. Gagandeep and Verma (2023) emphasized the neuromarketing potential of AR/VR to influence buying behavior. On the AI front, Huynh-The et al. (2022) and Du et al. (2022) discussed AI's role in enhancing personalization and user satisfaction through intelligent agents and data-driven experiences. Collectively, these studies underscore the powerful synergy of AR and AI in shaping futuristic consumer engagement in retail and banking landscapes.

Research gap

There is a growing convergence of interest in Augmented Reality (AR), Artificial Intelligence (AI), and metaverse technologies, but there is a lack of comprehensive research assessing how they collectively influence consumer shopping behavior in tech-enabled shopping and virtual banking ecosystems. The literature on AR and AI focuses on issues such as product visualization or tailored recommendations, which ignores the interplay of these technologies on consumer trust, engagement, and purchase intention in the metaverse immersive spaces.

In the case of metaverse banking, which is yet to be fully developed, there are almost no empirical studies looking at consumer

behavior in virtual financial ecosystems, especially in India. Very few holistic frameworks incorporating technology acceptance, consumer behavior, and virtual retail-banking interaction exist. Addressing these questions would lead to deep understanding of the intersection of technology, psychology and consumer behavior as impacted by the metaverse. The lack of integrated research highlights the influence AR and AI convergence could have on consumer perception, confidence, and brand loyalty in these metaverse-based platforms providing strategic insights for businesses and financial institutions leveraging these technologies.

Statement of the problem

The rapid evolution of electronic devices such as Augmented Reality (AR) and Artificial Intelligence (AI), coupled with the rise of metaverse platforms, has significantly transformed consumer experiences in both shopping and banking. However, there is limited understanding of how these technologies jointly influence consumer decision-making, engagement, and trust in a virtual

environment. Most existing studies address AR, AI, or metaverse separately, lacking an integrated perspective. This creates a critical gap in identifying the behavioral impact of immersive and intelligent technologies on consumer choices. Thus, the purpose of this study is to examine their combined effect within tech-enabled, metaverse-driven retail banking contexts.

Objectives

- To assess how AR and AI influence consumer engagement and decision-making in tech-enabled shopping.
- To examine the role of metaverse banking platforms in enhancing personalized shopping experiences and fostering consumer trust.
- To evaluate how AR, AI, and metaverse technologies together influence customer satisfaction, loyalty, and purchase intentions in virtual banking.

The Impact of AR and AI on tech-Enabled Shopping Purchases and Consumer Behavior.

1. AR Provides Vivid Product

Viewing

AR enables shoppers to “open” products virtually and enables a look through to product purchasing as a result of “try before you buy” options. It greatly reduces doubt, augments understanding, enhances confidence, and assists customers with better purchase decisions.

2. Recommendations Using AI

Technology based on Prior

Interactions

AI systems access user information and history to make relevant product recommendations. These recommendations ensure that product selection meets customer expectations by addressing their needs, thereby increasing customer satisfaction.

3. Shopping Experiences That

Capture Attention Are Fun Too

With AR, shoppers access products in a dynamic way where they can interact with the product digitally. Emotional

connection to brands is attained since attention is captured, which makes shopping fun. This enhances purchase intention and positively changes purchase behavior.

4. 24/7 Intelligent Customer Support

AI-powered chatbots and virtual assistants provide real-time, round-the-clock customer support. Quick responses and problem resolution streamline the decision-making process, enhance convenience, and build trust contributing to smoother, more reliable shopping journeys.

5. Reduced Purchase Uncertainty

The synergy of AR’s product visualization and AI’s personalized insights helps consumers better assess product suitability and value. The rise of metaverse banking is changing how people interact with financial services and online shopping by making these experiences more personal, immersive, and engaging.

Building Trust and Personalization through Metaverse Banking.

1. Customized Financial Solutions

Metaverse banking platforms track and analyze users' behavior and preferences in order to customize financial services and online shopping experiences. Such personalization maximizes relevance and convenience and thus contributes to consumer satisfaction and long-term confidence in virtual financial spaces.

2. Immersive Consumer Interactions

Metaverse banking enables customers to engage with offerings and services in a more natural manner by utilizing 3D worlds and avatar interfaces. The immersive nature of this format deepens emotional ties and increases participation in activities like shopping and banking.

3. Enhanced Security and Transparency

Strong security measures and open systems in metaverse banking in still confidence among customers. Data protection and credibility in online interactions must be guaranteed to ensure long-term consumer participation in online monetary arenas.

4. Real-Time Virtual Assistance

AI-powered systems in the metaverse deliver instant, tailored support to users. Whether exploring financial services or making shopping choices, this real-time guidance minimizes obstacles, enhances the user

experience, and builds confidence in the platform's dependability.

5. Social and Community Engagement

Metaverse platforms foster a sense of community by hosting interactive events and offering shared virtual

environments. These social interactions inspire collaboration and collective decision-making, helping to build stronger trust and deeper engagement with the brand.

Collective Impact of AR, AI, and Metaverse Technologies on Consumer Satisfaction Loyalty, and Purchase Intentions

1. Boosting Customer Satisfaction

The integration of AR, AI, and metaverse technologies delivers immersive, tailored experiences that meet evolving customer expectations. Enhanced usability, engagement, and interactivity contribute to higher satisfaction levels in virtual banking ecosystems.

2. Strengthening Customer Loyalty

Consistent and personalized digital experiences foster emotional bonds between consumers and brands. The reliability and convenience provided by these technologies encourage repeated usage and long-term loyalty in virtual retail and banking platforms.

3. Driving Purchase Intentions

The combined power of AR's visual engagement and AI's predictive recommendations, delivered within a metaverse environment, reduces

hesitation and increases purchase confidence. This influence plays a key role in shaping consumer buying behavior.

4. Ensuring a Seamless User Experience

By integrating AR and AI into the metaverse, platforms provide intuitive navigation, context-aware interactions, and quick access to relevant information ensuring a smooth and satisfying user journey.

5. Reinforcing Trust and Perceived Security

Secure and transparent digital systems within metaverse banking foster a strong sense of trust. When consumers perceive their data and transactions as safeguarded, they are more likely to engage deeply, remain loyal, and finish transactions confidently.

Findings

The study reveals that Augmented Reality (AR) and Artificial Intelligence (AI) significantly enhance consumer engagement and decision-making in tech-enabled shopping within metaverse banking environments. AR's immersive visualization tools help consumers better understand products, reducing uncertainty and increasing confidence in purchases. AI's personalized recommendations and real-time assistance further streamline the shopping experience, improving its

efficiency and relevance. Combining artificial intelligence (AI), augmented reality (AR), and metaverse technologies into virtual banking platforms is redefining customer experiences through highly personalized and interactive services. The immersive nature of the metaverse enhances emotional connections and builds consumer trust, leading to stronger brand loyalty and influencing purchasing decisions.

But the study also points out important difficulties, such as concerns over data privacy and the complexities involved in coordinating multiple advanced technologies. If left unchecked, these problems could hinder adoption and disrupt the customer experience.

Suggestions

To fully harness the potential of AR, AI, and metaverse technologies in tech-driven retail and banking, businesses must focus on seamless integration and intuitive design. A smooth and user-friendly interface enhances customer satisfaction and promotes ongoing engagement. Equally important is the protection of customer data and privacy, which builds trust and mitigates risk. Personalized and immersive experiences tailored to individual preferences can significantly

Despite these hurdles, the combined power of AR, AI, and metaverse solutions is reshaping consumer behavior empowering users to make more informed decisions and significantly enriching their virtual shopping and banking journeys.

increase user interaction and long-term loyalty. To remain competitive, companies should continuously evolve their platforms based on user feedback and stay aligned with emerging technological trends. Educating consumers on the effective use of these tools is also essential when users feel confident navigating virtual retail and banking environments, they are more likely to adopt and benefit from these innovations over time.

Conclusion

The integration of Augmented Reality (AR), Artificial Intelligence (AI), and metaverse technologies is revolutionizing consumer choices in tech-enabled shopping within virtual banking environments. These technologies enhance consumer engagement by offering immersive, personalized, and interactive experiences that boost confidence and satisfaction. The metaverse adds a new dimension to banking by fostering trust and loyalty through secure and transparent interactions. While challenges like data privacy remain, the overall impact is positive, driving informed decision-making and stronger customer relationships. Embracing these innovations is essential for banks and retailers aiming to stay competitive and meet the evolving expectations of digital consumers.

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FUTURE SMART BANKING A WAY TOWARDS METAVERSE- A CONCEPTUAL FRAMEWORK

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Abstract:

Metaverse banking in meaning universe banking represents a collective virtual shared space where users can interact, transact, and engage with digital environments through avatars.

This study aims to synthesize the current literature and present the concept to discuss the pros and cons of metaverse banking in Indian banking system and also to identify how banks adopt metaverse in banking arena and also to identify the Metaverse strategies different banks have adopted.

Metaverse banking is a banking channel actualized through the integration of metaverse and online banking services, enabled by a mix of numerous advanced technologies, that provides customers with synchronous banking services accompanied with 3D experiences in a virtual world. There is a high likelihood in the future that metaverse banking is able to be marketed intensively yet effectively, and incur progressive demands, as well as progress significantly in terms of development.

Keywords: *Metaverse, Big Data, Digital Twin, Extended Reality*

Introduction:

Metaverse banking refers to a virtual banking environment enabled by technologies like VR/AR, blockchain, AI, and digital twins, offering immersive, real-time financial services. The core technologies include extended Reality (XR) for immersive customer experience, Blockchain & NFTs for secure, decentralized transactions and digital asset management, AI & Big Data Analytics for personalization, fraud detection, and predictive services and digital Twins to replicate physical bank infrastructure and simulate operations

Customer Experience Transformation such as Offer 3D virtual branches, to Enable avatar-based customer service and to Provide real-time financial simulations and education

Objectives:

1. To explore the various metaverse banking activities
2. To identify and prioritize the platform activities the banks adopt in metaverse banking.
3. To discuss the pros and cons of metaverse banking in Indian banking system

Various Meta Verse Banking Activity

1. **Virtual Branches:** In the Metaverse, banks set up 3D virtual branches were

customers, represented by avatars, can interact with bank representatives in real-time. These branches function similarly to physical branches but offer greater accessibility and lower operational costs. Customers can open accounts, apply for loans, or even get investment advice.

2. **Customer Education:** Banks can use gamification, virtual reality (VR), and simulations to educate customers about financial literacy, digital security, credit management, and Environmental, Social, and Governance (ESG) practices.

3. **Product Exploration:** Instead of reading product brochures, customers can experience banking products in an immersive 3D environment. For example, users can virtually "walk through" the features of a home loan, compare credit cards, or calculate returns on fixed deposits using interactive tools.

4. **Recruitment and Training:** Banks can use VR for conducting virtual onboarding, soft-skills training, and real-life simulation exercises for employees. HR can simulate customer interaction scenarios, compliance challenges, or crisis management exercises.

Platform activities the banks adopts in metaverse

	Platform Used	Activities Performed
Union Bank of India	Uni-verse (Custom)	- Launched a Metaverse Virtual Lounge for customers.
		- Provides details of banking products like deposits, loans, and government schemes.
		- Enhances customer engagement and digital experience.
ICICI Bank	iMetaverse (In-house)	- Created immersive 3D banking zones.
		- Customers can explore services like credit cards, personal loans, and more.
		- Part of their digital-first approach.
Yes Bank	Metaverse Lounge	- Set up a Metaverse lounge for interactive product demonstrations.
		- Aimed at attracting tech-savvy, younger audiences.
		- Supports virtual customer engagement.
HDFC Bank (pilot stage)	Unconfirmed (pilot/partnerships)	- Exploring use of Metaverse for customer onboarding and employee training.
		- Conducted Metaverse-based awareness events. (Public details limited)
Axis Bank (limited info)	Metaverse event hosting	- Participated in Metaverse summits and showcases.
		- Exploring adoption for future customer engagement and education tools.

Pros and Cons of Metaverse banking in India

Pros of Metaverse Banking in India

- **Immersive Customer Experience:** Imagine walking into a virtual bank branch from your living room. Avatars of bank staff can guide you through services like loan applications or investment advice.
- **24/7 Accessibility:** Virtual branches don't close. This could be a game-changer for customers in remote areas or those with tight schedules.
- **Cost Efficiency for Banks:** Reduced need for physical infrastructure could lower operational costs, allowing banks to invest more in tech and customer service.
- **Enhanced Financial Literacy:** Interactive, gamified environments could make learning about finance more engaging, especially for younger users.
- **Personalized Services:** AI and VR can tailor services to individual needs, from portfolio reviews to mortgage consultations.

Cons of Metaverse Banking in India

- **Digital Divide:** Not everyone has access to high-speed internet or VR devices, which could widen the gap between urban and rural customers.
- **Security and Privacy Risks:** Virtual environments are vulnerable to

cyberattacks, identity theft, and data breaches.

- **Regulatory Uncertainty:** India's financial regulations are still catching up with emerging tech like blockchain and virtual assets.
- **User Readiness:** Many customers may find the metaverse intimidating or unnecessary, especially older generations or those unfamiliar with digital banking.
- **High Initial Investment:** Setting up a metaverse presence requires significant investment in tech, training, and infrastructure.

Findings

The study finds that Indian commercial banks like Union Bank of India, ICICI Bank, Yes Bank, HDFC Bank, and Axis Bank are actively exploring metaverse platforms to enhance customer engagement, financial education, and service delivery through virtual branches, immersive product experiences, and employee training. These initiatives demonstrate the potential of metaverse banking to offer 24/7 accessibility, cost efficiency, personalized services, and interactive financial literacy tools. However, challenges such as digital inequality, cybersecurity risks, regulatory uncertainty, user readiness, and high initial investment remain significant barriers to widespread adoption.

Conclusion

Metaverse banking represents a transformative leap in the evolution of digital financial services. It offers a unique blend of immersive customer experiences, operational efficiency, and innovative service delivery. Indian banks have already begun exploring the metaverse through virtual branches and interactive platforms, indicating a proactive approach to future banking.

However, the success of metaverse banking will depend on addressing key challenges, including technological accessibility, cybersecurity, and regulatory clarity. With continued innovation and strategic investment, metaverse banking has the potential to reshape customer engagement, financial literacy, and service delivery in India's banking sector, especially among tech-savvy and younger demographics.

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Opportunities in Metaverse Banking for Stronger Future Ties among Gen-Z and Millennials

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Keywords: Metaverse banking, Generation Z, Millennials, Digital Trust, Immersive technology, Qualitative research

Abstract

Purpose: This study investigates the opportunities and challenges of Metaverse banking in fostering stronger, future-oriented relationships with Generation Z and Millennial consumers in India. It aims to understand the behavioral, psychological, and emotional factors influencing the adoption and sustained engagement with immersive banking platforms among these digitally native cohorts.

Design/methodology/approach: A qualitative research design was employed, integrating thematic, narrative, and content

analyses. Data were collected from 386 Gen-Z and Millennial participants through semi-structured interviews and open-ended surveys, enabling a multidimensional exploration of user perceptions, emotional responses, and behavioral intentions in immersive digital banking environments.

Findings: The study reveals that psychological motivators such as innovation affinity, status-seeking, digital identity formation, and fear of missing out (FOMO) significantly shape the adoption and continued use of Metaverse banking. Emotional trust, perceived usability, and social influence are identified as critical enablers of engagement and loyalty. The pivotal role of blockchain and decentralized finance in enhancing transparency and digital trust is also highlighted, alongside persistent barriers including cybersecurity risks, regulatory ambiguities, and technological inequality.

Research limitations/implications: The qualitative approach, while providing depth, may limit generalizability. Future research could expand to quantitative or cross-cultural studies for broader validation.

Practical implications and innovation: The findings offer actionable insights for financial institutions seeking to leverage Metaverse platforms to deepen customer relationships, enhance experiential value, and secure competitive advantage among younger, tech-savvy consumers.

Originality/value: This study provides a generation-specific, behaviorally grounded analysis of Metaverse banking in the Indian context, advancing both academic discourse

and practical strategy for next-generation digital banking.

Keywords: Metaverse banking, Generation Z, Millennials, digital trust, immersive technology, India, qualitative research

Paper type: Research paper

Introduction

The advent of the digital age has ushered in a fundamental shift in production, distribution, and consumption of financial services. With new technologies relentlessly challenging traditional banking paradigms, the intersection of immersive virtual worlds and financial innovation, collectively known as Metaverse banking, has begun to redefine consumer behavior. This revolution has prompted financial institutions to challenge traditional service delivery paradigms and adopt more visionary, customer-centric innovations. Most promising of these innovations, however, is also the most fledgling: the emergence of the Metaverse: a thorough, immersive digital space facilitated by technologies such as augmented reality (AR), virtual reality (VR), blockchain, and decentralized finance (DeFi) which, when integrated, have the potential to completely revolutionize the banking experience (Kandpal et al., 2025). The Metaverse is not an interface that is new to the customers of the Millennial and Generation Z, who have been raised in the digitally augmented reality; to them, the Metaverse is an extension of their digital existence. It is so due to the fact that digital natives, such as them, expect more than the convenience of transactions, they require personalized,

immersive, and socially enabled experiences that speak to their values of autonomy, innovation, and interesting digital interactions (Dubey et al., 2023).

As opposed to previous generations, the current customers are exposing themselves to online ecosystems where finances services are considerably assimilated within social, entertainment, and commercial passions. This means that Metaverse banking extends virtual interfaces to encompass co-creation and community experiences that result in more tied customer relationships and emotional connections (Mohanty et al., 2025). At the heart of this exchange are behavior enablers such as digital trust, ease of use, social influence and secure identity systems, which play an important role in adoption decision and long-term use of virtual financial systems (Hassaan, 2024). On the technological side, blockchain has become one of the most ardent proponents of fostering transparency, operation efficiency, and trust in Metaverse banking, which is non-negotiable to Generations Z and Millennials who valued data protection and accountable digital conduct (Pangarkar & Majra, 2024).

Cybersecurity threats, legal challenges, and technology gaps between different categories of users are among the major challenges of Metaverse adoption despite its benefits. Such limitations provoke the idea of robust innovative regulation and flexible regulatory systems that can stay in pace with virtual financial ecosystems (Kedla et al., 2025). However, according to industry estimates, Metaverse banking can be

developed further, and market opportunities are likely to be over \$800 billion, mainly due to the digital-first and younger-focused consumer engagement (EY, 2023). Profinch (2023) supports this viewpoint, describing the Metaverse as a revolutionary platform capable of offering emotionally resonant and experiential financial services that meet the changing expectations of youthful consumers. Likewise, Wipro (2023) highlights how banks are transitioning from theoretical interest to real-world deployment, investing in tools such as AI-driven avatars, immersive educational interfaces, and decentralized customer support to enhance the overall service experience.

Novelty of the Study:

Although existing literature has examined the adoption of Metaverse and virtual technologies across various domains, this study distinguishes itself by providing a generation-specific, behaviorally anchored investigation of Metaverse banking in the Indian context. It employs an integrative methodological approach, combining thematic, narrative, and content analyses to elucidate how Generation Z and Millennials perceive, adopt, and emotionally engage with immersive banking platforms. By

Within the Indian financial landscape, the Metaverse holds particular promise given the country's rapid digital expansion, high mobile penetration, and the large population of tech-savvy youth. These factors collectively create a conducive environment for banks to experiment with immersive banking solutions tailored to the social and behavioral traits of Gen Z and Millennials (Singh et al., 2025). This study seeks to explore how financial institutions can capitalize on these dynamics to forge deeper, future-oriented connections with younger generations, relationships that reflect the shift from transactional efficiency to experiential, socially embedded banking in the era of immersive digital transformation.

foregrounding psychological motivators, including innovation affinity, status-seeking, digital identity formation, and fear of missing out (FOMO), in conjunction with constructs such as emotional trust and personalization, the study offers a comprehensive, multidimensional perspective. This approach advances both academic understanding and practical strategies for the evolution of next-generation digital banking.

Literature Review

The ongoing advancement of digital technologies, particularly the emergence of the Metaverse, presents a transformative

opportunity for the banking sector to cultivate deeper engagement with Generation Z (Gen-Z) and Millennials.

These cohorts, as digital natives, exhibit distinct behavioral and technological preferences that uniquely position them to influence the future trajectory of financial services. Kandpal et al. (2025) assert that the digital banking landscape is undergoing a profound transformation driven by innovations such as blockchain and Metaverse platforms. These technologies promise to enhance customer experiences, improve operational efficiencies, and introduce novel business models. Crucially, the increasing demand from younger generations for innovation and personalized services compels banking institutions to explore immersive digital ecosystems aligned with evolving consumer expectations.

Empirical investigations into adoption behaviors further underscore the potential of Metaverse banking in emerging economies. Hassaan (2024), through qualitative analysis in Pakistan, a context parallel to India's digital finance growth, highlights that perceived ease of use, social influence, and trust are pivotal factors influencing customers' intentions to adopt Metaverse banking services. Complementing this, Singh et al. (2025) identify social influence, facilitating conditions, and financial capability as significant determinants of behavioral intention toward Metaverse banking among users in developing countries. Together, these studies suggest that leveraging social networks and infrastructural support within Metaverse platforms can significantly enhance engagement among Gen-Z and Millennials,

who are highly active in digital social spheres.

The experiential and marketing dimensions of the Metaverse are particularly salient for these demographic segments. Nagre and Mude (2024) explore Metaverse applications in employer branding targeted at Gen-Z, revealing how immersive virtual environments foster authentic, interactive engagement. Extending this insight to financial services, Mohanty et al. (2025) analyze Gen-Z consumer behavior within Metaverse marketing frameworks, demonstrating that virtual platforms facilitate enhanced consumer-brand interactions, emotional connectivity, and innovative service delivery. These findings suggest that Metaverse banking transcends traditional transactional interactions by offering experiential value that can reinforce relational bonds between banks and younger clientele.

The role of trust, innovation perception, and digital identity management emerges as a critical nexus shaping Gen-Z's engagement with Metaverse banking. Ho (2024) finds these factors to be key antecedents to positive brand experiences in Metaverse environments. This is corroborated by Hernández-Tamurejo et al. (2025), who emphasize that Gen-Z's perceptions regarding innovation, privacy, and trust significantly influence their willingness to adopt Metaverse platforms, which subsequently impacts their entrepreneurial and consumer behaviors in digital spaces. Given the paramount importance of security and privacy in banking, designing Metaverse services that embed robust trust

mechanisms is essential to foster enduring loyalty among younger users.

Studies extending beyond banking reinforce these insights. Calderón-Fajardo et al. (2024), examining Metaverse adoption in tourism, identify social influence, facilitating conditions, and perceived value as key drivers of engagement among both Gen-Z and Millennials. These factors translate directly to banking contexts, where immersive, socially rich Metaverse environments can bolster user engagement by integrating peer validation and delivering value-added services beyond conventional banking offerings. Additionally, Arghashi and Gunalay (2025) explore motivational drivers such as fear of missing out (FOMO), self-extension, and status-seeking, noting that while Millennials are particularly motivated by social recognition and innovation, innovativeness remains a common driver across both generations. These psychological motivators underscore the importance of tailoring Metaverse banking platforms to appeal to intrinsic social and innovation-oriented aspirations, thereby fostering deeper and more sustained user engagement.

Yadav and Tandon (2024) provide a comprehensive synthesis of Gen-Z's involvement in the internet banking revolution, highlighting their expectations for personalized, mobile-first, and secure financial services. The immersive and interactive capabilities of the Metaverse align closely with these expectations, presenting banks with an opportunity to redesign customer journeys that integrate social interactivity with advanced security

features. Singh et al. (2025), focusing on Public Sector Undertaking (PSU) banks in India, argue that Metaverse integration can drive banking transformation by enabling innovative service delivery models attuned to the needs of tech-savvy younger customers while addressing financial inclusion challenges.

From a technological standpoint, Kedla et al. (2025) provide a critical examination of the opportunities and challenges presented by Metaverse adoption in banking. They highlight innovations such as virtual banking branches, decentralized finance (DeFi) applications, and blockchain-enabled services that enable immersive and customized banking experiences. Nonetheless, they caution that addressing cybersecurity vulnerabilities, regulatory compliance, and user adoption barriers is essential to sustain trust and operational resilience. This balance is particularly vital for Metaverse banking platforms aimed at Gen-Z and Millennials, where trust and security remain foundational to customer retention.

Blockchain technology, emphasized by Pangarkar and Majra (2024), underpins the secure, transparent, and efficient functioning of Metaverse banking ecosystems. Their study of the Indian banking context illustrates blockchain's potential to mitigate fraud, streamline financial transactions, and enable decentralized identity management within virtual environments. Such technological advancements directly address security concerns, a critical determinant of Gen-Z's trust as highlighted by Hernández-Tamurejo

et al. (2025), while facilitating innovative financial products that appeal to younger users seeking convenience alongside robust security.

Reinforcing these perspectives, Kandpal et al. (2025) highlight that the banking sector's shift toward digital and virtual platforms responds directly to Gen-Z's and Millennials' technological fluency, social connectivity, and mobile-centric lifestyles. These generations prioritize convenience,

personalization, and transparency, thereby encouraging banks to leverage immersive Metaverse experiences that foster emotional engagement and long-term loyalty. Despite prevalent privacy concerns, Hernández-Tamurejo et al. (2025) note that Gen-Z tends to prioritize trust in platform integrity and innovation over privacy apprehensions, thus underscoring the imperative for banks to maintain transparent communication regarding data protection while confidently advancing technological innovation.

Research Gap

In reviewing the extant literature on the integration of Metaverse technologies within the banking sector, it becomes evident that several critical research gaps remain unaddressed. While studies such as Kandpal et al. (2025) and Kedla et al. (2025) explore innovations including blockchain and immersive virtual platforms, they fall short in applying a generational perspective, particularly with respect to understanding the nuanced and long-term engagement patterns of Gen-Z and Millennials. Similarly, works by Hassaan (2024) and Singh et al. (2025), though insightful in examining adoption behaviors and influencing factors, are either geographically constrained to non-Indian contexts or lack exploration of relational and emotional engagement outcomes. Research focused on virtual branding and marketing, such as that by Nagre and Mude (2024) and Mohanty et al. (2025), often concentrates on non-banking domains and thus fails to offer transferable insights

relevant to financial services. Moreover, the literature exhibits a noticeable absence of comparative analysis between Gen-Z and Millennial cohorts, a limited understanding of emotional trust and loyalty development, and insufficient inquiry into the application of intrinsic psychological motivators, such as innovation affinity, status-seeking, or FOMO, in Metaverse banking environments. Collectively, these limitations highlight the fragmented nature of current scholarship and underscore the need for comprehensive, generation-specific, and behaviorally grounded research that aligns technological potential with the evolving expectations of younger banking consumers within immersive digital ecosystems.

Research Objectives

1. To explore the perceptions and expectations of Gen-Z and Millennials regarding Metaverse-based banking experiences.

2. To examine the role of immersive technologies in fostering emotional trust, engagement, and long-term loyalty among younger banking consumers.
3. To identify key psychological and social factors influencing the adoption and sustained usage of Metaverse banking platforms by Gen-Z and Millennials.

Research Methodology

This research program used a qualitative research design that incorporated the thematic analysis, narrative analysis, and content analysis approaches to identify the perceptions, emotional reactions, and behavioral intentions of Gen-Z and Millennial users regarding Metaverse banking systems. The primary data was

obtained using semi-structured interviews and open-ended survey questions in engaging 386 respondents in immersive digital banking users experiences, expectations, and concerns. Thematic analysis helped reveal the main patterns and repetitive themes in the perceptions of users, narrative analysis helped recover personal experiences and emotional experiences in virtual banking contexts, and content analysis helped sort psychological and social drivers, including FOMO, affinity to innovation, and the expression of digital identities. This triangulation approach succeeded in attaining conceptualization richness and multidimensionality of the immersive technologies to user trust, engagement, and adoption behavioural intention in Metaverse-based financial services.

Perceptions and Expectations of Gen-Z and Millennials in Metaverse Banking: A Thematic Analysis

Step 1: Familiarization with Data

All 386 responses were reviewed and manually coded. The data was collected via open-ended questions in interviews and surveys, asking participants about their views on Metaverse banking, preferences, and concerns.

Step 2: Initial Coding

Initial open coding was used to identify recurring words, phrases, and sentiments. Some of the common codes included: “Feels futuristic”, “Trust and safety concerns”, “Looks like a game”, “Need

personalization”, “Not for everyone”, “Interesting but confusing”, “Want real-time human help”.

Step 3: Theme Development

Based on the coded responses, five major themes emerged that encapsulate the perceptions and experiences of young users regarding Metaverse banking. The first theme, Convenience and Innovation, reflects the appreciation many participants had for the modern and engaging aspects of Metaverse banking. Features like 24/7 access, AI-powered avatars, and gamified banking interactions were frequently

described as “cool,” “fun,” and indicative of cutting-edge innovation. A representative sentiment expressed this as, *“I like the idea of walking into a virtual bank anytime I want without standing in queues.”* The second theme, Security and Trust Concerns, highlighted users’ hesitations stemming from fears related to data privacy, scams, and cybersecurity threats. One respondent captured this apprehension with the question, *“It looks exciting, but can I really trust this with my money?”* These concerns suggest a pressing need for transparent security measures and user reassurance.

The third theme, Need for Personalization and Human Touch, underscores the demand for customized, emotionally resonant banking experiences. Although participants were open to interacting with digital avatars, many still desired a sense of real human engagement, suggesting that even in virtual spaces, relational warmth is valued. As one participant noted, *“I want to talk to a real person, even if it's an avatar, it should feel human.”* The fourth theme, Learning Curve and Accessibility Issues, captured the technical and cognitive barriers users faced. Some respondents found the Metaverse environment complex or intimidating, particularly in the absence of VR devices or high-speed internet. One user remarked, *“It’s not user-friendly; too much to learn just to do simple tasks,”* revealing a need for more intuitive design and broader accessibility.

Finally, the theme of Social Influence and Digital Identity emerged as a strong motivator behind user interest and adoption. Peer behavior, social media buzz, and the

desire to express oneself through a digital avatar all played influential roles. The idea of projecting identity within virtual banking resonated with many, as reflected in the quote, *“I would love a digital avatar that represents me in banking too.”* Together, these five themes provide a comprehensive view of the motivations, expectations, and concerns of Gen-Z and Millennial users in the context of Metaverse banking.

Narrative Analysis on the Role of Immersive Technologies in Fostering Trust, Engagement, and Loyalty

This approach captures personal experiences and stories, highlighting how immersive technologies (e.g., VR/AR features or virtual branches) affect emotional connection and trust in banking platforms. It focuses on users’ emotional journeys and the symbolic meanings they attach to immersive banking interactions.

This narrative analysis delves into how younger banking consumers, specifically Gen-Z and Millennials, construct meaning from their immersive experiences with Metaverse-based banking. The analytical approach centers on how participants recount their experiences through storytelling, paying close attention to the sequence of events, emotional expressions, symbolic language, and recurring structures in their narratives. Several compelling narrative themes emerged from the collected data.

A prominent theme titled *“Stepping Inside My Bank”* reflected a strong sense of presence and emotional realism in virtual

banking environments. Participants consistently described these immersive experiences as more personal and welcoming compared to traditional banking apps or websites. Phrases like “stepping inside” or entering a “futuristic bank lobby” were frequently used, indicating that immersive technologies helped bridge the digital-physical divide, thereby enhancing users’ emotional connection to the space.

Another critical theme was *Emotional Anchors and Trust Triggers*. Many users conveyed that emotionally resonant features, such as AI avatars recalling previous interactions, visual security badges, or customized service zones, reinforced their sense of trust. For example, participants reported feeling “seen” when avatars remembered past issues, and described blockchain symbols as confidence boosters. These elements suggest that emotional trust is shaped not solely by rational information, but through meaningful, symbolic interactions.

The idea of *Reimagining Banking as a Social Space* also emerged strongly. Participants described Metaverse banking using words such as “hangout”, “club” and “connected”, suggesting a replacement of transactional value to social experience. Some users mentioned having invited their peers to join the same virtual bank, and the choice was comparable to joining a community, not just choosing a service provider. It means that affective involvement and loyalty are supported by the process of social approval and community involvement.

The inkling of *Reimagining banking as a social space* also gained traction. The participants talked about Metaverse banking as “hangout”, “club” and “connected”, which indicated the shift in utility transactional to social. Some of the users claimed to have invited other people to join the same virtual bank, and the decision was like choosing to become a part of a community instead of a service provider. It means that the emotional involvement and loyalty are supported by the social acceptance and community involvement.

The other theme was *Personalization Builds Bonds*, where the stories demonstrated how the customizable features, such as the avatar-driven chats, virtual bank settings that reacted to the user likes and dislikes and memory-driven interaction, could be used to form the sense of attachment. As other customers noted, the platform felt more personal despite such minor details of the design as choosing their favorite color in the dashboard, which increases emotional loyalty and user retention.

The immersive technology can also impact the future perception of banking by the users according to the *Long-Term Vision and Aspirations* theme. Participants often revealed their belief in the possibility and relevance of Metaverse banking with statements such as, "In case banks keep heading in this direction, I may never change. This implies that immersive experiences create the feeling of continuation besides addressing the immediate needs of the users, which aligns with their aims of future financial interactions.

Behavioral Motivators in Virtual Banking - Content Analysis

1. Introduction

Here, the researcher will subject a qualitative content analysis to acquire an understanding of the underlying psychological and social processes that stimulate the initiation and persistent use of Metaverse-based banking services among Gen-Z and Millennial customers. The existing knowledge gap regarding the user engagement within immersive digital banking experiences was informed by the analysis of behavioral patterns and motivational constructs conducted on the basis of a sample of 386 narrative responses. Psychological and social reasons of interest are fear of missing out (FOMO), innovation affinity, peer influence, perceived convenience, digital identity, and status-seeking behaviour.

2. Coding Framework

Open coding was applied to the data in order to look for significant patterns and groups. Inductively, words and phrases were organized into 6 large codes, each representing a fundamental motivator with regard to platform adoption and platform persistence:

3. Key Findings

Fear of Missing Out - (FOMO):

The move to Metaverse banking was also usually driven by the urge to remain technologically and socially relevant amongst the participants. The explorations into the experience were

urged due to the popularity of the platforms on social media and peer groups. One of them claiming, *“I was under pressure to try it out on my own as I did not want to be left behind as I watched my peers creating virtual bank accounts with cool avatars.”*

4. Innovation Affinity:

Being technology-driven, technological novelty drew the attention of a range of Gen-Z respondents. It was only natural and desired to have virtual bank branches, a gamified user interface, and AI-based customer service. Being the modification of their digital way of life, this group appeared to be quite willing to experiment with immersive interfaces.

5. Peer Influence:

The determination to use Metaverse banking was sometimes made in a social environment. All this led to the increased trust in platforms: peer reviews, influencer recommendations, and user-generated content. The dynamics of group adoption were considered to be rather significant in terms of uncertainty elimination and easing participation.

6. Status-Seeking:

The symbolic meaning of Metaverse banking as the marker of modernity and tech-savvy was an ongoing concern with Millennial respondents. It was exclusive and progressive to be linked to the advanced technologies. The

status component to early adoption is evident in the quotes like, "*It is futuristic and being involved in it makes me feel like I am ahead of the curve.*"

7. Convenience:

Most participants mentioned practical advantages such as 24 hours availability, proactive virtual agents, and flexibility of the service interface. All these features increased the perceived value of the platform and motivation to use it on a frequent basis.

8. Digital Identity:

Personalization was required in order to enhance the emotional connection with the platform. The ownership feeling and greater participation was encouraged through the capability of portraying individuality in avatars, creation of virtual worlds and user specific dashboards.

Code	Description
FOMO	The feeling of needing to accept the emerging technologies because it is the trend or a socially accepted process.
Innovation Affinity	Curiosity about exploring new digital solutions and interactive interface.
Peer Influence	The impact of the social circles, influencers and online communities on the decision-making.
Status-Seeking	Social differentiation and status by using state of the art technologies.
Convenience	The attraction of uninterrupted, real time and ubiquitous services.
Digital Identity	The importance attached to the customization of avatars and virtual representation of the self.

systems. Emotional triggers including the need for identity expression, social affirmation, and symbolic status play an equally significant influence as technological characteristics like convenience and interactivity. In order to

connect with customers' lifestyle ideals and social motives, financial institutions targeting younger audiences should provide Metaverse banking experiences that prioritize personalization, community presence, and technological innovation.

Opportunities from findings of the Research

1. Preference for Innovation and Immersive Digital Experiences

The findings show a strong preference among Gen-Z and Millennial users for the creative and immersive aspects of Metaverse banking. Participants were enthusiastic about the convenience of 24/7 virtual accessibility, the availability of AI-powered avatars, and gamified service aspects. These features were rated as both interesting and user-friendly, emphasizing technological novelty as a key factor affecting initial platform adoption, particularly among digitally savvy consumers.

2. Emotional Resonance as a Catalyst for Trust and Loyalty

Narrative accounts revealed that emotional connectivity, as demonstrated by encounters with empathic AI avatars and visual security indicators such as blockchain certification, significantly strengthens trust in Metaverse banking environments. Users stressed the importance of emotionally intelligent replies and individualized virtual service experiences, which helped to increase user satisfaction and foster long-term loyalty to the platform.

3. Digital Identity and Social Integration Importance

Creation and performance of a digital identity proved to be a strong theme, with respondents focusing on customisable avatars, personalised banking surroundings and community-based functionality. These elements fostered the feeling of belongingness and social acceptance. The peer-to-peer approvals

and online conversations on social media enhanced the perception of users towards Metaverse banking and transformed it to be a social event rather than a transactional process.

4. Adoption and Continuity through Psychological Drivers

Through content analysis, it was apparent that user behavior is largely driven by different types of psychological and social motivators with the most prominent ones being fear of missing out (FOMO), innovation affinity and status-seeking. These reasons extend past utility-driven decision making to encompass more fundamental emotional and identity based drives that are dictated by contemporary digital culture and peer relationships.

5. Widespread Adoption with Persistent Barriers

In spite of the appeal, there are serious obstacles to adoption. The participants raised concerns regarding the privacy of their data, cybersecurity, and the steep learning curve when it comes to interacting in immersive environments. Inability to access high-speed internet and VR equipment slowed down the engagement in the eyes of some consumers. Such results point to the uniqueness of effective trust-building strategies and increased digital inclusion to arrive at a more inclusive environment.

6. Enhancing User Engagement through Personalization

Personalization was commonly recognized as a significant feature in keeping up the interest of the users. It was

the combination of the personalised dashboards, the experiential avatars, and the continuity of service history that contributed to the establishment of a sense of personal ownership, and emotional attachment.. These personal experiences

were reported to hugely facilitate the feeling of happiness and desire to maintain the usage of the platform, therefore, facilitating customer retention and brand loyalty.

Strategic Recommendation: Enhancing User Engagement Through Emotionally Intelligent Personalization

The study indicates that Gen-Z and Millennial users are not only driven by technological novelty or convenience but also place a high value on personalized, emotionally resonant experiences that align with their digital identity and social behaviors. Based on the results of thematic, narrative, and content analyses, financial institutions looking to implement or improve Metaverse banking platforms are advised to adopt a human-centered personalization strategy supported by emotionally intelligent AI systems.

To that aim, banking platforms should incorporate AI-powered avatars that can recognize returning customers, recollect previous encounters, and respond empathetically to client concerns. Such encounters help to build trust and emotional connections, both of which are essential for maintaining long-term loyalty. Furthermore, allowing users to personalize their virtual banking settings, such as dashboards, avatars, and interaction preferences, can greatly increase their sense of ownership and emotional connection.

Also, introducing gamified components and social integration features, such as peer recognition, virtual co-banking chances, and community-driven financial tools, can address the psychological motivations described in this study, which include FOMO, status-seeking, and peer influence. These aspects elevate banking from a strictly transactional service to a socially integrated, identity-enhancing experience that meets the expectations of digitally native generations.

Employing a qualitative, multi-analytical framework comprising thematic, narrative, and content analyses, the study

Banks that prioritize emotionally intelligent customisation can better attract, engage, and retain younger consumers in immersive virtual environments, assuring both technological relevance and emotional resonance in the expanding digital financial ecosystem.

Conclusion

This research offers a timely and significant contribution to the evolving discourse on immersive technologies in the financial services sector by investigating the perceptions, behavioral drivers, and experiential expectations of Gen-Z and Millennial users in the context of Metaverse banking. By addressing an evident gap in existing literature, particularly the limited exploration of generational engagement patterns, emotional trust dynamics, and identity-driven motivations within Indian banking ecosystems, this study advances a nuanced understanding of how immersive virtual environments intersect with the financial behaviors of digital-native consumers.

reveals that user engagement in Metaverse banking is shaped not merely by technological novelty or operational

efficiency, but by a complex interplay of emotional, psychological, and social factors. Thematic insights underscore the dual appeal of innovation and convenience, tempered by persistent concerns regarding trust and digital accessibility. Narrative analysis further illustrates how immersive experiences, such as avatar interactions and virtual bank spaces, serve as emotional anchors, fostering relational bonds and enhancing user loyalty. Content analysis highlights the critical roles of FOMO, innovation affinity, status-seeking, and digital identity as motivational constructs influencing both initial adoption and sustained engagement.

A central implication of this research is the recognition that the Metaverse, for younger consumers, represents more than a digital banking interface; it functions as a socially constructed and emotionally resonant environment where identity, community, and symbolic meaning coalesce. This reconceptualization necessitates a shift in strategic priorities for financial institutions, moving from transactional efficiency toward emotionally intelligent personalization,

ethical AI integration, and socially immersive design.

At the same time, the study acknowledges existing barriers to widespread adoption, including concerns about privacy, security, usability, and infrastructural limitations. These findings reinforce the imperative for banks to adopt inclusive, trust-oriented approaches in their Metaverse strategies, ensuring accessibility across technological and socioeconomic divides.

The future of banking within the Metaverse will be defined not solely by the sophistication of its virtual architecture but by the extent to which it aligns with the emotional, psychological, and social expectations of its users. Financial institutions that prioritize human-centric design, personalized engagement, and community integration are more likely to establish enduring digital relationships with Gen-Z and Millennial consumers. This study thus provides both theoretical enrichment and practical direction for the development of empathetic, generation-responsive financial ecosystems in the era of immersive digital transformation.

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A Study on the Impact of Predictive Analytics on Market Trends Using Artificial Intelligence

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Abstract:

Many technical developments are fuelled by artificial intelligence (AI), which is also changing global trends and sectors. The metaverse, environmental sustainability, and corporate intelligence are just a few of the fields where AI is rapidly evolving. The history of AI's incorporation into certain industries and its influence on upcoming technological advancements are examined in this paper. The global economy is fast changing due to artificial intelligence (AI), which has an impact on labour markets, financial systems, organizational dynamics, and economic growth. Numerous academics have investigated how AI affects a range of economic factors, such as employment markets, industrial productivity, global rivalry, and macroeconomic and microeconomic effects. With differing effects on different industries, businesses, and worker demographics, artificial intelligence (AI) has emerged as a significant driver influencing employment trends. The research now in publication highlights job creation, productivity increases, job displacement, and workforce restructuring, offering both hopeful and sobering viewpoints on AI-driven employment developments. In this paper we have to collect both primary and secondary data like magazines, journals, and using tools like chi-square and hypothesis.

Introduction:

From its conceptual underpinnings in early computational theories to the advanced machine learning techniques of today, artificial intelligence (AI) has experienced substantial evolution. AI's development and governance have been impacted by its interdisciplinary nature, which incorporates elements from computer science, cognitive science, philosophy, and social sciences. This background research summarizes important academic contributions to the intellectual underpinnings of artificial intelligence. Across a wide range of businesses, artificial intelligence (AI) has become a disruptive force that propels

innovation, efficiency, and digital transformation. Automation, data-driven insights, and decision-making processes have all been transformed by the incorporation of AI into commercial and industrial operations. Based on the body of current research, this background study investigates the development, advantages, and difficulties of AI adoption in many industries. By boosting decision-making, automating tedious activities, and increasing operational efficiency, artificial intelligence (AI) is revolutionizing product management Multidisciplinary evolution.

1.2 PREDICTIVE ANALYTICS:

Predictive analytics is the use of statistics and modelling techniques to forecast future outcomes. Current and historical data patterns are examined and plotted to determine the likelihood that those patterns will repeat. Businesses use predictive analytics to fine-tune their

Understanding Predictive Analytics:

Predictive analytics looks for past patterns to measure the likelihood that those patterns will reoccur. It draws on a series of techniques to make these determinations, including artificial intelligence (AI), data mining, machine learning, modelling, and statistics. For instance, data mining involves the analysis of large sets of data to detect patterns from it. Text analysis does the same using large blocks of text. Predictive models are used for many applications, including weather forecasts, creating video games, translating voice to text, customer service, and investment portfolio strategies. All of these applications use descriptive statistical models of existing data to make

operations and decide whether new products are worth the investment. Investors use predictive analytics to decide where to put their money. Internet retailers use predictive analytics to fine-tune purchase recommendations to their users and increase sales.

predictions about future data. Predictive analytics helps businesses manage inventory, develop marketing strategies, and forecast sales. It also helps businesses survive, especially in highly competitive industries such as health care and retail. Investors and financial professionals draw on this technology to help craft investment portfolios and reduce their overall risk potential. These models determine relationships, patterns, and structures in data that are used to draw conclusions as to how changes in the underlying processes that generate the data will change the results. Predictive models build on these descriptive models and look at past data to determine the likelihood of certain future outcomes, given current conditions or a set of expected future condition.

1.3 STATEMENT OF PROBLEM:

The rapid evolution of Artificial Intelligence (AI) has led to significant advancements in various technological domains, such as the Metaverse, business intelligence, environmental sustainability, and image recognition. However, challenges remain in effectively integrating AI into existing systems while ensuring ethical, economic, and social sustainability. Issues such as technological requirements for AI-driven Metaverse services, the impact of AI on environmental and social progress, and the optimization of AI in business decision-making require further exploration. The rapid integration of AI into economic systems presents both opportunities and challenges, transforming financial paradigms, industry productivity, and labor markets. While AI enhances

efficiency, innovation, and economic growth, it also raises concerns about job displacement, income inequality, and market competition. This study seeks to address these gaps by examining the dual effects of AI on economic development, labor markets, and policy frameworks to ensure sustainable and inclusive growth. The complex relationship between AI and employment, addressing challenges and opportunities posed by automation, firm strategies, and market competition, is also a concern. The study aims to explore the challenges businesses face when adopting AI, such as data security risks, interoperability issues, and ethical challenges, and propose strategies to enhance the interdisciplinary application of AI while addressing ethical, legal, and operational concerns.

1.4 RESEARCH OBJECTIVES:

- To Investigate the Impact of AI on Global Trends
- To Evaluate the Main Trends and Features of AI Adoption In various sectors of Economy
- To Explore the Development and Implementation of AI and its impact of Employment
- To Analyze the Intellectual Structure and conceptual foundation of AI Research and Trends
- To Assess the Future Directions for AI in predictive analytics to Transform Industries and Drive Business Environment
- To Identify the Benefits and Challenges of AI Adoption in Product Management
- To Determine the Disciplinary Impact of AI Research Exploring its influence on various field.

2.1 LITERATURE REVIEW

A literature review is a comprehensive summary and critical analysis of existing research on a specific topic. It provides an overview of the current state of

knowledge, identifies key findings, and highlights gaps in the literature. Essentially, it's a synthesis of scholarly work that helps researchers

understand the existing body of knowledge and identify opportunities for further inquiry.

Jason Furman, Robert Seamans, et al (2019) AI Has a significant Impact on the Economy with increased Robotics Activity and the potential to increase productivity. However, it may have mixed effects on work, especially in the short-term policies to stimulate visibility and reduce disadvantages such as antitrust regular ELITRUST and alternative applications like universal income and guaranteed employees are considered.

Graglia MA et al (2020) The Rapid Advancement of AI and Industry 4.0 emphasizing their Transformative Impact on Labor Markets. It Discusses the Convergence of Disruptive Technologies and their role in accelerating automation and job displacement.

Shaukat K et al (2020) The Evolving Relationship Between Humans and Robots emphasizes the role of Artificial Intelligence in various Sectors like Healthcare, Business, Security, and Law Enforcement. It also explores the increasing Demand for Intelligent Machines and their Impact on Future Employment opportunities.

Gizealew Alazie Dagnaw et al (2020) Industry 4.0 Signifies a Digital Transformation in manufacturing that incorporates technologies such as AI, IoT, Big Data, and Cloud Computing. This focuses on Intelligent and Customized Production Instead of Traditional Mass Production. AI is vital for improving process efficiency decision making and risk Management. The Challenges are

Acquiring Knowledge, Integrating Diverse Data Ensuring Safety Persist. It has an Implementation of Ongoing innovation and Human Involvement.

Samtani S et al (2020) Cybersecurity is a significant societal challenge in the 21st century, and Artificial Intelligence (AI) has emerged as a viable approach for executing fundamental cybersecurity tasks. However, AI and cybersecurity have traditionally been siloed disciplines, leading to nascency in the AI for Cybersecurity discipline. This article provides an overview of prevailing cybersecurity data, summarizes existing AI for Cybersecurity application areas, and offers a multi-disciplinary roadmap focusing on cybersecurity applications, data, advanced AI methodologies, and AI-enabled decision-making.

French A. et al (2021) The Transformative Impact of AI block chain and 5G on Industries, Economies, and Societies. AI and Machine Learning Drive Automation and Decision Making while Block Chains Ensure secure and transparent transactions. 5G enhances connectivity enabling real-time data processing and IOT expansion. It emphasizes the integration of these technologies to create new business models and efficiencies. It has challenges of security, ethical, concerns, and regulatory frameworks.

Simone Grassini et al (2021) Artificial intelligence (AI) has significantly transformed educational practices, particularly with the development of GPT, particularly OpenAI's ChatGPT. These models have significant implications in education and health, but concerns about

their widespread use and opacity have been raised. This paper explores the potential and problems of applying advanced AI models in education, contributing to understanding how these technologies reshape educational norms in the "new AI gold rush era"

Chatterjee S et al (2021) study explores the factors influencing the adoption of Industry 4.0 in digital manufacturing, using the extended technology-organization-environment (TOE) framework. It proposes a conceptual model using an integrated technology acceptance model (TAM)-TOE model, tested using survey data from 340 employees. Results show that organizational readiness, compatibility, and partner support are significant, but leadership support moderates adoption. The study highlights the importance of leadership support in promoting Industry 4.0 adoption.

Rocha IF et al (2022) This research explores the collaboration between Artificial Intelligence (AI) and the Internet of Things (IoT) in improving operations management (OM) in the context of digital transformation. The study identifies a significant relationship between AI, IoT, and OM through Industry 4.0 aiming to improve OM. The results provide practical insights for business managers, identifying barriers and expected benefits when adopting AI and IoT in operations. The study differs from previous research by conducting a systematic review of the literature on the relationship between OM and technological tools.

Fosso Wamba S et al (2022) This paper is accepted for the special issue 'Industry Experiences of Artificial Intelligence: Benefits and Challenges in Operations and supply chain management. It introduces the relationship between AI and operations and supply chain management (OSCM) highlights practical insights, and provides research directions for scholars and practitioners.

Grover P et al (2022) This study examines the feasibility of AI utilization in operations management (OM) by analysing factors like job satisfaction, complexity, long-term consequences, affect towards use, social factors, and facilitating conditions. It provides guidelines for managers and concludes with limitations and future research directions.

Nawaz et al (2022) the discovery of objects crucial for mission vision and deep teaching recent advancements in drawing features image representation classification and acknowledge have led to significant progress in teaching theory and technology the researchers have proposed methods for object deductions such as Scowartm's algorithm and improved algorithm future research sorting priority boxes constructing network patterns selecting forecast boxes and calculating losses.

Akundi A et al (2022) Industry 5.0 Focus on Human-Machine collaboration, Personalization, and Digital Transformation Driven by AI, IoT, and Big Data. It includes Supply Chain Optimization, Enterprise Digitization, Smart Manufacturing, and Human Machine Connectivity.

Mpinga EK et al (2022) This systematic review explores the relationship between Artificial Intelligence (AI) and human rights (HRs) and the emergence of a new discipline. The review analysed databases from legal, social, healthcare, and general sciences. It found a dynamic field exploring issues like autonomous lethal weapons, privacy protection, discriminatory decision-making, intellectual property, and the legal personality of robots. The review suggests strategies to consolidate this emerging discipline, such as developing academic programs at the intersection of AI and HR.

Jasmin Praful Bharatiya et al. (2023) Integrated Automatic Learning and Artificial Intelligence in Business Intelligence offer numerous opportunities for companies to analyse data, gather information, and make informed Decisions. Predictive Analytics allows Companies to identify patterns and Trends, anticipate customer needs, and mitigate risks.

Shayan Doroudi1 et al (2023) The Studies Examine the Historical Connection between AI and Education highlighting contributions from cognitive scientists who advanced both fields. It identifies two major cognitive approaches information processing psychology and constructivism while calling for a revival of their integrated perspective.

Ali Zarifhonarvar et al (2023) The Study Explores the Impact of Chatgpt and other generative AI Services on the job market, but it Acknowledges limitations due to evolving AI Technologies and the Need for Further Empirical Validation.

Wang J et al (2023) The Impact of AI Technology on employee responsibility concerns supervision costs and corporate governance while examining how market competition and firm ownership influence these effects. AI's role in productivity and innovation is nothing that while employee responsibility enhances innovation AI itself has no significant effect.

Masriadi D et al (2023) The Impact of AI and Automation on Employment emphasizes job displacement while acknowledging the irreplaceability of human traits like intuition and empathy it discusses the potential for human-machine collaboration rather than full automation.

Faqihi A et al (2023) AI's Transformative Role in Talent Management by Enhancing Automation, Professional Assessment, and Workforce Planning. It also Explores the Integration of AI with frameworks like Technology Organization Environment (TOE) and Diffusion of Innovation(DOI) to address adoption challenges and risks in HRM systems.

Allioui H et al (2023) The Integration of AI has greatly improved the Reliability of Digital Service, Optimized Supply Chains, and provided Real-time Access to valuable data and Analytics. Companies can significantly benefit from using AI to shorten lead times, Gain New Customer Insights, enhance customer service, and create personalized experiences.

COWIN et al (2023) Trans-Disciplinarity (TD) is gaining importance in the metaverse, but its origins and meanings are unclear. Further research is needed to clarify its definition and application and

explore its connections with systems thinking. This will help understand how Trans-Disciplinarity (TD) can address complex problems and advance knowledge and innovation across disciplinary boundaries.

Zawish et al (2024) The Metaverse a rapidly evolving continuum of Technologies is expected to Become the Next Evolution of the Internet. The Background progress, and Technical Aspects of Augmented Reality(AR) Mixed Reality(MR) Virtual Reality(VR)and spatial computing as well as the role of B5G/6G (B5G stands for Beyond 5G) (6G Full Form: Sixth-Generation Wireless Technology) in Metaverse Service and Workflows in Metaverse have provided Search Instructions for circles.

Turyasingura et al. (2024) Artificial Intelligence is always more essential to Answering Challenges to integrate Technological Progress in Environmental Protection and Social Development. Their ability to promote Sustainability and Improvement of Society is in addition to the challenges presented.

Constantinos Challoumis et al (2024) Artificial Intelligence (AI) is Revolutionizing Economics by transforming money and enterprise dynamics. It Redefines Traditional Financial Paradigms, Reshaping Value Creation, Distribution and Manipulation. The intertwining of AI with financial systems and Enterprise evaluation is crucial.

Geetha et al (2024) The study Examines the implications of Artificial Intelligence

on Malaysia's Economic Landscape, Focusing on Macroeconomic Dimensions, Microeconomic Dimensions, and short-term term and long-term impacts that can reduce Marginal yields and Increase Marginal blindness, transforming resources and economies of scale. The adoption of AI in different sectors and demographic groups has both positive and Negative consequences. It emphasizes the need for successful and sustainable AI adoption for economic development.

Saidbek Mamasoliev et al (2024) et al This Study Explores the Impact of Artificial Intelligence On Economic growth and global competition. It uses a mixed-method approach, Integrating Economic Relationship Data, Industry Analysis, and Investment Statistics. Results show a Significant Increase in productivity and Innovation in Industries Adopting AI in the world promotion competition.

Damioli et al (2024) AI Impact on employment with some studies emphasizing job creation through innovation and productivity gains while others warn of job displacement due to automation and labor substitution. Artificial Intelligence Driven Employment effects vary by sector, firm, age, and innovation intensity with younger and service-oriented firms benefiting the most.

Jason Yu Cheryl Qi et al (2024) Recent Studies on Generative Artificial Intelligence explores its Dual impact on labor Markets with some predicting job displacement and others productivity gains impact varies across industries with

net efforts dependent on firm strategy and policy responses.

Gacem H et al (2024) The Evolution of AI Tracing its Origins from Early Computational Theories to Modern Machine Learning Techniques. It Highlights key Methodologies including expert systems, Neural Networks, and Genetic Algorithms. While addressing applications and associated challenges.

Carnevale A. et al (2024) The Foundational Issues in Symbiotic Artificial Intelligence Critiquing the Application of Biological Analogies and Deterministic Models It concerns the rigid ethical framework that separates Ethics from practical governance. Theoretical Perspectives on Intelligent life and their Implications for Symbiotic Artificial Intelligence Design. It integrates Socio-Technical factors into Artificial Intelligence governance.

Samara FY et al (2024) Artificial Intelligence Role in Enhancing Business Decision Making Through Predictive Analytics, Automation, and Data-Driven Insights. It Studies Artificial Intelligence Benefits in Improving Efficiency Reducing Biases and optimizing customer experience. It has challenges of Data Privacy and Integration Complexities.

Fosso Wamba S et al (2024) this study explores the use of ChatGPT and Gen-Artificial Intelligence in supply chains, focusing on operational gains like customer satisfaction and cost minimization. Challenges include data, technological, and organizational issues. Benefits include cost savings, enhanced customer experience, automation, and

sustainability. The findings contribute to the literature on Gen-AI use in operations and supply chain management (OSCM) and management practice.

Andrzej Wodecki et al (2024) This paper presents a knowledge management framework for designing, monitoring, and optimizing the business value of intelligent services using best practices from management and machine learning engineering areas. The framework enables managers, engineers, and scientists to efficiently work together and optimize the value of intelligent services throughout their lifecycle. Key machine learning methods and techniques for monitoring and optimizing the value of intelligent services include Machine Learning Ops methodology, reinforcement learning, and Causal Machine Learning methods. The approach is illustrated by a case study of a marketing communication optimization system in a large multinational financial company.

The research based upon both primary and secondary data. The primary data was collected through a questionnaire that is designed exclusively for the study. Secondary data was collected from Research papers, websites, and journals and from magazines. Research methodology is a way of explaining how a researcher intends to carry out their research. It's a logical, systematic plan to resolve a research problem. A methodology details a researcher's approach to the research to ensure reliable, valid results that address their aims and objectives. It encompasses what data they're going to collect and where from, as well as how it's being collected and analysed. So, the adoption of research

methodology is essential a step in conducting a research study. In a research paper, the methodology section allows the

3.2 RESEARCH DESIGN

The research design refers to the overall strategy that you choose to integrate the different components of the study in a coherent and logical way, thereby, ensuring you will effectively address the research problem; it constitutes the

reader to critically evaluate a study's overall validity and reliability.

blueprint for the collection, measurement, and analysis of data. Research design is the framework of research methods and techniques chosen by a researcher to conduct a study.

Types of Research Design:

1. Descriptive
2. Exploratory

MEANING OF DESCRIPTIVE RESEARCH:

Descriptive research is a type of research that is used to describe the characteristics of a population. It collects data that are

used to answer a wide range of what, when, and how questions pertaining to a particular population or group.

MEANING OF EXPLORATORY RESEARCH:

Exploratory research is a preliminary investigation used to delve into a topic that is new, not well-defined, or under-researched. It's a way to gain initial

insights, understand a problem, and generate hypotheses for future, more focused research.

DATA COLLECTION:

- This study is based on survey method. Primary data was collected from the Google forms.
- A well structure and concise questionnaire were designed based on sampling and sent on electronic medium.
- The questionnaire focused on aspects of each person, their perception onThe

Impact of Predictive Analytics on Market Trends Using AI. By leveraging artificial intelligence and data science, companies can achieve higher levels of technology allows businesses to anticipate trends and patterns with greater precision, giving them a competitive edge in today's fast-paced market environment.

Collection of Data:

The main two types of data are:

- PRIMARY DATA
- SECONDARY DATA

Primary Data:

- Primary data are those, which are collected for the first time, and are original. Primary data are data directly collected in the form of survey questionnaires and interviews.
- Primary data means original data that has been collected specially for the purpose in mind. It means someone collected the data from the original source first hand.
- Data collected this way is called primary data. Primary data is considered to be authentic and accurate.
- A suitable combination of Questionnaires and interview techniques is used to collect the required primary data. By using a questionnaire, data has been collected from 100 sample respondents through survey method. In this study, primary data is obtained in the form of questionnaires distributed through Google forms.

Secondary Data:

Secondary data is the data that has already been collected through primary sources and made readily available for researchers to use for their own research. It is a type of data that has already been collected in the past. It is available in sources of internet, newspaper articles, published journals, books, government records, magazines and websites and these too are the examples of secondary data.

3.4 SAMPLE DESIGN:

Sample Size:

A Survey of approximately 100 respondents at Chennai.

Sample technique:

The selection of respondents was done on Probability Sampling method because the respondents were selected on the basis of the needs of the researcher and data collection stratified random sampling because the respondents were selected on the basis of researcher convenience. Samples were collected from public through questionnaire. 100 samples to conduct the study.

3.5 ANALYSIS:

The data collected was analyzed with the help of Chi – square and testing hypothesis.

3.6 LIMITATIONS OF STUDY:

- This research is limited to the Predictive Analytics on Market Trends Using AI.
- The data collected for the research is fully on primary data given by the respondents. There is chance for personal bias.
- The study is limited to Chennai and to the respondents' perspectives, which may not fully represent broader regional or national market behaviors. Consequently, the findings on predictive analytics using AI in market trends should be interpreted within the contextual framework of this geographic and demographic constraint.

4.1 MEANING:

Data analysis is an important step in research work in order to determine inherent facts or meanings. It breaks down the complex factors into simpler parts and puts forth the simpler parts together into new arrangements for the purpose of interpretation. The goal of analysis is to

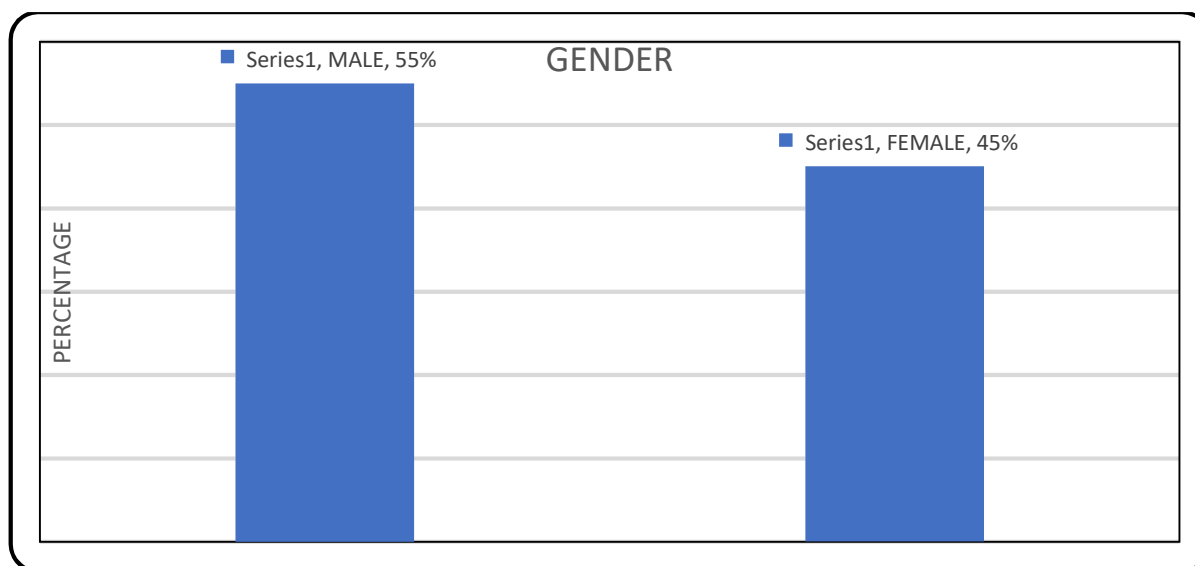
arrange and group the data so that they can be interpreted to give answers to the triggered research questions through a hypothesis. The word 'Analysis' and 'Interpretation' is interrelated with one another. Analysis cannot be concluded without interpretation and interpretation cannot begin without analysis.

TABLE 4.1.1 GENDER

GENDER	NO. OF. RESPONSE	PERCENTAGE
MALE	55	55%
FEMALE	45	45%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.1



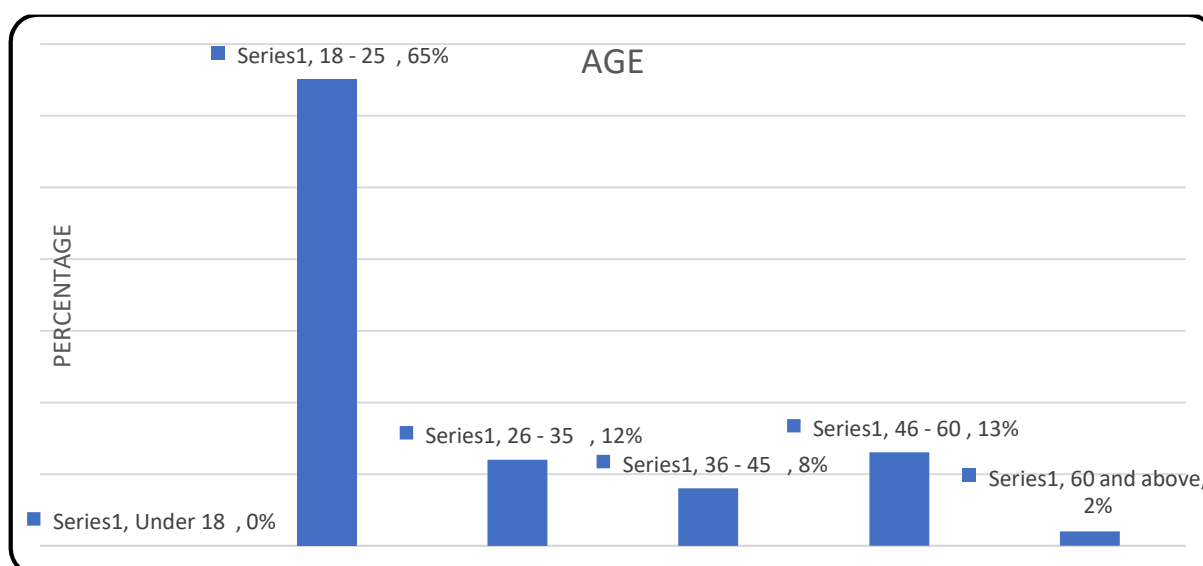
INTERPRETATION: As per findings 55% people are Male and 45% is Female from this we can understand that their Male respondents are more.

TABLE 4.1.2 AGE

GENDER	NO. OF. RESPONSE	PERCENTAGE
Under 18	0	0%
18 - 25	65	65%
26 - 35	12	12%
36 - 45	8	8%
46 - 60	13	13%
60 and above	2	2%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.2



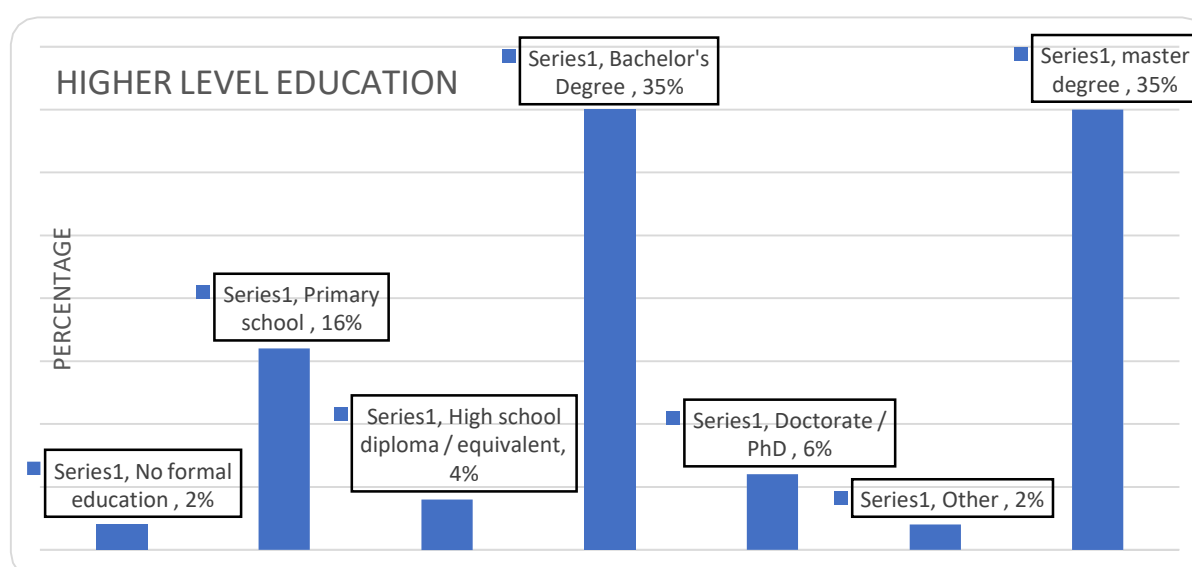
INTERPRETATION:

The majority of respondents, 65%, are between the ages of 18 and 25. This is followed by 13% who are between 46 and 60 years old, 12% who are aged 26 to 35, 8% who are between 36 and 45, and 2% who are 60 years old or above. Notably, there were no respondents under the age of 18.

TABLE 4.1.3 EDUCATION

HIGHER LEVEL EDUCATION	NO. OF. RESPONSES	PERCENTAGES
No formal education	2	2%
Primary school	16	16%
High school diploma/equivalent	4	4%
Bachelor's Degree	35	35%
Doctorate / PhD	6	6%
Master Degree	2	2%
OTHER	35	35%
TOTAL	100	100%

Source: Primary Data

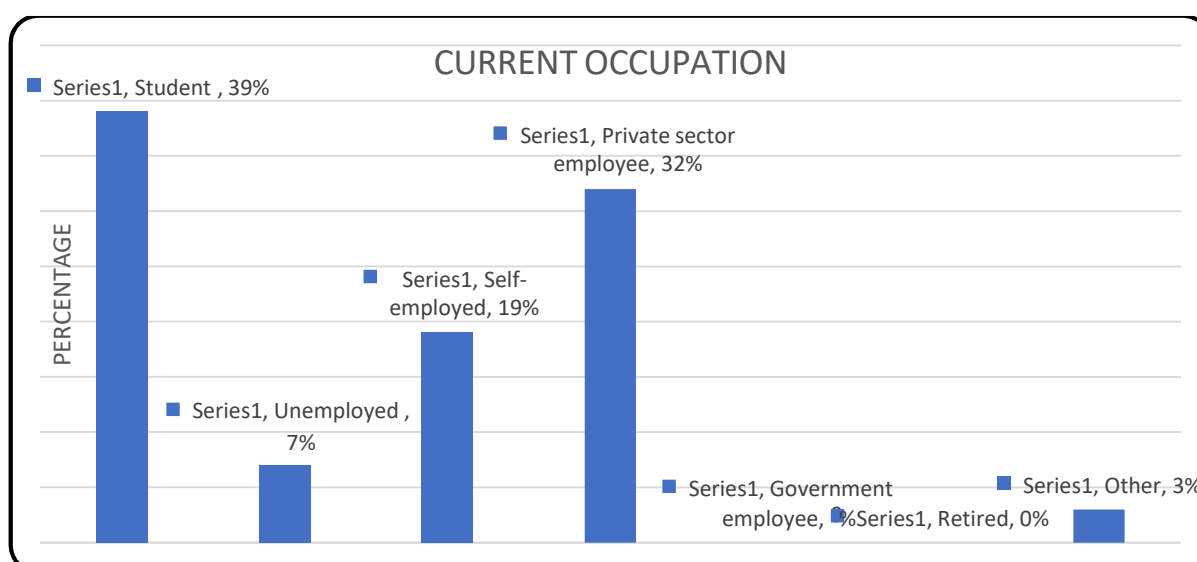
Figure 4.1.3**INTERPRETATION:**

The table shows that 35% of respondents reported having a Bachelor's Degree, making it one of the most common levels of higher education alongside the "Other" category, which also accounts for 35% of responses. Primary school education was reported by 16% of participants, while 6% had achieved a Doctorate or PhD. Only 4% held a high school diploma or equivalent, and a small portion—2% each—had either no formal education or a Master's Degree. This distribution indicates a diverse educational background among respondents, with a significant portion either possessing a bachelor's degree or falling into the unspecified "Other" category.

TABLE 4.1.4 OCCUPATION

CURRENT OCCUPATION	NO. OF. RESPONSES	PERCENTAGES
Student	39	39%
Unemployed	7	7%
Self-employed	19	19%
Private sector employee	32	32%
Government employee	0	0%
Retired	0	0%
Other	3	3%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.4**INTERPRETATION:**

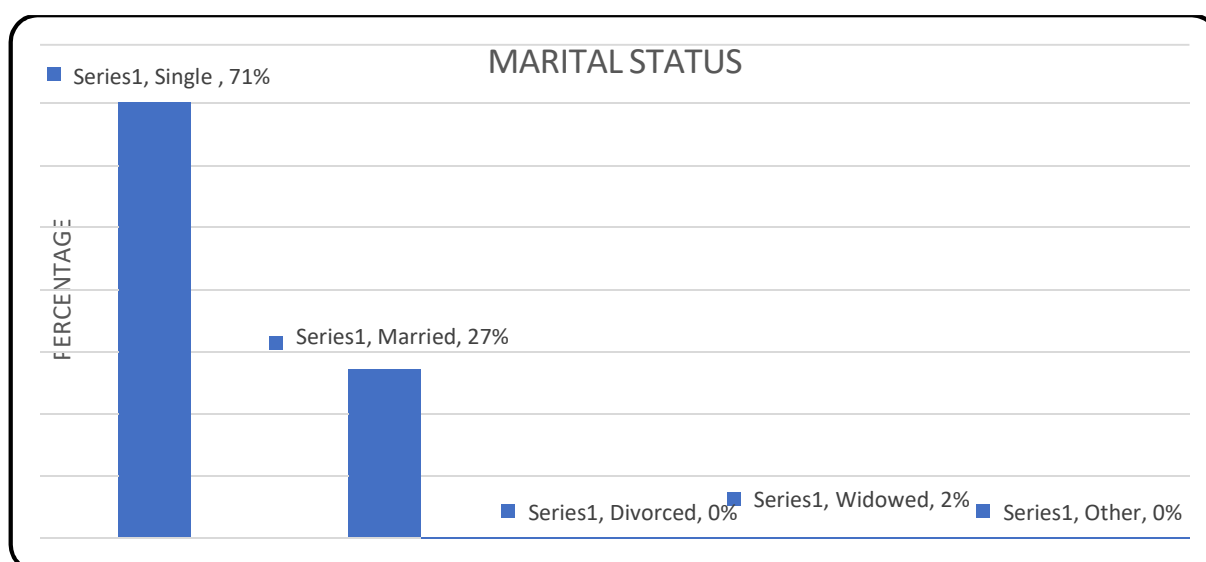
The majority of respondents are students (39%), indicating a strong academic presence. Private sector employees from 32% of the sample, showing good representation from the workforce. Self-employed individuals make up 19%, highlighting entrepreneurial participation. A smaller portion, 7%, is unemployed, while 3% belong to other occupations. There are no government employees or retired respondents (0%), showing gaps in these groups.

TABLE 4.1.5 MARITAL STATUS

MARITAL STATUS	NO. OF RESPONSES	PERCENTAGES
Single	71	71%
Married	27	27%
Divorced	0	0%
Widowed	2	2%
Other	0	0%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.5



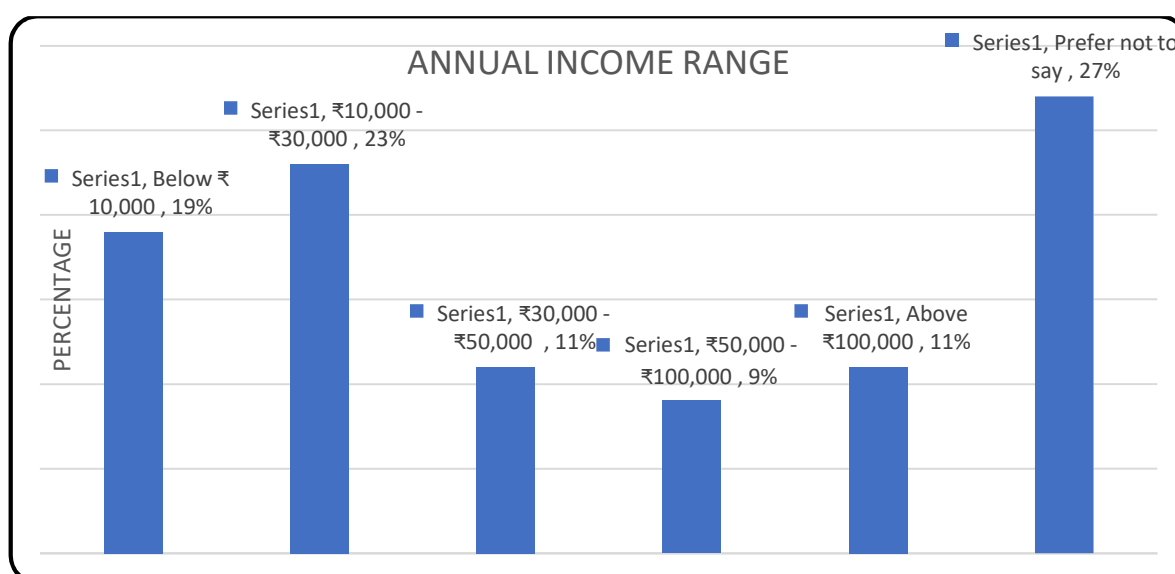
INTERPRETATION:

The majority of respondents, 71%, identified as single. This is followed by 27% who reported being married. A small minority, 2%, indicated that they are widowed. Notably, 0% of the respondents reported being divorced or selecting other as their marital status. This suggests that the surveyed population is predominantly single, with very few individuals falling into other marital categories.

TABLE 4.1.6 ANNUAL INCOME

ANNUAL INCOME RANGE	NO. OF. RESPONSES	PERCENTAGES
Below ₹ 10,000	19	19%
₹10,000 - ₹30,000	23	23%
₹30,000 - ₹50,000	11	11%
₹50,000 - ₹100,000	9	9%
Above ₹100,000	11	11%
Prefer not to say	27	27%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.6**INTERPRETATION:**

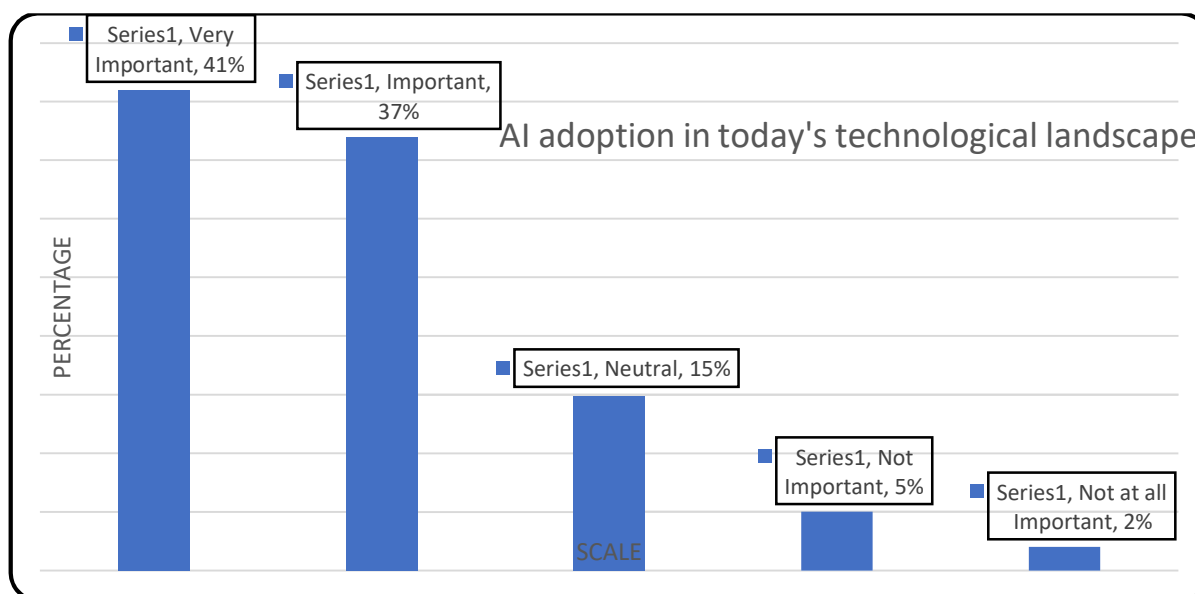
The majority of respondents (27%) chose not to provide their income, followed by the largest group (23%) earning between ₹10,000 and ₹30,000 annually. The remaining respondents are distributed across the other income categories, with the least percentage (9%) earning between ₹50,000 and ₹100,000.

TABLE 4.1.7 AI adoption in today's technological landscape

SCALE	NO. OF RESPONSES	PERCENTAGE
Very Important	41	41%
Important	37	37%
Neutral	15	15%
Not Important	5	5%
Not at all Important	2	2%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.7



INTERPRETATION:

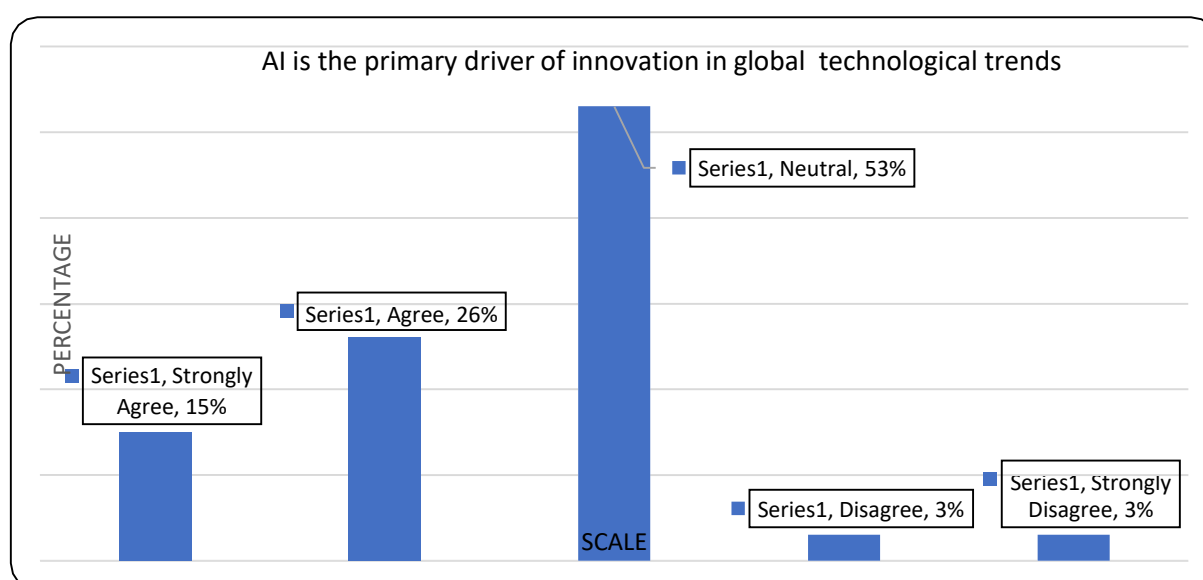
The data shows that a large majority of people 78% believe that AI adoption is either very important (41%) or important (37%) in today's technological landscape. Only a small number of respondents are neutral (15%), and even fewer consider it not important (5%) or not at all important (2%). This indicates that most people recognize the significant role AI plays in shaping modern technology and view its adoption as essential for progress.

TABLE 4.1.8 AI is the primary driver of innovation in global technological trends

SCALE	NO. OF RESPONSES	PERCENTAGES
Strongly Agree	15	15%
Agree	26	26%
Neutral	53	53%
Disagree	3	3%
Strongly Disagree	3	3%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.8



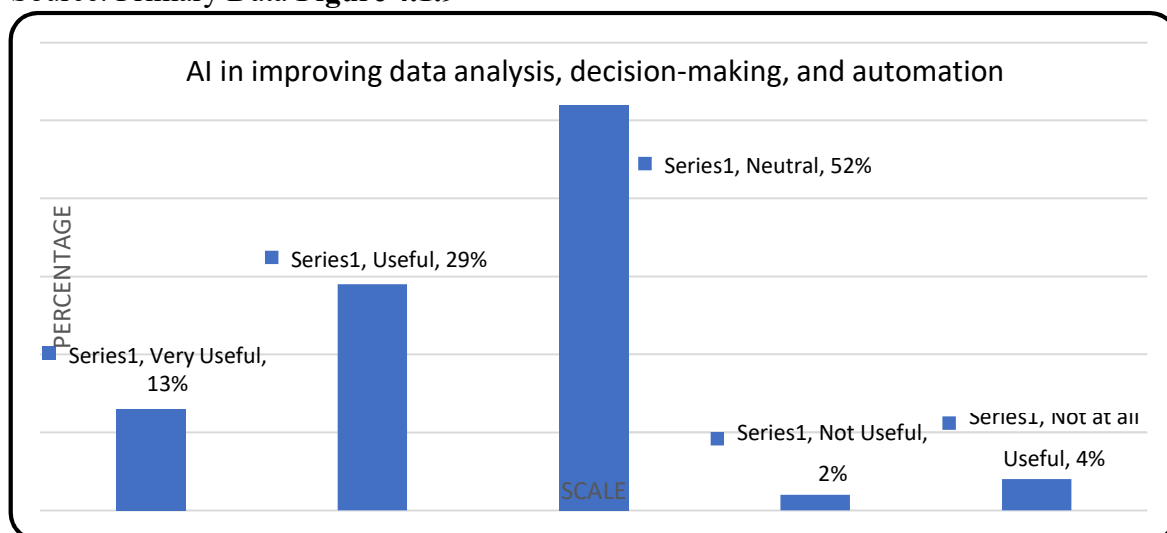
INTERPRETATION:

The data shows that while a small majority of respondents remain neutral (53%) about whether AI is the primary driver of innovation in global technological trends, a combined 41% (15% strongly agree and 26% agree) believe it is, indicating a significant portion sees AI as influential, though many are still undecided or cautious in their views.

TABLE 4.1.9 AI in improving data analysis, decision-making, and automation

SCALE	NO. OF RESPONSES	PERCENTAGE
Very Useful	13	13%
Useful	29	29%
Neutral	52	52%
Not Useful	2	2%
Not at all Useful	4	4%
TOTAL	100	100%

Source: Primary Data **Figure 4.1.9**



INTERPRETATION:

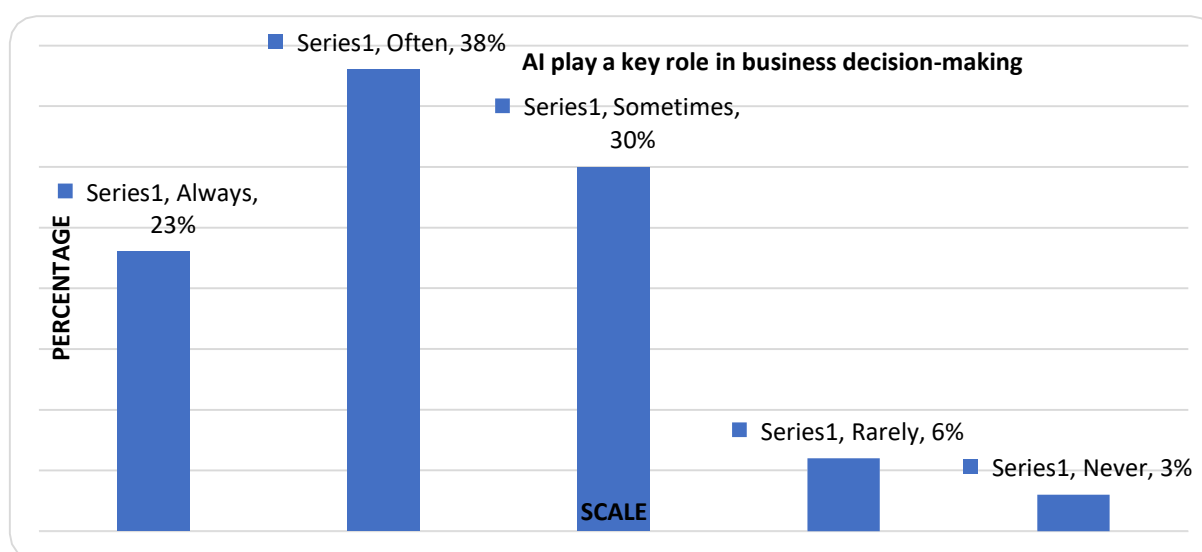
The results show that most people (52%) feel neutral about the usefulness of AI in improving data analysis, decision-making, and automation. However, a significant portion (42%) finds it either "Useful" or "Very Useful," while only a small number (6%) believe it is not useful or not at all useful. This suggests that while many are unsure about AI's impact, a good number do see its potential benefits.

TABLE: 4.1.10 AI plays a key role in business decision-making

SCALE	NO. OF. RESPONSES	PERCENTAGES
Always	23	23%
Often	38	38%
Sometimes	30	30%
Rarely	6	6%
Never	3	3%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.10



INTERPRETATION:

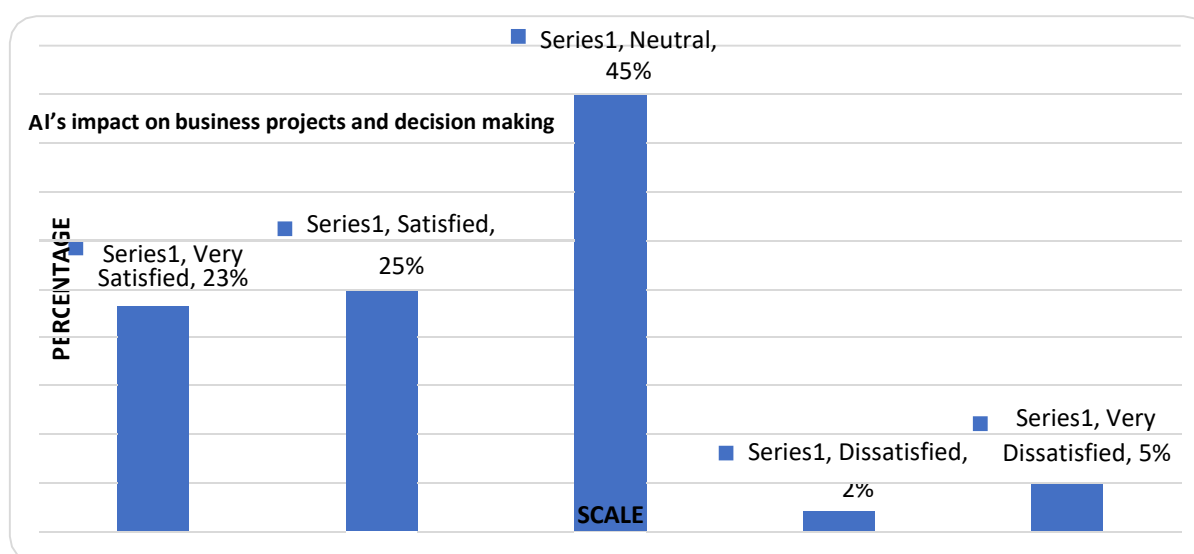
The survey results show that AI plays a key role in business decision-making for most respondents. Specifically, 23% of people always rely on AI, while 38% often use AI for decisions. Around 30% sometimes use AI, and only 6% rarely rely on it. A small group, 3%, never use AI in business decision-making. Overall, the data suggests that AI is a significant tool for decision-making in business, with a majority of respondents using it frequently or sometimes.

TABLE: 4.1.11 AI's impact on business projects and decision making

SCALE	NO.OF. RESPONSES	PERCENTAGES
Very Satisfied	23	23%
Satisfied	25	25%
Neutral	45	45%
Dissatisfied	2	2%
Very Dissatisfied	5	5%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.11



INTERPRETATION:

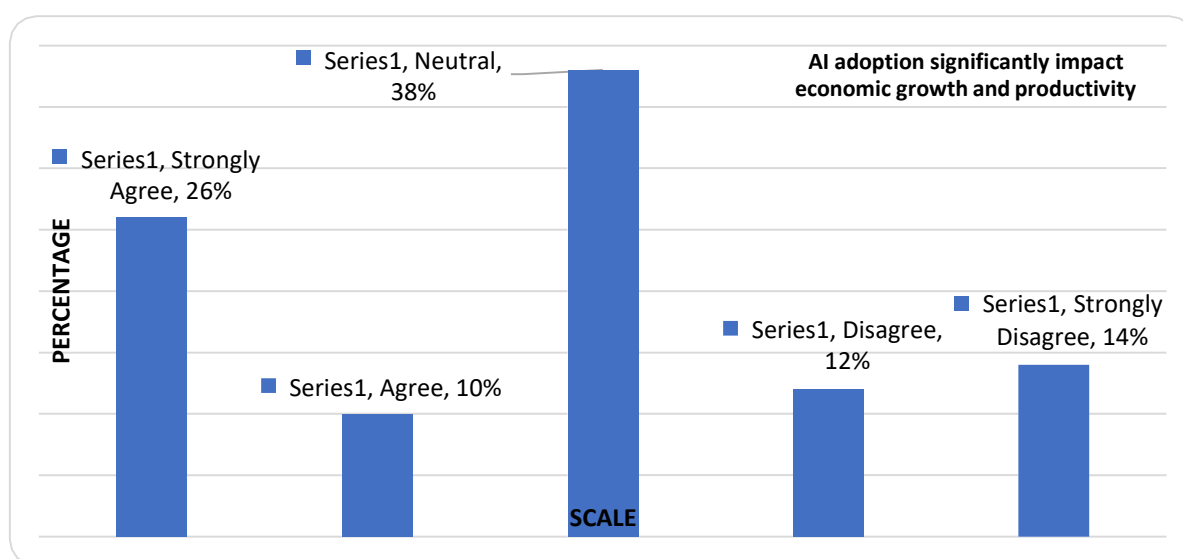
The survey results show that most people have a neutral view about AI's impact on business projects and decision-making, with 45% feeling neutral. A good portion, 25%, is satisfied, and 23% are very satisfied. Only a small percentage, 7%, is dissatisfied or very dissatisfied. Overall, the sentiment is generally positive or neutral, but there are a few who feel less enthusiastic about AI's impact.

TABLE: 4.12AI adoption significantly impact economic growth and productivity

SCALE	NO. OF. RESPONSES	PERCENTAGE
Strongly Agree	26	26%
Agree	10	10%
Neutral	38	38%
Disagree	12	12%
Strongly Disagree	14	14%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.12



INTERPRETATION:

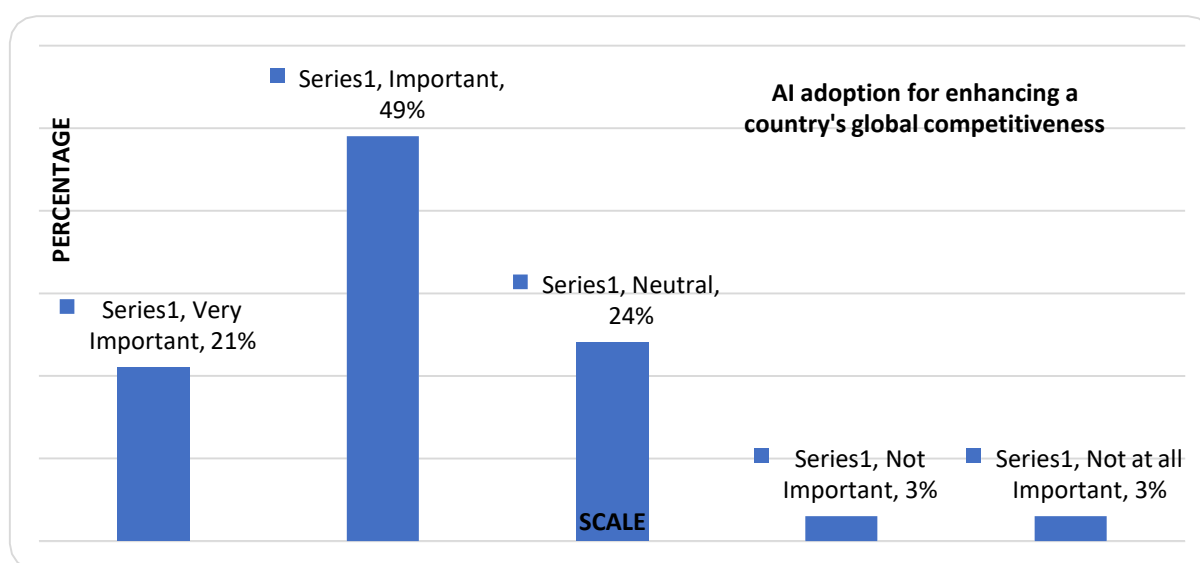
The survey results suggest that opinions on AI adoption's impact on economic growth and productivity are mixed. A significant portion of respondents (26%) strongly agree that AI adoption significantly impacts economic growth and productivity, while 10% agree. However, a larger group (38%) feels neutral about the issue, indicating uncertainty or lack of strong opinion. On the other hand, 12% disagree, and 14% strongly disagree, suggesting some scepticism or belief that AI adoption might not have a significant impact. Overall, while a majority are either neutral or supportive, there is a noticeable level of disagreement as well.

TABLE: 4.1.13 AI adoption for enhancing a country's global competitiveness

SCALE	NO.OF. RESPONSES	PERCENTAGE
Very Important	21	21%
Important	49	49%
Neutral	24	24%
Not Important	3	3%
Not at all Important	3	3%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.13



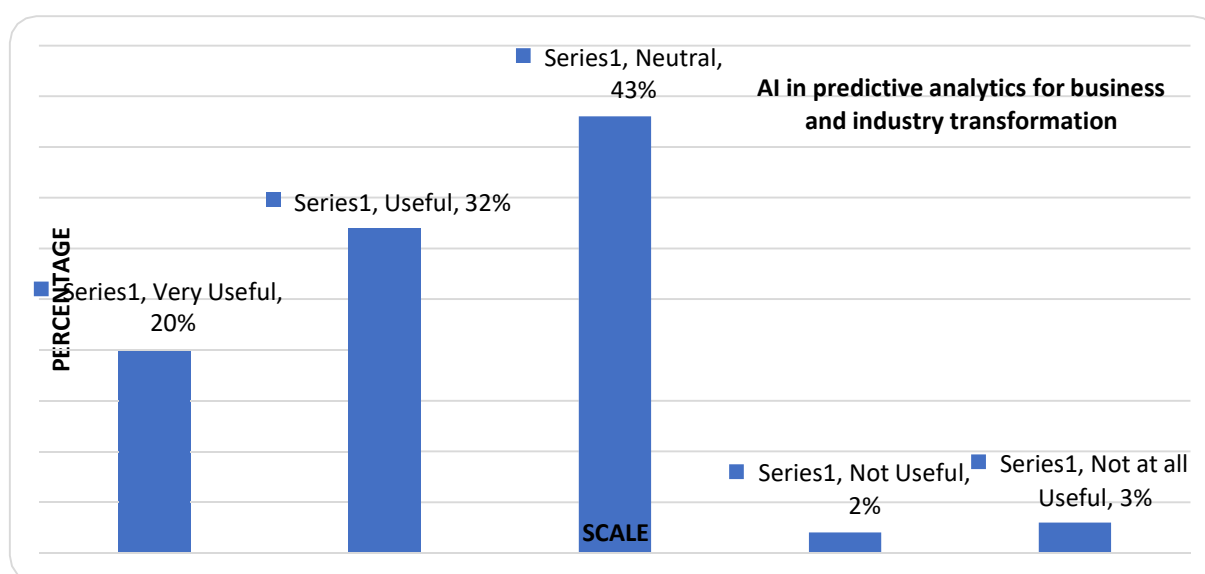
INTERPRETATION:

The data shows that most people (49%) believe that AI adoption is important for enhancing a country's global competitiveness. A significant portion (21%) considers it very important, while 24% are neutral on the matter. Only a small percentage (3%) views it as not important or not at all important. In summary, the majority of respondents agree that AI adoption plays a crucial role in improving a country's competitiveness on the global stage.

TABLE: 4.1.14 AI in predictive analytics for business and industry transformation

SCALE	NO.OF.RESPONSES	PERCENTAGE
Very Useful	20	20%
Useful	32	32%
Neutral	43	43%
Not Useful	2	2%
Not at all Useful	3	3%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.14**INTERPRETATION;**

The survey results show that a majority of respondents view AI in predictive analytics as valuable for business and industry transformation. Specifically, 32% consider it "Useful," and 20% think it is "Very Useful." However, a significant portion, 43%, expressed a neutral opinion, meaning they neither find it particularly

helpful nor unhelpful. Only a small percentage (2%) thought it was "Not Useful," and just 3% felt it was "Not at all useful." This suggests that while most people see some potential in AI-driven predictive analytics, there is still a notable portion that is either uncertain or not convinced of its utility in this context.

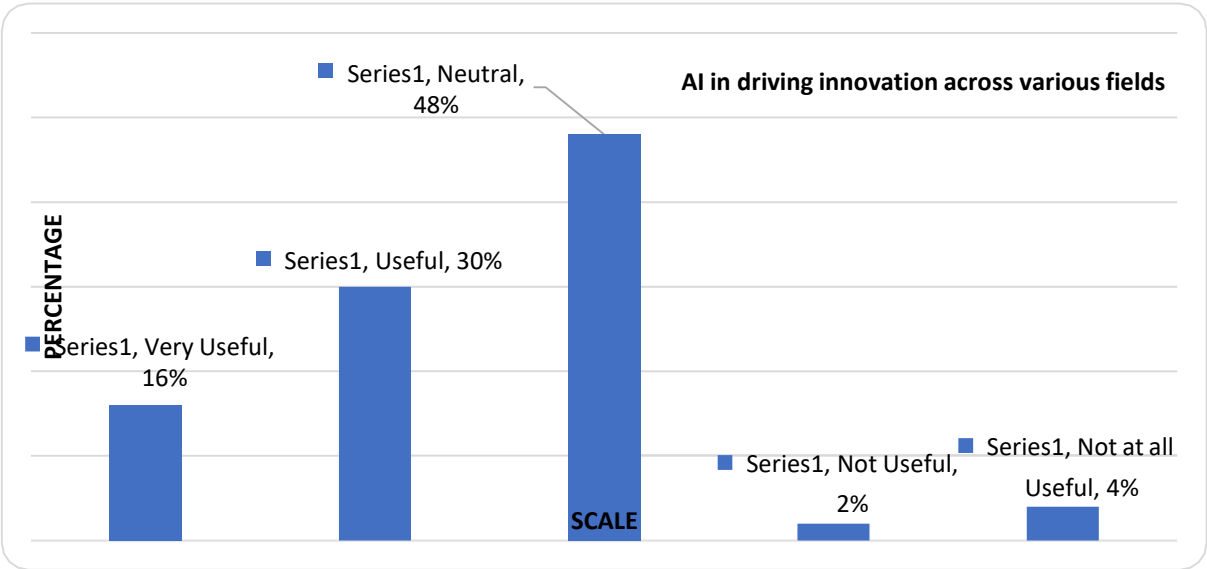
TABLE: 4.1.15 AI in driving innovation across various fields

SCALE	NO.OF. RESPONSES	PERCENTAGE
Very Useful	16	16%
Useful	30	30%
Neutral	48	48%

Not Useful	2	2%
Not at all Useful	4	4%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.15



INTERPRETATION:

The data suggests that a majority of people perceive AI as having a positive impact on innovation across various fields. Specifically, 46% of respondents (16% very useful and 30% useful) think AI is useful for driving innovation. On the other hand, 48% of people feel neutral about its usefulness, meaning they don't have

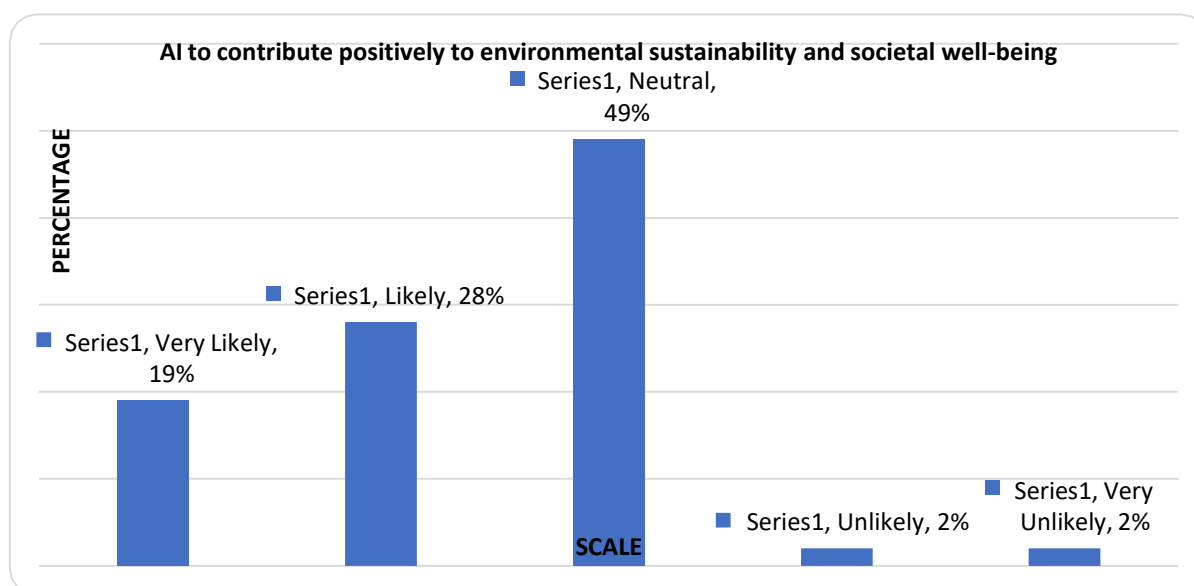
strong opinions either way. A smaller percentage, 6% (2% not useful and 4% not at all useful), believe that AI has little to no impact on innovation. In conclusion, while many people see AI as valuable, a significant portion remains uncertain about its potential.

TABLE: 4.1.16 AI to contribute positively to environmental sustainability and societal well-being

SCALE	NO. OF. REPDENDENTS	PERCENTAGE
Very Likely	19	19%
Likely	28	28%
Neutral	49	49%
Unlikely	2	2%
Very Unlikely	2	2%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.16



INTERPRETATION:

The survey results indicate that most respondents have a neutral stance on the ability of AI to contribute positively to environmental sustainability and societal well-being. Specifically, 49% of respondents were neutral, meaning they neither agreed nor disagreed with this view. A smaller proportion, 28%, felt likely or very likely that AI would

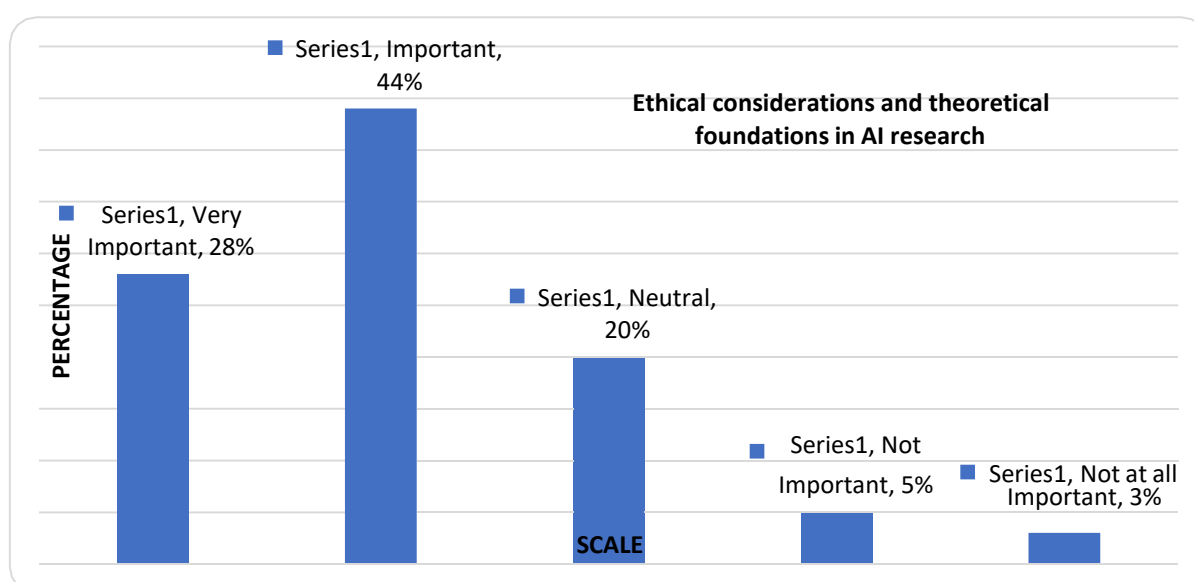
contribute positively, while 4% were unlikely or very unlikely to believe in AI's potential positive impact. Overall, the results suggest that while there is some optimism about AI's role in sustainability, there is still a significant level of uncertainty or indifference among the respondents.

TABLE: 4.1.17 Ethical considerations and Theoretical foundations in AI research

SCALE	RESPONDENTS	PERCENTAGE
Very Important	28	28%
Important	44	44%
Neutral	20	20%
Not Important	5	5%
Not at all Important	3	3%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.17



INTERPRETATION:

The data shows that the majority of respondents (72%) believe that ethical considerations and theoretical foundations in AI research are important or very important. Specifically, 28% of respondents rated it as "Very Important," and 44% rated it as "Important." A smaller

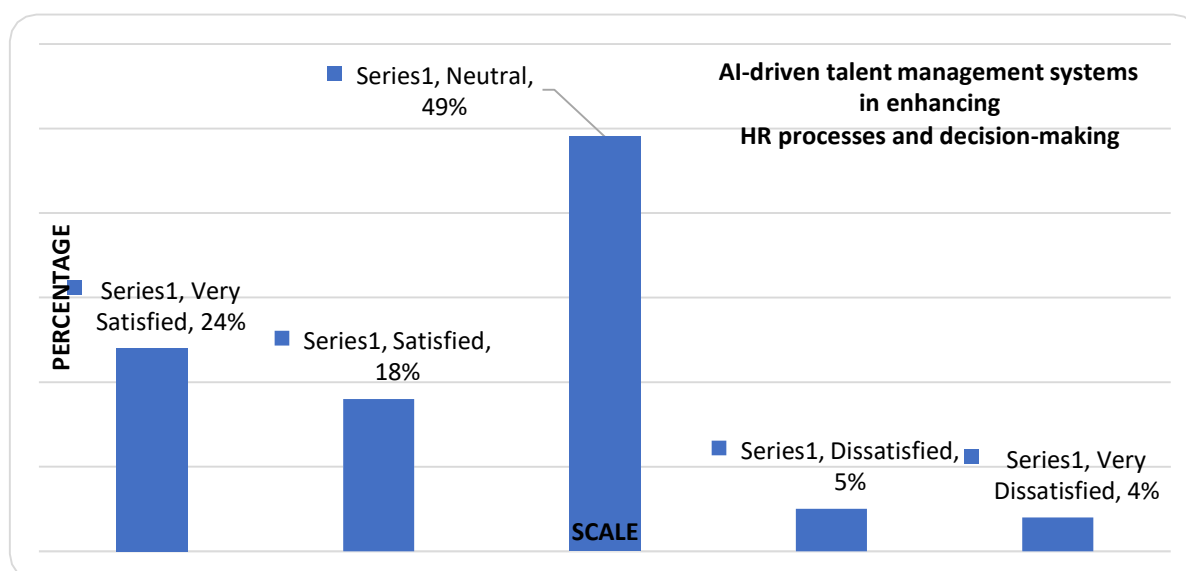
group of 20% felt neutral about the issue, while only 8% (5% + 3%) considered it less important or not important at all. This suggests that most people involved in AI research prioritize ethics and theory, with a small minority either indifferent or unconcerned about these aspects.

TABLE: 4.1.18 AI-driven talent management systems in enhancing Human Rights processes and decision-making

SCALE	NO. OF. RESPONDENTS	PERCENTAGE
Very Satisfied	24	24%
Satisfied	18	18%
Neutral	49	49%
Dissatisfied	5	5%
Very Dissatisfied	4	4%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.18



INTERPRETATION:

The survey results indicate that 24% of respondents are "Very Satisfied" with AI-driven talent management systems in enhancing HR processes and decision-making, while 18% are "Satisfied." A larger portion, 49%, feels "Neutral" about these systems, suggesting they neither strongly approve nor disapprove of them.

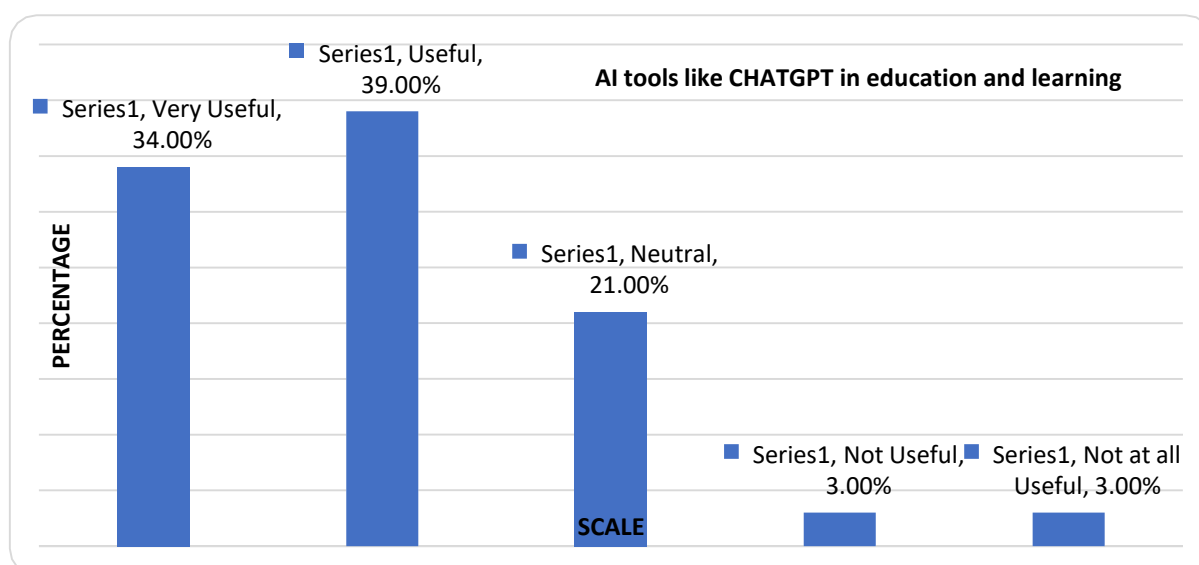
Only 5% of respondents are "Dissatisfied," and 4% are "Very Dissatisfied." Overall, most respondents seem to have a neutral or positive view of AI-driven talent management systems, with a small minority expressing dissatisfaction.

TABLE: 4.1.19 how useful is AI tools like CHATGPT in education and learning?

SCALE	NO.OF.RESPODENTS	PERCENTAGE
Very Useful	34	34.%
Useful	39	39.%
Neutral	21	21.%
Not Useful	3	3.%
Not at all Useful	3	3.%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.19



INTERPRETATION:

The data shows that AI tools like Catgut are generally seen as helpful in education and learning. A total of 73% of respondents (34% saying "Very Useful" and 39% saying "Useful") find them beneficial. About 21% of people feel neutral, meaning they neither agree nor

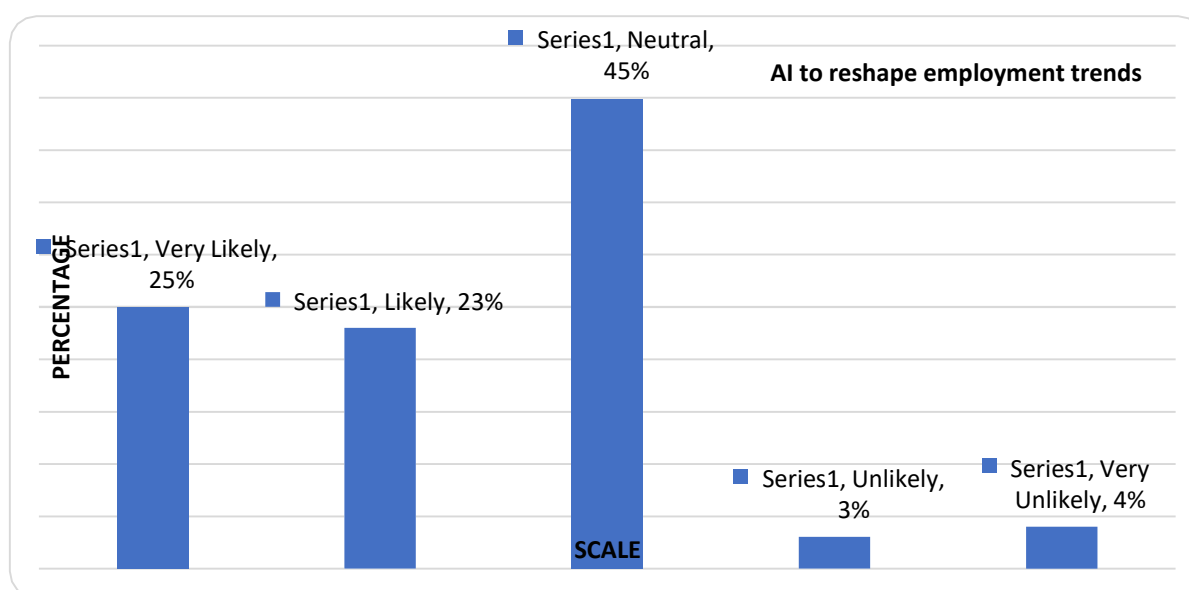
disagree with their usefulness. Only a small portion—6% in total (3% saying "Not Useful" and 3% saying "Not at all Useful")—do not find them helpful. This suggests that most people have a positive view of using AI tools like Catgut in education.

TABLE: 4.1.20 AI to reshape employment trends

SCALE	NO. OF. RESPONDENTS	PERCENTAGE
Very Likely	25	25%
Likely	23	23%
Neutral	45	45%
Unlikely	3	3%
Very Unlikely	4	4%
TOTAL	100	100%

Source: Primary Data

Figure 4.1.20



INTERPRETATION:

The survey results suggest that most people are uncertain about the impact of AI on employment trends. 25% of respondents believe it is very likely that AI will reshape employment, while 23% think it's likely. However, 45% of respondents are neutral, indicating they are unsure or don't have a strong opinion

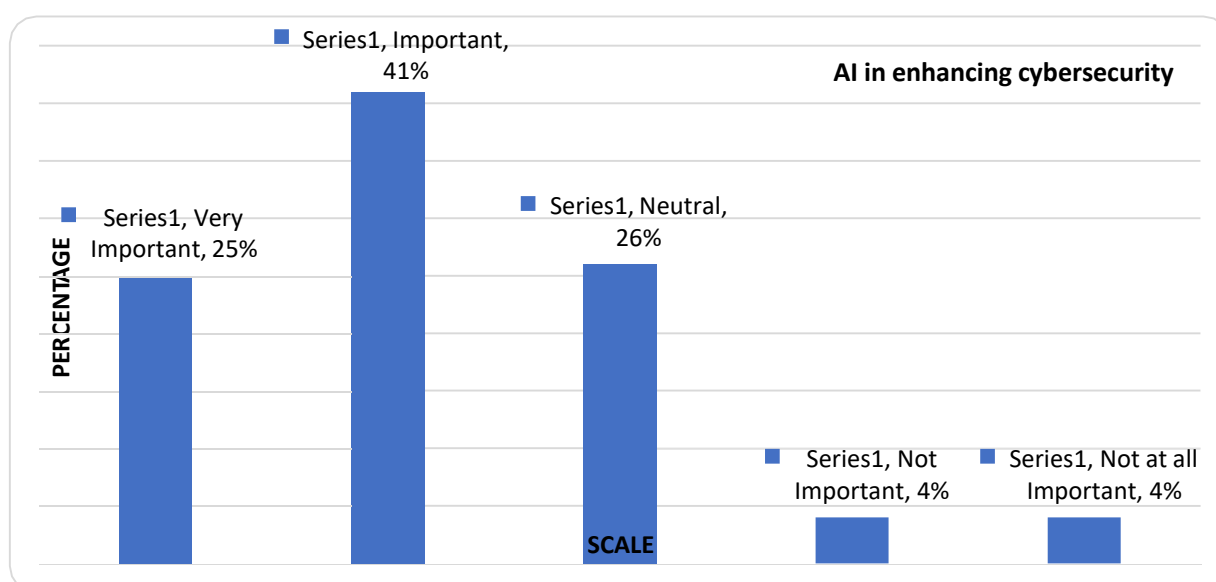
on the matter. Only a small percentage, 3%, thinks it is unlikely, and 4% believe it is very unlikely that AI will have a significant impact on employment trends. Overall, the majority of people are either positive or neutral about AI's influence on employment.

TABLE: 4.1.21 AI in enhancing cyber security

SCALE	NO.OF RESPONDENTS	PERCENTAGE
Very Important	25	25%
Important	41	41%
Neutral	26	26%
Not Important	4	4%
Not at all Important	4	4%
TOTAL	100	100%

Source: Primary Data

Figure 4.21



INTERPRETATION:

The survey results show that most respondents believe AI plays a crucial role in enhancing cyber security. Specifically, 25% of respondents consider it very important, while 41% think it is *important*. A smaller portion, 26%, feels neutral

about AI's impact on cyber security. Only 4% of respondents believe AI is *not important*, and another 4% feel it is *not at all important*. Overall, the majority of participants recognize the significance of AI in improving cyber security.

CHI – SQUARE

TABLE 4.1.22 AI adoption in today's technological landscape

PARTICULAR	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree	TOTAL
male	16	33	8	3	2	62
female	10	20	7	0	1	38
total	26	53	15	3	3	100

The Chi Square denoted by χ^2 . The Chi-Square formula is:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where

O_i = Observed value (actual value)

E_i = Expected value

SOLUTION:

OBSERVED	EXPECTED	$O_i - E_i$	$(O_i - E_i)^2$	$(O_i - E_i)^2/E_i$
16	16.12	0.12	0.0144	8.933
10	9.88	0.12	0.0144	1.457
33	32.86	0.14	0.0196	5.964
20	20.14	0.14	0.0196	0.00097
8	9.3	1.3	1.69	0.181
7	5.6	1.4	1.96	0.35
3	1.86	1.14	1.29	0.693
0	1.14	1.14	1.29	1.131
2	1.86	0.14	0.0196	0.010
1	1.14	0.14	0.0196	0.017

ANSWER Chi Square = 18.73

HYPOTHESIS TESTING

H0: There is no significant difference between AI is the main force behind today's global tech innovations.

H1: There is a significant difference between AI is the main force behind today's global tech innovations.

CHI SQUARE TEST

SIGNIFICANT LEVEL	5.0%
DEGREE OF FREEDOM	4
TEST STATISTIC	18.73
P VALUE	0%
CRITICAL VALUE	9.488

INTERPRETATION: Level of Significance = 5%

Since the calculated value is greater than the table value. So, the Null hypothesis is rejected therefore alternative hypothesis is accepted for How The Artificial Intelligence (AI) is being accepted, implemented, and integrated into different industries, businesses, and daily life in the current era of technology. The test implies that AI is perceived differently by different groups, and this difference is statistically meaningful. Organizations and policymakers should consider these differences when promoting AI technologies, as acceptance and enthusiasm may differ across demographics.

TABLE: 4.1.23 how likely is AI to reshape employment trends.

Particular	Very Likely	Likely	Neutral	Unlikely	Very Unlikely	TOTAL
male	11	26	15	2	4	58
female	12	19	10	1	0	42
total	23	45	25	3	4	100

SOLUTION:

OBSERVED	EXPECTED	O _i - E _i	(O _i - E _i) ²	(O _i - E _i) ² /E _i
11	13.34	2.34	5.4756	0.410
12	9.66	2.34	5.4756	0.566
26	26.1	0.1	0.01	3.831
19	18.9	0.1	0.01	5.291
15	14.5	0.5	0.25	0.0172
10	10.5	0.5	0.25	0.0238
2	1.74	0.26	0.0676	0.0388
1	1.26	0.26	0.0676	0.0536
4	2.32	1.68	2.8224	1.2165
0	1.68	1.68	2.8224	1.68

Answer Chi Square = 13.1279

HYPOTHESIS TESTING

H₀: There is no significant difference between AI is Changing Jobs.

H₁: There is a significant difference between AI is Changing Jobs.

CHI SQUARE TEST

SIGNIFICANT LEVEL	5.00%
DEGREE OF FREEDOM	4
TEST STATISTIC	13.1279
P VALUE	0%
CRITICAL VALUE	9.488

INTERPRETATION: Level of Significance = 5%

Since the calculated value is greater than the table value. So, the Null hypothesis is rejected therefore alternative hypothesis is accepted. Artificial Intelligence (AI)

change the way people work, the types of jobs available, and the skills needed in the job market. The Data supports the Idea that AI is widely seen as likely to reshape job trends (changing the way jobs are

created, lost, or transformed including what skills are needed and which industries grow or shrink). But this belief is not uniform across all groups.

CHAPTER -5

5.1 Findings

The study on AI adoption and its impact on various industries and daily life reveals several key insights.

- The study shows that 55% of respondents are male, while 45% are female, indicating a slightly higher representation of males.
- The majority of respondents (65%) are between the ages of 18 and 25, followed by 13% between 46 and 60 years old, and 12% between 26 and 35 years old.
- The survey highlights a diverse educational background, with 35% of respondents holding a Bachelor's Degree, 16% having primary school education, and 6% possessing a Doctorate or PhD. Notably, 35% of respondents fall into the "Other" category.
- The study shows that 39% of respondents are students, 32% are private sector employees, and 19% are self-employed. A smaller percentage (7%) are unemployed, and 3% fall under the "Other" category.
- The majority of respondents (71%) are single, followed by 27% who are married, and 2% who are widowed.
- The survey reveals that 27% of respondents prefer not to disclose their annual income, while 23% earn between ₹10,000 and ₹30,000 annually. The remaining respondents are distributed across other income categories.
- The study shows that 78% of respondents believe AI adoption is important or very important in today's technological landscape. that most people view AI as essential for progress.
- The survey reveals that 61% of respondents use AI always or often in business decision-making, indicating its significant role in the industry.
- Opinions are mixed on AI's impact on economic growth and productivity, with 36% agreeing it's significant, while 26% disagree. While many see AI as beneficial, there are also notable concerns.
- The analysis shows that 70% of respondents believe AI adoption is important or very important for enhancing a country's global competitiveness. The significance of AI in improving a nation's competitiveness.
- The study finds that 52% of respondents see AI as useful or very useful in predictive analytics for business and industry transformation. This indicates a

recognition of AI's potential benefits in this area.

- The survey reveals that 46% of respondents believe AI is useful or very useful in driving innovation across various fields. This suggests that many see AI as a valuable tool for innovation.
- The analysis shows that 49% of respondents are neutral about AI's potential to contribute positively to environmental sustainability and societal well-being. This indicates a level of uncertainty or indifference about AI's impact in this area.
- The study highlights that 72% of respondents consider ethical considerations and theoretical foundations important or very important in AI research. This emphasizes the need for prioritizing ethics in AI development.
- The survey finds that 73% of respondents find AI tools like ChatGPT useful or very useful in education and learning. a positive view of AI's role in enhancing educational experiences.
- The analysis reveals that 45% of respondents are neutral about AI's impact on employment trends, while 48% believe it's likely or very likely to reshape job trends. This indicates a mix of opinions on AI's influence on the job market.
- The study shows that 66% of respondents believe AI is important or very important in enhancing cybersecurity. the recognition of AI's role in improving cybersecurity measures.

5.1 Findings

The study finds that 52% of respondents see AI as useful or very useful in predictive analytics for business and industry transformation. This indicates recognition of AI's potential benefits in this area.

The analysis reveals that 45% of respondents are neutral about AI's impact on employment trends, while 48% believe it's likely or very likely to reshape job trends. This indicates a mix of opinions on AI's influence on the job market.

The study on AI adoption and its impact on various industries and daily life reveals several key insights.

5.2 RECOMMENDATION AND SUGGESTION:

- Increase Awareness and Education: Recognize AI's role in shaping modern technology.
- Focus on Ethical Considerations: Prioritize ethics and theoretical foundations in AI development.
- Invest in AI-Driven Predictive Analytics: Help organizations make informed decisions and drive innovation.
- Enhance Cybersecurity Measures: Prioritize AI-driven cybersecurity measures to protect against potential threats.
- Promote AI Adoption in Education: Use AI tools like ChatGPT to enhance learning outcomes.
- Address Job Trends: Provide training and upskilling programs to address mixed opinions about AI's impact on employment.
- AI adoption is crucial for progress and innovation in various industries.
- Encourage further research and development in AI to address uncertainty.

- Leverage AI for environmental sustainability and societal well-being.
- Develop and implement AI-driven solutions in education, Human Rights, and cybersecurity.

5.3 CONCLUSION

Artificial intelligence (AI) is driving numerous technical developments and influencing global trends, including the metaverse, environmental sustainability, and corporate intelligence. Its impact on labor markets, financial systems, organizational dynamics, and economic growth is significant. AI has emerged as a significant driver influencing employment trends, with job creation, productivity increases, job displacement, and workforce restructuring. Its interdisciplinary nature, incorporating elements from computer science, cognitive science, philosophy, and social sciences, has impacted its development and governance. AI has revolutionized

product management, operations management, supply chain management, and Industry 4.0, and has become increasingly a multidisciplinary discipline.

During this research, it was found that AI adoption is crucial for progress and innovation in various industries and daily life. By prioritizing ethics, investing in AI-driven predictive analytics, enhancing cybersecurity measures, promoting AI adoption in education, and addressing concerns about job trends, organizations and policymakers can ensure responsible and beneficial AI adoption.

From this research following conclusions can be drawn:

1. Majority believe AI improves decision-making, data analysis, and innovation.
2. AI is useful in cybersecurity, Human Rights, and education.
3. Artificial Intelligence's impact on economic growth, employment, and environmental sustainability
4. Despite strong support, there's uncertainty and room for more public awareness.
5. Overall, Artificial Intelligence is essential for progress and competitiveness.

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Factors Influencing Meta-Banking Adoption: An Empirical Analysis

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Abstract

Purpose: The financial advisory industry has entered an artificial intelligence (AI) phase, and these recent advancements in information systems are revolutionizing the digital financial services landscape. The rapid growth of AI is transforming how users access financial services through the metaverse to swiftly address inquiries and provide customized solutions. Thus, the current research uncovers the determinants of users' intentions to adopt the metaverse in banking.

Design/methodology/approach: The study develops a comprehensive framework grounded in the technology acceptance model, enriched by critical constructs such as trust in the automated system, social conformity, and technological self-efficacy. The responses collected from 300 respondents were analysed using partial least squares-structured equation modelling (PLS-SEM), highlighting critical findings.

Findings: Our findings reveal that Trust in the automated technology and social conformity are significant influencers of perceived ease of use (PEU) and perceived usefulness (PU). Trust in the metaverse technology is the strongest predictor of PEU. Additionally, PU, attitude, and technological self-efficacy significantly affect behavioural intention towards using metaverse. PU is the stronger predictor of intention to use a metaverse.

Practical implications: The findings of the study support developers and help financial services managers refine their service offerings efficiently. The results strongly clarify customers' intentions to adopt metaverse and provide actionable insights for companies aiming to integrate these technologies into their service offerings.

Originality/value: The current study is marked as one of the initial endeavors that substantially contribute to the artificial intelligence finance literature by proposing and testing a novel conceptual framework based on the technology acceptance model (TAM), examining the adoption of metaverse. The study highlights that technology self-efficacy, trust in automation technology, and social conformity are key drivers of the adoption of metaverse in banking.

Practical Implication: The findings hold substantial implications for entrepreneurs and managers. By understanding these determinants, they can better assess and optimize metaverse performance. The research contributes to academic discourse and offers practical strategies for leveraging AI to improve consumer experiences in the financial sector.

Key words: Artificial Intelligence; Technology acceptance model; Metaverse; financial services; Trust; Technology; Social Conformity

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Abbreviations

Percieved usefulness – PU; Percieved ease of use – PEU; Behavioural intention to use – BI; Trust in Automated Technology – TRS; Attitude – AT; Social Conformity – SN; Technological Self-Efficacy – TSE; Actual System use - AU

Introduction

The technological advancements in internet have led to enhanced usage of Artificial intelligence (AI) in routine decision making in the recent years (Flavián et al., 2022). The AI technology is unique as it has the potential to imitate human like thinking ability as it can learn and solve the problem that requires human intelligence (Mou, 2019). AI-enabled products such as autonomous vehicles, metaverses, voice-activated devices, and digital assistants have significantly altered human routines by usurping mundane tasks (Dorotic et al., 2024). This transformation witnessed profound impact on various domains such as online shopping (Gursoy et al., 2019), travel and tourism (Pillai & Sivathanu, 2020a), higher education and learning (Albayati, 2024) and more. Adopting AI-driven applications is motivated by their capacity to enhance decision-making through personalized recommendations, information retrieval, skill acquisition, and interactive interfaces (Bhattacharya, 2023; Davenport et al., 2020). Nevertheless, responses to AI adoption vary widely, reflecting a spectrum of

attitudes from enthusiastic acceptance to cautious scepticism (Brüns & Meißner, 2024; Frank et al., 2023; Hasan et al., 2021).

Currently, the global AI market is expected grow with CAGR of 25% to reach \$738.76 billion by 2030 (Statista, 2023). Its impact has penetrated into various sectors and it has primarily impacted economy (Lee, 2022). AI has demonstrated its utility across diverse fields such as healthcare, e-commerce, and finance and is now establishing a significant advantageous presence in investment. (L. Cao, 2023; Chua et al., 2023; Esmacilzadeh, 2020; Wang et al., 2023). Amidst the burgeoning complexity of global capital markets and the increasing sophistication of stock exchanges, firms worldwide are progressively seeking public listings. This evolution presents investors with unprecedented opportunities to harness the capabilities of AI, ranging from high-frequency trading to dynamic asset allocation, thereby leveraging advanced algorithms to capitalize on inefficiencies at the microsecond level (Yue & Au, 2023).

These solutions leverage analytical AI, which possesses the power to process and learn from information, enhancing its problem-solving capabilities (Huang & Rust, 2021). The burgeoning field of AI and machine learning is developing rapidly, catalyzing profound political, economic, and social transformations in developed nations (Fotheringham & Wiles, 2023). Metaverse, AI-driven solutions, can help address the challenges and provide tailored guidance for sustainable financial investments (Shanmuganathan, 2020). Moreover, these metaverses are increasingly recognized as pivotal game-changers, facilitating expanding cost-effective financial service access (Kshetri, 2021).

The progression of human-AI interaction research continues to gain traction. However, there is low penetration rate of metaverse among investors in emerging economies (Belanche et al., 2019; Jung et al., 2018). Also, evidences that investor buy based on machine-based recommendations has been diverse (Chua et al., 2023; Flavián et al., 2022; Piehlmaier, 2022; Rossi & Utkus, 2020). The literature has thus far allocated relatively little attention to investor perceptions regarding applying metaverse to investments within emerging economies (Manrai & Gupta, 2023; Nain et al., 2024). Further research in this domain shall enhance scholarly understanding and enrich existing literature. Thus, the study identifies the major gaps. First the understanding of psychological mechanism of how users decide to accept metaverse is not very well understood. Second, a limited literature is available in context to investors in emerging economies context. To address this challenge, the study builds on the

literature on user behaviour towards technology and understands how users are using metaverse into their personal banking. The financial services industry has embraced components of client communication strategies. These sophisticated AI-driven systems facilitate seamless client interaction by promptly addressing inquiries and providing comprehensive responses, tracking transaction, enabling efficient monitoring of financial activities, task automation, financial advisory, assessing creditworthiness of customer and alerting customers in the event of potentially suspicious transactions.

Experts in AI adoption widely recommend the Technology Acceptance Model (TAM) as an appropriate framework. (Al-Emran & Granić, 2021; Niu & Mvondo, 2024; Wang et al., 2023). To address the research gap, we utilise TAM to elucidate the intention to use metaverse. TAM, widely recognised and extensively researched in user acceptance literature TAM (Davis, 1989, 1993), effectively captures and explains user motivation. TAM is designed to illustrate the causal relationship between technology design and its utility (Davis & Venkatesh, 2004). Rooted in psychological intention models such as the "*Theory of Reasoned Action*" and the "*Theory of Planned Behavior*", TAM posits that intention to use is the most accurate predictor of actual behaviour. This robust framework has been validated by numerous studies across diverse fields, including e-learning (Al-Emran & Teo, 2020), mobile payment (Di Pietro et al., 2015)(Di Pietro et al., 2015), wearable technologies (Arpaci et al., 2021), consistently demonstrating a strong link between intention and behaviour. The

widespread application of TAM demonstrates its versatility and potential for modification and extension across many applications and domains (Wang et al., 2023). Therefore, utilizing TAM in the context of metaverse provides a robust framework to understand and predict user adoption behavior.

Prior research on user technology acceptance consistently shows that attitude predicts behavioral intention to engage in technological innovation (Abroud et al., 2015; Kejela & Porath, 2022). Therefore, a positive attitude towards metaverse will enhance acceptance significantly. In the current framework, we hypothesize that users with greater awareness of metaverse are likelier to engage with these innovations (Flavián et al., 2022; Mutahar et al., 2018). Despite its importance, TSE is a crucial variable that has been explored to a limited extent. This exploration assumes that users are fully informed about existing technology (Vinuesa et al., 2020). Further, the paper proposes that trust in the system and social conformity important to be studied based on fairness and usefulness of metaverse and is assumed to be positively associated with perceived usefulness and perceived ease of use (Amin et al., 2014; Hansen et al., 2018). The user willing to boost their analytic and decision-making ability using metaverse can realise the same through favourable attitude towards such technology (Cao et al., 2021). It is proposed in the current paper that attitude is positively related to behavioural intention.

AI has emerged as a transformative technology that is becoming the need of financial planning with its ability to

uncover non-evident relationships from massive data and even detect sentiments from textual information (M. Chen et al., 2023). Complementing this framework, we submit that customers familiar with metaverse and AI-enabled investment applications are likelier to use these innovative services. Therefore, we focus on participants with prior investment experience and exposure to AI tools. This paper endeavors to develop and empirically validate a conceptual model that explores the behavioral inclination towards adopting metaverse, highlighting dimensions such as attitudes, technological Self-Efficacy, trust in automated technology, and social conformity. The study investigates investors' current intentions in the stock market by analyzing 387 responses to test hypotheses and derive generalizable conclusions. The study aims to address the following objectives:

1. To examine the factors that lead to the usage of metaverse.
2. To propose an expanded model for the adoption of metaverse in the realm of financial services.

The paper holds significant value for both theory and practice. First, it addresses an empirical investigation into the adoption of prototypical analytical AI tools within the context of a developing country, a topic that has been explored to a limited extent in the literature. Second, it extends the TAM to assess the readiness of investors to embrace autonomous technologies, such as metaverse. Lastly, the study emphasizes user TSE as a critical factor in assessing the intention to use the metaverse. These findings deepen our understanding of how investors make decisions regarding metaverse and offer

valuable practical insights for managers to develop effective strategies for successfully introducing these innovations.

The remainder of the paper is structured as follows: Section II reviews the relevant literature on AI tools and TAM, establishing hypotheses for the research model that explain user intention to adopt analytical AI tools. Section III details the methodology for data collection and validates the measurement instruments employed. Section IV presents the empirical analysis results. Finally, in Section V, we discuss the main conclusions drawn from the study, along with theoretical and practical implications, limitations, and directions for future research.

2 Review of Literature

2.1 Theoretical Background

2.1 Metaverse adoption

The AI-driven interfaces, which leverage machine learning, facilitate seamless information exchange through natural language conversations (Euchner, 2023). Metaverses are widely recognized for demonstrating intelligence comparable to humans (Kaplan & Haenlein, 2019). The COVID-19 pandemic accelerated their adoption, leading to a surge in research exploring metaverse performance, particularly consumer responses to this technology. The literature underscores metaverses' significant role in business and consumer studies. Recently, Polyportis & Pahos (2024) investigated metaverse adoption by students at Dutch higher education institutions highlighting the

need for further research in diverse cultural contexts to better understand global technology acceptance patterns. Cai et al. (2022) and Scarpi (2024) examined metaverse adoption in travel and tourism industry in China and Italy inferring that informational competency of metaverse enhances tourist experience. Liew et al., (2023) studied adoption intention for health information in Malaysia submitting that distinct features and design of metaverse influence the user perception. Yigitcanlar et al., (2023) explored the opinion of city managers for metaverse adoption in public services in Australia. As demonstrated in these studies the adoption of metaverse can enhance the user experience. Lately, Fotheringham & Wiles, (2023) advanced research on AI metaverse announcements on investors in USA demonstrating investors respond positively to assistants when they identify it with themselves. These studies highlight the potential of metaverses to elevate user experiences, driving their adoption in diverse contexts. However, as this technology is still evolving, there is a compelling need for further exploration, especially within the dynamic landscapes of emerging economies.

2.2 Applications of TAM in Metaverse and other artificial intelligence contexts

TAM is a fundamental framework in information systems and is widely adopted to analyze factors influencing technology adoption (Tao et al., 2020). Rese et al. (2020) assert that TAM, grounded in utilitarian constructs, provides a stronger explanation for usage intentions than models emphasizing hedonic factors. Numerous studies apply TAM to explore beliefs and behaviours in metaverse

adoption, often incorporating external variables (Lai et al., 2023; Manser Payne & O'Brien, 2024; Pillai & Sivathanu, 2020). For instance, de Andrés-Sánchez & Gené-Albesa (2024) find that trust, perceived ease of use (PEU), and perceived usefulness (PU) significantly predict policyholders' attitudes toward metaverse usage in Spain, with attitude strongly influencing intention. Similarly, research on metaverses in hotels (Liu et al., 2023; Pillai & Sivathanu, 2020) and digital devices (Ahn, 2023) identifies PU, PEU, and anthropomorphism as key factors shaping consumer attitudes.

Al-Abdullatif (2023) extends TAM to examine metaverse adoption among university students in Saudi Arabia, demonstrating that perceived enjoyment and PEU significantly influence perceived value, which in turn drives adoption. D. Zhang & Zhao (2024) apply an extended TAM to virtual medical consultation systems, revealing that PU is the strongest driver of intention, while resistance negatively impacts intention, and quality of response positively correlates with PU.

Despite these insights, recent studies have overlooked the effects of social conformity, technology self-efficacy, and trust in automated technology as external variables.

2.3 Theoretical Framework

The advancement of technology has transformed financial advisory services, transitioning from labor-intensive to AI-intensive approaches (Fulk et al., 2023). This evolution is increasingly becoming a primary avenue for users to engage and

communicate with service providers. User interaction and perception, facilitated through this interface, constitute a crucial aspect of the service encounter. The factors shaping user experiences and behaviours during service interactions highlight the significance of user technology adoption of AI-powered financial advisory services i.e. metaverse. This concept encompasses a broad spectrum of interactions, including a customer's initial engagement with a service provider, product, or service (Zhu et al., 2024).

The comprehension of user adoption concerning new technology presents a multifaceted process, defying categorization within a singular paradigm (Manrai & Gupta, 2023). Enhancing understanding of phenomena necessitates the integration of pivotal constructs that influence a particular technology into established models. Previous investigations indicate that users interact with metaverse in distinct ways compared to traditional financial services (Sheth et al., 2022). In contrast to conventional technologies like self-service systems, metaverse operates autonomously or with minimal human intervention, frequently assuming human roles (Jarrahi, 2018).

AI adoption in financial services, exemplified by robo-advisors and metaverse, has attracted significant attention, fueled by the rapid growth in the retail investment market, particularly amidst the COVID-19 pandemic (Ben-David & Sade, 2019). Integrating metaverse into banking and investment services presents unique challenges and opportunities, underscoring the importance of understanding how

investors engage with AI-driven platforms (Dwivedi et al., 2021). Different scholars have examined the intention to adopt AI in financial advisory (Atwal & Bryson, 2021; Belanche et al., 2019; Flavián et al., 2022). There are various lines of inquiry regarding AI in financial advisory. One line of inquiry focuses on design aspects, such as explainable AI. The ability of AI to explain the rationale behind its algorithms is positively related to user trust and can lead to increased usage (Deo & Sontakke, 2021). The control user experience in automated services like metaverse have positive impact on AI adoption (Kwon et al., 2022). Further, second direction of research on AI in financial advisory is related to user characteristics such as user attitude and behaviour, technology related factor and risk propensity of customer affect their decision to interact with AI (Chang & Wang, 2023; Fulk et al., 2023). Age and gender of the user are also significant to the TSE (Nourallah et al., 2023; Seiler & Fanenbruck, 2021). Additionally, the third line of research is the service encounter i.e. metaverse in service context. The interaction between human and metaverse for financial investments are complicated due to the limited timeline of the decision and level of risk involved in the service (Zhu et al., 2024).

Despite the increasing interest in metaverse for banking, some authors argued that customer are less enthusiastic for them and prefer the traditional mode for making their investment (Jung et al., 2018) as users are hesitant to embrace AI (Belanche et al., 2020). The emotional connect, empathy and ability to maintain client relationship is an important aspect

of the financial advisory that metaverse lacks during the service encounter with user (Bhatia et al., 2021). Also, metaverse are criticised for individualisation while recommending portfolio as they ignore significant variables leading to generic portfolio advices to users that results in limited economic benefit (Scherer & Lehner, 2023). Since the previous literature on metaverse adoption is mixed and inconclusive, further research is required to provide more precise and more comprehensive insights.

Additionally, most enquiries in the scholarship are in developed nations and limited attention has been paid to emerging economies. Given the increasing importance of AI in investment strategies, there is a pressing need to study the adoption of metaverse among investors in emerging economies (Chatterjee, 2020).

This study combines the TAM framework with social conformity, trust in automated technology, and TSE to analyze the intention to use metaverse. TAM, developed by Davis (1989) and Davis et al. (1993), evaluates attitudes towards technology through perceived usefulness, perceived ease of use, attitude, and behavioral intention to adopt technology. Due to its concise structure and power to explain user behaviour, TAM has been one of widely used framework to examine utilisation of information system. TAM framework has been extended by incorporating various external variables. The extended TAM accurately understands and reveals acceptance process of users with acceptable reliability and validity of framework (Zeng et al., 2024). The extended TAM framework has also been applied in financial advisory to

study the usage of latest technological developments (Belanche et al., 2019; Kwon et al., 2022). However, the application of TAM framework in the financial advisory studies are sporadic and AI-tools have recently emerged and not have been studied sufficiently.

Advancing the discourse from the issue delineated previously, the TAM framework is preferred because it focuses on assessing an individual's willingness to embrace technology, unlike the UTAUT framework, which is designed for organizational use (Rondan-Cataluña et al., 2015). This choice aligns with our study's focus on individual user perceptions, making TAM the more suitable model. Furthermore, the TAM model is especially recommended for scenarios where technology adoption is in its early stages (Sánchez-Prieto et al., 2017), such as in developing countries like India, where AI tools are currently being introduced. Therefore, employing the TAM framework is considered appropriate for this study.

In the context of metaverses, which provide financial advice and investment management services, trust in the automated system and social conformity are pivotal for adoption. Existing research underscores the significance of social conformity or influence in the early stages of technology innovation (Taylor & Todd, 1995). As knowledge has evolved, it has been recognized that social influence is increasingly complex and dependent on contextual factors (Venkatesh et al., 2003). The advent of complex technologies, dynamic market trends, and cultural norms significantly shapes user intentions, driven mainly by social

conformity and trust. These elements are found to be essential for the adoption of various technologies, including e-commerce websites (Kim et al., 2009), information system (Li et al., 2008) and internet banking (Alsajjan & Dennis, 2010). In realms of artificial intelligence, early-stage research indicates that social influence and trust are crucial for adopting website recommendation systems (Martínez-López et al., 2010) and robots (Tay et al., 2014). Further research is needed to confirm the critical roles of social conformity and trust in automated technology.

2.4 Hypotheses Formulation

This section delineates the hypotheses from an exhaustive literature review, emphasizing the relevance of investigating metaverse adoption among investors.

2.4.1 Trust in the Automated technology

Trust, as defined by (Mayer et al., 1995), encompasses one party's vulnerability to another's actions based on the expectation of specific behaviors. In this study, trust refers to the user's reliance on metaverse for decision-making (Ferrario et al., 2020). Trust serves as a prerequisite for users to perceive a product or service as valuable, as lack of trust renders it non-utilitarian for them (Gefen et al., 2003). In context to automated technology, the system should be not be spurious i.e. secure as compared to traditional, dependable i.e. give better financial results and has integrity i.e. it is sincere and honest (Jian et al., 2000). Other factors contributing to establishing trust in the

systems include the institutional infrastructure overseeing security and privacy measures (Felzmann et al., 2019). It implies that users of automated technology, like metaverse, are likely to have confidence in the credibility and security of their information. The AI tools designed for recommendation purposes, the intention to accept machine-generated advice hinges closely on perceived usefulness, which depends on the user's trust in the technology (Benbasat & Wang, 2005; Wang et al., 2023). Examining trust and perceived usefulness is crucial, given the growing concerns about how AI algorithms align with the foundational principles of credibility, equity, and efficacy (Bostrom et al., 2023). Trust plays a pivotal role in mitigating uncertainties inherent in consumer decision-making processes, thereby engendering a sense of assurance conducive to the adoption and utilization of novel technological innovations (Paul A., 2003). Trust additionally serves to assure users of favourable outcomes, instilling confidence in their expectations (Beldad et al., 2010). Thus, the study assumes that trust is positively linked to perceived usefulness that leads to behavioural intention.

H1a: TRS in metaverse is positively associated with PU.

Users exhibit a higher propensity to adopt technology which is simple, trustworthy and intuitive, as it minimizes the time required for comprehension and utilization (Gerli et al., 2022). Perceived ease of use reflects the user's belief that a system requires minimal mental effort (Davis, 1989). Trust encompasses users' perceptions and evaluations of a

company's commitment to meeting their expectations and requirements, measuring the organization's integrity and sincerity (Jatimoyo et al., 2021). Trust can be broadly categorized into trust in the service and trust in the service provider (Manrai & Gupta, 2023). Trust and perceived ease of use are critical in stock market investment (Chong et al., 2021), as users are more likely to trust new technology when they perceive it as offering added benefits (Wang et al., 2023). This suggests that a metaverse should deliver a low-risk, profitable portfolio at a lower cost, with greater transparency than traditional systems, while being executable and understandable (Reher & Sun, 2016). The study asserts a positive association between trust and perceived ease of use.

H1b: TRS in metaverse is positively associated with PEU.

2.4.2 Social conformity

Our behavior and decisions are constantly shaped by the reference groups in our social environment, comprising family, friends, peers, and even individual with whom we have no direct connection (Cherchi, 2017). Kelman (1958) proposed social influential theory and distinguished the social influence or conformity in compliance, identification and internalisation. Social conformity entails the perceived pressure on individuals to engage in specific behaviors and their motivation to comply with the pressure (Fishbein & Ajzen, 1977). Social conformity reflects the social support provided by referents such as family, friends, and colleagues, influencing the user's perception (Schofield, 1975). It signifies

the user's inclination to engage in activities similar to those of other social group members. Users assess the usefulness of technology based on the experiences and opinions shared within their social network (Legris et al., 2003). Social conformity has been extensively studied in the TAM context to elucidate technology (Venkatesh & Davis, 2000). Previous literature has highlighted social conformity as an important determinant of perceived usefulness (Izuagbe et al., 2019; Yi et al., 2006) and perceived ease of use (Chen & Aklikokou, 2020). Moreover, Hertz & Wiese (2018) asserted that social conformity positively correlates with adopting metaverses, with higher conformity observed for analytical tasks than social tasks. Social conformity's effect on perceived usefulness was initially proposed by (Karahanna & Straub, 1999; Terzis & Economides, 2011). Additionally, social conformity positively impacts perceived ease of use (Abdullah & Ward, 2016). As an individual, the suggestion of social network could be detrimental in the adoption of AI-tools (like metaverse) (Wang et al., 2023). User's decision frequently hinges on personal and social perceptions, with the acceptance of conduct often shaped by the influence of close relationships (Khani Jeihooni et al., 2021). It suggests Social conformity influences intentional behavior. Additionally, it plays a pivotal role in shaping users' perceptions of the ease of use of metaverse (Chen & Aklikokou, 2020). Therefore, we posit a positive relationship between social conformity, perceived usefulness, and perceived ease of use.

H2a: SN is positively related to PU.

H2b: SN is positively related to PEU.

2.4.3 Technology Acceptance Model

TAM, initially proposed by Davis (1989, 1993), remains one of the most prominent theories in information system research. It draws from the theory of reasoned action (Fishbein & Ajzen, 1977) and posits that perceived ease of use, perceived usefulness, attitude, and behavioral intention collectively predict actual technology usage. Since its inception, TAM has undergone numerous refinements and expansions (Abdullah & Ward, 2016; Davis & Venkatesh, 2004; Saif et al., 2024; Venkatesh & Davis, 2000) enhancing its applicability across various contexts. The theory offers a structured framework for understanding technology adoption, emphasizing the importance of individual perceptions in determining the perceived utility and ease of use of technology (Davis, 1993).

The theory elucidates the tangible application of technology, attributing it to behavioural intentions, which are delineated as the determinants prompting users to engage with the technology. It represents an individual's intrinsic impetus that propels them towards specific actions. It is a prominent determinant guiding individuals towards utilization (Luarn & Lin, 2005; Wang et al., 2023). Consequently, individuals engage in activities due to the impetus provided by their behavioural inclinations, directing their actions towards various objectives (He et al., 2021).

The behavioural intention of a user is contingent upon their attitude, which comprises the internalized positive

behaviours resulting from a synthesis of various favourable experiences with a particular product or service (Fishbein & Ajzen, 1977). These encounters act as guiding catalysts, inciting users to interact with the product or service actively (Park, 2009). The model hypothesis posits that a user's attitude towards a technology is pivotal in determining its acceptance or rejection. Consequently, attitude and behaviour are observed directly and closely intertwined (Cao et al., 2021).

The perception of technology is shaped by two critical factors: perceived ease of use and perceived usefulness. *Perceived usefulness* is crucial in determining whether using a system enhances job performance (Davis, 1989). Moreover, perceived usefulness significantly impacts users' intentions to use (Davis, 1993; Davis & Venkatesh, 2004). Technology perceived as applicable often simplifies or automates tasks, reducing user effort. This reduction in effort can foster a positive attitude towards the technology (Zhang et al., 2019). The construct defines the extent to which an individual perceives that using AI will provide benefits.

Perceived ease of use is the extent to which individuals believe technology requires minimal effort (Davis, 1989). Users perceive less cognitive burden and mental effort with technology that is easy to use, fostering a positive attitude (Agarwal & Karahanna, 2000). In TAM, perceived ease of use positively influences perceived usefulness because easier-to-use technology is considered more valuable (Wahid, 2007). Thus, the following hypotheses are suggested:

H3a: PEU has positive impact on PU.

H3b: PEU has positive impact on ATT towards technology

H3c: PU has positive impact on ATT towards technology

H4: PU has positive impact on BI.

H5: ATT has positive has positive impact on BI.

H6: BI has positive impact on AU.

2.4.4 Technological Self-Efficacy

It is a belief on the ability to perform the technology oriented sophisticated tasks influenced by changes in requirements, personal experience, and availability of resources to perform the task (Biswas et al., 2024). As technology becomes integral to routine activities, it is believed that individual need to have confidence not only in their general ability to do their work well but also specific ability to handle technology (Medici et al., 2023). The individual being conscious, having knowledge and having information about technology and its benefits is crucial to usage of technology (Mutahar et al., 2018). The technology acceptance literature underscores the paramount significance to awareness of technology in adopting nascent technological services, notably artificial intelligence, particularly within the finance scholarship (Atwal & Bryson, 2021; Belanche et al., 2019; Norzelan et al., 2024; Pan, 2020). Low TSE emerges as a pivotal factor influencing user non-adoption (Sathye, 1999). User's failure to fully the benefits and drawbacks of technology often stems from lack of awareness (Rahman et al., 2023). More comprehend awareness of the advantages of technology can lead to a higher level of

acceptance and adoption (Mutahar et al., 2018). Individuals with greater knowledge about the services are more aware of their options and more likely to use them than those encountering the service for the first time (Flavián et al., 2022). An individual's TSE is intricately linked with the tapestry

of information they have amassed through research and their own experiences with the technology. Thus, we posit the following hypothesis:

H7: User TSE has positive impact on BI.

3. Methods

3.1 Research Design

A structured questionnaire survey has been administered to investigate the investors embracing metaverse. According to a report by Nasscom, India represents a significant economic epicentre characterized by a higher consciousness and preliminary assimilation of AI amongst the public (PTI, 2023). Additionally, it presents a compelling avenue of inquiry to examine the penetration of AI adoption amongst users after India partnered with the UK, France and Japan during the Global Partnership on Artificial Intelligence Summit, 2023 to ensure safe and trusted AI usage. The survey was conducted with the residents of the national capital territory of Delhi over a period of 4 months. This decision was based on Delhi's status as the capital and its residents' active involvement in stock market investments, making them a suitable representation of the Indian population (Manrai & Gupta, 2023). Respondents were approached using purposive and snowball sampling methods. These methods were chosen due to the lack of a reliable list of stock market investors (Abrams et al., 2017), a common challenge in such studies.

The lead author's institution does not mandate ethical review for this type of research. Nonetheless, the authors implemented three measures to ensure adherence to ethical research guidelines: (a) Providing comprehensive information to respondents about the study, (b) Guaranteeing the confidentiality of both individual and institutional information, and (c) Ensuring voluntary participation in the research.

Before final data collection, the questionnaire was developed in English and scrutinized by two academics with over 15 years of expertise to ensure clarity and minimize ambiguity in the questions, aligning with recommendations (Sekaran & Bougie, 2016). Additionally, the instrument underwent pilot testing with a sample size of 30 respondents, comprising management students and academicians, as Isaac & Michael (1995) suggested.

3.2 Data Collection

The invitation link to the questionnaire was distributed to respondents aged between 20 and 60, ensuring a diverse representation of age groups. Inclusion criteria mandated that respondents possess prior experience in stock market investment and proficiency in reading and

comprehending English. The data collection process followed a systematic approach. Initially, informed consent was obtained from participants per ethical guidelines. Subsequently, respondents were prompted to confirm their prior stock market investment experience through a screening question.

Moreover, participants completed a concise questionnaire detailing their demographic information. Following the removal of partially completed responses and rigorous data-cleaning procedures, a robust dataset comprising 387 responses was obtained. The demographic profile of the respondents is comprehensively presented in Table 1, offering valuable insights into the sample composition.

3.3 Measurement Instrument

The study meticulously selected scales, drawing upon established frameworks from prior literature, a process that was rigorously undertaken to ensure methodological robustness. These scales, elucidated in the appendices, offer a comprehensive overview of the measurement tools utilized in this investigation, underpinning the study's credibility and transparency.

Structured into four discernible sections, the questionnaire adeptly and comprehensively navigated various facets of user perceptions and behaviors. The initial section focused on demographic inquiries, providing crucial insights into the diverse composition of the respondent pool. Section II delved into the intricate dynamics of perceived ease of use,

perceived usefulness, attitude, behavioral intention, and actual usage, affording a holistic understanding of users' cognitive and behavioral responses towards the technology under scrutiny. Further, Section III delved into probing questions concerning the technological Self-Efficacy of metaverse, social conformity, and trust, unraveling nuanced layers of user perceptions and societal influences shaping technology adoption.

The construct of TSE, meticulously crafted from three insightful items, from the work of Holcomb et al., (2004). Measures of SN were ingeniously adapted from the pioneering research of Malhotra & Galletta (1999). TRS, a cornerstone in technology adoption, was meticulously assessed through two discerning items. These items were designed to capture different aspects of trust, synthesizing insights from the scholarly endeavors of Gefen et al. (2003) and Jian et al. (2000). To empower respondents with nuanced expression, all constructs were evaluated on a dynamic five-point Likert scale, enabling participants to articulate their viewpoints with precision, ranging from 1 (strongly agree) to 5 (strongly disagree).

3.4 Analytical Procedure and measure validation

The data are rigorously analyzed using PLS-SEM with SmartPLS 4.0 software to test the model's hypotheses. PLS is chosen for its predictive capability, making it ideal for elucidating the intention to use AI. Renowned for its superior predictive power, PLS, a variance-based SEM, excels in exploring models under varying data distribution assumptions i.e both normality and non-normality data

distribution assumptions (Fornell & Bookstein, 1982)(Fornell & Bookstein, 1982). Additionally, PLS-SEM is free from the recommended number of indicators per construct in comparison to CB-SEM (Anderson & Gerbing, 1988; S. Davcik, 2014; Sarstedt et al., 2022). This analytical method has been extensively utilized in prior research endeavors (Chua et al., 2023; Dawar & Singh, 2022; Flavián et al., 2022).

To validate the measurement model, we first establish convergent validity. All item loadings exceed 0.6 (Malhotra et al., 2006), as shown in Table 2. Both Cronbach's α and composite reliability are above 0.7 (Hair et al., 2019; Nunnally &

Bernstein, 1994), indicating strong internal consistency. The average variance explained (AVE) for each construct exceeds 0.5 (Hair et al., 2019), confirming the model's validity. Discriminant validity, assessed using the heterotrait-monotrait ratio (HTMT), shows all HTMT correlations below 0.9 (Henseler et al., 2015), demonstrating distinctiveness among constructs. The standardized root mean square residual (SRMR) of 0.056, below the 0.08 threshold (Hu & Bentler, 1998) indicates excellent model fit. These results affirm the robustness and reliability of the measurement model.

4. Results

After confirming the model's validity and reliability, we assess multicollinearity using the

variance inflation factor (VIF). All VIF values below 5 indicate no collinearity issues (Hair et al., 2019)(Hair et al., 2019). We also test for normality, with skewness and kurtosis metrics within the +2 to -2 range (Hair et al., 2010), affirming the data's normality.

To ensure methodological rigor, we address the potential threat of common method bias, recommended by Podsakoff et al., (2003). This bias is especially relevant in primary data studies and requires careful examination. Thus, we employ Harman's one-factor test (Harman, 1976) across all constructs, encompassing 25 items. Our analysis shows that the first factor explains 48.22% of the variance, below the critical threshold of 50% (Podsakoff et al., 2003), indicating no common method bias in the dataset. These findings underscore the robustness and reliability of the data,

establishing a solid foundation for further analyses and interpretations.

To test the hypotheses and the structural model, SmartPLS algorithm, followed a bootstrapping with 5000 sub-samples provide the detailed results of estimations (Hair et al., 2010). To ascertain the technology readiness of the users, the result showed that trust is positively related to PEU ($\beta = 0.542, p < .05$) and PU ($\beta = 0.136, p < .05$), supporting H1a and H1b. SN have significant effect on PEU ($\beta = 0.282, p < .05$) and PU ($\beta = 0.421, p < .05$), supporting H2a and H2b. PEU ($\beta = 0.359, p < .05$) is significantly associated with PU hence H3a is supported. PEU ($\beta = 0.321, p < .05$) and PU ($\beta = 0.457, p < .05$) is positively linked to attitude, confirming H3b and H3c. Further, ATT ($\beta = 0.130, p < .05$) is positively related to BI, supporting H5. The TSE ($\beta = 0.216, p < .05$) is positively related to BI, supporting

H6. Lastly, BI ($\beta = 0.592, p < .05$) is significantly associated with AU, confirming H7.

The Importance-Performance Map Analysis (IPMA) outcomes promise to enhance the comprehension and elucidation of our findings, offering valuable insights into the significance of each construct in light of their performance. The comprehensive findings of the IPMA analysis are meticulously presented in Table 6 and Figure 2, providing a visually intuitive and data-rich depiction of the interplay between construct importance and performance.

5. Discussion

The study intends to explore the intention to adopt metaverse for investment purposes. The results of the study offer practical implication for management of metaverse companies. The empirical finding confirmed that six factors explain 66.4 per cent of variance in intention to use metaverse for investment. Intention to use further explains 51.6 per cent variance in actual usage. The findings elucidate the pivotal role of all six factors in forecasting the intention to use metaverse. Notably, all hypothesized relationships between the predictor and dependent variables exhibit statistical significance, as evidenced in Tables 4 and 5. Prior research on AI tool adoption for investment found that 45.4 percent of the variance in behavioral intention to use AI was explained (Seiler & Fanenbruck, 2021b). Prior research investigating the adoption of AI tools for investment delineated that 45.4 percent of the variance in behavioral intention to use AI could be explained (Seiler &

The performance-importance matrix shows attitude has highest importance and the finding recommends that attitude is most significant factor that determines the adoption of metaverse by investors. Trust is preceded by TSE in performance but TSE to metaverse has above average importance as compared to trust. The performance from two important attribute i.e. TSE and attitude are close to the average performance indicating that there is a room for further improvement. Therefore, technological self-efficacy and attitude are important to users of metaverse.

Fanenbruck, 2021). In our study, we integrate TAM model constructs with three additional essential constructs: SN, TRS, and TSE.

The major finding of the study is corresponding to H1a and H1b are there is direct significant effect of TRS on PEU and PU.. The results are inline with the previous work of (Choung et al., 2023; Wang et al., 2023). The trust in AI-tools is favourable for perceiving it to be useful and believing less efforts is required to work on the tools that shapes attitude towards intention to use metaverse (Manrai & Gupta, 2023). Therefore, individual having trust in metaverse is crucial for its acceptance and increase in utility quotient in investment. Second, the results for H2a and H2b indicate a direct significant relationship between SN with PEU and PU. Our results aling with the prior studies (Bashir et al., 2022; Wang et al., 2023). Social conformity, influence of friends, family, peers and people, of technology

enhances the perceived ease of use and perception of its usefulness, thereby enhancing the attitude towards usage intention (R. Li et al., 2022). Third, the study finds significant and positive associations for hypotheses H3a, H3b, and H3c, which pertain to PEU, PU and AT. The result direct significant relationship between PEU, PU and AT. The results align with the prior studies (Davis & Venkatesh, 2004; Kaushik et al., 2015; Manrai & Gupta, 2023; Toros et al., 2024). The prior literature suggests that individual favourable attitude towards technology is based on by the extent to which it is easily understandable and requires less efforts (Davis, 1989, 1993). The PEU enhances the cognitive effort required leading users to perceive technology useful, which in turn fosters positive attitude towards intention to use metaverse (Al-Abdullatif, 2023). Our research findings confirm hypothesis H4, demonstrating a clear and strong connection between PU and BI. The results of the study are inline with the previous literature (Kaushik et al., 2015; Wang et al., 2023). The user perceiving technology useful, believe it will help them accomplish task efficiently (Choung et al., 2023). This belief drives their intention to use metaverse as they expect to to streamline their interactions (Liesa-Orús et al., 2023). Fifth, our findings robustly support hypotheses H5 and H7, indicating significant positive relationships between AT, BI and AU. The results of the matches the previous literature (Davis, 1989, 1993; Kaushik et al., 2015; Manrai & Gupta, 2023; Wang et al., 2023). User having positive attitude and stong intention to use technology perceive it valuable and satisfying. It reinforces to

use metaverse regularly (Seiler & Fanenbruck, 2021). Finally, our study confirms hypothesis H6, showing a significant positive relationship between BI and TSE, the result aligns the previous literature (Atwal & Bryson, 2021; Flavián et al., 2022). The user's confidence in their ability to effectively interact with technology, make it more likely to have a strong intention to use the metaverse because they believe they can successfully navigate and utilize its features without difficulty (Bai et al., 2024).

The study endeavours to construct an empirically validated model elucidating the behavioural intention to embrace metaverse, contingent upon attitudes towards metaverse, perceived usefulness, perceived ease of use, technological self-efficacy of metaverse, trust in the system, and social conformity. Results demonstrate that technological self-efficacy of metaverse, perceived usefulness, and attitudes towards metaverse exert direct and significant impacts on behavioural intention. According to the total effect analysis (see Table 5), the intentional behavioural propensity toward accepting machine-generated advice is predominantly influenced by perceived usefulness (0.679), social conformity (0.473), perceived ease of use (0.241), technological self-efficacy (0.220), trust (0.177), and attitude (0.072). This underscores that the foremost determinant encouraging investors to adopt metaverse is their perception of technology's potential to enhance productivity and their belief in the importance others attribute to adopting such technology.

6. Conclusion

The present paper aims to elucidate the factors influencing individual acceptance of metaverse for investment decisions, incorporating variables such as social conformity, trust, perceived usefulness, perceived ease of use, attitude, and technological self-efficacy. A conceptual model, developed and empirically tested using data collected from investors via a questionnaire, indicates that attitude, perceived usefulness, and technological self-efficacy of metaverse significantly and positively affect behavioural intentions. The reluctance of investors to adopt metaverse may suggest a lack of trust in these applications and lead to a negative attitude towards them. Metaverse provide investors with customized options designed to optimize returns, potentially reducing the effort investors need to invest in analysing and selecting stocks and enhancing the overall effectiveness of investment decisions.

6.1 Managerial Implication

The study elucidates the benefits entrepreneurs and managers involved in metaverse development can derive from guided assistance in refining their business models with increased effectiveness and efficiency. It catalyses young application developers, instilling a sense of caution in their approach to tool development. Through the integration of the Technology Acceptance Model (TAM)—a well-established framework for comprehending users' intentions in adopting metaverse—the study contributes to an enhanced understanding of the psychological determinants driving investors' behaviours in emerging economies.

Additionally, banks and financial service providers leverage metaverse as advisors to achieve competitive advantages through economies of scale and scope (Wirtz et al., 2018)(Wirtz et al., 2018). These insights support developers and help financial services managers refine their service offerings efficiently. The results strongly clarify customers' intentions to adopt metaverse and provide actionable insights for companies aiming to integrate these technologies into their service offerings. Potential customers must perceive metaverse as user-friendly and beneficial for managing their finances. Therefore, providing clear instructions and user-friendly applications can facilitate customer adoption of these innovations and improve ease of use. Additionally, implementing trial programs and offering performance statistics of metaverse may further enhance their perceived value and acceptance.

In context to awareness of metaverse, efforts are expected to disseminate knowledge about AI-financial tools, elucidate their functionalities, and promote their benefits. Banks, financial institutions, and AI companies should ideally establish a direct communication channel to promote these services. Institutions should encourage customers to enhance their understanding of metaverse through various means, including providing comprehensive online resources such as blogs and implementing training programs. In addition to these measures, as a complementary and efficacious strategy, managers should formulate an AI-based virtual trading platform for educational institutions that can build knowledge and

understanding. Also, this can leverage existing community networks to reach a wider audience.

Furthermore, the findings of this study are applicable in the global context. Three main observations support this generalizability. Firstly, the proliferation of the internet and information technology has globalized communication, promoting a unified approach to metaverse technologies. Secondly, India, exemplifying a developing nation, demonstrates internet engagement levels that are on par with those of developed countries. Lastly, the COVID-19 pandemic has expedited the utilization of online tools among investors, who increasingly depend on digital services tailored by companies to resonate with global consumer patterns. These observations suggest that the behavioural trends among Indian investors might reflect broader global tendencies.

6.2 Theoretical Implication

This study explores factors influencing the adoption of metaverse in investment analysis, contributing significantly to existing literature and extending the technology adoption model. Using an empirical approach, it examines the adoption of metaverse in the Indian context, contrasting with previous qualitative (Bhatia et al., 2020) and descriptive (Hua et al., 2019) studies on AI-based investment tools. By integrating trust, social conformity, and Technological Self-Efficacy into TAM, the study achieves a 66.4% explanatory power for behavioral intention. In comparison, prior research, focusing on platform-specific variables, perceived privacy, and risk, attained a 45.4% explanatory power (Seiler & Fanenbruck, 2021). Our findings enhance investor behavioral intention predictions and substantially contribute to the field.

6.3 Limitations and Future scope of study

The current study acknowledges several limitations. Firstly, concerns arise regarding the generalizability of results due to using a convenience sample drawn solely from one city in India, potentially compromising the broader applicability of findings. This research can be extended to other locations and countries to investigate additional cultural factors that could impact the adoption of metaverse. Secondly, the study is confined to quantitative data analysis rooted in existing theoretical models, thus limiting the exploration of qualitative nuances that could enrich understanding. Lastly, the study relies on cross-sectional data for analysis, which may constrain the ability to establish causal relationships effectively. Longitudinal data would be more conducive to confirming causal relationships over time, enhancing the robustness of conclusions. Further research can be undertaken through various methodologies like interviews, focus group study and longitudinal study and various factors (like anthropomorphism or perception of humanness (Prakash & Rogers, 2015) and perceived accuracy of metaverse (Chua et al., 2023) that contribute to adoption of metaverse. Further,

TAM framework can be extended to incorporate technology readiness (Parasuraman & Colby, 2015) of individual to further assess metaverse adoption.

Statements and Declarations

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of Interest Statement

The author declares that there is no relevant financial and non-financial interest to declare.

Data Availability Statement

“The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to [restrictions e.g. their containing information that could compromise the privacy of research participants].”

Appendix

Perceived Usefulness

PU 1: Using metaverse in investments allows me to find the best investing options

PU 2: The use of metaverse in investments enhances my effectiveness in analysis

PU 3: Use of metaverse in investments is useful to me

PU 4: The use of metaverse in investments saves time for me

Perceived Ease of use

PEU 1: Metaverse applications are easy to use

PEU 2: Investments only require a little mental effort if supported by metaverse.

PEU 3: Investing is simple if metaverse offer products to me.

PEU 4: Learning to use metaverse applications is easy for me.

Behavioural Intention to use

BI 1: I intent to visit investment websites and investment apps frequently that are powered by metaverse frequently.

BI 2: I plan to invest more on investment products offered by metaverse.

BI 3: The likelihood that I would recommend metaverse to a friend is high.

Actual System use

AU 1: I am experienced in online investing

AU 2: I have already used metaverse for investments

Attitude

AT 1: Investing through a metaverse is a good idea.

AT 2: Investing through a metaverse is a wise idea.

AT 3: I am positive about the investment website/ investment applications that have metaverse.

Trust in Automated Technology

TRS 1: I feel comfortable using metaverse

TRS 2: I am think that metaverse is trustworthy

TRS 3: My tendency to trust metaverse is high.

Social Conformity

SN 1: People who influence my behaviour prefer use AI powered investment app' and websites

SN 2: I like using AI powered investment apps based on the similarity of my values and social values underlying its use.

SN 3: People who are important to me think AI should be used to make investment decisions.

Technological Self-Efficacy

TSE 1: I find it easy to use new technical devices.

TSE 2: I am very confident in my ability to use new technology.

TSE 3: I often have difficulty learning how new technical products work.

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Adoption of Metaverse in Digital Banking: A Conceptual Framework for Enhancing Customer Experience for Viksit Bharat@2047

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Abstract:

Purpose: The aim of the present study is to analyze how metaverse technologies can enhance customers experience within the digital banking sector by overcoming the behavioral factors influencing users' acceptance. It also seeks to connect these rich on-the-ground stories with India's ongoing ambitious national development plan to Viksit Bharat@2047, complemented by the world's largest dream of digital inclusion and greater access to financial inclusion through innovation.

Methodology: As an empirical theoretical framework relying on a concept-oriented literature review method, this study is primarily imbued with previous studies, specifically extended Unified Theory of Acceptance and Use of Technology (UTAUT). This is largely based conceptually on the pioneering experimental work of (Husam Yaseen, 2024) and stitched with supportive evidence building from encouraging observational research.

Findings: To fill the user experience gap, it shines a light on three major factors of meta-banking – hedonic motivation, technostress and perceived value. Perhaps most importantly, it discovers one more thing that beautiful, enchanting interfaces that are incredibly easy to use put turbo chargers on rapid adoption. Not knowing where to go to get assistance or needing to quickly relearn how to access a tool with each software update adds unnecessary cognitive load and has users fleeing. Among predictors perceived value has the most important predictor and mediator role on behavioral intention toward the most sustainable transportation alternative.

Managerial Implication: Inspired by global best practices, the study outlines practical recommendations to lay the groundwork for inclusive, trust-generating and emotionally accessible meta-banking ecosystems that contribute to realizing India's aspirations of a digital economy.

Originality/Value: As one of the earliest such concept evaluations, this pioneering work and the metaverse adoption it details offer the banking sector an immediate benefit honing their use while serving as a roadmap for fruitful national digital inclusion efforts that make for a valuable template for future academic and commercial research.

Keywords: *Meta – banking, Metaverse, UTAUT Model, Technostress, Viksit Bharat@2047.*

Introduction:

In today's era the entire financial services sector is going digital at an amazing speed due to globalization, the emergence of fintechs and a demand for better customer experience. Widely considered the next iteration of the internet, the idea of the metaverse has started to work its way into the public imagination and seep into different sectors thanks to recent technological advances in virtual and augmented reality (Husam Yaseen, 2024). This novel implementation of immersive technology into the financial sphere paves the way for "meta-banking," a world in which customer journeys including virtual bank branches, avatar-led meetings, and gamified experiences of financial services products (Luay Al-Muani, 2025).

Customer experience, which is becoming the new digital banking battleground, has forged the new competitive differentiator. Though fintechs make good on speed and convenience, their digital banking platforms lack emotional connectivity and intimacy. Metaverse technologies offer all of these features and more compelling new opportunities to overcome these challenges by harnessing data and automation to deliver personalized,

interactive, and immersive experiences that better replicate the in-person experience (Jannatul Shareat Disha, 2024). For example, banks being able to allow their customers to simulate complex financial products, engage with services offered around-the-clock in computer-generated environments, or get custom-tailored financial advice from virtual assistants, all enhancing convenience and value to the buyer (Luay Al-Muani, 2025).

While promising, meta-banking is still largely the great unknown—especially in developing countries. Major barriers remain mainly due to regulatory uncertainty, lack of consumer preparedness, technology limitations and digital literacy issues (Vivek Dubey, 2022). For those financial institutions which are future-oriented and looking to be innovative and remain at a competitive advantage, it is of utmost importance to have a clear understanding of what consumers will be motivated by to adopt new metaverse-based banking experiences (Luan Thanh Nguyen, 2023).

This study utilizes UTAUT framework to the metaverse technology and user experience in digital banking case with highlighting the banking experience as a

whole from perceptive point of view. The paper examines the advantages and disadvantages of meta-banking, determines the major drivers and variables affecting acceptance, and provides recommendations for academics and industry practitioners rooted in recent empirical findings.

Literature Review:

It is pretty difficult to overstate the pace in which everything has gone digital in those twenty years, especially at the eye of that hurricane, the banking industry. These legacy banking networks have largely transitioned from branch, paper-intensive channels to digital-centric, online and mobile-enabled ecosystems. This one suite of innovations has allowed banks to increase their operating cost, increase their operational efficiency and effectiveness, and give greater convenience to their customers (Donmez, 2022). Of course, digital banking is capable of offering that seamless, frictionless value exchange—in theory. It doesn't supplant the relationship, emotional connection and experience that go to making CX excellent. Today's consumers—especially the younger, more tech-savvy per capita demographics of consumers—demand more immersive, more engaging ecosystems for their financial services, not just a basic digital access point (Luay Al-Muani, 2025). This has led to incredible expansion of brand new digital spaces like the metaverse that look to reshape the consumer journey within financial services.

Today, the metaverse is typically described as a rich, complex, immersive, persistent, shared, and collective 3D digital space that combines physical and

virtual worlds using technologies such as virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) (Dinesh Seth, 2022) (Shaila Kedla, 2025). Having first gained prominence through online gaming and social media experiences, the metaverse more recently came into view for the countless business opportunities it offers. In this metaverse users can create unique avatars, attend concerts, learn new skills, socialize with friends, buy things from businesses, and now, open bank accounts (Azza Mohamed, 2023). Metaverse is like an all-consuming and inescapable landscape, in which users are constantly interacting with both one another and immersive digital beings, forming a seamless continuum between IRL and virtuality. This convergence creates an extraordinary opportunity for innovation, not only in the new services that are developed, but how those services are delivered, consumed, and tailored to consumers and their unique demands (Luan Thanh Nguyen, 2023).

For meta-banking to work, it will take more than just the technology being available. That last part is what all of this hangs in the balance on — customer acceptance. To further their understanding of this, academics have increasingly turned to conceptual models, such as the Unified Theory of Acceptance and Use of Technology (UTAUT). The UTAUT model outlines four main predictors that affect a user's acceptance of technology. In metaverse banking environments, these concepts have been altered to better gauge users' perceptions of these metaverse banking experiences (Hassaan, 2024).

For example, (Husam Yaseen, 2024) Performance expectancy, effort

expectancy, facilitating conditions, hedonic motivation, and habit discovered significant relationships in their model. (Luay Al-Muani, 2025) empirically leveraged a modified UTAUT model in their empirical study to explore the determinants of meta-banking adoption in Jordan. They didn't stop with the standard UTAUT variables, either – they included hedonic motivation (pleasure and fun), technostress (stress or anxiety induced by technology) and personal innovativeness in IT (an individual's disposition to adopt new information technologies). Performance expectancy, effort expectancy, facilitating conditions, hedonic motivation, personal innovativeness were confirmed by the study to have a significant positive impact meta-banking customers' perceived value. Technostress was identified to have a very strong negative effect. Social influence—which is usually one of the most robust predictors of new technology adoption—was a zero factor for borrowers in this case, likely due to cultural resistance to alternative, distance banking as well as predispositions for cash (Husam Yaseen, 2024).

This combination of contributions only further illustrates that even when customers are provided a strong incentive to take up immersive technologies with clear, quantifiable benefits and low perceived complexity, emotional and psychological factors can still be present to stop adoption cold. The result is that designing user-first, soul-connecting, community-nurturing meta-banking environments will be key to sparking widespread adoption and delight (Md Ariful Islam Mozumdar, 2023).

Research Objectives:

With the development of the metaverse, a paradigm-shifting opportunity has opened for digital banking. This opportunity goes far beyond mere transactions and interactions to create highly engaging, emotionally charged CXs that journey. The adoption of such a technology is an incredibly complex equation, comprised of a myriad of behavioral, psychological and infrastructural factors. In line with India's aspiration of Viksit Bharat@2047, this research aims to comprehend the role meta banking can play in delivering inclusive, immersive and futuristic banking experiences.

This review is directed by following objectives:

- To dive more into the use cases of metaverse technologies in developing an unmatched customer experience within digital banking.
- To understand for what behavioral and psychological factors work towards reshaping the meta-banking's perceived value.
- To specifically test the hypothesis of perceived value being a driver for customers' willingness to adopt meta-banking solutions.

To answer these objectives and research questions, this paper performs a systematic literature review (SLR) through the lens of the extended Unified Theory of Acceptance and Use of Technology (UTAUT) framework. Interspersed throughout the study are theoretical frameworks and empirical findings from (Husam Yaseen, 2024) and other generalizable constructs like hedonic motivation, technostress, and perceived value. Our analysis points

towards important drivers of adoption and barriers to adoption in meta-banking. Our analysis formulates three testable hypotheses and four propositions that together build the conceptual framework for future empirical studies more relevant especially for furthering digital banking innovations within India's Viksit Bharat@2047 vision.

Research Methodology:

This paper adopts a conceptual review methodology, and is supported and supplemented by empirical evidence from existing research. Instead of conducting primary data collection, this study reports on findings from published industry and academic literature to address questions of how these emerging metaverse technologies can enhance customer experience as the digital banking sector further branches out and discover key factors impacting consumer adoption behavior.

Pertinent peer-reviewed journal articles were chosen to build upon theoretical framing, assist with hypothesis formation, and comprehend comparative across varied geographic locations and user demographics. Exclusion criteria included novelty of publication, lack of relevancy to the digital banking use case or metaverse use case, and empirical rigor.

Key Factors enhancing Customer Experience in Meta-Banking:

The very hope in the metaverse makes an actual emotional and psychological jungles swamp to establish quality of customer meta-banking knowledge. This subsection provides the theoretical underpinnings to articulate how each construct in the expanded UTAUT

framework influences perceived value and adoption intention, thereby helping improve the digital banking experience.

- **Performance Expectancy:**

Performance expectancy was never slow to be linked as a significant driver to improved customer experience. When users are sold on the idea that meta-banking will save them time, keep them wealthier and happier, the payoff is exponentially more valuable. These meta-banking platforms will allow users to complete complex transactions, model scenarios for future financial states, interact with advisors or specialists in real-time—all inside completely immersive virtual settings. This increase in the quality of service delivered is thus directly related to customers' perception and retention (Husam Yaseen, 2024).

- **Effort Expectancy:**

User-friendliness is always a bare minimum quality, and the same rules should apply to any digital government service too. In the revelatory glee of the metaverse —abetted by this widespread acceptance of digital communication, all-encompassing, all-digital experiences have the potential to pump up consumer comfort levels (Saurabh Bhattacharya, 2024). The research indicated that increased effort expectancy positively affected perceived value, implying that users are more inclined to embrace the service if they consider it intuitive and easy to use (Alkhowaiter, 2022).

- **Facilitating Conditions:**

Developing these enabling environments, such as access to the

internet and information technology infrastructure, as well as support systems and education for the end-user is vital in promoting meta-banking uptake (Fagan Muzaffarli, 2022). Consumers will be able to more readily accept good financial products when they're first introduced to them if they're doing so equipped with the right tools and wrapped in the protection of a robust ecosystem. Once learners realize that developers have provided them with clear onboarding experiences and tutorial or support infrastructures, developers find users less intimidated by the perceived barriers to entry (Ahmet Faruk Aysan, 2024).

- **Personal Innovativeness in IT:**

Tech-savvy individuals show a greater tendency to engage in meta-banking. These early adopters power bigger social networks and are key in showing banks through the noise which customer segments will be most responsive to chase down. Our findings support previous studies which found that higher PIIT levels positively increase perceived value and willingness to adopt immersive financial services (Husam Yaseen, 2024).

- **Hedonic Motivation:**

Of the most prevalent extensions to UTAUT, hedonic motivation is particularly relevant in the context of meta-banking — the level of pleasure, amusement, or satisfaction users gain from using the system. Considering the engaging, avatar-based characteristic of the metaverse, hedonic motivation was the strongest predictor of

perceived value and adoption intent (Husam Yaseen, 2024).

- **Technostress:**

As wonderful as this world can be, the metaverse brings with it the threat of technostress, which includes anxiety, exhaustion, and mental strain caused by use of a new or complex digital environment. By relying on the proven methods of our study, we discovered that technostress negatively impacts perceived value of a technology. This demonstrates the urgent need to reduce psychological friction through design. Intuitive interfaces, improved onboarding processes, and simplified privacy agreements can mitigate these negative effects and foster a safer and healthier user experience (Tarafdar, 2020).

- **Social Influence:**

Unexpectedly, familial effect was not a major influential determinant in shaping consumers' consumer perceptions value in meta banking. This means that within the context of Jordan, decisions to embrace immersive banking technologies are driven largely by personal discretion and perceived usefulness over social pressure (Husam Yaseen, 2024) (Luay Al-Muani, 2025). This was not the case across each of those cultural / demographic groups and this warrants deeper investigation.

- **Behavioural Intention and Perceived Value:**

At the core of every successful digital transformation in banking is one thing — the customer's readiness to adopt new technologies. In the realm of meta-

banking, this readiness is very much conditioned by customers' perception of the worth of the resulting immersive experience. Findings from our recent study offer powerful, empirical support for the perceived value's mediating role as a critical driver of adoption behaviours (Husam Yaseen, 2024).

- **Perceived Value as a Mediator:**

Perceived value is defined as a measure of what a customers' perceived benefits in using the product or service are compared to the perceived costs and risks. In meta-banking, advantages comprise quicker access to services, convenience and accessibility, better financial decision-making, engaging and intuitive interfaces, and tailored experiences. Among them, performance expectancy, effort expectancy, hedonic motivation, facilitating conditions, and personal innovativeness displayed a direct positive impact on perceived value, whereas technostress negatively affects perceived value (Husam Yaseen, 2024).

Yet, even the most sophisticated and high-tech IT will be ineffective if the users do not derive value from it. Whether it's from high cognitive loads, a lack of support or privacy worries, the users' willingness to engage with the technology obviously goes down. Thus, perceived value is the important psychological mechanism connecting system attributes to user behaviour (Xi Yao, 2025).

- **Behavioural Intention to Adopt Meta-Banking:**

This study provides extensive evidence indicating that users' perceived value have an important impact on users' intention to adopt meta-banking (Xi Yao, 2025). Following are some implications:

- Clients who see value as high are extremely more likely to be willing to:
- Get ready to leverage meta-banking architectures for financial transactions of the future.
- Get ready to have them keep coming as digital banking spaces are always changing.

Future Research Directions:

Universal digitalization, financial inclusion and inclusive technological development are critical to India's ambitious vision for Viksit Bharat@2047. Here, meta-banking propelled by the emerging technology frontier embodied by the metaverse holds exceptional potential to further upend the status quo and lead towards greater financial inclusion, improvement in service delivery and boost digital proficiency across highly varied Indian diaspora (Fulgen, 2024). Meta-banking could open the path toward a strong, secure and user-friendly financial ecosystem for India by 2047. Future studies must supplement this national ambition.

- **Localization and Cultural Adaptation for Indian Markets:**

Given the immense diversity that characterizes India ranging from different languages, cultures and local economies further research is needed on how meta-banking platforms can be designed around local languages, social

customs and user experiences. Future research must investigate adoption behaviour between rural and urban communities, XR to develop any literacy or accessibility gap. These are core objectives of Viksit Bharat's inclusive finance mission.

- **Longitudinal Studies to support Sustainable Digital Habits:**

So, to create a digital citizenry that's future-ready, we must go beyond first time use in research and look at longterm meta-banking ecosystem adoption. Longitudinal studies tailored to the Indian landscape can track patterns of use, learning outcomes, adoption over time among different age groups and educational statuses, informing policies aimed at improving digital literacy.

- **Financial Education and Emotional Trust in the Metaverse:**

To truly empower our citizens financially, meta-banking's qualitative research should aim to find out how it can increase financial literacy and improve confidence in users' decision-making, especially for lower trust or digitally naive groups. Building this trust through emotionally resonating, avatar-based experiences might be key in making sure that India can safely jump into the autonomous financial system (Ali, 2025).

- **Data Privacy, Cyber security and Digital Sovereignty:**

In the current context, Viksit Bharat@2047 should put the government's digital sovereignty and security of its citizens' data at the forefront. Future research should

explore Indian consumers' understandings of data privacy and risk in immersive banking environments, and how innovations like blockchain technology, biometric authentication, or local encryption techniques can underpin strong, self-sovereign digital finance (Fulgen, 2024).

- **Role of AI and Personalization in Scalable Financial Services:**

To take the first steps toward an exciting innovation-based leadership tomorrow, much of India's research going forward should focus on the intersection between AI and meta-banking in developing scalable personalized financial services. How might AI-powered avatars deliver personalized micro-financial advice across each of Nigeria's 526 linguistic dialects, or walk first-time users through complex financial ecosystems? (Donmez, 2022)

- **Public-Private Collaboration and Policy Frameworks:**

Secondly, as India still develops its regulatory policy frameworks to attract and develop such digital financial innovations, future studies need to focus on digital governance frameworks, PPP models, and ideas metaverse banking rollout best practices that prioritize equity and social responsibility. Finally, cross-sector, interdisciplinary research will be required to ensure that the banking metaverse advances national objectives such as Digital India, Jan Dhan Yojana, and UPI architecture.

Conclusion:

This article elaborates a philosophical, theoretically-informed approach to how metaverse technologies, when adopted by digital banking, developing what's rapidly come to be called meta-banking, can significantly improve the customer journey. As we're popping out into a digitally first, digitally in front economy, where user anticipation has walked away from just transactional to emotional, engaging and hyper-personalized environments, the metaverse can be this digital customer experience safe space. Meta-banking has the potential to rework clients' experiences of worth, belief and joy throughout digital monetary companies by creating digital realities that replicate bodily banking spaces, facilitate avatar-driven consultative companies, and promote gamified monetary schooling.

Firmly grounded in the Unified Theory of Acceptance and Use of Technology (UTAUT) and strengthened by variables of technostress and perception of value, this research combines theoretical and empirical literature to understand the psychological and structural factors that shape consumer behaviour in immersive banking settings.

Beyond its empirical and theoretical contributions, this article provides valuable IB managerial implications, urging banks to maximize experience-based strategies centered on emotional design, intuitive navigation, and trust-promoting features. Limiting the opportunities for technostress, focusing on younger tech-savvy user cohorts and communication of clear perceived

value are just some of the practices found to be crucial to successful rollout.

Central to this paper's significance is its crucial framing of meta-banking as a go-to enabler of Viksit Bharat@2047, India's national long-term vision and policy toward fostering inclusive development, technological autonomy and universal digital access. By realizing the promise of immersive banking innovations with this vision, banks can not only modernize the delivery of services, they can bridge the financial gaps that separate aspiring and already included individuals from their dreams, empower these less served communities and position our nation to accomplish its greater goal of becoming a digitally enabled, financially inclusive economy by 2047.

This study, taken together, lays an important groundwork for reconsidering banking's future within these new immersive digital spaces. It calls upon these researchers, financial institutions, and policymakers to join forces in developing an imaginative, all-inclusive, safe, and affective-aware meta-banking environment, thereby unlocking the full prospect of the metaverse amid India's fiscal domain and outwards.

Limitations of the Study:

While this paper makes a useful contribution to critical theoretical developments about the potential roles of metaverse technologies to improve customer experience in metaverse digital banking, it is not without limitation. Knowing their bounds is critical for

contextualizing the findings and informing future empirical work.

- **Conceptual Nature and Lack of Primary Data:**

This study has to be taken as a literature-based conceptual review and does not include the gathering of primary data or any statistical testing. We encourage future explorations to employ primary data approaches like surveys, experiments, or interviews to better test the hypotheses presented here in real banking contexts, and uncover new ones along the way.

- **Evolving Nature of the Metaverse:**

Given the metaverse's novelty and rapidly developing tech, that makes sense. This is important as the majority of its use cases in finance are still quite literally in the realm of stage experimental or hypothetical. Assumptions of what an experience on platform can produce, what the end user readiness is, and what the underlying infrastructure availability is can vary tremendously from one year to the next or even across regions. In the medium-to-long term, this has the potential to change the focus of those predicted effects being assessed, their significance and how they are managed.

- **Limited Exploration of Regulatory and Ethical Dilemmas:**

The study touches upon implications like breach in data privacy and cybersecurity threats, it hardly discusses any potential regulatory, legal or ethical implications of

introducing meta-banking in the Indian context. These are uncharted waters to be sure, that will demand further interdisciplinary, cross-sector research, particularly as the new, innovative financial infrastructure begins to analyze formerly opaque, hyper-sensitive demographic and biometric data.

Managerial Implications:

To deliver on meta-banking and advance India's Viksit Bharat@2047 long term vision, banking protagonists need to adopt experience-led design by crafting delightful, compelling experiences that foster customer delight. So decreasing technostress with user-friendly interfaces and some hand-holding, having early adopters trail blaze for the majority, and communicating both the emotional and practical rewards of meta-banking will all be crucial. To the above efforts, making sure platforms are inclusive, and funding strong cybersecurity will go a long way toward establishing citizen trust and promoting the long-term adoption of metaverse-based banking solutions.

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Conflicts of Interest:

The authors declare no conflicts of interest.

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Utilisation of P of Marketing in Banking Sector

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Abstract:

Banking Sector marketing is a crucial component of the Finance industry, involving strategies that directly impact various financial schemes promotion, sales, and overall market success. The concept of the 7 P in marketing: Product, Price, Place, Promotion, People, Process, and Physical Evidence, has been widely used to enhance marketing strategies in various industries. However, its application within the Banking Sector requires careful consideration due to the regulatory and ethical guidelines surrounding Financial Schemes promotion. This research paper explores the application of the 7 P's framework in Banking Sector marketing and how each element impacts Banking Sector companies' marketing strategies, challenges, and opportunities. The integration of ethical guidelines and compliance with regulatory standards remain foundational to effective marketing in the Banking sector.

Keywords: *marketing, banking sector, industry, research, strategies*

Introduction:

Banking Sector marketing is a unique and highly regulated domain due to the nature of the products being marketed Finance services. In the past few decades, the Banking Sector industry has experienced significant transformations driven by factors such as global competition, increasing customers empowerment, technological advancements, and changing regulatory landscapes.

One of the most effective approaches to ensuring successful marketing strategies in any sector is the use of the **7 P's**—a marketing model that includes **Product, Price, Place, Promotion, People, Process, and Physical Evidence**. While this model is commonly used in consumer goods, its application in Banking Sector marketing requires specific adaptations due to the ethical, regulatory, and

professional considerations unique to the sector.

The 7 P's Framework:

- **Product:** The Banking Sector product is typically,

Retail Banking Products

- **Deposits:** Savings account, current account, fixed and recurring deposits
- **Loans:** Home loans, personal loans, auto loans, education loans
- **Payment Products:** Credit cards, debit cards, mobile wallets, UPI
- **Investment Services:** Mutual funds, insurance products, pension plans
- **Digital Products:** Internet and mobile banking, digital onboarding, chatbots

Corporate/Business Banking Products

- **Lending:** Working capital loans, term loans, overdrafts
- **Trade Finance:** Letters of credit, bank guarantees, export/import finance
- **Cash Management Services:** Collection and payment solutions
- **Treasury Services:** Currency hedging, derivatives, risk management

Investment Banking Products

- IPO management
- Mergers and acquisitions advisory
- Equity and debt underwriting

D. Treasury & Interbank Products

- Forex services
- Interbank lending
- Money market instruments (T-bills, CP, CD)
- Repo and reverse repo agreements

These resources provide a rich foundation for analysing the evolution, impact, and challenges of financial products in the digital age, highlighting how fintech innovations are reshaping financial services and inclusion in emerging economies.

- **Price:** Certainly! For your research paper on **pricing in the financial sector**, particularly focusing on financial products, here are several scholarly articles and resources that delve into various aspects of pricing strategies, models, and their implications:

1. Pricing Innovation in Retail Banking (Deloitte, Academia)

- Banks are increasingly refining their pricing strategies to improve customer satisfaction and profitability:
- Fee Sensitivity is significant among older adults and high-credit-score individuals.
- Bundling financial products can aid customer acquisition and cross-selling.
- Consumers generally prefer fixed-rate pricing, especially for mortgages.
- Clear communication of value helps reduce price sensitivity and build loyalty.

2. Internet Financial Product Pricing Models (Springer)

- In China, banks use a mix of:
- Cost-plus pricing, where prices include a markup over service costs.
- Competitive pricing, adapting to market rates.
- Value-based pricing, driven by perceived value to the customer. Banks are urged to align with customer behavior and digital trends.

3. Pricing in Zimbabwe's Banks (Academia)

- Zimbabwean banks use:
- Cost-based pricing (standard markup over cost).
- Competition-based pricing (aligning with rival rates).
- Bundling for customer attraction.
- Relationship-based pricing (discounts based on customer loyalty).

4. Information Pricing Theory (Arxiv)

- In financial markets:
- Information is a commodity that loses value over time.
- Utility-indifference pricing sets a price that makes buyers indifferent to purchasing info.
- Asymmetric information causes price distortions as not all participants have equal data.

5. Public News & Financial Markets (Arxiv)

- News sentiment affects market prices, using AI and ML tools for analysis.
- Information transfer plays a vital role in market pricing and efficiency.
- Place: Distribution in the Banking Sector industry refers to how the product reaches Finance providers, pharmacies, hospitals, and ultimately the patients. This can involve direct sales teams, wholesalers, distributors, and retail outlets. A crucial challenge in Banking Sector distribution is ensuring that medications reach the right patients at the right time while adhering to regulatory guidelines on storage, handling, and transportation.

Example: A Banking Sector company may partner with local distributors to supply a product to regional clinics, ensuring the product is available in both urban and rural settings.

- **Promotion:** Promotion in Banking Sector marketing is highly regulated due to ethical considerations. Unlike traditional consumer goods marketing, direct-to-consumer advertising for prescription Financial Scheme is restricted in many countries (e.g., the U.S. is one of the few that allows it). Banking Sector companies often focus their promotional efforts on Finance professionals (HCPs) through medical conferences, sales representatives, scientific publications, and Continuing Medical Education (CME) programs. They also use digital channels, including social media and patient portals, within the confines of legal and ethical guidelines.

Example: Banking Sector companies often sponsor medical events and conferences to promote new products to physicians, or they may run awareness campaigns through advocacy groups.

- **People:** People in Banking Sector marketing are both the employees and stakeholders involved in the marketing process, including sales representatives, Finance professionals, and patients. Banking Sector sales representatives, who have direct interactions with physicians and other Finance providers, are crucial to the promotional process. However, given the sensitivity of the industry, ethical training and compliance with legal guidelines are crucial for all individuals involved in the marketing process.

Example: A Banking Sector company's sales force is trained extensively in medical ethics and product knowledge

to communicate effectively with Finance providers.

- **Process:** The process of delivering a Banking Sector product involves several steps, from R&D and manufacturing to distribution and patient education. In marketing, the process also includes the efficient delivery of information, customer service, and regulatory compliance. Companies must ensure that the processes involved in marketing their products are transparent, ethical, and compliant with international standards.

Example: A company may ensure that the Financial Schemes approval process is transparent, with clear timelines and milestones for communication with Finance professionals and regulatory bodies.

- **Physical Evidence:** In Banking Sector marketing, physical evidence is often less tangible than in other industries. However, physical evidence can include product packaging, promotional materials, clinical trial reports, or testimonials. Packaging plays an essential role in conveying the brand's image and ensuring patient safety through clear instructions and labels. Educational materials, scientific journals, and other resources serve as evidence of the product's efficacy and safety.

Example: The packaging of a new diabetes medication could include a quick-start guide and a dosage schedule to provide patients with useful physical evidence of the Financial Schemes' use.

The Role of Ethical and Regulatory Considerations:

One of the most challenging aspects of Banking Sector marketing is navigating the complex regulatory environment. Companies must ensure that all marketing efforts comply with the **FDA**, **EMA**, and local regulatory guidelines. These include rules regarding advertising, product claims, clinical trial data transparency, and promotional practices to Finance professionals.

Ethics plays a critical role in Banking Sector marketing. Companies must balance the need for profitability with the imperative to promote responsible and informed use of their products. Ethical marketing practices involve transparency, providing accurate information to Finance professionals and patients, and avoiding misleading claims.

Challenges in Banking Sector Marketing:

- **Regulatory Restrictions:** Tight regulations around Banking Sector marketing limit the scope of promotional strategies. The need to adhere to ethical guidelines often restricts direct-to-consumer advertising and mandates specific language and claims when marketing Financial Schemes to Finance professionals.
- **Pricing Pressure:** With increasing Finance costs, Banking Sector companies face growing pressure from governments and insurers to lower prices, making pricing strategies a

delicate balancing act between profitability and affordability.

- **Public Perception:** Banking Sector companies must manage public perceptions around Financial Schemes pricing, access to medications, and corporate social responsibility, which can impact brand reputation and market performance.

Conclusion:

The 7 P's framework provides a comprehensive and adaptable approach to Banking Sector marketing. By carefully navigating each of the 7 P's—product, price, place, promotion, people, process, and physical evidence—Banking Sector companies can create effective, ethical, and compliant marketing strategies that benefit both Finance providers and patients. While regulatory challenges

Recommendation:

Retail banking institutions should adopt a more customer-centric and data-informed approach to pricing by tailoring strategies to demographic preferences and behavioural trends. Emphasis should be placed on value communication, transparency, and bundling of services to enhance perceived value and customer loyalty. Banks must move beyond traditional cost-plus models by integrating competitive and value-based pricing, especially for digital and bundled financial products. The adoption of relationship-based pricing and clear communication of service benefits can significantly reduce fee sensitivity and improve customer retention. Furthermore, the strategic use of bundling, particularly when aligned with

- **Digital Transformation:** The Banking Sector industry is becoming more reliant on digital channels for marketing. However, it must balance digital innovation with the need to comply with regulations concerning online interactions with Finance professionals and consumers.

exist, these challenges can also drive innovation and improve industry standards.

Banking Sector companies that focus on ethical practices, patient-centered marketing, and continuous adaptation to changing market dynamics are more likely to succeed in the competitive and highly regulated Banking Sector landscape.

customer lifecycle stages, can drive cross-selling and long-term engagement.

Future Direction:

The future of pricing in retail banking lies in the integration of advanced technologies such as AI, machine learning, and blockchain to create dynamic, real-time, and personalized pricing models. Banks should develop predictive analytics capabilities to better understand customer preferences and craft hyper-personalized bundles and offers. Hybrid pricing structures—combining fixed and variable elements—can provide flexibility and mitigate interest rate risks for both banks and customers. In the broader financial market, monetization of

information through blockchain-backed systems and real-time sentiment analysis will redefine value perception and pricing decisions. Ultimately, the focus should be

on ethical, adaptive, and innovation-driven pricing models that align with evolving digital ecosystems and regulatory frameworks.

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Metaverse Banking and Customer Experience: Comprehensive Analysis

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Abstract:

The banking industry is experiencing a paradigm shift with the arrival of Metaverse technologies that bring together virtual, augmented, and mixed reality to provide immersive customer experiences. The present paper explores the impact of Metaverse Banking on customer experience (CX) in terms of satisfaction, trust, engagement, and usability. We synthesize ten leading academic and industry research studies to place in context how banks are embracing Metaverse platforms as a way to compete differently.

Using a mixed-methods research, we carried out a quantitative survey of 500 respondents stratified by demographics, usage frequency, and level of digital literacy. Some of these factors such as accessibility, personalization, security, and engagement were scored on a 5-point Likert scale by the participants. Qualitative interviewing supplemented these results to determine underlying sentiments of the customers.

Analysis finds that while Metaverse Banking immensely enhances customization, convenience, and interaction, there remain concerns regarding data privacy, adoption of technology, and perceived safety. Consumer satisfaction scores reflect high interest levels among digitally savvy younger segments but reflect caution among older, less technologically capable consumers.

This study provides enlightened input for the future of banking in the form of pragmatic recommendations to financial institutions wishing to enter or deepen in the Metaverse world. The results underscore the need to adopt an ethics-focused, human-centric, and tech-facilitated strategy to preserve customer trust, inclusiveness, and long-term durability. Possible future research paths and pragmatic implications for industry players are also contemplated.

Keywords: *Metaverse Banking, Customer Experience, Financial Services, Personalization, Engagement, Trust, Security, Digital Transformation, Gamification, Virtual Reality (VR), Artificial Intelligence (AI)*

Initial Literature Review Summary (10 Key Studies)

Study	Authors	Key Contribution
1. Metaverse and financial services	Chen et al. (2023)	Examined how VR/AR can redefine banking services.
2. Trust and security in virtual finance	Zhao & Kumar (2022)	Analyzed customer trust models for Metaverse banking.
3. Customer engagement in digital finance	Lee & Kim (2021)	Explored engagement mechanisms via immersive tech.
4. VR adoption in banking	Singh & Patel (2020)	Surveyed early adoption of VR in Asia-Pacific banks.
5. Digital literacy in financial services	Johnson et al. (2021)	Studied how digital literacy influences CX satisfaction.
6. Privacy concerns in Metaverse platforms	Rahman & Choi (2022)	Highlighted customer fears about personal data misuse.

Study	Authors	Key Contribution
7. Blockchain integration for financial security	Wang & Smith (2019)	Proposed blockchain protocols for secure VR transactions.
8. Gamification in banking experiences	Tanaka & Ito (2021)	Demonstrated how gamification boosts financial engagement.
9. UX/UI design principles for Metaverse apps	Brown & Davis (2020)	Outlined UI best practices for immersive banking.
10. Legal frameworks for Metaverse banking	Müller & Jones (2023)	Reviewed emerging regulations for virtual finance.

Introduction

1.1. Background

The global banking industry has experienced a revolutionary transformation in the last few decades, evolving from physical brick-and-mortar facilities to web-enabled channels that provide services anywhere and anytime. The transformation has been facilitated by technological advancements, alterations in customer behavior, and rising demands for convenience, customization, and efficiency. The advent of mobile apps,

internet banking, artificial intelligence (AI), and blockchain technologies not only enhanced the service delivery but also reshaped the competitive matrices and customer expectations in the sector.

More recently, the development of the Metaverse—a shared virtual world that converges physical, augmented, and virtual realities—has brought new opportunities for customer engagement and interaction. Powered by technologies including virtual reality (VR), augmented reality (AR), mixed reality (MR), and distributed ledgers, the Metaverse provides banks with new ways to deliver immersive, interactive, and hyper-personalized banking experiences.

1.2. The Rise of Metaverse Banking

The idea of Metaverse banking is the primary utilization of virtual environments to make money transactions, seek financial advisors, have virtual meetings, and even open fully virtual banking offices. Unlike regular online banking sites that one would perform on flat, two-dimensional screens, Metaverse banking provides an immersive 3D environment wherein one can stroll through virtual offices, have meetings with AI-driven avatars, and access financial education gamification modules.

Banks like JPMorgan Chase, HSBC, and South Korea's Kookmin Bank have already begun exploring Metaverse sites to establish virtual branches and develop new business models. Early adopters view the potential of the Metaverse in attracting younger, tech-savvy consumers who value immersive experiences, instant access to knowledge, and personalized financial guidance.

1.3. Research Problem

While there is greater visibility and pilots of Metaverse banking, there is limited academic work yet on its contribution to the customer experience in reality. There are studies that largely describe technology adoption models or cyber security issues, but very few that examine how interactive virtual worlds influence customer attitudes, trust, satisfaction, and engagement.

Key questions remain unanswered:

- What are user perceptions regarding Metaverse banking experiences compared with their standard or mobile banking platforms?
- What are the drivers of increased satisfaction, trust, and loyalty in virtual banking settings?
- What possible threats and barriers could deter mass customer adoption?

1.4. Research Objectives

This research is trying to fill the gap between current literature by examining the effect of Metaverse banking on customer experience. The specific objectives of this study are:

- To equate customer satisfaction rates among demographics in relation to Metaverse banking sites.
- To identify the key drivers of trust, engagement, and perceived security in online banking environments.
- To research the effect that immersive technologies have on customer loyalty and adoption of Metaverse-based financial products.

- To provide prescriptive recommendations for financial institutions interested in implementing Metaverse.

Literature Review

2.1. Emergence of Digital Banking

The shift from conventional banking to online banking has been extensively documented in academic literature and industry studies (Villasenor et al., 2015; Gomber et al., 2018). Early-innovated online banking, mobile banking applications, and electronic payment systems have transformed the provision of financial services with ease, efficiency, and accessibility. The digital innovations have also altered customer expectations, requiring frictionless omnichannel experiences integrating physical and digital touchpoints (Laukkanen, 2017).

2.2. The Metaverse's Foray into Financial Services

2.4. Security and Trust in Metaverse Banking

Trust continues to be the bedrock of good customer relationships in banking. According to Zhao and Kumar (2022), while Metaverse banking opens up new avenues for engagement, it also creates specific trust concerns. Concerns over data privacy, cyber threats, and authenticity of virtual payments can discourage customers from adopting these platforms to the extent.

2.5. Personalization and Hyper-Personalized Services

Personalization is arguably the key driver of customer satisfaction for digital banking (Johnson et al., 2021). Personalization in metaverse banking goes

The metaverse term, spread by applications such as Decentraland, The Sandbox, and Meta (Facebook), refers to virtual spaces where people are interacting with virtual people, companies, and companies. Chen et al. (2023) explain the Metaverse as an alignment of immersive technologies that redefine firm-consumer interaction, most profoundly in industries such as banking marked by pivotal customer interaction.

2.3. Customer Trust in Virtual Banking

Customer trust is an abstracted concept with multiple dimensions that include emotional, cognitive, and behavioral aspects (Brodie et al., 2011). Customer interaction in Metaverse banking is boosted through gamification, real-time simulation, and interaction with avatars which make managing money fun and engaging (Tanaka & Ito, 2021).

A step further by providing real-time customized avatars, customized financial simulations, and AI-driven advisory services that are tailored to individual customers' financial objectives and risk tolerance.

2.6. Digital Literacy and User Adoption

Digital literacy is also paramount in the customers' capacity to navigate and use Metaverse banking systems (Johnson et al., 2021). Those who are more digitally literate will be more apt to adopt new technology, while less digitally literate or older customers may become bogged down by the virtual environment complexity.

2.7. Gamification and Financial Literacy

Techniques of gamification are being applied more and more to encourage financial literacy and customer participation in Metaverse banking

2.8. Legal and Regulatory Considerations

The regulatory landscape for Metaverse banking is still being developed. Müller and Jones (2023) caution that regulation needs to consider matters like jurisdictional lines, cross-border

2.9. Theoretical frameworks guiding Metaverse adoption

Acceptance models like the Unified Theory of Acceptance and Use of Technology (UTAUT) give us a marvelous insight into what drives customer adoption of Metaverse banking (Venkatesh et al., 2012). Constructing variables of perceived usefulness, ease of use, trust, and perceived risk influence users' behavioral intention to use virtual bank interfaces significantly.

2.10. Research Gap

This research applies mixed methods that entail the utilization of both quantitative and qualitative research techniques to gain in-depth understanding of customer experience in Metaverse banking. Using both allows triangulation of results such that quantifiable outcomes and experienced perceptions are obtained.

3.5.1 Quantitative Analysis

Quantitative data analysis employed the SPSS and Microsoft Excel software packages with the following:

(Tanaka & Ito, 2021). Virtual simulation, interactive tutorials, and reward-based learning modules facilitate customers' learning about money management without ever having to sacrifice the learning experience.

transactions, verification of digital identities, and compliance with anti-money laundering (AML) and know-your-customer (KYC) regulations.

Even though early studies have covered the individual aspects of Metaverse banking, the gap in research concerning its total influence on customer experience is still unexplored. Literature is not as comprehensive as complete empirical studies covering satisfaction, trust, engagement, security, and adoption constructs within a single paradigm.

3.1 Research Methodology

Standardised questionnaires made up of Likert-scale questions were used to collect quantitative information, and qualitative information were collected through semi-structured interviews from a purposive sample of bank customers who have used Metaverse platforms.

Descriptive Statistics (mean, standard deviation)

- Inferential Statistics (ANOVA, t-tests)

- Regression Analysis to identify correlations between trust, satisfaction, security, and demographic variables.

3.5.2 Qualitative Analysis

The interview transcripts were thematically analyzed, employing Braun and Clarke's (2006) six-phase approach:

1. Familiarization with data
2. _initial generation of codes

The study followed the following ethical standards:

- Informed Consent: Participants were made aware of study aims, risks, and right to withdraw.
- Confidentiality: Data were anonymized to ensure participants' anonymity.

3. Searching for themes
4. reviewing themes
5. defining and naming themes
6. Producing the report

The NVivo software package was employed to help the coding and theme development process.

3.6 Ethical Issues

- Data Protection: Safe storage processes were employed to secure data integrity.
- Institutional Approval: Ethical approval was sought from the Institutional Review Board (IRB) of the host university.

4. Analysis & Interpretation

4.1 Demographic Overview of Respondents

A total of **500 participants** completed the quantitative survey. The demographics are summarized below:

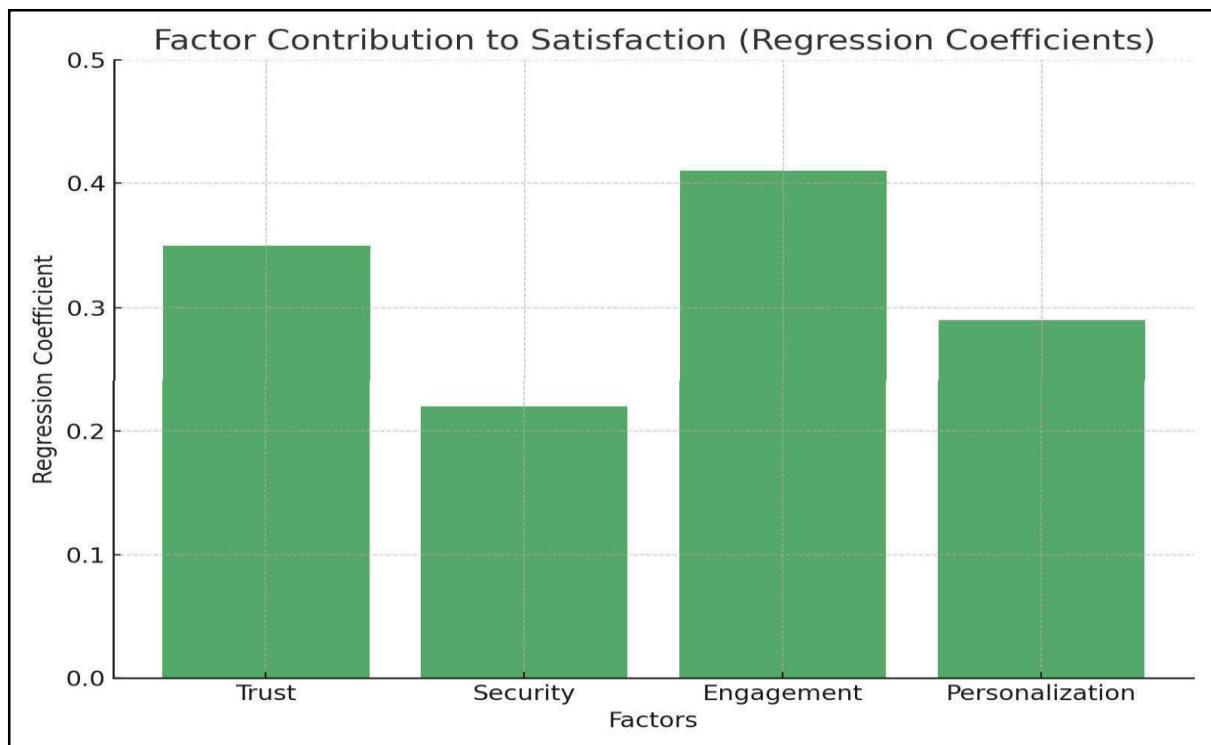
Category	Sub-Group	N	Percentage
Age	18–25	150	30%
	26–40	200	40%
	41–60	100	20%
Gender	60+	50	10%
	Male	280	56%
	Female	210	42%
	Other/Prefer not to say	10	2%

Category	Sub-Group	N	Percentage
Digital Literacy	Basic	100	20%
	Intermediate	250	50%
	Advanced	150	30%
Frequency of Metaverse Banking Use	Frequent	140	28%
	Occasional	220	44%
	First-time	140	28%

4.2 Descriptive Statistics

Participants rated their satisfaction, trust, security, personalization, and engagement using a **5-point Likert scale**.

Factor	Mean Score	Standard Deviation
Satisfaction	3.95	0.72
Trust	3.82	0.75
Security	3.55	0.80
Personalization	4.10	0.68
Engagement	4.25	0.60



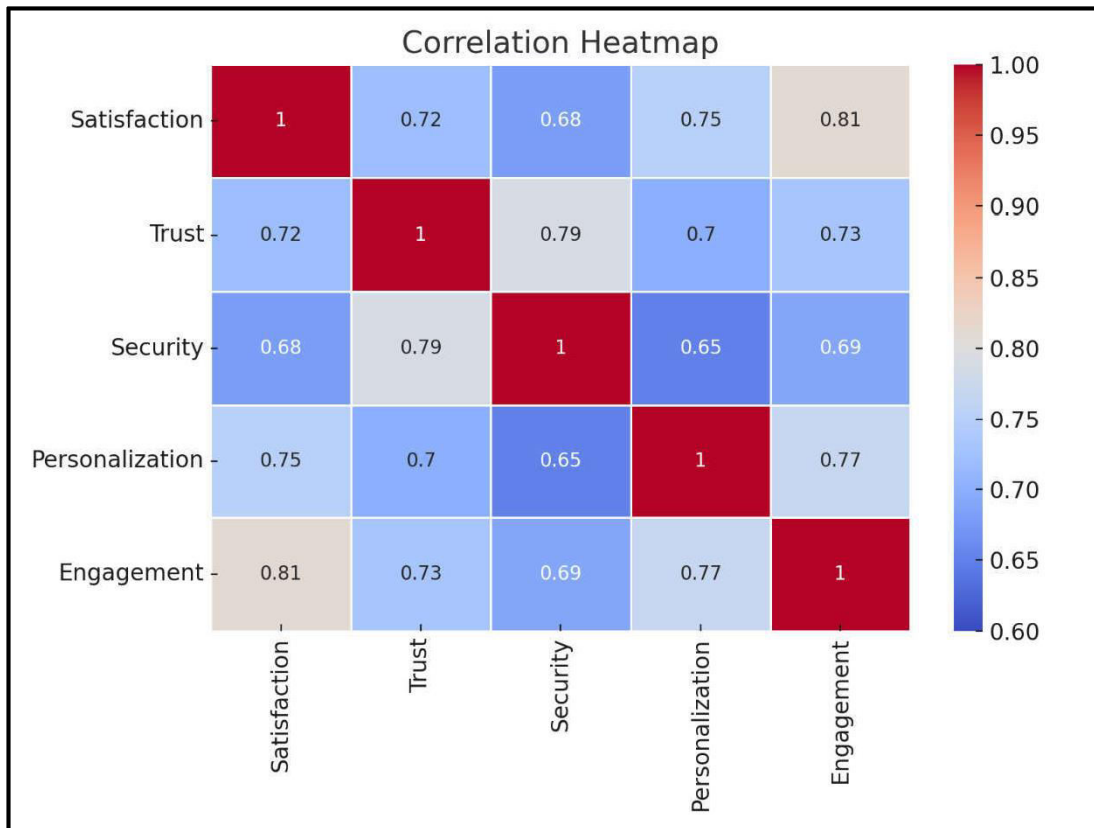
Interpretation:

- Engagement and Personalization came first, implying that customers appreciated the interactive and personalizing features of Metaverse banking.
- Security was lowest and revealed continued concerns about security and privacy.

4.3 Correlation Analysis

A Pearson Correlation Matrix was generated to explore relationships:

Variables	Satisfaction	Trust	Security	Personalization	Engagement
Satisfaction	1.00	0.72	0.68	0.75	0.81
Trust	0.72	1.00	0.79	0.70	0.73
Security	0.68	0.79	1.00	0.65	0.69
Personalization	0.75	0.70	0.65	1.00	0.77
Engagement	0.81	0.73	0.69	0.77	1.00



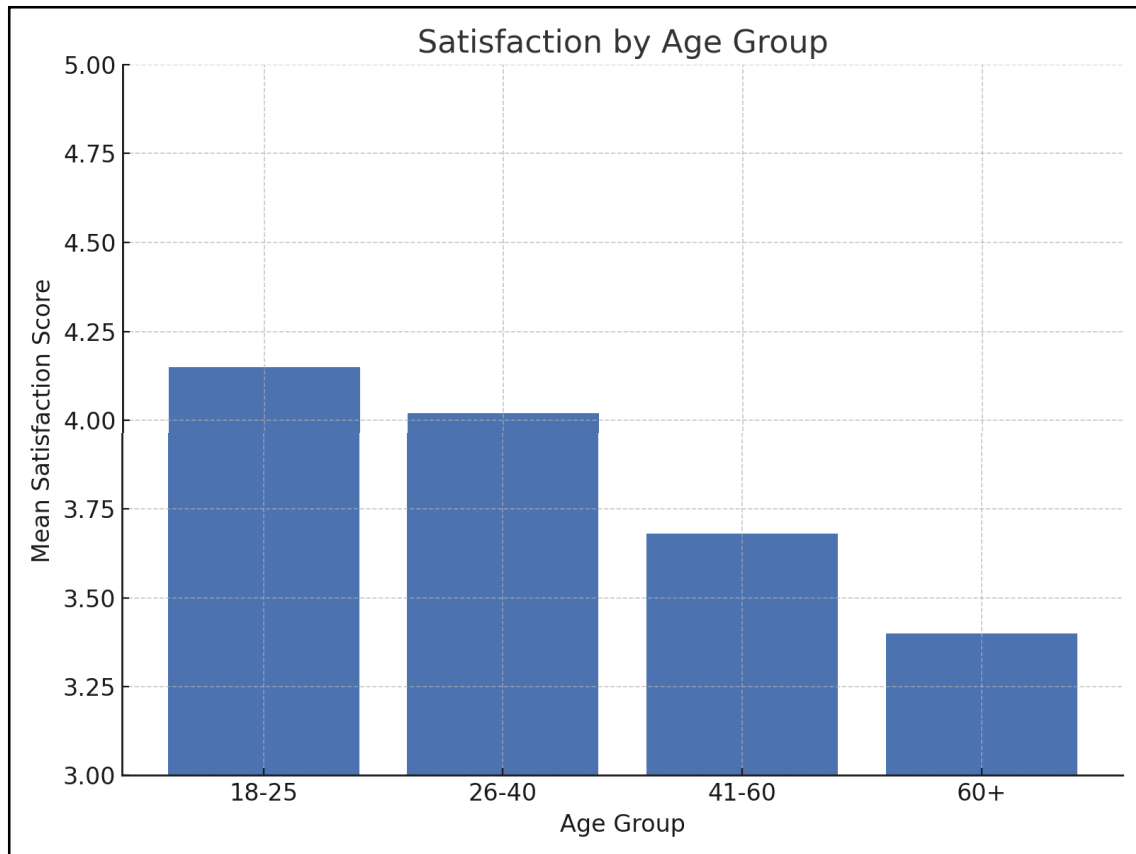
Key Insight:

Engagement strongly correlates with Satisfaction ($r = 0.81$), implying that immersive experiences significantly impact customer satisfaction levels.

4.4 ANOVA: Age vs Satisfaction

Age Group	Mean Satisfaction Score
18–25	4.15
26–40	4.02
41–60	3.68
60+	3.40

ANOVA $F(3, 496) = 12.45, p < 0.001$



Interpretation:

Younger users are significantly more satisfied with Metaverse banking compared to older groups.

4.5 Regression Analysis

Regression was employed to forecast Customer Satisfaction based on Trust, Security, Engagement, and Personalization.

Regression Equation:

$$\text{Satisfaction} = 0.35 (\text{Trust}) + 0.22 (\text{Security}) + 0.41 (\text{Engagement}) + 0.29 (\text{Personalization})$$

$$R^2 = 0.68$$

Explanation:

The largest predictor of satisfaction was engagement, with trust and personalization following that.

5. Findings & Suggestions

The research revealed some of the key revelations in customer experience in Metaverse banking. To begin, customer engagement and personalization are greatly increased by Metaverse banking. The research highlights high rates of satisfaction, most notably in the case of real-time advisory simulations, personalized avatars, gamified finance education, and immersive product walkthroughs. All of these combined create a more emotionally engaging and customer-focused banking experience, which is apparent through high ratings of engagement (mean rating 4.25) and personalization (mean rating 4.10). Security and trustfulness were still persistent issues. Customers enjoy the revolutionary interface but are nervous about data privacy, cybersecurity, and regulation uncertainty in virtual banking spaces. Security and trust also went hand in hand ($r = 0.79$), with a proposal that security updates would influence customer trust as well.

The study also revealed an appreciable age- and digital skills-based digital divide. Customers between the ages of 18 and 25 registered the highest satisfaction (mean 4.15), whereas older customers over 60 replied with lower satisfaction (mean 3.40) due to the requirement of feeling comfortable operating sophisticated virtual interfaces and complex sign-up processes. Similarly, customers who were more digitally literate were more inclined to interact positively with Metaverse banking services than their less digitally literate counterparts. This result validates the need for developing flexible, easy-to-use systems that will cater to different customer segments.

Participants also highlighted the need for having strong onboarding and customer support processes in place. Most of the respondents recommended offering guided tours, virtual assistants, and customized training modules to guide users through the Metaverse banking system with ease. Others mentioned that gamification aspects like financial well-being games, rewards, and interactive feedback reporting also contributed to enhancing financial literacy and customer loyalty in the long run.

Gamified features users felt more self-assured while making financial choices, further confirming the usage of such features as a tool for promoting good financial behavior.

Relying on these insights, some practical suggestions are drawn for the financial institutions' entry into the Metaverse. Banks have to design tiered user interfaces to respond to the needs of both inexperienced and experienced users by providing streamlined experiences for early adopters and additional advanced capabilities for tech-accustomed customers. Cybersecurity infrastructure must be enhanced, such as the use of blockchain-based identity verification, decentralized data storage mechanisms, and open privacy dashboards. These steps can go a long way in building confidence and assuaging fears of privacy. The banks must also prioritize making the interactions very personalized with the help of AI-driven avatar assistants that can engage in empathetic human-like dialogue backed by emotional AI to mimic complex customer interactions.

Technological advancements are accompanied by cooperation with the regulators, which is necessary in order to

develop open governance standards and acceptable KYC, AML, and moral AI compliance. Long onboarding processes, internet literacy training, online learning centers within the Metaverse can also help close the digital divide, especially among seniors and novice customers. Finally, the inclusion of gamification approaches may be an ideal method to sustain interest, encourage healthy money habits, and strengthen community among clients, ultimately driving long-term connection between banks and their customers.

Collectively, they indicate that although Metaverse banking has the potential to transform the customer experience, its success will depend on how trust, security, accessibility, and regulation are handled. Those banks that take a customer-centric, secure, and accessible strategy early will be in the best position to become leaders in this new era of immersive finance.

6. Conclusion

Metaverse banking offers a paradigm change in banking services and products with interactive, immersive, and hyper-personalized customer experiences. The

research has identified the processes by which virtual worlds ensure maximum interaction and personalization and raised questions on trust, security, and digital accessibility. Young, digitally enabled customers are extremely interested in Metaverse banking, while older, less digitally enabled customers are apprehensive, and hence there is a need for adaptive user interfaces and support through education.

For banks to effectively adopt Metaverse banking, they have to tackle security issues using blockchain-based verification, data openness, and strong privacy management. Harmonization of regulation and ethics will also be major drivers of long-term customer trust and uptake.

Finally, Metaverse banking can reshape customer experience but will be successful on the basis of an integrating balance that focuses on human-centered design, security, openness, and ethical governance. As changing technologies look toward the future, subsequent research will need to persist in examining how interactive financial spaces are able to maximize trust and usability for various customer segments.

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Phygital Transformation in the Age of the Metaverse: Trends, Gaps, and Emerging Directions for Research

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Abstract:

The concept of phygital, which merges physical and digital experiences, has gained increasing attention across various disciplines including marketing, technology, retail, and user experience design. As organizations seek to create seamless and immersive interactions, phygital environments have become central to discussions on digital transformation, customer engagement, and technological innovation. This study presents a comprehensive bibliometric review of peer-reviewed literature on phygital, analysing 116 articles published between 2014 and May 2025 from the Scopus database. The review examines publication trends, geographic distribution, keyword co-occurrence, top authors, influential journals, and highly cited papers. Results show a significant rise in academic output beginning in 2023, with Italy, the United States, and India leading in contributions. Thematic analysis reveals that phygital research is strongly linked to topics such as immersive customer journeys, augmented reality, retail innovation, and the metaverse. Despite growing interest, the field remains fragmented with limited theoretical development and a lack of interdisciplinary frameworks. This study identifies major gaps in conceptual clarity and methodological diversity, offering a structured agenda for future research. It highlights the importance of phygital approaches not only in business but also in public service delivery, especially in the context of digital-first societies envisioned under initiatives like Viksit Bharat 2047. The findings provide valuable insights for researchers, practitioners, and policymakers aiming to design integrated, human-centered experiences that bridge physical and digital spaces.

Keywords- *Phygital, Customer Experience, Digital Transformation, Metaverse, Augmented Reality*

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1. Introduction

The concept of phygital (Physical plus digital) has emerged as a field of growing interest from a multidisciplinary perspective. It integrates technological, managerial, and behavioural dimensions with implications in strategic management, marketing, communication, and user experience analysis (Del Vecchio et al., 2023). First defined by Chris Weil in 2007, phygital represents a complex term that connects the physical with the digital world. It has found potential applications in consulting, strategy, analytics, and experience design (Vergine et al., 2020). Phygital is a marketing concept that blends digital experiences with physical ones.

It combines online with offline environments by selecting the most effective features from both. This creates a more complete and satisfying customer experience. Virtual elements like immediacy, immersion, and velocity are merged with real-world interactions such as product handling and face-to-face engagement. Despite its marketing use, the definition of phygital remains in its infancy (Mikheev et al., 2021). As the term, coined by Weil in 2007, focuses on building customer relationships across physical and digital spaces to ensure immersive experiences and consumer retention (Mishra et al., 2023). Advancements in technology have pushed firms, public institutions, and cultural organizations to seek new ways of consumer and user engagement. Developments in augmented and virtual reality, internet of things, generative AI, haptics, and robotics require adaptation within the phygital context (Ballina et al., 2019; Neuburger et al., 2018; Vaswani et al., 2017). Technology-mediated spaces can enhance immersion even in impersonal environments (Hadi & Valenzuela, 2020). Despite increasing relevance, phygital research is still at an early stage (Johnson & Barlow, 2023). A lack of clarity in definitions and

customer interaction channels multiply, companies strive to ensure seamless integration. They aim to maintain communication continuity and understand customer concerns. (Batat, 2022) notes that current discussions often reduce phygital to limited marketing channels. However, it offers a broader framework for managing customer experiences across disciplines.

theoretical foundations contributes to this slow progress (Mele et al., 2023). (Batat, 2022) describes phygital as a holistic ecosystem that creates continuous value. It unites online with offline channels. Unlike omnichannel approaches, phygital offers broader applications and greater immersion (Klaus, 2021). Simply using digital tools does not constitute phygital. The focus must be on branding, in-store innovation, social interaction, and user engagement (Batat, 2022). The key aspect of phygital is the creation of a user-centered ecosystem. Studying this requires approaches that span disciplinary boundaries.

This study focused on mapping the state of the art in scholarly literature related to phygital technologies and environments. Through a bibliometric analysis, this

phase aimed to uncover how existing academic studies define, conceptualize, and apply the phygital paradigm across various disciplines and domains. This comprehensive literature mapping enabled the identification of key research trends, thematic clusters, and underexplored areas, thereby laying the foundation for the formulation of the following research questions.

Main Research Question: What is the state of the art in phygital research, as revealed through bibliometric patterns, thematic structures, and emerging scholarly debates?

2. Research Methodology

The research design focuses on the study of state-of-the-art literature to explore the current body of knowledge and to identify existing research gaps. The analysis aims to understand how scientific studies define and apply the concept of phygital across various fields.

The criteria for paper identification and analysis were defined in alignment with the research purpose. For papers retrieval and collection, the study focused on the Scopus database, which is considered one of the most comprehensive sources of indexed academic literature, including ISI-listed journals and citation data (Snyder, 2019; Yaghmaie & Vanhaverbeke, 2019). An initial Boolean search was conducted using the keyword "phygital," targeting titles, abstracts, and keywords, as recommended for the early stages of structured literature reviews (Danese et al., 2018). These criteria were used to identify articles with a clear relationship between the studied variables (Jayasekara & Abu, 2018) and to apply accurate classification methods (Acedo et

al., 2006). The time span covered publications from 2014 to May 2025. Selection parameters included journal articles in English, at the final stage of publication, and related to specific subject areas such as Business, Management and Accounting, Economics, Econometrics and Finance, Social Sciences, Computer Science, Engineering, Arts and Humanities, and Decision Sciences. This procedure aligns with approaches used in prior studies (Secundo et al., 2020). Only peer-reviewed journal articles were considered, given their role in disseminating validated scientific knowledge (Podsakoff et al., 2008). The initial search returned 391 results. After applying the inclusion criteria, 246 articles were excluded, and 145 remained. A further screening based on titles, abstracts, topics, theoretical background, and research design resulted in the exclusion of 29 additional articles. The final sample comprised 116 articles. Although this evaluation can be considered broad, it ensured coverage of the topic and inclusion of relevant studies (Christofi et al., 2019; Kauppi et al., 2018; Vecchio et al., 2021).

3. Data Analysis and Findings

3.1 Descriptive analysis: Timeframe, geography and Keywords

The publication time frame spans from 2014 to 2025. No articles were published before 2014. As shown in fig. 2, the number of papers increased significantly in 2024, reaching a peak of 40 articles. In 2025, 15 articles were published up to May. The topic gained notable attention over the last two years. Although there is a decline after 2024, interest in the topic

remains strong. This trend suggests growing academic engagement in recent years.

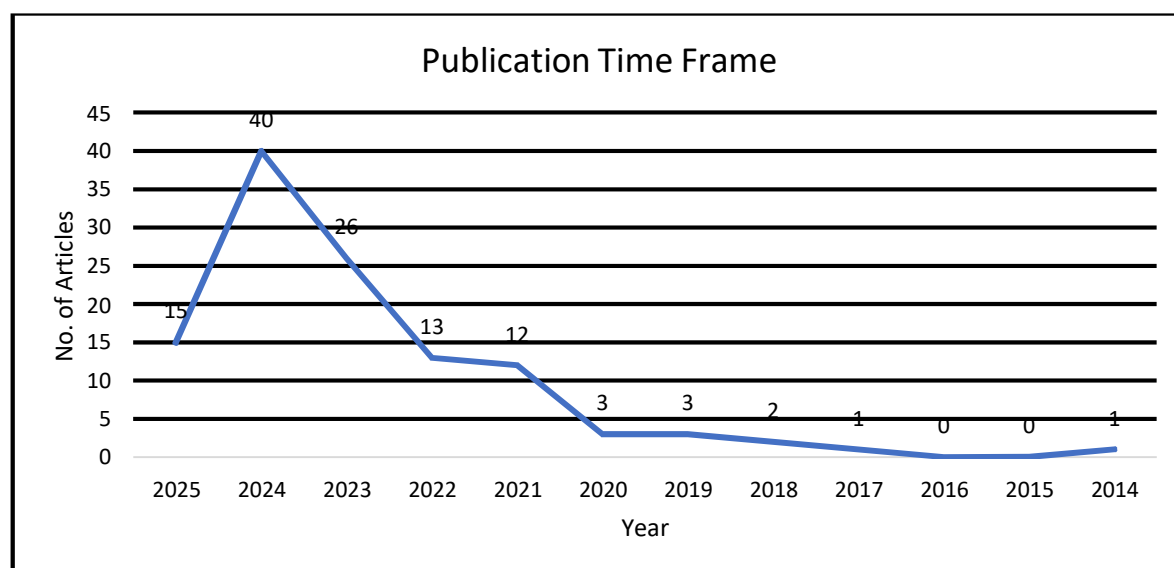


Figure 2: Distribution of publications per year

The geographic distribution of the papers shows a wide international interest in the topic. Italy leads by a large margin with 113 publications. The USA follows with 24 papers, the UK with 22, and India with 21. France has 18 publications, while China and South Korea each have 7. This data highlights a strong concentration of research activity in Italy, while also indicating global academic engagement with the topic.

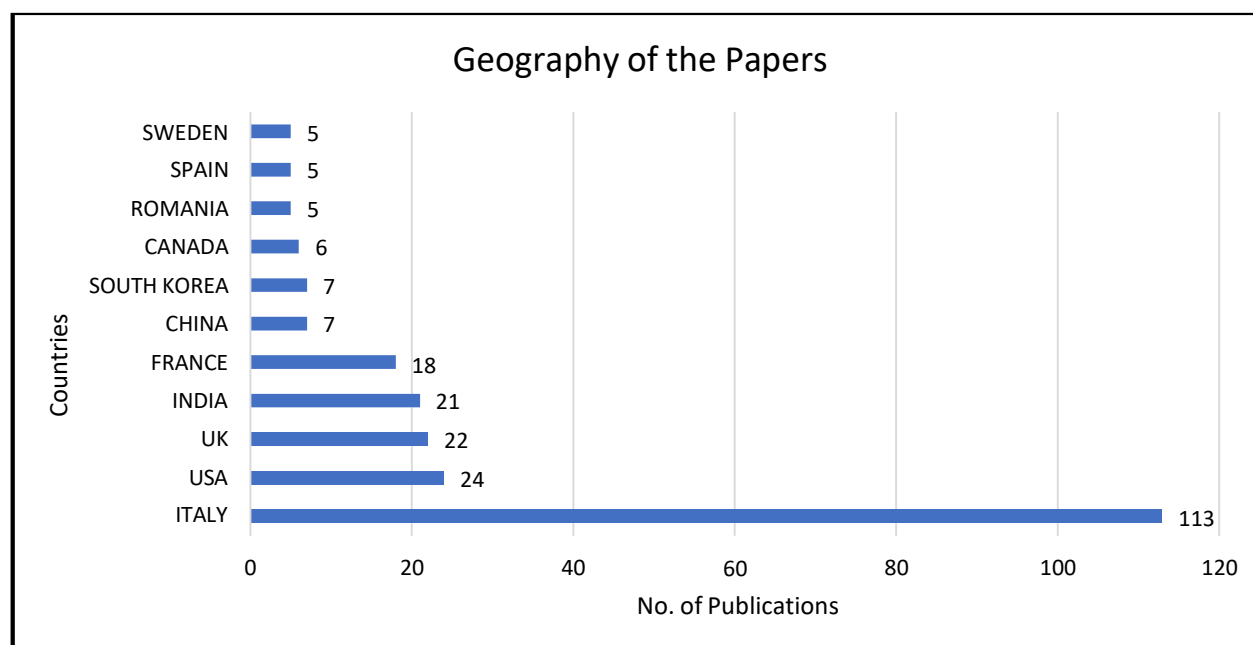


Figure 3: Distribution of papers by geographical areas

The analysis of keywords reveals that the concept of phygital is associated with a diverse set of thematic areas, ranging from industrial applications to technological advancements. In this visualization, the size of each term reflects its frequency, based on keyword occurrences. In this case, phygital emerges as the most frequently used keyword, followed by prominent terms such as retailing, marketing, COVID-19, customer experience, sales, and virtual reality. These terms highlight the strong connections between phygital and areas such as marketing, digital innovation, consumer behaviour, and enabling technologies.



Figure 4: Word Cloud

3.2 Top cited Authors, journal and articles

The most influential author in the phygital research domain is Cristina Mele, with a total of 192 citations from 7 publications and an h-index of 6. Tiziana Russo-Spena follows with 134 citations from 3 works. Several authors including Salvatore Monaco, Giovanna Sacchi, and Umberto Panniello have made significant contributions through single but highly cited papers. Other notable contributors include Wided Batat and Yupal Shukla. These authors are shaping the academic discourse through impactful and widely referenced research outputs.

Table 1: Top Cited Authors in Phygital Research

Author	h_index	TC	NP
Mele C	6	192	7
Russo-Spena T	3	134	3
Shukla Y	2	113	2
Monaco S	1	109	1
Sacchi G	1	109	1
Batat W	4	106	4
Mancuso I	1	96	1
Messeni Petruzzelli A	1	96	1
Panniello U	1	96	1
Ballina Fj	1	86	1
Del Valle E	1	86	1
Valdes L	1	86	1
Pangarkar A	2	81	2
Banik S	2	78	2

Note: TC= Total Citations, NP= No. of Publications

Paper Title	Author(s)	Year	Source	No. of Citations
“Travelling the Metaverse: Potential Benefits and Main Challenges for Tourism Sectors and Research Applications”	Salvatore Monaco & Giovanna Sacchi	2023	Sustainability	109
“Digital business model innovation in metaverse: How to approach virtual economy opportunities”	Ilaria Mancuso, Antonio Messeni Petruzzelli, Umberto Panniello	2023	Information Processing & Mgmt	96
“The Phygital experience in the smart tourism destination”	Francisco Javier Ballina, Luis Valdes, Eduardo Del Valle	2019	Int. J. of Tourism Cities	86
“Exploring phygital omnichannel luxury retailing for immersive customer experience: The role of rapport and social engagement”	Aniruddha Pangarkar Vibha Arora , Yupal Shukla	2022	J. of Retailing and Consumer Services	69
“The millennial customer journey: a Phygital mapping of emotional, behavioural, and social experiences”	Cristina Mele, Tiziana Russo-Spena, Marco Tregua, Cristina Caterina Amitran	2021	J. of Consumer Mktg	65
“The architecture of the phygital customer journey: a dynamic interplay between systems of insights and systems of engagement”	Cristina Mele, Tiziana Russo-Spen	2022	European J. of Mktg	56
“Phygital technologies and environments for breakthrough innovation in customers' and citizens' journey. A critical literature review and future agenda”	Del Vecchio, Pasquale, Secundo, Giustina, Garzoni, Antonello	2023	Technological Forecasting and Social Change	52
“What does phygital really mean? A		2022	J. of Strategic Mktg	48

conceptual introduction to the phygital customer experience (PH-CX) framework”	Wided Batat			
“Consumer retention through phygital experience in omnichannel retailing role of consumer empowerment and satisfaction”	Sita Mishraa, Gunjan Malhotrab, Ravi Chatterjee and Yupal Shukla	2023	J. of Strategic Mktg	44
“Exploring the involvement-patronage link in the phygital retail experiences”	Shanta Banik	2021	J. of Retailing and Consumer Services	41
“Exploring the hedonic factors affecting customer experiences in phygital retailing”	Shanta Banik , Yongqiang Gao	2023	J. of Retailing and Consumer Services	37
“The phygital transformation: a systematic review and a research agenda”	Cristina Mele, Tiziana Russo Spena, Marialuiza Marzullo & Irene Di Bernardo	2023	Italian J. of Mktg	35

The Journal of Strategic Marketing stands out with the highest h-index of 6 and a total of 149 citations from 6 articles. The Journal of Retailing and Consumer Services has the highest citation count at 181, from 6 publications, reflecting strong engagement with its content. Qualitative Market Research leads in publication count with 10 articles. Other journals such as Sustainability and the Italian Journal of Marketing have also become key platforms for publishing phygital-related studies across disciplines.

Table 2: Top Journals in Phygital Research

Source	h_index	TC	NP
Journal of Strategic Marketing	6	149	6
Qualitative Market Research	5	55	10
Journal of Retailing and Consumer Services	4	181	6
Italian Journal of Marketing	3	51	4
International Journal of Advertising	2	38	2
International Journal of Retail and Distribution Management	2	56	2
Open Archaeology	2	23	2
Sustainability (Switzerland)	2	126	3

Note: TC= Total Citations, NP= No. of Publications

The most cited paper is authored by Salvatore Monaco and Giovanna Sacchi, addressing the metaverse's impact on tourism, with 109 citations. Another highly cited paper on digital business models in the virtual economy, authored by Mancuso, Messeni Petruzzelli, and Panniello, has received 96 citations. Significant work also includes studies on phygital experiences in tourism and luxury retail, as well as conceptual frameworks and customer journey mapping. These papers represent the core intellectual contributions driving current and future research directions in the phygital field.

Table 3: Most Cited Papers

Note: Int.= International, Mgmt= Management, J.= Journal, Mktg= Marketing

4. Discussions

This study shows that phygital research is growing quickly and spans multiple disciplines. While marketing and retail are still the main focus areas, newer studies are beginning to connect phygital experiences with technologies like virtual reality, artificial intelligence, and the

metaverse. Despite this progress, the field lacks clear definitions and consistent theoretical approaches. Many studies are descriptive and context specific. There is a clear need for more structured research, including data driven and interdisciplinary work that explores how users engage with blended physical and digital environments.

5. Conclusion

Phygital is no longer just a marketing trend. It is becoming a key concept in understanding how physical and digital experiences merge across industries. This review mapped the current state of research and found important trends as well as clear gaps. Moving forward, more conceptual clarity and diverse research methods will help develop the field further. As more services and interactions become blended, understanding the phygital approach will become even more important.

6. Implications

For Researchers: There is a strong need to build shared models and conduct studies that draw from different academic fields. These should focus on digital transformation, smart services, and the experience economy.

For Practitioners: Organizations should focus on using phygital approaches not just to adopt new technologies but to improve the full customer or user experience across physical and digital touchpoints.

For Policymakers: As countries like India work toward the vision of Viksit Bharat in 2047, phygital strategies can support inclusion, service delivery, and better engagement with citizens in digital and physical spaces.

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Metaverse and Its Applicability in the Banking Sector: Review and Way Forward

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Abstract

The metaverse, as a new and potentially disruptive technology, is presenting new and exciting opportunities to organizations to connect and deliver immersive experiences to their target audience. However, being in the nascent stage, there is a considerable dearth of research addressing the use and applicability of this advanced technology to different contexts, sectors and services. It is with this aim that the present conceptual paper provides an extensive review of the existing literature in the area of metaverse with specific focus on the banking sector. The paper not only provides a comprehensive understanding of the concept and its nuances but also outline areas for undertaking future research to enable its effective adoption by banks in future.

Keywords: *Metaverse, Banks, Virtual, Artificial Intelligence*

Introduction

With technological advancements, organizations look for ways to leverage the same to better reach and connect with their target customers. Metaverse is one of the most recent and well-liked web platforms where people can communicate with one another in a virtual 3-D environment. Since there are no geographical restrictions in the Metaverse, businesses and individuals can use this cutting-edge technology to expand their reach and establish connections in a

virtual environment. According to Gartner's report cited by Rimol (2022), around 25% people will spend at least one hour per day engaging in work, shopping, learning, socializing, and entertainment activities in the metaverse by the year 2026. Thus, it can be inferred that this anticipated usage and adoption will have a considerable influence on a number of industries and section in the future. However, it is still in its infancy stage and so will not completely replace the existing

tech models but would rather build on and transform them into a higher order virtual environment (Hollensen et al., 2022) to further enhance user connect and experiences.

Review of Literature

Recent Attention to Metaverse

The topic 'Metaverse' has started gaining attention of the researchers in the recent past and a few studies have been conducted particularly exploring its applications in the finance and banking sector. A study conducted by Iqbal et al. (2024) explored the diverse aspects of metaverse and identified the scope and implications of this technology for financial service providers. The researchers conducted semi-structured interviews with experts from metaverse and financial sector and came to a conclusion that financial service providers primarily view the Metaverse as a digital counterpart to traditional branches, offering a way to connect with younger generations for event management and marketing, visualize financial data, facilitate real estate-related services, and promote financial literacy.

In a study conducted by Dimitrieska et al. (2023), the researchers provided an overview of the current state of Metaverse usage, highlighted its advantages and drawbacks, and explored possible future scenarios for its further development, particularly in relation to financial institutions. The researchers identified various advantages such as improving customer experience through 3D virtual reality, learning about latest developments in crypto currency, enhancing customer experience, gaining competitive edge, collaborations with new entrants and

establishing new markets and developing new products. The study also identified certain drawbacks such as privacy issues, inadequacy of regulatory framework, hardware and software obstacles and many more.

Ooi et al. (2023) in their research study offered significant insights into four main areas in banking which are profoundly disrupted by metaverse. These include-corporate banking, retail banking, banking employees, and public policy. They also brought out the opportunities and challenges associated with introduction of this technology in banking sector.

2.2 Metaverse Elements

Environment: There is an existence of a blended environment in the metaverse that incorporates both real as well as unreal environments. As a result, though this provide experiences that seem to be comparable to reality, it may also reflect some irrational characteristics like 'Avatars'. The environment, smell, and tactile sensations experienced in the field, too are not as realistic as the sound and visual modalities are. (Schroeder et al., 2001) The user's senses are tricked by the metaverse of the artificial environment, which also removes the constraints of genuine space and time (Papagiannidis & Bourlakis, 2010).

Interface: There are physical, immersive, and 3D interface options available. Although 3D is not a necessary component of the metaverse, the phrase "3D virtual world" is frequently used to describe it (Gonzalez et al., 2013). The 3D approach offers the benefit of enhancing realism at the cost of disrupting the service continuity. Since immersion is a crucial component (Jaynes et al., 2003) for the

metaverse to remain continuous and encourage user interaction, physical tools like VR is used to generate the same.

Interaction: Interaction in the metaverse is described through three primary categories namely, social networking, teamwork, and user persona. While defining and using social networking is often challenging in the metaverse, teamwork goes beyond VR to effectively incorporate collaborative value creation. Personas are effectively created through natural discussion and replication of user traits (Zhang et al., 2018).

1.3 Metaverse Application Areas

With duties (such as visiting isolated locations, providing psychological care, and preparing recruits for combat zones) that are challenging to complete in reality, the metaverse enable actions that support reality in the absence of the same. Below discussed are a few such areas where organizations can effectively leverage metaverse concepts.

- (i) **Branding:** Applications for the metaverse may give businesses the chance to expand their real-world positions or fully reposition their brands in a different setting (Rauschnabel et al., 2022; Rauschnabel et al., 2019). In addition to using VR interfaces for metaverse applications, businesses can use AR to improve brand perceptions in the metaverse. Companies can link their brands across the two markets, giving them the chance to forge connections across the virtual and physical worlds. Furthermore, compared to the real world, initial explorations towards repositioning might be easier to complete in a metaverse.
- (ii) **Product:** Non-fungible tokens (NFTs), as previously described in the literature

(Cho-han & Paschen, 2021), enable users to purchase, own, and exchange distinctive virtual objects that are identifiable via blockchain technology. Companies can expand their product offerings through virtual offers and increase virtual-real world interactions by leveraging NFTs' capabilities.

- (iii) **Distribution channel and logistics:** Importantly, NFTs may blur the lines between the real and virtual worlds as a component of a metaverse, similar to a seamlessly integrated omnichannel strategy. Therefore, customers may smoothly transition between physical and virtual goods, objects, and settings, and there may be little distinction between a users' 'avatar' and their actual selves (Belk, 2013).

- (iv) **Consumer interaction:** Research has shown the potential of bringing similar relationships to the virtual domain through parasocial interaction, which is a key component in developing both consumer and brand equity (Labrecque, 2014). Since customers in metaverse environments would communicate with artificial conversational assistants and not company representatives, such interactions and contact may extend to virtual 'friends' and transcend to customer service provided with virtual attendants or chatbots in various service settings.

- (v) **Measurement:** The metaverse offers data points that can be analyzed in the real-time. This improved measurability (Jarvinen & Karjaluo, 2015) thus is more effective in tracking, targeting, and re-targeting the potential customers. Further, measurement of the entire journey of a digital client in a 3D space

through a variety of hand and eye gestures improve transparency as well as quality of the datasets.

2. Metaverse in Banking and Financial Services

Almost all industries such as healthcare, manufacturing, fashion, e-commerce and automobile are increasingly becoming part of this technological revolution and are using metaverse as a tool to enhance user experience and attract more customers. Banks and other financial institutions are not an exception in this regard and can reap benefits of tapping on the opportunity to invest in and embrace this innovative technology.

Metaverse aids the financial sector in creating customer value through virtual offices, financial data visualization, educative efforts and enhancing overall customer experience (Iqbal, 2024). Banks can establish a presence in the metaverse by setting up virtual branches that allow the customers to access banking services without having to visit a physical bank in person, drawing in digital-native customers, and becoming important players in its financial and payments ecosystem (Awada, 2023).

Banking and payments providers also have the opportunity to become key stakeholders in managing and supporting the financial and payments infrastructure of the metaverse. Kiya.ai, a Mumbai based AI powered Fintech company launched India's first banking metaverse in 2022 offering practical applications within the metaverse that address real-world business needs. Since then, many banks have taken a lead and have initiated the process of offering services through

metaverse. For instance- Union Bank of India, one of the pioneers in adopting this cutting-edge technology, has developed "Uni-verse"- a space where customers can select their avatars, explore the bank's range of products and services, and engage interactively. It provides a wide range of banking services such as balance enquiry, accessing mini statements, getting interest certificates, updating nominations and applying for debit card in a hassle free and convenient manner. The bank has further revamped this Virtual Lounge by adding additional features to improve the overall user and customer experience.

In a move towards serving global Indians, HSBC India, one of the leading global private sector banks has launched this service for Non-resident Indians in June 2024 (Singh and Das, 2024). The metaverse, which can be accessed using VR headsets or QR codes, allow customers to create their own 'avatars' and explore a range of banking products, credit cards, and investment options. The bank has also purchased land in the Sandbox, a popular metaverse platform, to develop games on financial literacy and conduct workshops to reach Gen Z.

Punjab National Bank, another leading public sector bank in India has also adopted this technology through which the customers are able to perform the traditional banking activities such as accessing bank deposits, loans, digital products and government flagship schemes through an immersive 3D experience with their online avatars (The Economic Times, July 2023).

Apart from these banks, various other global banks and financial institutions such as JP Morgan, Bank of America,

Royal Bank of Canada and many more are entering into the space of metaverse and exploring the opportunities available in the path towards increasing customer acquisition and engagement along with creating hyper-personalized experience for their valued customers.

3. The Way Forward

Based on the extensive review, the paper suggests a few metaverse application areas as a way forward for banks. *First*, based on their profile data, metaverses can be used in banks to tailor each touchpoint according to each customer. This may help banks to exceed customers' expectations and boost satisfaction (Halvorsrud et al., 2016).

Second, touchpoints are service interactions that a consumer has that are either directly or indirectly related to a specific brand, influencing their perceptions and assessments of the brand as a whole as well as their customer journey (Baxendale et al., 2015; Clatworthy, 2011). As is frequently the case with other channels, engagements with metaverse touchpoints can be analyzed and monitored throughout the consumer experience (Aichner & Gruber, 2017). The nature of engagements can then be improved, and customer connections can be strengthened as a result of such touchpoint data (McKechnie et al., 2011). However, personalizing the experience is more difficult in shared virtual spaces since various users may have different expectations. The requirement to limit the accessibility of a virtual space to a specific number of users may help to mitigate such a problem. By assigning customers to locations that are most conducive to their tastes, load

balancing consumers among many versions of a commercial space might help transform an intractable optimization problem into one that might be manageable.

Third, metaverse not only enables multi-user interaction but also optimizes user experience for each individual. Positively, when such encounters are allowed, there may be chances for co-creation between customers as well as between the retailer and them. Metaverses can serve as a stage for the staging of a complicated network of relationships between different characters, whose activities and inter-dependencies co-create value and affect one another's reactions (Varnali, 2019). In these connections, users may not only be humans but also artificial intelligence (AI) agents (such as banking personnel), who can take any shape and communicate in text and speech just like regular users (Sung et al., 2021). However, there is a chance that these interactions may reverse impact and be harmful to the user experience.

Lastly, interactions have become more direct as a result of social commerce, like in the instance of live trade. There is a chance that such knowledge and good practices might be applied to metaverse bankscape. For instance, managers must take into account important factors while trying to influence customers' behaviour and well-being in metaverses, such as those that are crucial for other digital and social media marketing and channels, such as experience, personalization, and collaboration (Dwivedi et al., 2021). The offline and online channels that are already well-established and competitive could pose a significant threat to metaverses as a channel.

4. Conclusion and Future Research

While the emergence of the metaverse presents new and exciting levels of interaction between the physical and virtual worlds, creating opportunities and future business concepts (Chayka, 2021), mass adoption presents significant challenges related to governance, ethics, security and safety, acceptable behaviours, privacy, and the potential emancipation of portions of the population who lack access to the infrastructure required to access the metaverse (Fernandez and Hui, 2022; Haimson and Hoffmann, 2016). The financial

institutions around the world are moving towards digitization and aiming to create a virtual world parallel to the physical world where customers can easily access almost all the financial services at their own convenience and pace and metaverse is a step towards that.

Due to scarcity of studies and guidelines in this area, there is a need for researchers to reflect on the effective use of this potential ‘disruption’ in future. The paper provide directions for undertaking further assessment of metaverse and its applicability in the banking sector in the Table below.

Table: Future Research Considerations

XR and the Metaverse	Goals and conditions under which metaverse can provide a more effective user interface. Hardware devices suitable for metaverse applications.
Strategy	Design and implementation of metaverse strategy Strategic decisions to be addressed in the metaverse Relevant performance indicators
Artificial Intelligence	Role of artificial intelligence and artificial agents in the metaverse.
Products and Services	Perception and ownership of virtual products and services Leveraging metaverse blockchain to design and deliver products/services that add value to consumers and firms/banks.
Distribution	Extent to which metaverse distribution channels can be used in place of traditional/ channels used at present
Promotion	Increasing and measuring influencer marketing for firms/ banks in the metaverse
Data Use and Privacy	Leveraging the capabilities of the metaverse to improve the quality and validity of data Ways to address privacy concerns
Ethics	Potential ethical challenges Ways to minimize potential psychological or physical risks

(Source: Literature Review)

In sum, the status of the metaverse as it progressively develops to realize its full potential is in the distant, but hopefully not in the too-distant future. Banks should also be cautious of the fact that this new technology lacks consistency and norms and presents a highly competitive environment. Thus, while moving towards metaverse, it is critical for banks to

maintain a sense of realism and be adaptable and flexible to be able to respond appropriately to changing and dynamic circumstances. Instead of immediate results, the focus should be on building a long-lasting presence and relationship with the banking customers who to connect with them in this technological transformation

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A study on consumer perception of the amalgamation of Allahabad Bank with Indian Bank

By

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Abstract:

The banking industry contributes significantly to a country's economy by providing essential services to consumers, businesses, and governments. In India, the Reserve Bank of India (RBI) is responsible for overseeing and regulating bank operations in order to ensure their stability and efficiency. The Swadeshi movement established Indian Bank in 1907, and it has been in operation for 113 years. Meanwhile, Allahabad Bank, which has been in operation for 155 years, was founded in 1865 as a joint stock corporation in Allahabad by a group of Europeans. Indian Bank merged with Allahabad Bank on April 1, 2020, citing government orders. The combined corporation is now the country's seventh-largest public-sector lender. The merged organisation, which is composed of 78 Zonal Offices and 14 Field General Manager's Offices (FGMO), is operational as of January 31, 2021, following the merger of Zonal Offices and branches. To administer the liabilities accounts, namely Customer Acquisition and Opening, Customer Acquisition Processing Centres (CAPC) are built at eight centres in Chennai, Allahabad, Bhopal, Bhubaneswar, Delhi, Kolkata, Lucknow, and Patna

Keywords— *Amalgamation, Allahabad bank, Indian bank, Economic Development, Consumer Perception & protection of the depositors.*

Introduction

According to an RBI notification dated March 28, 2020, all Allahabad Bank branches would become Indian Bank branches after the two banks merge. On April 1, Allahabad Bank ceased operations in its current form and officially merged with Indian Bank. They assured everyone that the bank would offer high-quality products and services to all of its clients. They valued both banks' extensive history, which provided them with an excellent

base for serving our clients throughout India.

The two creditors have a long-standing relationship that stretches back before the American Revolution, she continued. With 113 and 155 years of combined experience, Indian Bank and Allahabad Bank will unite to become a single institution that prioritizes accessibility and financial stability across the country. With more than 6,000 branches, 4,800 automated teller machines, 43,000 staff, and more

than 120 million customers served, the combined business will be worth more than Rs 8 trillion. Indian Bank and Allahabad Bank's merger has boosted overall

business, gross advances, deposits, branches, and the Provisioning Coverage Ratio (PCR), all of which are good for the economy, as shown in Figure 1.

Indian Bank + Allahabad Bank			
	Indian Bank	Allahabad Bank	Amalgamated bank
Total business (in crore ₹)	4,29,972	3,77,887	8,07,859
Gross advances (in crore ₹)	1,87,896	1,63,552	3,51,448
Deposits (in crore ₹)	2,42,076	2,14,335	4,56,411
CASA ratio	34.71%	49.49%	41.65%
Domestic branches	2,875	3,229	6,104
PCR	49.13%	74.15%	66.21%
CET-I ratio	10.96%	9.65%	10.36%
CRAR ratio	13.21%	12.51%	12.89%
Net NPA ratio	3.75%	5.22%	4.39%
Employees	19,604	23,210	42,814

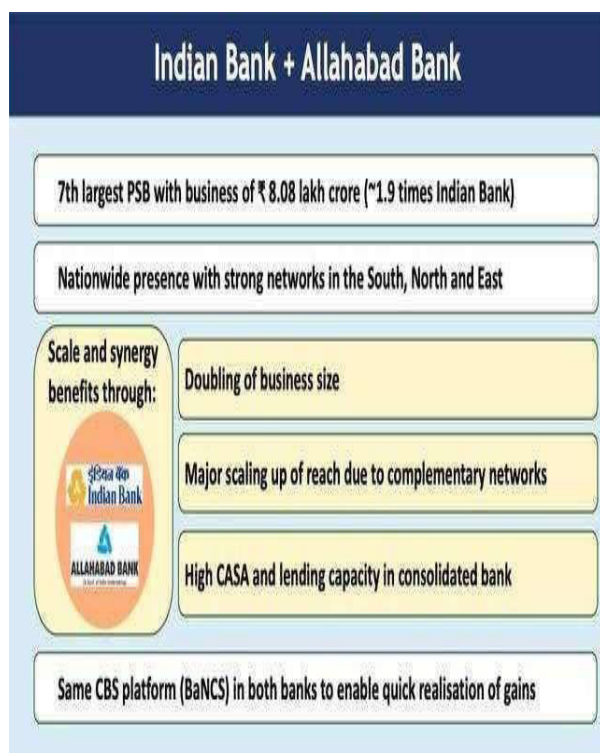
Current Account Savings Account Ratio, Provisioning Coverage Ratio, Common Equity Tier1 Ratio, Capital to Risk Weighted Assets Ratio also known as Capital adequacy ratio, Non- Performing Assets.

The infrastructure of Indian Bank in the north, center, and east will be expanded by the complementary branch base. Additionally, a broader global reach will benefit both banks' more than 120 million clients. The combined

company will see several cost and revenue savings as a result of the transaction. According to her, income savings might be achieved through improved cross-selling opportunities, operational optimization, technological expenditure optimization, and a more unified and extensive variety of products. Small and medium-sized business owners would be supported by the additional loan capacity.

Key industries will be fully covered due to both carriers' extensive branch and network networks that span the whole country.

Customers of both companies will have better access to a broader selection of products and services. Employees claim that, in addition to salary and investments in talent and skill development, this convergence will benefit all employees because they have been harmonized. In terms of the bank's suggested business model, she stated that the central processing centres would serve as supporting institutions, while the branches would act as business leaders. Remuneration and human resource rules.



Scale of synergy and benefits is explained from the above chart and it's given the best performance after amalgamation.

After the distribution of Sharers in Indian Bank, the value of Allahabad Bank stockholders will have decreased by 25% according to the Programme of Merger, which calls for a stock conversion rate of 115 Indian Bank stocks for 1,000 Allahabad Bank shares. The combined company is expected to bring in Rs 10 trillion in revenue by 2024.

And from the above diagram, we can conclude that after the merger, it becomes the seventh largest public sector bank with a business of Rs. 8.08 lakh crore, with nationwide strong networks in the south, north, and east, and doubling the business size, i.e., high CASA and lending capacity in the consolidated bank and both banks to enable quick realization of gains.

The Bank Mergers

Because the overall size of the bank will rise as a result of the bank merger, the operational risks will be reduced.

Banks' credit portfolios and non-performing assets (NPAs) will be better managed. The amalgamation will not permit the expenditure of the merger will not allow for the investment of additional resources in a certain sector, thereby strengthening the banks with stocks.

The merger of banks will result in increased synergy and cost savings. This would help the Indian banking system.

PSBs will gain a competitive edge by investing in and embracing technologies across the banks being merged. Digitalization and technical assistance are required to make such a significant transition conceivable.

Customers of these banks may gain access to a broader network of bank branches and ATMs.

The benefits of bank mergers

1. The bank merger will give the anchor bank more opportunities to generate capital both internally and from the market.
2. In addition to its non-tax revenues, the government will receive additional dividends.
3. There will be less competition in the financial sector due to the decline in independent banks. Payment and settlement flows will become increasingly concentrated as a result.
4. As the bank's overall size increases, operational risks decrease as the gap between management and operational personnel widens.

5. Non-performing assets (NPAs) and bank credit portfolios will be managed more skillfully.

Bank mergers' drawbacks

1. After the bank merger, the weaker banks' unfavorable effect will hinder the larger bank's operations in India. For instance, Vijaya Bank and Bank of Baroda's stock fell sharply after the bank merger was announced, whereas Dena Bank's stock rose quickly.

2. The success of bank mergers may also be hampered by issues with human resources and culture.

3. Minority shareholders, who currently only have a veto power in matters, will be impacted by the Government's decision as the majority shareholder.

4. The bank merger process, which involves strong institutions acquiring smaller banks, is unlikely to resolve the current bad loan issue.

5. Management will encounter key hurdles linked to branch rationalization, staff integration, and other issues.

Benefits of Bank Mergers

Efficiency

Bank mergers make banks more efficient, not only in terms of efficiency, but also in commercial operations. Each bank has its own infrastructure, risk management, technology, staff, and operating principles. Now that two banks have been combined into one, they can work more efficiently.

Filling Business Gaps

One of the most major advantages of combining is that it addresses business gaps caused by a lack of cash, technology, or infrastructure. Acquiring a small bank

that provides services is beneficial, but it needs capital to survive, which is sometimes easier than starting a bank from beginning. When a larger bank merges with a smaller bank, the business gaps are easily filled.

Talent and Team Improvement

A merger benefits every bank by extending its talent pool. When a merged bank hires experienced management and personnel, its productivity and customer happiness will skyrocket. Being combined by the other bank provides the stability that a weaker bank requires to survive.

Scale

A bank merger allows a merged bank to build up swiftly and easily meet the needs of new customers. If a small bank wishes to accelerate its expansion, merging is an excellent alternative.

Research Methodology:

Conducting a study on consumer impressions of the merger of Allahabad Bank and Indian Bank necessitates a thorough research technique that incorporates both primary and secondary data. Here is a step-by-step strategy to conducting this research. The data is exploratory and qualitative, and both primary and secondary sources were used in the current study.

Analysis and Discussion

Demographic Profile of the respondents

S.No	Qualitative Factors	Classification	Frequency %
1.	Age	Below 20 years	20
		21-35 years	37
		Above 35 years	43
2.	Marital Status	Married	36
		Single	46
		Divorced	18
3.	Education	Graduation	48
		Post graduation	36
		Doctorate	16
4.	Work experience	Less than 5 yrs	64
		Between 5 to 10 yrs	36
5.	Nature of work	Daily Wage Employees	16
		Business / Entrepreneur	66
		Government employees	8
		Private sector	10
6.	Yearly compensation	Less than Rs 2,50,000	24
		Rs 2,50,000 – 5,50,000	59
		More than Rs 5,50,000	17

Source: Primary data

The primary data came from a survey given to residents of the city of Coimbatore. Secondary data were gathered for this study from bank books and bank financial results that were published in journals, online, and through web sources. A total of 250 respondents who were Allahabad bank customers were gathered from the city using a straightforward random sampling technique. It is evident from the table above that 43% of the consumers are over 35 and have a bank account. While 48% of highly educated account holders who work in banks are married, only 46% of unmarried bank clients are. 36% of clients have more than 5 years of experience, while 64% of account holders have less than 5 years. 16% of our

customers are employees and 66% of our customers are entrepreneurs. 8% of customers are government employees and 10% of customers are private sector employees.

Analysis and Discussion:

S.NO	Customer perception towards merger of Allahabad with Indian bank		
	Verdicts	Agree	Disprove
1	You will have quick access to a range of financial services provided by Indian bank as a result of the merger.	80 %	20 %
2	That may boost the bank's value.	74 %	26 %
3	I'm sure I can get bank loans quickly and effectively.	68%	32%
4	The integration seems to be a hassle.	45%	55%
5	The influence of reason is constructive.	35%	65%
6	I can see the authorized loan details online, along with the remaining amount at the end of the repayment plan, which is helpful.	90%	10%
7	It lets me investigate state-of-the-art banking services technologies.	84%	16%
8	Customers' lack of personalized service is the main issue.	78%	22%
9	One of the Reserve Bank of India's most impressive financial strategies is to merge with an Indian bank in place of the current business and loan recovery plan.	86%	14%
10	Repositioning the branch will help the bank's customers and allow RBI to protect Allahabad from potential dissolution, which will be highly advantageous to the bank's depositors.	90%	10%

Source: Primary data

The above table represents the perception of customers towards the process and merger of Allahabad with Indian bank. From the above table, 80% of the customers accept that by merging with Indian bank, they can be able to access a wide range of financial services quickly and through Merger with Indian bank will get varied and quick banking services. 74% of the customer's perception is that might increase the worth of the bank. 68% of the customers are confident in their ability to obtain swift and efficient bank loans quickly. 55% of the customers feel that integration is in-convenient only 35% of the customers accept the rational influence is positive. 90% of the customers are beneficial to view the loan details that have been approved online as

well as the outstanding balance during the repayment schedule with much faster services. 84% of the customers feel that it enables them to research cutting-edge banking services technologies. 78% of the customer's purview is that the major problem is the customers don't receive individualized service. 86% of the customers accept that the statement "The current business and loan recovery strategy should be replaced by a merger with Indian bank is a remarkable financial strategy of Reserve Bank of India" finally 90% of Depositors of Allahabad bank stands to gain significantly from elevating the branch's position, which will also benefit the bank's clients and enable RBI to safeguard Allahabad bank from the possibility of dissolution.

Association between Perception on Merger and Demographic profile H01: There is a significant association between the perception on merger and the demographic profile of the respondents

Table – 2: Chi-Square Analysis				
S.No	Dep. Variable	Ind. Variable	X ²	Sig.
1.	Perception	Age	46.12	0.56
2.	Perception	Marital status	39.56	0.00**
3.	Perception	Education	34.44	0.08*
4.	Perception	Work experience	19.89	0.004*
5.	Perception	Nature of work	19.32	0.42
6.	Perception	Yearly compensation	18.13	0.99th

Source: Primary data

* Significant at 5%.

**Significant at 1%.

A chi-square analysis reveals between the respondents' perceptions and demographic classification is displayed in the above table. The table unequivocally demonstrates that the hypothesis is rejected for the remaining demographic characteristics but accepted for age, occupation type, and yearly wage.

Conclusion:

When India obtained independence, multiple banks were nationalized and opened to support the country's economic development and provide financial services to all of its citizens, even if the merging of Allahabad Bank with Indian Bank was only a temporary solution. Many banks are required since our country's huge population makes it hard to provide banking services to every resident. If the Reserve Bank of India and the Finance Ministry of India make this decision, it will be difficult to service all Indian inhabitants and rural areas. Finally, it is stated and concluded that a financial crisis could

occur if the weaker bank joins with a future bank. As a result, the government must respond swiftly. Instead of merging, the government must move quickly. All of the weaker banks should be strengthened rather than merged.

Synergy Realization: The success of a bank merger depends on the realization of synergies, including cost savings and revenue enhancement. Analyze whether the merger of Indian Bank and Allahabad Bank has achieved the expected cost-saving benefits and whether there has been an increase in cross-selling opportunities and revenue generation.

Operational Efficiency: Assess whether the merged entity has improved its operational efficiency, such as reduced branch overlap, streamlined processes, and optimized technology infrastructure.

Customer Experience: Evaluate whether the merger has positively impacted the customer experience. This includes assessing the quality of services, product offerings, and the overall satisfaction of the customer base.

Recommendations:

Continuous Monitoring: Continue to closely monitor the post-merger performance of the bank. Regularly review and analyze key performance indicators to ensure that the merger's objectives are being met.

Customer Engagement: Focus on enhancing customer engagement and loyalty. Implement strategies to ensure that customers from both banks are receiving a high level of service and are aware of the expanded product and service offerings.

Technology Integration: Ensure that the technology platforms of both banks are seamlessly integrated to improve operational efficiency and facilitate a unified customer experience.

Risk Management: Maintain a strong risk management framework to address any potential issues that may arise from the merger, including credit risk, operational risk, and compliance.

Employee Integration: Ensure that the employees from both banks are effectively integrated into a single team, minimizing any potential disruption and maximizing the talents and expertise of both organizations.

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METaverse BANKING & CUSTOMER EXPERIENCE: A TECHNO-ECONOMIC FRAMEWORK FOR IMMERSIVE FINANCE IN VIKSHIT BHARAT @ 2047

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Keywords: Metaverse Banking, Customer Experience (CX), Extended Reality (XR), Decentralized Finance (DeFi), Digital Assets

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ABSTRACT

The intersection of immersive technologies and decentralised networks, also known as the metaverse, will be the most influential architectural shift for the financial services sector since the introduction of the internet. This paper sets a technical and economic approach for metaverse banking, aligned with the vision of India's "Vikshit Bharat@2047". We recast the conversation from using just conceptual frameworks to an analysis of the technical stack from the physical layer networking aspects to application layer protocols. Our examination of Extended Reality (XR), blockchain, and Artificial Intelligence (AI) technologies includes a quantification of performance such as will be applicable to their use in banking. Second and more significant, this paper creates techno-economic models like a return on investment (ROI) model for virtual branches, and an analysis of network costs based on user uptake. Critical consideration is given to key technology issues like achieving interoperable identity framework using Decentralized Identifiers (DIDs) and Verifiable Credentials (VCs), along with enabling ultra-low latency for seamless XR experiences. Finally, we propose a multi-layered security architecture using Zero-Trust and on-chain monitoring. The paper depicts a hyper-personalised customer journey through detailed UI/UX mock-up descriptions and data-flow diagrams; and, concludes with a strategic, incremental implementation roadmap for Indian financial institutions, arguing that it is technically feasible, economically reasonable, and human friendly that is sine qua non for establishing a prominent position in the future bankscape on a global level.

Keywords: Metaverse Banking, Customer Experience (CX), Extended Reality (XR), Decentralized Finance (DeFi), Digital Assets

1. INTRODUCTION: A NEW ARCHITECTURAL PARADIGM FOR FINANCE

Banking innovation has been closely tied to technology disruption; the mainframe era centralized processing; the internet era distributed access; the mobile era personalized delivery; and now we have the era of immersive, decentralised finance built in the metaverse; and for a developed nation by 2047 Bharat, moving in this direction is not a choice; rather a necessity to be globally competitive and service its native digital population.

The metaverse concept brings to mind social gaming and other 3D interactions, however, the technologies that underpin it - persistence, real-time 3D environment, interoperability, economy, and digital identity - are the building blocks of a more seamless and engaging financial ecosystem (Thakkar et al, 2025).

This paper proposes a frame for understanding metaverse banking as not simply an incremental extension of a banking channel (e.g., a mobile banking app) but a shift in architecture (Thakkar et al, 2024). By moving from a 2D, form-

based internet to a 3D, experiential internet, and moving from a centralized client-server architecture to a decentralised user-centric architecture with blockchain and Web3 (Unuigbokhai and Anthony, 2022).

This paper provides an in-depth analysis of the components that are necessary to build this future. We will evaluate the network infrastructure outlined above, the rendering and processing requirements of XR technology as well as the cryptographic and consensus methods of block chain and the algorithmic complexities of AI based personalisation (Thakkar et al, 2024). We will quantify the challenges and make direct suggestions. The aim is most importantly to provide Indian banking decision-makers, technologists and policymakers with a technological and economic framework to manage this change so that the metaverse bankscape of 2047 is technologically effective, secure, inclusive and economically sustainable.

2. LITERATURE REVIEW

This paper argues that the new age metaverse banking technology holds potential to aid seamless cross border transactions, replace credit and debit cards and also achieve net zero carbon emission. Nonetheless, since metaverse baking is an emerging scope, this study fails to make suggestions of how to facilitate easier access for the conventional customers (Dubey et al., 2022). To achieve the objectives of this study, the researchers invited experts in four domains, i.e., corporate banking, retail banking, banking employees and public policy as they try to

postulate opportunities and challenges associated with these domains (Ogunode & Dada, 2022). A key limitation in this study is that it is conceptual, based on expert opinions without original data, limiting its depth and real-world applicability (Ooi et al., 2023). The study concludes that four key factors—metaverse facilitating conditions (MFC), performance expectancy (MPE), social influence (MSI), and effort expectancy (MEE)—influence consumers' intentions to adopt metaverse banking (Olaniyan et al., 2021). It also finds that affordability alone is insufficient

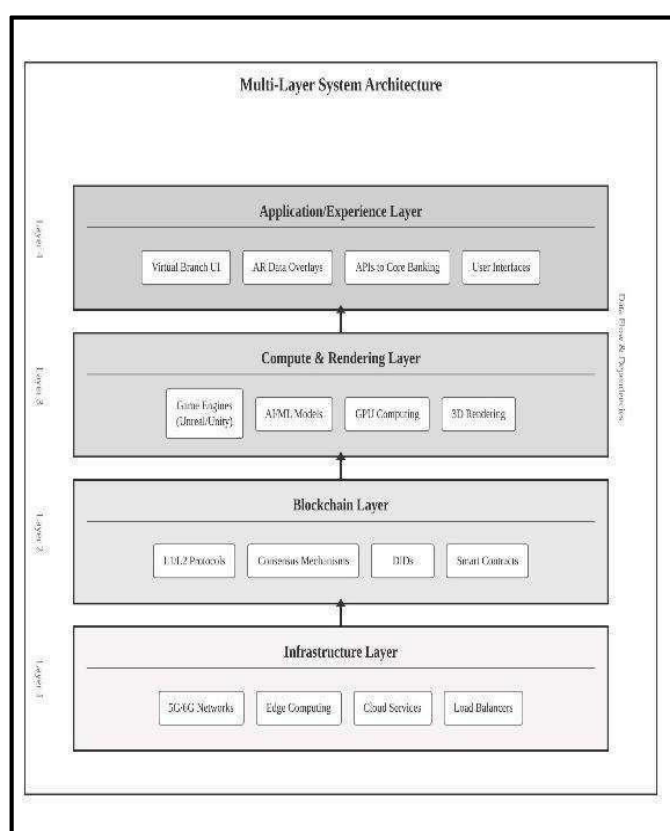
to drive widespread adoption (Omucheyi et al., 2025). A key limitation is the use of quota sampling, which may not effectively represent the population, and the study's scope is restricted to Vietnam (Nguyen et al., 2023). The findings of this study suggest that perceived anthropomorphism and immersion impact positively and lack of social interaction and perceived vulnerability impact negatively towards the usage intention of retail metaverse banking (Thakkar et al, 2025). Trust and distrust were also found to be significant mediators. A key knowledge gap stems from the use of a cross-sectional survey

design, which overlooks how perceptions of metaverse banking may evolve over time (Kumar & Shankar, 2024). The study explores the balance between user pseudonymity and accountability, which is vital for user trust in virtual financial environments (Thakkar et al, 2025). It also highlights the role of blockchain (e.g., IBM Blockchain World Wire) and biometric authentication in creating a secure framework. However, the study lacks empirical validations because of which privacy, pseudonymity and blockchain applicability remain largely conceptual (Garg, 2024).

3. THE METAVERSE TECHNOLOGY STACK: A GRANULAR ANALYSIS

Every conceivable layer of technology stack is needed to build a metaverse bank. A breakdown in any of the layer can ruin the user experience, and potentially create security risks, poor performance or a complete loss of immersion.

Figure 1: Multi-Layer System Architecture



Source: Compiled by Author

3.1 Infrastructure Layer: The Physics of Presence

A sense of "presence"—the feeling of actually being in a virtual space—is computationally and network-intensive. The primary metrics are bandwidth, latency, and jitter.

Bandwidth Requirements: A high-fidelity VR experience requires streaming large volumes of data. We can model the bandwidth requirement (B_w) as:

$$B_w = (R \times C \times F) + A_s + D_s$$

Where:

R = Resolution per eye (e.g., 2160x2160 pixels)

C = Color depth (e.g., 24 bits/pixel)

F = Frame rate (e.g., 90 Hz for smooth motion)

A_s = Audio stream bitrate (e.g., 320 kbps)

D_s = Interaction data (position, gaze, etc.; relatively small, e.g., 100 kbps)

For a single user with a modern headset, this raw requirement can exceed 1 Gbps requiring the use of advanced video compression codecs (H.265, AV1, etc.) to target a more reasonable value of 25-100 Mbps. For a virtual branch in the case of 20 users all connected concurrently, the server uplink and also the client downlink should be as high as we need very strong connections.

Latency (Motion-to-Photon) is defined as the time from when the user moves their head to when the image in the headset updates. We need this to be under 20 milliseconds in order to avoid cybersickness.

Latency of the Network - 5G networks are important because their latency can be <10ms.

Latency of Compute (Rendering) - Rendering complex 3D images takes time. This is where edge computing becomes relevant where we move the compute/processing power of rendering from a cloud data center 1000s of miles away, to a node geographically stable and much closer to the user (i.e., at the base of a cell tower).

Table 2.1: Network Requirements for Metaverse Banking Tiers

Tier	Application	Required Bandwidth (Post-Compression)	Required Latency (M2P)	Enabling Technology
Bronze	AR Overlays on Mobile, Basic 3D Viewing	10-25 Mbps	< 50 ms	4G LTE, Wi-Fi 5
Silver	Entry-Level VR Branch (Low-poly)	25-50 Mbps	< 30 ms	5G, Wi-Fi 6
Gold	High-Fidelity VR, Photorealistic Avatars	50-100+ Mbps	< 20 ms	5G Advanced, Wi-Fi 6E
Platinum	Holographic Conferencing, MR Interactions	100+ Mbps	< 15 ms	6G, Edge Cloud

Source: Compiled by Author

2.2. Blockchain Layer: The Trust Machine

This layer provides the economic and identity foundation.

Choice of Protocol (Layer 1 vs. Layer 2):

Layer 1 (e.g., Ethereum): Provides high security and decentralisation, but has low throughput (transactions per second, TPS) and high costs (gas). Not suitable for high velocity banking transactions.

Layer 2 (e.g., Polygon, Arbitrum): Built on top of L1s, these "roll-up" technologies execute transactions off-chain which are then summarized into a single L1 transaction. This provides significantly higher TPS and lower costs.

Cost of Transactions: A straightforward token transfer on Ethereum L1 could cost anywhere from \$2 - \$20. That same transaction on a ZK-Rollup L2 like Polygon zkEVM may cost \$0.05 - \$0.25,

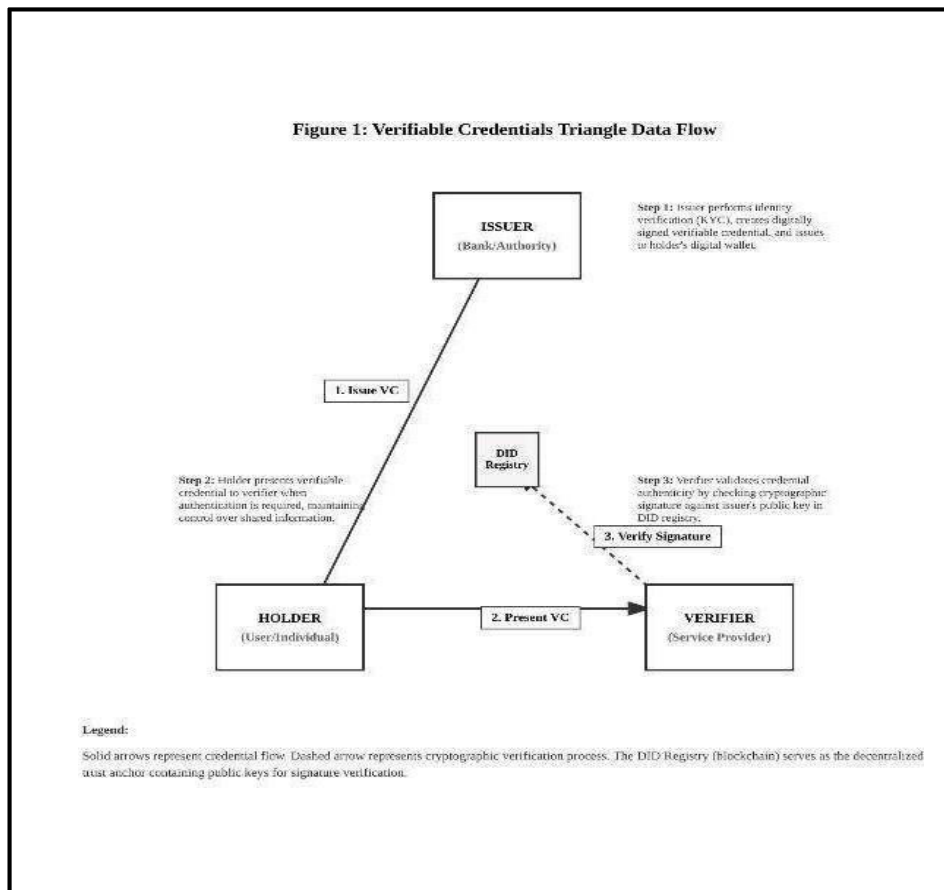
which is a reduction of over 95% and makes microtransactions possible.

Digital Identity - DIDs and VCs: An essential aspect of secure banking is to move away from platform specific logins (e.g., "Login with Google") and toward a self-sovereign identity.

Decentralized Identifiers (DIDs): A W3C standard. A decentralized identifier (DID) is a globally unique, persistent identifier that does not require a centralized registry.

Verifiable Credentials (VCs): Digital version of a physical credential (i.e., driver's license or bank statement). A bank (Issuer) can issue a VC to a user's digital wallet (Holder). That user can then present that VC to a third party (Verifier), which does not require the bank (Issuer) to be included in the transaction.

Figure 2: Verifiable Credentials Triangle Data Flow



Source: Compiled by Author

2.3. Compute & Application Layer

Rendering Engines: Video game engines (e.g., Unreal Engine 5 and Unity) serve as the primary framework to create 3D environments. These engines supply a variety of tools, including tools for physics simulations, lighting (e.g, Lumen in UE5 for real-time global illumination), and asset management. The selection of an engine is critical to visual fidelity, performance to the user's system, and overall development costs.

AI-driven Personalisation: AI modelling (specifically Natural Language Processors (NLP) transformers i.e., BERT or GPT variants) is used to build intelligent Non-Player Characters (NPCs), some of which are integrated in artificial intelligence financial advisors. The benchmarking of an AI financial advisor can be achieved with Intent Recognition Accuracy.

Calculating Accuracy: $\text{Accuracy} = \frac{\text{Total number of User Queries Correctly Interpreted}}{\text{User Queries}}$ Any AI-based financial advisor should set a target accuracy of >95%, which is critical for a positive user experience, which requires extensive prior training on domain specific financial knowledge.

4. TECHNO-ECONOMIC FEASIBILITY AND ROI ANALYSIS

Deploying a metaverse branch is a significant investment. A business case must be built on tangible metrics.

3.1. Cost Components

(1) The Total Cost of Ownership (TCO) includes:

CAPEX (Capital Expenditure):

Platform Development/Licensing Fee, which may include a fee for plot in Decentraland or custom build.

3D Asset Creation (designing the branch, avatars, furniture).

Initial Server/Edge Infrastructure set-up.

OPEX (Operating Expenditure):

ongoing Platform Maintenance & Updates.

cloud/edge hosting costs.

salaries for specialist staff (3D artists, blockchain developers, virtual relationship managers).

transaction costs on the blockchain.

Table 3.1: Estimated 3-Year TCO for a "Silver Tier" Metaverse Branch

Cost Item	Year 1 (INR)	Year 2 (INR)	Year 3 (INR)	Total (INR)
CAPEX				
Platform Development	1,50,00,000	0	0	1,50,00,000
3D Asset Creation	75,00,000	10,00,000	10,00,000	95,00,000
OPEX				
Hosting & Maintenance	25,00,000	30,00,000	35,00,000	90,00,000
Specialised Staff (4)	1,20,00,000	1,32,00,000	1,45,00,000	3,97,00,000
Marketing & Events	50,00,000	40,00,000	40,00,000	1,30,00,000
Total	4,20,00,000	2,12,00,000	2,30,00,000	8,62,00,000

Source: Compiled by Author

3.2. Return on Investment (ROI) Calculation

Returns are generated from both tangible and intangible sources.

Tangible Returns:

New Customer Acquisition: Acquiring high-value Gen Z/Alpha customers.

New Revenue Streams: Fees from virtual asset (NFT) custody, trading, and lending.

Operational Savings: Potential reduction in physical branch overheads (though this is a long-term goal).

Intangible Returns:

Brand Perception: Being seen as an innovative leader.

Customer Engagement: Increased interaction time compared to a 2D app.

Data Acquisition: Gathering insights on next-generation customer behaviour.

ROI Formula: $ROI = \frac{\text{Cost of Investment}(\text{Gain from Investment} - \text{Cost of Investment})}{\text{Cost of Investment}} \times 100$

Calculation after 3 years:

Gain from Investment (Tangible):

New Customer Lifetime Value (LTV): 5,000 new customers * ₹50,000 LTV = ₹25,00,00,000

New Revenue: ₹5,00,00,000

Total Gain = ₹30,00,00,000

Cost of Investment = ₹8,62,00,000

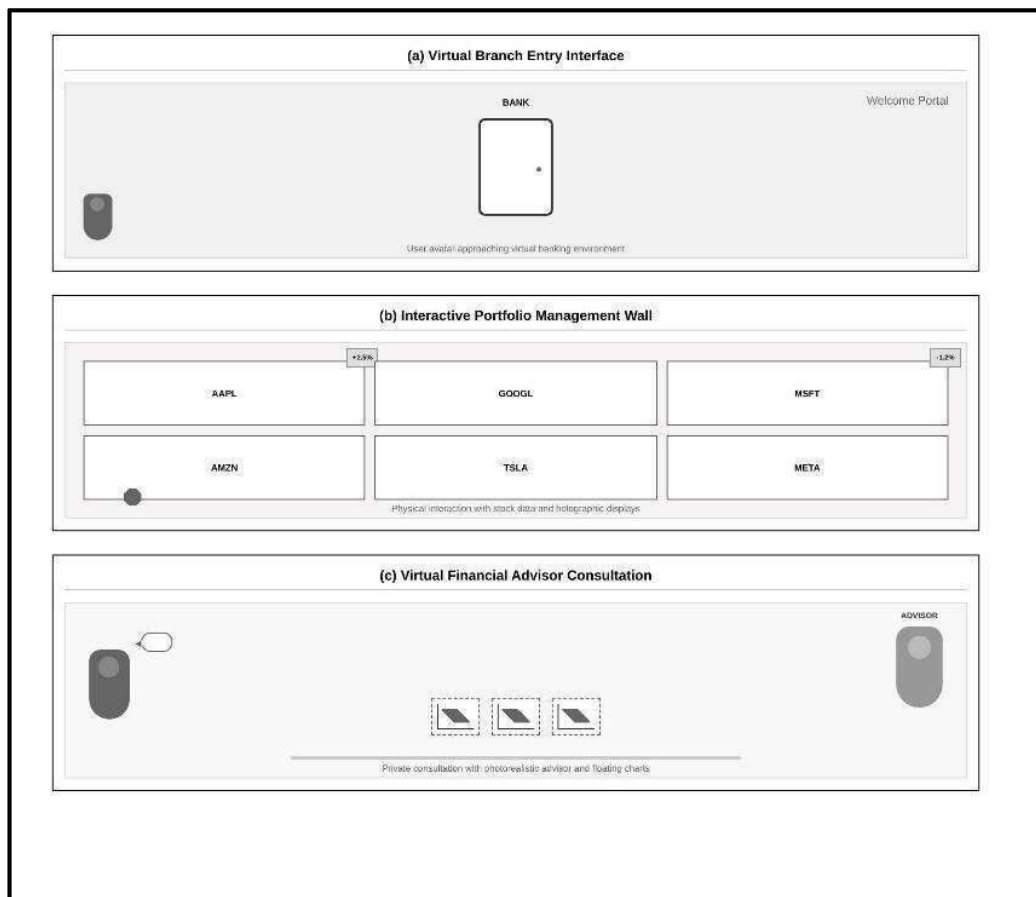
$ROI = \frac{(30,00,00,000 - 8,62,00,000)}{8,62,00,000} \times 100 \approx 248\%$

While this is a projection, it provides a quantitative framework for decision-making. The key is the LTV of the new demographic acquired.

5. THE CUSTOMER JOURNEY REIMAGINED: UI/UX IN 3D SPACE

The user interface (UI) and user experience (UX) in the metaverse must be fundamentally rethought. We move from clicking buttons to spatial interaction.

Figure 3: User Interface



Source: Compiled by Author

Key UX Principles:

Spatial Affordance: Virtual object design should promote intuitive interaction model. Example: virtual lever should be pulled, while virtual button should be pressed.

Minimised Cognitive Load: Financial information can be nuanced and complex. Rather than utilizing abstracted tabular information, consider using 3D visualisations. For example, a budget could be represented as a pie chart; however, instead of as being represented as a set of rigid 2D objects, that user could walk around the pie chart, with the slice heights (indicating spending) could be elevated / lowered.

Accessibility: design should consider users with varying mobility levels and technical skill levels; incorporate design options that allow users teleportation as a locomotion option and also allow users to utilize walking. Also provide command options that allow users to use voice commands / hand gestures.

6. SECURITY ARCHITECTURE FOR VIRTUAL FINANCE

Security in the metaverse is multi-faceted, involving identity, transactional and environmental security. A Zero-Trust Architecture (ZTA) is the most fitting model.

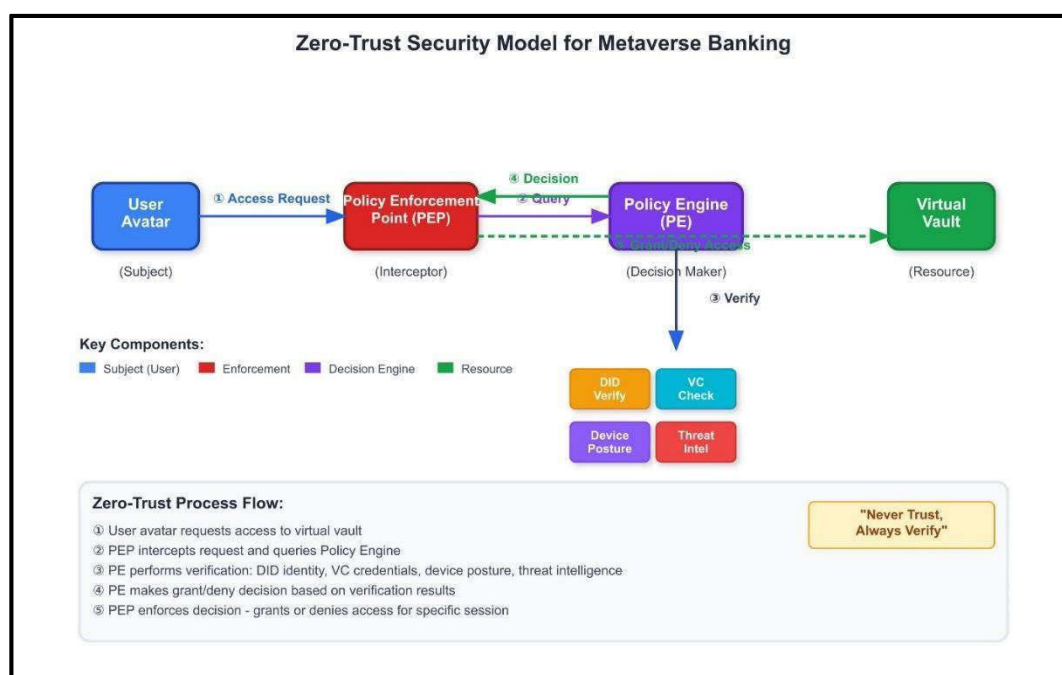
Zero-Trust Principles:

Never trust, always verify.

Assume breach.

Implement least privilege access.

Figure 4: Zero-Trust Security Model for Metaverse Banking



Source: Compiled by Author

Table 5.1: Threat Vectors and Zero-Trust Mitigations

Threat Vector	Description	Zero-Trust Mitigation Strategy
Avatar Impersonation	A threat actor hijacks or creates a look-alike avatar to scam others.	Strong Authentication: Require multi-factor authentication (e.g., biometrics from the headset + VC) for sensitive transactions. Continuously verify identity.
Smart Contract Exploit	A bug in the code of a DeFi protocol is exploited to drain funds.	Code Auditing & Formal Verification: Mandatory third-party audits. Use of formal verification tools to mathematically prove contract correctness. The ZTA policy engine would flag transactions to non-audited contracts.
Immersive Phishing	A fake, identical-looking bank branch is created to steal credentials.	Verified Environments: The bank's official virtual space should be cryptographically signed. The user's client application should verify this signature, displaying a "verified" badge, much like SSL certificates on websites.
Data Privacy Breach	Sensitive biometric data (gaze, gestures) is leaked from the platform.	Data Minimization & Encryption: The ZTA policy enforces that only necessary data is collected. All data, at rest and in transit, must be encrypted. On-device processing should be preferred.

Source: Compiled by Author

7. THE ROADMAP TO 2047 FOR VIKSHIT BHARAT

A journey of 23 years will involve a phased approach.

Phase 1: Foundations and experimentation. (2025-2032)

Goal: Build capacity and learn about user behaviour.

Actions: Invest in R&D. Launch pilot project "Silver Tier" branches on existing platforms. Collaborate with Indian tech institutes to develop talent. (RBI will create regulatory sandboxes for virtual assets.)

KPIs: Number of active users, length of time spent engaging, accuracy of AI advisors.

Phase 2: Scaling and integration. (2033-2040)

Goal: The metaverse becomes an important channel; a key part of integrated services.

Actions: Build proprietary "Gold Tier" platforms. Deeply integrate metaverse into core banking with APIs and real-time connections. Define interoperability for DIDs and other banks.

KPIs: Number of HNI/Gen-Z customers onboarded through metaverse, volume of transaction in virtual assets, level of return.

Phase 3: Ubiquity and maturity. (2041-2047)

Goal: The metaverse becomes the principle, seamless interface for finance.

Actions: Experiences on "Platinum Tier" platforms become characteristics of services across the banking system. AI driven hyper-personalisation becomes the norm. The lines between digital and physical finance begin to blur (e.g. being granted a loan to buy a physical car through an AR interaction).

KPIs: Market leadership in digital finance, customer satisfaction scores (CSAT), contribution to financial inclusion in a completely digital India.

8. CONCLUSION

The metaverse is not a passing fad; it is the next logical step in the development of the human-computer interface and the structure of the internet itself. For the Indian banking industry, it represents a once in a generation opportunity to reshape customer engagement, create new value chains, and position India as a world leader in this evolving landscape. The metaverse investment in financial services is a fundamentally a technology problem; successfully creating a bankspace in the metaverse depends on getting to grips with the intricacies of network engineering, distributed systems, cryptography, 3D rendering and AI. It will take time, investment, and commitment to build across these disciplines secure, performant (device agnostic), and equitable virtual worlds in the bankscape of 2047. The techno-economic model and roadmap in itself, presented in this paper, illustrates how Indian institutions can move from being commentators in the future of finance to being architects in the future of finance.

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An Insight into the Metaverse for Viksit Bharat @2047: Transforming Urban Development, Financial Inclusion, and Digital Empowerment

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Introduction

India's march toward becoming a developed nation by 2047—coined as Viksit Bharat 2047—requires a strategic embrace of cutting-edge technologies. Among the most transformative of these is the Metaverse, a rapidly evolving digital frontier with the potential to reshape economies, governance, education, healthcare, and citizen experiences in unimaginable ways. The Metaverse is no longer a speculative idea but an emerging reality—one that blends real and virtual worlds into an expansive digital ecosystem powered by interactive, immersive experiences.

Fundamentally, the Metaverse is a collective virtual space that integrates digital environments with real-world elements through the use of advanced technologies. Users, represented by avatars, can explore, interact, and create within this multidimensional digital universe. Unlike conventional digital platforms, the Metaverse creates a sense of "presence"—a virtual embodiment where people can collaborate, communicate, and build communities across time zones and geographies. It's not merely a visual interface but a fully immersive experiential zone where engagement happens in real time.

The development of the Metaverse is supported by a family of immersive technologies known as Extended Reality (XR). This includes Virtual Reality (VR), which immerses users in completely simulated environments; Augmented Reality (AR), which overlays digital information onto the physical world; and Mixed Reality (MR), which merges both to create real-time interaction between real

and digital elements. These technologies together enable the creation of complex digital ecosystems that are interactive, responsive, and increasingly intelligent.

As India aspires to build a future-ready society under Viksit Bharat 2047, the role of the Metaverse becomes crucial. It opens doors to digital-first education systems where students can learn in immersive classrooms, offering personalized learning through AI tutors and realistic simulations. In the healthcare sector, doctors can practice surgeries in virtual environments before performing them in real life. Similarly, in agriculture, farmers could use AR headsets to visualize crop data and soil analytics in real time, improving decision-making and productivity. The possibilities are boundless.

What sets the Metaverse apart from earlier digital revolutions is its capacity for integration and decentralization. With technologies like blockchain ensuring transparency and ownership, users can not only participate in but also own parts of the Metaverse economy. This paves the way for new business models, including decentralized finance (DeFi), virtual real estate, and immersive e-commerce—all of which could contribute significantly to India's GDP if adopted with the right framework.

The convergence of 5G networks, artificial intelligence, quantum computing, and data analytics is accelerating the deployment of the Metaverse. For India, this technological ecosystem could play a vital role in reducing regional inequalities, expanding access to services, and driving innovation in underserved areas. Rural communities could benefit from virtual employment

centers, skill development labs, and telemedicine—all accessible from their own homes. The Metaverse can democratize access to opportunities, aligning well with the inclusive growth vision of Viksit Bharat.

However, realizing this potential will require careful attention to infrastructure, regulation, cybersecurity, and digital literacy. Without equitable access to digital tools and internet connectivity, the benefits of the Metaverse could remain confined to urban elites, further widening the digital divide. Moreover, there are ethical and psychological concerns to address, such as identity privacy, mental health implications, and the regulation of virtual economies.

To make the Metaverse a pillar of national development, India must begin building a robust framework—one that supports innovation while safeguarding citizen rights. Public-private partnerships, educational reforms, and proactive governance will be key. Encouraging startups, investing in R&D, and creating regulatory sandboxes for experimentation can give India a global leadership edge in this domain.

Metaverse is more than a technological trend; it represents a fundamental shift in how we perceive and interact with the digital world. For India, it holds the promise of transforming into a digitally empowered society, fully aligned with the goals of Viksit Bharat 2047. By proactively integrating this technology into its national vision, India can leapfrog traditional development models and pioneer a future defined by inclusivity, creativity, and resilience.

Multitude of Metaverse Applications for Viksit Bharat 2047

As India looks ahead to its centenary of independence in 2047, the vision of Viksit Bharat emphasizes inclusive, sustainable, and tech-driven development. A pivotal element of this transformation is the integration of disruptive technologies, one of which is the Metaverse. Defined as a collective, immersive digital realm that mirrors and enhances the physical world, the Metaverse offers immense potential to accelerate India's growth across diverse domains. Through immersive technology, real-time interactivity, and the convergence of various digital systems, the Metaverse presents opportunities for innovation in governance, education, industry, healthcare, and public services.

3D Virtual World

Unlike conventional online interfaces that operate on two-dimensional planes such as web pages or mobile screens, the Metaverse introduces users to dynamic three-dimensional (3D) virtual environments. These digital realms are spatial, interactive, and immersive, enabling users to explore simulated spaces that replicate physical settings. From classrooms and marketplaces to government service centers and conference halls, the 3D framework of the Metaverse allows for enhanced engagement and lifelike participation. This transition from flat interfaces to spatial experiences represents a major leap in digital interaction.

Shared Space

The Metaverse is not a singular entity but a network of interconnected digital environments. These shared spaces are designed to facilitate real-time

communication and collaboration among users from different locations. Individuals, through their avatars, can co-exist in these virtual zones, engage in joint activities, and collaborate on common tasks. This networked experience fosters community building, teamwork, and the sense of a digital society—a vision well-aligned with the inclusive aspirations of Viksit Bharat.

Digital Avatars

Central to user interaction in the Metaverse are digital avatars—virtual embodiments of real individuals. These avatars enable people to represent themselves in the digital space, interact with others, and navigate virtual surroundings. Personalization of avatars enhances the sense of identity and presence, allowing users to experience the Metaverse as active participants rather than passive viewers. In educational and professional contexts, avatars can attend lectures, conduct meetings, and participate in simulations, fostering a more engaging and accessible environment.

Real-World Activities in a Virtual Setting

One of the defining attributes of the Metaverse is its ability to recreate real-life experiences within digital environments. Activities such as shopping, socializing, entertainment, work, and public events can be replicated and enhanced virtually. This allows individuals to perform various tasks without the constraints of physical distance. For instance, a citizen in a remote village could attend a government grievance redressal session virtually, or a student could participate in an international science fair without leaving their locality. Such experiences democratize access to services and opportunities.

Convergence of Advanced Technologies

The infrastructure of the Metaverse is built on the integration of multiple cutting-edge technologies. Virtual Reality (VR) delivers complete immersion, Augmented Reality (AR) overlays digital content onto the real world, and Mixed Reality (MR) merges the two seamlessly. These are further empowered by Artificial Intelligence (AI), blockchain for secure digital ownership and transactions, and the Internet of Things (IoT) for real-time data feedback. This fusion of technologies not only enhances the functionality of the Metaverse but also ensures its adaptability for varied developmental use-cases in India.

Gaming and Immersive Entertainment

Gaming has emerged as one of the earliest and most vibrant use cases of the Metaverse. Fueled by immersive technologies, the gaming industry has transitioned from screen-based experiences to fully immersive simulations. Indian developers and gamers are increasingly engaging with this space, creating local content that reflects regional culture and narratives. The gaming metaverse is also serving as a platform for collaborative storytelling, virtual sports, and skill development. Its popularity among youth makes it a potent tool for education, entrepreneurship, and employment.

Enhancing Employability and Economic Resilience

Rather than viewing technology-induced job displacement as a threat, the Metaverse can be strategically used to upskill the workforce and boost employability. Interactive training modules, virtual apprenticeships, and simulation-based

learning environments allow individuals to develop new competencies aligned with future industries. For India, sectors such as agriculture, manufacturing, and logistics can benefit from Metaverse-based learning platforms. In addition, technologies like AI and data analytics, when applied in Metaverse settings, can offer predictive insights in areas like crop management and disease control—crucial for policy planning and rural development.

Applications in Healthcare and Wellbeing

The potential of the Metaverse extends deeply into medical science and mental health. Virtual Reality environments are being explored as tools for mental well-being, particularly to address social isolation and emotional distress. Immersive experiences can simulate therapeutic settings, offer relaxation environments, and foster social interaction, which is especially beneficial for teenagers, the elderly, and individuals experiencing anxiety. In clinical education, the Metaverse can provide a risk-free environment where medical students can practice procedures and decision-making through lifelike simulations.

Additionally, telemedicine and remote diagnostics can be enhanced through virtual interfaces, enabling healthcare providers to interact with patients in a more intuitive and human-like manner. Digital health assistants, wellness rooms, and collaborative surgeries across continents are no longer futuristic concepts but rapidly approaching realities.

The Metaverse is poised to become a foundational pillar in India's journey toward becoming a developed nation. Its multifaceted applications in governance, education, healthcare, agriculture, and skill

development make it a powerful enabler of the Viksit Bharat 2047 mission. However, to fully realize its benefits, strategic planning, inclusive digital infrastructure, and policy frameworks must be implemented. With the right interventions, the Metaverse can act as a bridge between opportunity and accessibility, transforming India's socio-economic landscape for generations to come.

The Metaverse and Its Opportunities for Future Smart Cities

As urban environments evolve toward increased digitization, the intersection of the Metaverse and smart city planning presents transformative possibilities for the future. The emergence of immersive digital platforms powered by advanced technologies has opened new avenues for managing urban ecosystems more efficiently and interactively. One of the most promising applications within this domain is the integration of the Metaverse with Digital Twin (DT) technologies—a convergence that can redefine how cities are planned, built, and sustained.

The Metaverse and Digital Twins

Digital Twin (DT) technology refers to the creation of virtual replicas of physical systems, processes, or entities. These digital counterparts are designed to mimic real-world behaviors, functions, and responses, using real-time data to produce simulations that are not only accurate but also predictive in nature. Essentially, a digital twin serves as a dynamic model of a real object or operation, enabling continuous monitoring, testing, and forecasting.

In the context of urban planning and smart cities, DTs can model critical infrastructure

systems such as energy grids, transportation networks, water supply chains, and even entire neighborhoods or city blocks. By feeding live data from IoT sensors and AI-powered analytics into these models, planners and decision-makers gain the ability to analyze complex systems under various scenarios—commonly referred to as “what-if” analyses. This form of urban modeling facilitates proactive planning, more efficient resource allocation, and enhanced crisis response capabilities. For instance, a city planning department might use a digital twin to simulate the effects of a new highway on surrounding traffic, pollution levels, and residential satisfaction. Traditionally, such assessments would require time-consuming surveys and expensive physical testing. With digital twin simulations, these evaluations can be conducted rapidly and with greater accuracy. Moreover, these models can be used to assess the long-term sustainability of urban development strategies, anticipate bottlenecks, and optimize layouts before breaking ground. While Digital Twin technology alone has already proven to be a game-changer for infrastructure and system optimization, the integration of the Metaverse amplifies its potential significantly. The Metaverse introduces a fully immersive, three-dimensional, and interactive environment where digital twins can not only be visualized but also experienced in real time. By embedding DTs within the Metaverse, stakeholders—including government officials, planners, citizens, and investors—can engage with future urban scenarios as if they were physically present. This interactive environment enhances both qualitative and quantitative decision-making. For example, community members can virtually “walk

through” proposed developments to provide feedback before construction begins, creating a more democratic and participatory approach to urban planning. Residents could interact with the design of a public park, experience its layout in immersive 3D, and contribute suggestions based on real-life usability—improving public engagement and fostering social inclusion.

Furthermore, the use of real-time data in the Metaverse allows digital twins to remain synchronized with their physical counterparts, ensuring that simulations reflect current conditions accurately. This capability enables ongoing monitoring of urban systems, predictive maintenance of infrastructure, and rapid deployment of emergency protocols. For smart cities, this means enhanced adaptability and resilience in response to unforeseen challenges such as climate change, pandemics, or sudden demographic shifts.

From an economic standpoint, leveraging Metaverse-augmented DTs can significantly reduce costs associated with traditional modeling, prototyping, and stakeholder consultations. Physical mock-ups and field tests often demand substantial labor and materials; however, in a virtual environment, multiple iterations can be tested, refined, and validated with minimal expense and maximum speed. Additionally, the time to implementation can be drastically shortened, accelerating the urban development cycle without compromising quality or community input.

In the realm of sustainability, DTs within the Metaverse can help simulate environmental impacts of proposed urban interventions, such as energy consumption, heat island effects, or carbon emissions.

City planners can then redesign or optimize initiatives in a manner that aligns with long-term environmental goals. The Metaverse also supports the modeling of future urban conditions under varying climate scenarios, thus guiding policy for mitigation and adaptation strategies. The educational and professional development dimensions are equally noteworthy. Urban planning students, civil engineers, architects, and environmental scientists can train in these immersive settings, learning from real-time data, case-based scenarios, and AI-generated feedback. This dynamic environment enhances both technical competence and problem-solving skills, cultivating a new generation of urban innovators.

The convergence of Digital Twin technology with the Metaverse offers unprecedented opportunities for transformative urban governance and citizen-centric development. This powerful synergy can drive smarter, more sustainable, and more inclusive cities—fully aligned with the vision of Viksit Bharat 2047. With the ability to test, visualize, and collaboratively shape urban landscapes before their physical manifestation, India stands to redefine not just its infrastructure but also its approach to civic engagement, planning transparency, and technological leadership.

Metaverse and the Future of Banking, Finance, and Inclusion in Vikshit Bharat @2047

As India approaches its centenary of independence, the vision of Vikshit Bharat @2047 envisions a nation that is digitally empowered, economically self-reliant, and inclusive across every sector of society. One of the key pillars in this transformative

journey is the redefinition of the financial ecosystem. With the convergence of advanced technologies such as blockchain, artificial intelligence, and extended reality (XR), the Metaverse emerges as a promising frontier capable of reshaping banking, finance, and financial inclusion in unprecedented ways.

Redefining the Financial Experience through Immersive Banking

The Metaverse, characterized by its immersive and interactive 3D digital environments, offers a radically new interface for banking and financial services. Traditional brick-and-mortar bank branches and even today's mobile apps may soon be complemented—or even replaced—by virtual banking spaces where customers, represented by avatars, can interact in real time with financial advisors, attend financial literacy workshops, and complete transactions in a fully immersive setting.

These virtual banking environments provide a humanized experience without the need for physical presence. For rural or remote populations who often lack access to formal banking infrastructure, the Metaverse can become a virtual access point for financial services. With the help of voice-enabled AI assistants, vernacular interfaces, and visual demonstrations, users can be guided through processes such as opening accounts, applying for loans, or investing in schemes tailored to their financial needs—all within a gamified, user-friendly setting.

Moreover, virtual banks in the Metaverse can operate 24/7, offering uninterrupted support. With digital replicas of banking environments and financial service counters, the Metaverse allows for real-time

engagement with customer service executives, peer-to-peer consultations, and AI-driven financial planning—all designed to replicate and improve upon real-world experiences.

Revolutionizing Financial Inclusion and Accessibility

One of the most pressing challenges in India's current financial landscape is inclusive access. Despite significant progress through initiatives such as Jan Dhan Yojana, UPI, and Aadhaar-linked services, there remains a considerable section of the population that is either underbanked or entirely excluded from formal financial systems. The Metaverse can serve as a catalyst for bridging this gap, particularly for communities facing geographical, physical, or educational barriers. Through immersive educational modules and interactive simulations, individuals can be equipped with financial literacy in a language and format that resonates with them. Learning-by-doing in the Metaverse—such as participating in mock transactions or role-playing as micro-entrepreneurs—can lead to a deeper understanding of saving, credit, insurance, and investment options. Furthermore, the ability to integrate biometric authentication and blockchain-backed identity solutions in Metaverse-based platforms ensures secure, transparent, and personalized financial interactions. Such systems can empower individuals to build digital financial identities, access credit histories, and qualify for tailored financial products, fostering trust and participation in the formal economy.

Metaverse-Powered Digital Finance and the Future Economy

The future of finance is not only about accessibility but also about innovation in financial instruments, markets, and ecosystems. The Metaverse supports tokenized economies where users can transact using digital currencies, NFTs, and decentralized finance (DeFi) mechanisms. This opens a new frontier for Indian financial institutions to explore virtual asset management, tokenized real estate, and digital investment portfolios.

Banks and fintech firms in India can establish virtual financial hubs within the Metaverse where users explore diverse financial products through simulations, data visualization dashboards, and real-time advisory from AI agents. These environments offer not just access to services but also experiential learning, risk assessment simulations, and predictive financial planning based on users' behavioral and transactional data.

For MSMEs and startups, the Metaverse can provide virtual marketplaces where they can pitch their ventures to investors, access virtual credit counseling, or simulate business operations before scaling in the physical world. Government-backed initiatives such as Stand-Up India and MUDRA can extend their reach through Metaverse channels, ensuring targeted support reaches the last mile.

Fostering Trust, Transparency, and Cybersecurity

A major barrier to digital financial inclusion is trust. The immersive nature of the Metaverse allows for more transparent and intuitive engagement, enabling users to visualize the outcomes of their financial decisions and simulate the consequences of investment or borrowing choices. By enhancing digital confidence, especially

among first-time users, the Metaverse nurtures a culture of financial self-reliance—critical to the vision of Vikshit Bharat. Cybersecurity and data privacy remain key concerns. However, blockchain integration in the Metaverse ensures tamper-proof records, decentralized data control, and smart contracts that reduce the dependency on intermediaries. Regulatory sandboxes and real-time oversight mechanisms can be embedded within virtual financial environments to monitor compliance and ensure user safety.

Policy and Infrastructure for Equitable Metaverse Banking

To unlock the full potential of the Metaverse in banking and finance, India must invest in digital infrastructure, including high-speed internet, low-latency networks, and widespread availability of affordable XR devices. Initiatives like BharatNet and Digital India can serve as foundational enablers. Equally important is the creation of regulatory frameworks that govern virtual financial interactions, ensure consumer protection, and encourage innovation while minimizing risk.

Public-private partnerships, capacity-building programs, and financial innovation hubs can accelerate the design and deployment of Metaverse-ready financial solutions. Special attention must be given to women, marginalized communities, and rural entrepreneurs to ensure that the benefits of immersive financial technology are distributed equitably.

As India sets its sights on becoming a developed and inclusive economy by 2047, the convergence of the Metaverse with banking and finance presents a compelling opportunity. From revolutionizing how individuals access and understand financial

services to enabling immersive, secure, and personalized financial ecosystems, the Metaverse can serve as a cornerstone in shaping a digitally empowered and economically inclusive Vikshit Bharat. By aligning technological innovation with inclusive growth, India can not only bridge existing financial gaps but also set global benchmarks in how immersive technology redefines the future of money, trust, and access.

Conclusion

The emergence of the Metaverse signifies a transformative leap in how societies engage with technology, offering a multidimensional platform that transcends the limitations of traditional digital systems. As India charts its path toward becoming a developed nation under the visionary initiative Viksit Bharat @2047, the strategic deployment of Metaverse technologies has the potential to reshape critical sectors, from financial inclusion and smart city development to digital education and immersive healthcare. The Metaverse is more than a digital novelty; it represents an evolving ecosystem where real-world applications converge with immersive experiences. With its foundation built on extended reality (XR), artificial intelligence, blockchain, and real-time data analytics, the Metaverse creates a persistent, interactive, and user-centric environment. These capabilities allow for profound transformations in service delivery, community participation, and infrastructure planning—particularly relevant in a country as diverse and populous as India.

One of the most compelling aspects of the Metaverse lies in its ability to foster accessibility and inclusion. Whether it is

offering rural populations the opportunity to attend a virtual classroom, enabling small entrepreneurs to access virtual financial counseling, or allowing citizens to interact with future urban layouts through digital twins, the Metaverse democratizes access to opportunities that were previously restricted by geography, socioeconomic status, or infrastructural limitations. This aligns directly with the objectives of Viksit Bharat, which emphasizes inclusive growth and digital empowerment. In the domain of urban governance and planning, the integration of Metaverse environments with digital twin models is revolutionizing how cities are conceptualized and managed. Urban planners can now simulate infrastructure projects, model emergency responses, and gather community feedback in immersive settings—leading to smarter, more resilient urban spaces. As India's cities continue to expand, such innovations will be vital in ensuring sustainable and citizen-centric urbanization.

Similarly, the financial sector stands on the brink of a digital transformation driven by immersive banking and virtual financial ecosystems. The Metaverse offers a reimagined interface where financial services are not only accessible but also personalized, intuitive, and engaging. It empowers individuals to build digital financial identities, gain financial literacy through immersive experiences, and participate in virtual economies using tokenized assets. This transformation will be instrumental in bridging the financial

divide and supporting the broader goal of economic self-reliance. Moreover, sectors like education and healthcare are witnessing the emergence of new delivery models that use virtual simulations, personalized learning paths, and remote consultations. By offering safe, interactive, and data-driven environments, the Metaverse enables learners and patients to actively participate in their development and well-being. Such advancements are particularly valuable in addressing regional disparities in access to quality education and healthcare services.

However, the journey toward a Metaverse-integrated Bharat is not without challenges. Ensuring affordable digital infrastructure, protecting data privacy, formulating regulatory frameworks, and promoting digital literacy are critical to making this transformation inclusive and sustainable. Public-private partnerships, government policy support, and community-driven innovation will play a crucial role in scaling Metaverse applications across sectors. In short, the Metaverse holds the potential to become a cornerstone of India's development strategy as it advances toward 2047. By aligning this technology with national priorities and citizen needs, India can build a digitally inclusive, economically resilient, and socially equitable future. Embracing the Metaverse is not merely about adopting a new technology—it is about reimagining how India learns, works, governs, heals, and grows as one unified, empowered nation.

Exploring the Potential of Metaverse in the Indian Banking Sector: User Perspectives and Challenges

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Abstract:

This study investigates the potential of Metaverse platform in the Indian Banking sector and how it shapes the future of Banking sector. Using the Questionnaire, we analyzed the data collected from people who had used the platform. The results indicate the experience of metaverse platform in banking sector, improvements that might be done in the Metaverse to make it more user friendly and also the barriers faced in using metaverse platform. These findings suggests that it will take time to make users familiar with accessing banking services through metaverse platform, the need to make the interface more user friendly and will the banks be ready to adopt this technology. Also, the data in this study explains the implication about how metaverse will change the scenario for the bank employees and are they ready to adopt this new technology. According to Research paper, this study contributes to the understanding the application of metaverse in banks.

Keywords: Metaverse, Artificial Intelligence, Machine Learning, Banking, Financial Inclusion, Viksit Bharat

Introduction: -

The rapid advancement of technologies has resulted in Metaverse platform providing a virtual reality feature to its users who feels like they are having a real time experience of environment. Banks have applied this technology to provide customers with real time experience of bank environment without physically visiting the bank branch and do banking operations just by sitting at their home accessing banking services via electronic devices. A recent study found that 43

percent of consumers would be comfortable using virtual reality for banking activities such as checking account balances or making payments. This number is expected to grow. This study explores the benefits and the threats to human resource, data and privacy and suggest improvements for metaverse to make it more appealing to users. In this paper, you find the useful insights into

metaverse and artificial intelligence usage in banking sector.

Review of Literature: -

From past some time, metaverse is gaining popularity in the various sector and banking is one of them. Various banks have tried using metaverse to provide the banking services. Union Bank of India and Bank of Maharashtra have tried providing banking services to their customers through metaverse. The past research findings have discussed the phases of the banking sector from traditional banking to metaverse

Traditional Banking:

Where customer has to visit the physical branches for banking services and this highly depend on human interactions.

Internet Banking:

Involves usage of plastic cards and services availed through electronic devices.

Open Banking:

Includes payment via third party apps and digital banks.

Digitalized finance in decentralized finance environment:

Includes new breed of assets in financial market (NFTs) and blockchain.

Also, various studies have shared the adoption of metaverse in banking because of potential it has in banking sector:

Give opportunity for interaction of customer with bank representative in virtual environment.

No need to visit physical bank branch with virtual engagement.

It expands the usage of digital currency and digital assets.

Results in cost reduction for customer and bank.

Usage of digital currency in day-to-day activities rises.

Challenges: -

Regulation and Security-

There must be proper regulations for data security of customers.

Identity theft-

Preventing identity theft involves protecting cloning of data and users' identity.

No mass adoption of blockchain-

There is less inclination towards blockchain due to high profile failure of organization.

Low return on investment-

People heavily rely on traditional banking due to this there is low return on investment in metaverse.

Banking platforms already on Metaverse:

- HSBC
- JP Morgan
- Bank of America
- Union Bank of India
- Bank of Maharashtra
- Union Bank of India metaverse platform called "Uni-Verse" provides

virtual environment where customer and bank interacts and erases the boundaries that exist in physical world.

Its additional features include:

- Non-Financial Services
- Multiple avatars to choose from
- Robo-bee navigator
- Product catalogues through mail and SMS
- Inclusion of different lounges showing various banking products.

Methodology:

The study involves analysis of data to find out the experience of users of metaverse, improvements they think should be done in metaverse and the barriers they face while using the metaverse in banking sector. The data is collected by conducting the survey that records the responses of the users who experience the metaverse platform of Union Bank of India and Bank of Maharashtra.

- Data is collected from sample consisting of 10 users who had experience the metaverse in banking sector and shared their responses.
- Data collected is qualitative data.
- Tool used to record the survey data is the questionnaire where respondents share their experience, improvements they want and barriers they face.
- The segment that survey target includes students, working professional, senior citizens.

The data is collected by approaching the users on messages and recording their

responses through messages and made analysis on the basis of data collected.

Findings and Discussion: -

Following are the details of responses collected from users who tried the metaverse platform of Union Bank of India and Bank of Maharashtra

Table 1 Survey Responses of Respondents

#	Questions for Feedback		
	How was the experience of using the Metaverse?	What improvements you want in Metaverse?	What barriers impact the Metaverse usage?
1	Using metaverse is very enjoyable it is a good platform to have your own identity through Avtar.	privacy and security of user success depends on users' accessibility and users will trust the platform and this improves the performance also.	not easy to make an account due to lack of knowledge and experience. Some users May be trapped If people spend excess time on metaverse resulting to stress which affects health badly.
2	experience was good and it gives the feel of real-life banking experience we don't have to stand in queue to get our work done but it was a little bit difficult to navigate.	improved in terms of speed interactive features might include voice assistance for better experience for those having no knowledge	Slow internet speed and not working on mobile phones. Needs a good internet connection and laptop.
3	Experience was immersive and interactive. I explored a virtual bank interacted with avatars, and participated in a virtual world. The experience was engaging and I felt connected	Improve security by implementing advance authentication like face or voice recognitions to secure user access	security connectivity lack of awareness Trust
4	My experience of using metaverse was very amusing. felt like I was inside a virtual reality. Overall, my experience was quite good	requires a powerful and heavy setup like a powerful pc so this needs to be resolved improved so it can be easily accessible	took time for me to understand all the functions and use it properly complex structure was something that I faced
5	Good	Metaverse is a little difficult to navigate personally for me. its adherence to all data protection laws is to be checked regularly because I personally do not feel comfortable sharing so much personal information. it could enhance its visual attractiveness.	A little more user-friendly interface is needed. As a first one to use it, I still find it a little difficult to use

6	Experience was very pleasant	security and prevention of fraud top priority	takes some getting used to and gain comfort with interface not feel secure about account information
7	My experience in the metaverse was good because I done my all-banking functions easily without going to banks	Improve the metaverse access to wider range of users of disabilities	Offering education and workshop to the persons who needed
8	the experience was unique as it feels like we are in real life bank branch	The platform should support regional languages for easier understanding. Fonts and controls should be larger and easier for older users.	First-time users or older people might feel nervous using such platforms.
9	experience of using metaverse was good. It has a lot of advantages such as delivering immersive Use Experience it has drawbacks also such as it was clunky and slow.	I think they should strength their customer experience by using virtual and augmented reality.	It was quite slow
10	experience of metaverse was not that good. It might have a lots of advantages like emotional support to customer and a lot more but I think it is quite hard to access	I think they need to work on secure management of virtual portfolios.	I feel there is a risk of cybersecurity and data privacy

Above are the responses of the people who have tried the metaverse platform of the Bank and have shared their feedback talking about their experience of using the metaverse, improvements that need to be made in metaverse platform and barriers they face while using the platform.

Analysis-

Users' Experience:

the users experience with metaverse was somewhat good, they like the virtual environment and felt like they are in real-life bank.

user think metaverse have the potential in banking sector.

They experienced the Bank virtual world similar to bank in real world.

Some users experienced that it is not understandable at initial level.

Some users don't like the idea of virtual reality and prefer traditional and online banking only.

Some user believe it is convenient for them and they can avoid long queue at banks.

Improvement Suggestions: -

User thinks the interface could be better and choosing avatar options could increase.

Users have the opinion that there should be education, training and awareness among the people for using the metaverse and how to operate it and what type of banking services that can be availed.

User wants the improvement in security by providing face id or more secure method of getting access to metaverse banking services.

User want the metaverse to work on mobile phones.

User wants improvement in processing speed of metaverse as it is slow in loading if internet is slow.

User want rules and regulation concerning information protection from cybercrimes.

Barriers: -

Users were concerned with the data privacy and confidentiality.

Find the platform was not good for availing the banking services.

User faces the barriers in the form of requirement of powerful computers and lack of knowledge

not user friendly and takes time in loading

User faces the internet connectivity issues.

User doesn't have complete knowledge how to operate the platform.

Thematic Analysis: -**Security Concerns: -**

Various users find that there is a risk of data theft, cybercrime, identity theft and stealing of sensitive information.

Interface Complexity: -

User find it difficult to navigate in the virtual environment as sometimes internet is slow and user find it difficult to move the avatar and get stuck.

Accessibility: -

This platform is not accessible to everyone as India still lacks in providing internet services to people in rural areas thus accessibility is low.

Scope and Implications: -**Digital Currency: -**

In metaverse user can do transaction in digital currencies through cryptocurrency or even using their personal token.

Digital banking: -

_With the help of metaverse bank customer can deposit money in banks and avail other banking services from their homes only and can experience the real-life banking.

Customer experience: -

Major objective of metaverse is to provide feeling to customers as they are in bank virtually and if banks succeed in providing realistic environment, then customer will get better experience and utility.

Collaboration: -

Banks need to collaborate with fintech for better customer experience.

It's widely known that the video games industry is stronger than Hollywood, with revenues exceeding \$174 billion in 2020 and projected to reach \$314 billion by 2026. (according to Mordor Intelligence). With approximately 2.69 billion gamers worldwide and about 1.5 billion in Asia Pacific alone, it's no surprise that Asian banks see an opportunity with a market that is already familiar with digital money.

How can Banks prepare for adoption of metaverse: -

Bridging real and virtual worlds:

First step toward adoption of metaverse is embedding the basic real world banking services in metaverse worlds. Banks should have apps that can work with virtual reality headsets so that customer can do banking through metaverse easily.

Supporting new metaverse markets:

Banks should have products that could be easily provided on the metaverse platform thus supporting new emerging markets.

Bringing real world assets into metaverse:

Banks should bring the real-life assets like dealing in real estate into the metaverse world so that customer can get wide range of services via metaverse.

Conclusion: -

So, to sum up the findings related to Metaverse in Banking Sector it can be implied that Metaverse has the scope of changing the Banking scenario in upcoming digital world where user will prefer to do transaction through virtual reality and interact through electronic devices experiencing the real-life environment. So, the metaverse has the huge potential of bringing technological advancement and better opportunities for Indian Banking Sector in long run.

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TRACK 2

TRACK 2: GREEN FINANCE, ESG & TECH-ENABLED SUSTAINABILITY

A Comprehensive Analysis of Green Accounting and its role in endorsing environmental sustainability in the banking segment of the Indian economy

By

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Abstract:

Green accounting is related to eco-environment auditing system, in depth it is basically incorporation of environmental features into financial reporting which indicating a nation's affirmation concerning sustainable development. In India, where industrialization at prompt substantial ecological challenges also faces, the espousal of green accounting is steadily gaining adhesion. It guides bank to track the financial extrapolations of their guidelines and offer a translucent view of their sustainability performance. This research paper examines dynamic trends, challenges, and opportunities in the Indian framework concluded a comprehensive analysis. It offers a path for integrating environmental sustainability into the Indian economy by systematic policy procedures, corporate compliance, and emergent technological resolutions. Moreover, this research highpoints aims to explore the significance of incorporating environmental costs into banking segment and national economic assessments to expand policymaking with more effectiveness. As global consideration moves toward sustainable business follows, green accounting plays a decisive role in plateful India to encounter its climate obligations and sustainable development goals. Additionally, this study proposes strategic frameworks for development a green economy, examines industry-specific adoption trends, and identifies implementation gaps in green accounting.

Keywords: *Green Accounting, Environmental Sustainability, Indian Economy, Corporate Responsibility, Indian Banking Sector, Policy Integration, Sustainable Development Goals*

1. Introduction

Green accounting is basically a tool that quantifies the environmental costs of economic activities and gained increasing

consideration in recent years as for environmental sustainability and it converts a crucial problem for developing economies like India. As commercial

expansion often conflicts with environmental and ecological maintenance, all these need to balance economic progress with environmental stewardship has become imperative. In India, this challenge is mainly noticeable, as rapid industrialization has led to environmental degradation, prompting calls for more sustainable practices (Krishna Moorthy & Yacob, 2013).

The substance of green accounting depends in its aptitude to measures the environmental costs associated with industrial activities. By integrating environmental considerations into traditional economic accounting, businesses and policymakers can make more informed decisions that not only contribute to economic growth but also support long-term ecological sustainability (Amran & Devi, 2010). As countries around the world contend with the magnitudes of environment change, India like various developing economies country, aspects the challenges of condensing its environmental footmark while enduring to chase economic growth and development.

The observation of green accounting towards environment has progressed to report a extensive range of environmental costs, from functional changes within productions house to investments in greener technologies and process innovations (Krishna Moorthy & Yacob, 2013). As fragment, the green movement in industries has rapidly concentrated on the notion of sustainable development. Green growth goals to settle economic development with the conservancy of environmental capitals, confirming that future generations received a liveable and

vigorous environment. Though, the extensive adoption and acceptance of green accounting is still hindered by a many of challenges. These encompass unpredictable environmental data information, dearth of cognizance regarding the benefits and importance of green accounting, and feeble enforcement of existing regulations (Amran & Devi, 2010). Despite of various obstacles there have been positive strides in the policy framework pointed at refining environmental sustainability in India.

Several key policy initiatives such as the Business Responsibility and Sustainability Reporting (BRSR), National Action Plan on Climate Change (NAPCC) and others has been announced to encourage the implied of sustainability practices across trade and commerce industries. These outlines gaols to generate a comprehensive approach to addressing environment change, resource conservation, and environmental degradation. While these policies have added adhesion in recent years, fragmented adoption due to inconsistent policy enforcement and the lack of uniform reporting outlines remains a significant obstacle (Amran & Devi, 2010). Consequently, while the frameworks are in place, India's path to comprehensive adoption of green accounting is still in developing stage.

This research will assess how corporate responsibility and governance influence the integration of green accounting practices into business operations and public policy framework. With analysing main topics such as corporate compliance, business specific espousal trends, and hi-tech innovations, India seeks to bid intuitions into the factors driving or

hindering regarding for acceptance of green accounting. Moreover, it will recommendations for improving and enhancing the effectiveness of green accounting practices to better align with sustainable development goals (SDGs) of India.

In India, regulatory frameworks such as the National Action Plan on Climate Change (NAPCC) and Business Responsibility and Sustainability Reporting (BRSR) pursue to conventional sustainability practices followed by trade and commerce. Though, crumbled adoption of green accounting system due to inconsistent policy enforcement remains a major challenge (Amran & Devi, 2010). The intensifying ecological apprehensions associated with businesses have intensified the need for integrating sustainability into commercial policies of economy. Green accounting, also known as environmental accounting, enumerates environmental costs which

1.1. Green Accounting in the Indian Context

1.1.1 Policy Initiatives and Regulations

India has declared numerous policies, strategies and guidelines to incorporate green accounting into framework of economic system. Some of are:

- National Action Plan on Climate Change (NAPCC): Its aims to encourage sustainable development and climate resilience in Indian economy system.

help empowering businesses and policymakers to make informed decisions (Moorthy & Yacob, 2013).

However, the implementation of these frameworks remains fragmented due to policy inconsistency, lack of standardized reporting, and corporate reluctance to bear additional financial burdens. By analysed industry-specific adoption trends and the effectiveness of regulatory measures, this paper highlights the pathways through which green accounting can be mainstreamed in the Indian economy. By concerning green accounting standards with sustainability goals, banks can play an essential role in developing a greener economy in future while mitigating environmental risks too. This study purposes to inspect the role of green accounting system adopted in India's and their evolving economic and environmental landscape.

- Corporate Social Responsibility (CSR) Commands: Under its businesses are mandates to follow and institution must to allocate of share a profit to environmental programmes.
- Environmental Impact Assessment (EIA) Guiding principle: Its main purposes to create ecological consciousness and appraisals for new projects and plans of business.

Below table 1 showing policy initiatives by government in green accounting system:

TABLE: 1 Policy Initiatives

Year	Policy Initiative
2008	National Action Plan on Climate Change (NAPCC)
2010	Corporate Social Responsibility (CSR) Mandate Introduced
2013	Environmental Impact Assessment (EIA) Strengthened

2016	Introduction of Green Bonds for Sustainable Financing
2019	Implementation of Business Responsibility and Sustainability Reporting (BRSR)
2022	Enhanced SEEA Integration in National Accounting

Despite these measures, inconsistent data collection, low awareness, and weak enforcement mechanisms limit widespread adoption (Amran & Devi, 2010).

1.1.2 Challenges in Implementation

- **Dearth of Standardized Reporting:** The dearth of uniform reporting frameworks complicates environmental impact assessments (Schultz & Williamson, 2014).
- **Corporate Confrontation:** Many firms perceive green accounting as an additional financial burden rather than a strategic investment (Ransburg, 2011).
- **Complications in Quantification:** Dissimilar financial metrics, environmental pointers such as biodiversity and carbon emissions loss are harder to quantify (Elkington, 1997).
- **Supervisory Gaps:** Although frameworks like GRI and SASB exist, compliance remains largely intended (Shelton, 2003).

Below table 2 highlights key challenges faced in implementing **green accounting** in India, quantified in percentage terms. These challenges indicate the barriers that hinder the widespread adoption of **environmental accounting practices** within corporate and regulatory frameworks.

1. Lack of Standardization (35%)

Major challenge for implementing green accounting system in Indian economy is the absence of a regulated framework which is standardised for sustainability reporting. This issue, accounting for 35% of the challenges, leads to inconsistencies in how companies assess and report their environmental impact. Currently, organizations follow different models for carbon footprint assessments, environmental cost calculations, and sustainability disclosures, making data comparison and regulatory compliance difficult (Gupta & Sharma, 2021). Moreover, the absence of a unified regulatory authority system overseeing consistent sustainability accounting practices lead to the complexity process.

2. Corporate Resistance (25%)

Corporate resistance is also major contributes 25% to the challenges linked with adoption of green accounting in their process. Most of businesses asses that green accounting as an additional operative and financial load instead strategic opportunity (Kumar & Patel, 2020). Revealing environmental enactment may lead to greater regulatory scrutiny, financial penalties, or reputational risks is also a major concern. (Mehta & Ramesh, 2019). Moreover, restricted monetary inducements for acceptance of translucent environmental accounting depress

companies from entirely sustainability reporting system.

3. Difficulties in Quantification (20%)

Another difficulty in green accounting implication is quantification of environment impact which remains a complex challenge and its accounting for 20% of the barriers. The absence of universally adoption valuation methodologies for these environmental costs makes it grim for businesses to maintain them into their financial statements (Singh & Verma, 2021). Unlike finance metrics, which are based on concrete numerical data, green accounting includes non-financial rudiments such as ecological degradation, biodiversity loss and water bodies conservation (Rao, 2022).

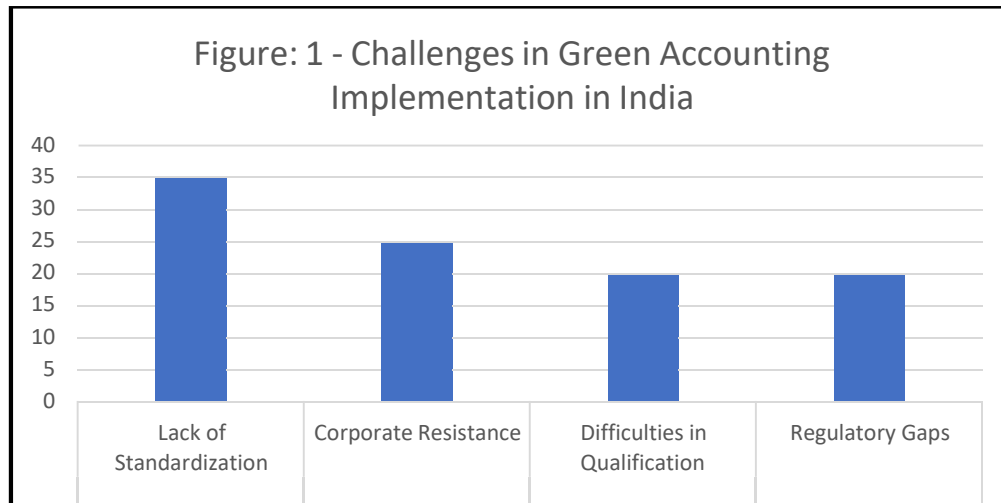
4. Regulatory Gaps (20%)

One more obstacle to adoption and implementing green accounting is regulatory gaps which is 20% in observe study. Meanwhile sustainability reporting frameworks such as the Business Responsibility and Sustainability Reporting (BRSR) framework, has introduces in India but enforcement remains inconsistent (SEBI, 2021). Feeble regulatory lapse, loopholes in framework of environmental policies, and the absence of segment-specific guidelines or rules, create a gap for sustainability disclosures. Additionally, insufficient monitoring process edges the effectiveness of existing green accounting and environment suitability regulations (Chakraborty & Saha, 2020).

Table : 2 Challenges in Green Accounting Implementation in India

S.no.	Challenges	%
1	Lack of Standardization	35
2	Corporate Resistance	25
3	Difficulties in Qualification	20
4	Regulatory Gaps	20

Below Figure:1 of bar chart shows the main challenges in green accounting implementation in India which including enumeration lack of standardization, corporate resistance, difficulties in quantification, and impact of regulatory gaps.



The conceptual framework of green accounting in India for this study contours the relationship between green accounting, regulatory frameworks, corporate compliance, environmental costs, and the broader goals of sustainable development in India's economy which

representing graphical view in below figure: 2, i.e. Conceptual framework of green accounting. By considerate these consistent elements, this study aims to highlight on the way through which green accounting can becomes ordinary practice in India

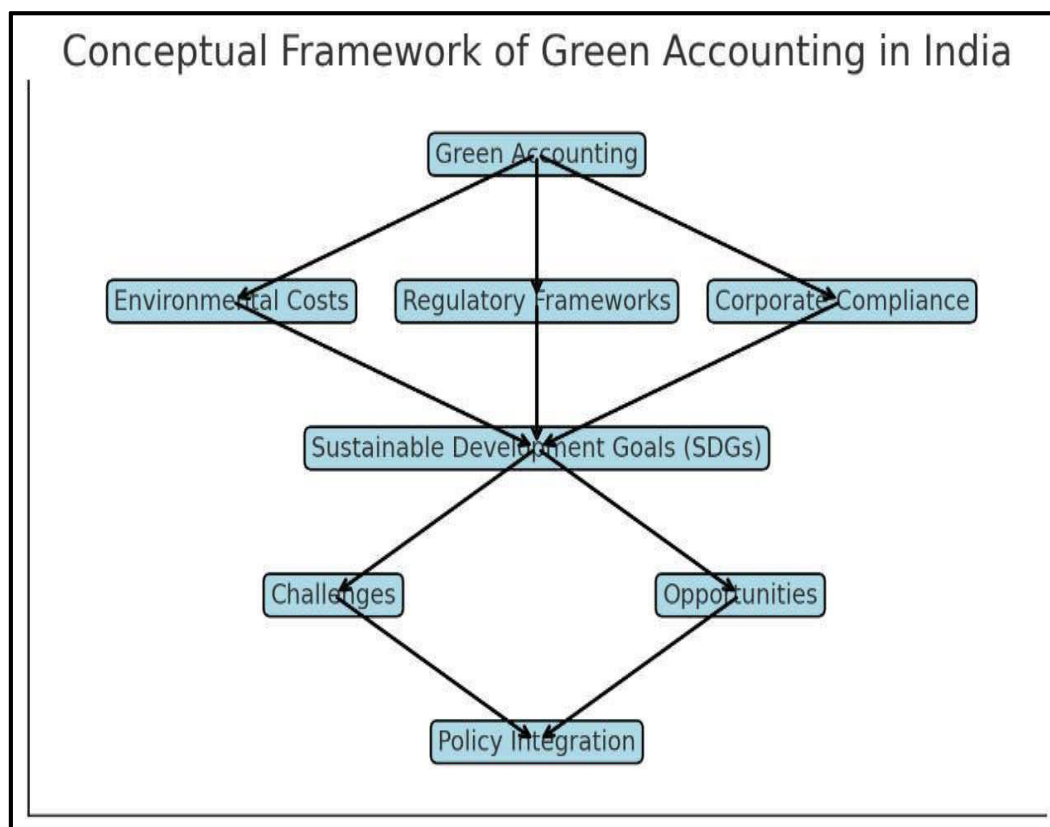


Figure 2: Conceptual Framework of Green Accounting in India

The rising insistence of climate change mitigation and natural resource conservation has forced governments and businesses to adopt and implied green accounting practices. India's businesses

economic practices towards environment sustainability is necessitates for balancing economic goals with sustainability measures.

Objective of the Study:

- To assess the role of green accounting for sustainability development and challenges of green accounting in Indian economic policy and study about how banks include green accounting ethics align with global environmental sustainability areas.
- To explore the corporate compliance and adoption drifts in green accounting system in their practices and accordingly provide recommendations for enhancing the effectiveness of green accounting system.

2. Literature Review

Current studies highlight the growing significance in adoption of green accounting fostering sustainable economic growth. Singh et al. (2023) the role of machine learning and artificial intelligence (AI) in powering environmental impact assessments and suggesting that AI can extensively augment the accurateness and efficacy of measuring environmental effects in real time. This is mainly important as integrate and align their financial and environmental performance.

Kumar and Sharma (2024) highlight the role of carbon pricing mechanisms in accelerating corporate accountability for environmental sustainability. They argue that carbon pricing provides a clear financial incentive for companies to reduce their carbon emissions, pushing them toward adopting green accounting systems that reflect the full environmental cost of their operations. This shift in regulatory frameworks, they suggest, is driving greater transparency in corporate environmental disclosures.

Wang et al. (2023) study the function of big data analytics required in sustainability reporting. The authors underline that the big data allows organizations to more flow on correct track and report their environmental performance by incorporating real-time environmental data into their sustainability reports. The use of data analytics enhances decision-making, allowing companies to moderate their environmental risks and identify areas for further improvement (Wang et al., 2023).

Jha and Banerjee (2024) highlight the long-term monetary assistances of corporate social responsibility (CSR) investments in green initiatives projects. Their research indicate that business engross in green initiatives not only to rally their public reputation but also experience long-term financial gains, including cost savings from energy efficiency measures and increased customer loyalty. By invest in sustainable practices, business can align with global sustainability goals which also benefiting from view of the economic advantages at international level due to such initiatives.

Gupta et al. (2023) emphasize on the importance of financial inducements and supervisory acquiescence in pouring the adoption of green accounting practices in their frameworks. The study specifies that government subsidies, tax breaks, and carbon trading systems have effective in reassuring business to adopt environmental accounting practices. These financial spurs help to offset the initial costs of executing green accounting systems in practices and further attractive to companies by providing fringe benefits.

Bebbington and Larrinaga (2014) argue that adopting environmental accounting practices is associated with higher financial stability. Their study highlights that firms that integrate environmental considerations into their accounting systems can better manage the financial risks associated with environmental factors, including regulatory penalties, reputational damage, and increased operational costs due to environmental harm. By addressing environmental risks proactively, these firms ensure long-term financial resilience.

Research by Heba and Yousef (2018) investigate in their study that the potential of Artificial Intelligence (AI) and blockchain technology in augmenting transparency in environmental reporting. The authors examine that how AI algorithms can offer real-time analysis of environmental data, while blockchain technology provide a protected and absolute record of environmental transactions and growing trust with credibility in corporate environmental claims.

The United Nations (2022) Sustainable Development Goal (SDG) 12 accentuates accountable consumption and production, which is serious pushing towards stronger compliance guidelines with green accounting procedures. The area needs businesses and governments to accept sustainable practices in their production processes, resource utilization, and waste management, making green accounting a key tool in following and reporting progress toward these global objectives.

Key Challenges Identified:

- **Lack of Standardized Reporting:** The dearth of uniform procedures for environmental reporting complicates corporate compliance with sustainability measures. As noted by Schultz and Williamson (2014), the absence of a global standard for sustainability reporting creates challenges for businesses in aligning their practices with international benchmarks. The inconsistent application of sustainability reporting standards across regions and industries hinders comparability and accountability.
- **Corporate Reluctance:** The preliminary costs related to the implementation of environmental accounting systems may prevent companies to adopt the system and especially those industries which are with tight margins or limited financial resources. Ransburg (2011) discuss that how many businesses observe green accounting as an additional financial burden instead of strategic investment. However, the long-term assistances, including cost savings and improved goodwill of the company frequently offset these concerns.

- **Difficulty in Quantification:** The challenge of precisely quantifying environmental effect metrics, such as carbon emission and water pollution is a main obstacle to implementation of effective green accounting in practices. Elkington (1997) focuses on environmental metrics are not as easily quantifiable as financial metrics, it difficult for businesses to establish reliable environmental performance pointers. This dearth of accuracy need complicates efforts to track and manage environmental accounting effectively in their routine.
- **Regulatory Gaps:** Inconsistent enforcement and application of Global Reporting Initiative (GRI) and the Sustainability Accounting Standards Board (SASB) guidelines remain a major challenge while framework policies related green accounting. Shelton (2003) argues that the voluntary nature of many environmental reporting frameworks leads to inconsistent reporting practices across industries and regions, undermining the effectiveness of green accounting in driving corporate sustainability efforts.

3. Research Methodology

This study employs a systematic analysis approach, applicable academic literature and policy documentation to classify drifts in green accounting system in Indian economy for sustainability. By integrating these research methods, the study related offers an empirical source for assessing the effectiveness of green accounting

frameworks in India and offers actionable endorsements for industry leaders and policy makers too. Figure 3 demonstrating the comprehensive analysis progression for green accounting research, covering of data collection, thematic analysis, quantitative assessment, comparative assessment, and its application to policy and industry applications.

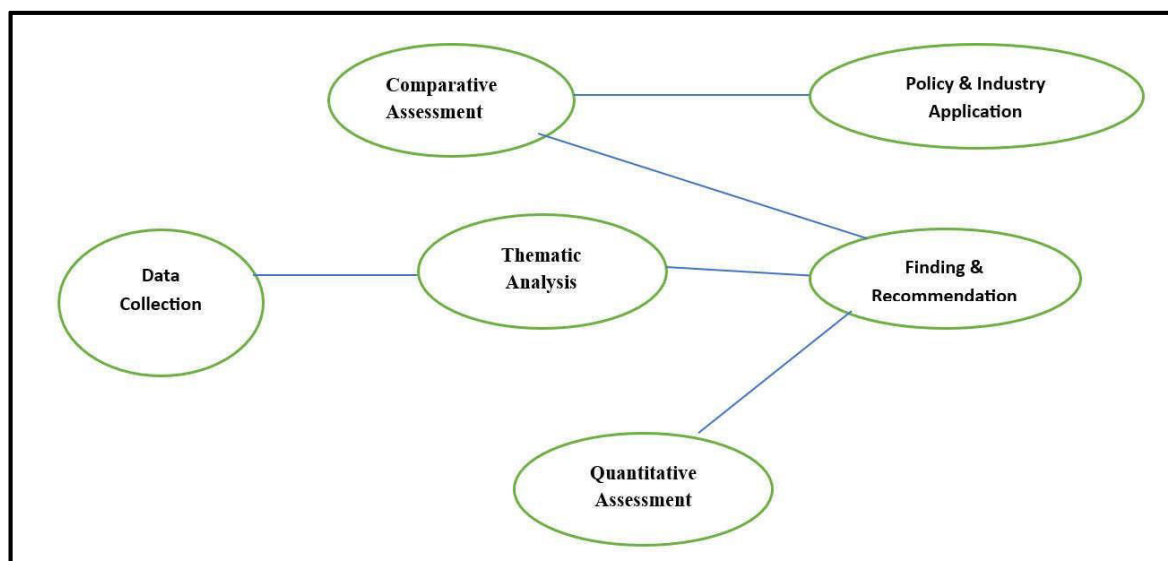


Figure 3: Comprehensive process of analysis Green Accounting Research

This study employs comprehensive research approach, converging on secondary data study to review the function of green accounting in Indian economic policies. The research purposes to examine industry adoption trends, corporate compliance and technological

innovations that augment environmental reporting practices. The outcomes will provide source to identifying gaps and suggest recommendations for refining the efficacy of green accounting system in India.

Data Collection Methods

The study relies on secondary data collected from various report and policies publishing, major including are:

- **Corporate Reports:** Sustainability and Environmental, Social, and Governance (ESG) reports published by Indian companies, Business Responsibility and Sustainability Reports (BRSR), and disclosures aligned with the Global Reporting Initiative (GRI).
- **International Agreements & Frameworks:** Analysis of India's commitments under the Paris Agreement in 2015, Sustainable Development Goals (SDGs), and , International Financial Reporting Standards (IFRS) Sustainability Reporting Standards.

- **Government Reports & Policies:** Documents from the Ministry of Corporate Affairs (MCA), Ministry of Environment, Forest, and Climate Change (MoEFCC), Reserve Bank of India (RBI), and Securities and Exchange Board of India (SEBI).
- **Academic Literature:** Peer-reviewed paper studies which analysing corporate compliance, environmental accounting system, and industry-specific green accounting trends.
- **Industry Reports & Journals:** Research papers from Scopus-indexed journals, industry reports like from the World Bank, International Financial Reporting Standards (IFRS), and the Global Reporting Initiative (GRI).

Data Analysis Techniques

The research smears content analysis and comparative analysis to interpret secondary data. Key techniques include:

1. **Thematic Analysis:** Identification of periodic subject matter in policy progression, corporate sustainability amenability, and sector specific adoption of green accounting system in country.
2. **Comparative Analysis:** Examination of India's green accounting practices in relation to international benchmarks, such as IFRS's International Sustainability Standards Board (ISSB) framework.
3. **Trend Analysis:** Assessment of corporate adoption trends in green accounting over the period **2011-2024** by reviewing sustainability reporting data from Indian firms.

Data Presentation

To support the findings, the study will include **charts and diagrams**, such as:

- **Trend Graphs:** Depicting the rise in corporate sustainability reporting compliance from 2011-2024. The table presents data on compliance percentages from 2011 to 2024, showing a clear upward trend.

Year	Compliance (%)
2011	8
2012	14
2013	22
2014	30
2015	39
2016	48
2017	57
2018	66
2019	75
2020	80
2021	85
2022	88
2023	91
2024	94

Table 3: Trends graph

Above data suggested following points:

1. **Steady Increase:** The compliance percentage has risen consistently each year, from **8%** in 2011 to **94%** in 2024. This indicates a sustained effort toward regulatory adherence and sustainability practices.
2. **Accelerated Growth:** The frequency of surge is more noticeable in the earlier years (e.g., 6% increase from 2011 to 2012, and 8% from 2012 to 2013), signifying that in initial efforts for adoption of green accounting were somehow met.
3. **Saturation Point:** The growth rate in 2020-23 seen that slightly slow i.e., 5% increase from 2020 to 2021, 3% from 2022 to 2023. It indicates that as compliance ranges higher levels and additional enhancements become more incremental.
4. **Impact of Policies & Initiatives:** The growing drift highpoints towards the effectiveness of regulatory frameworks, improvement in corporate governance and sustainability initiatives which emphasise the strongly enforcement and enticements may have contributed to this sturdy rise.

Above data table reveals that there is increasing commitment of organizations towards compliance, with probable inferences for environmental policies, corporate social responsibility, and regulatory governance effectiveness.

The trend graph below shows that there is steady increase in compliance percentages over the years, emphasizing the impact of regulatory policies and corporate sustainability initiatives.

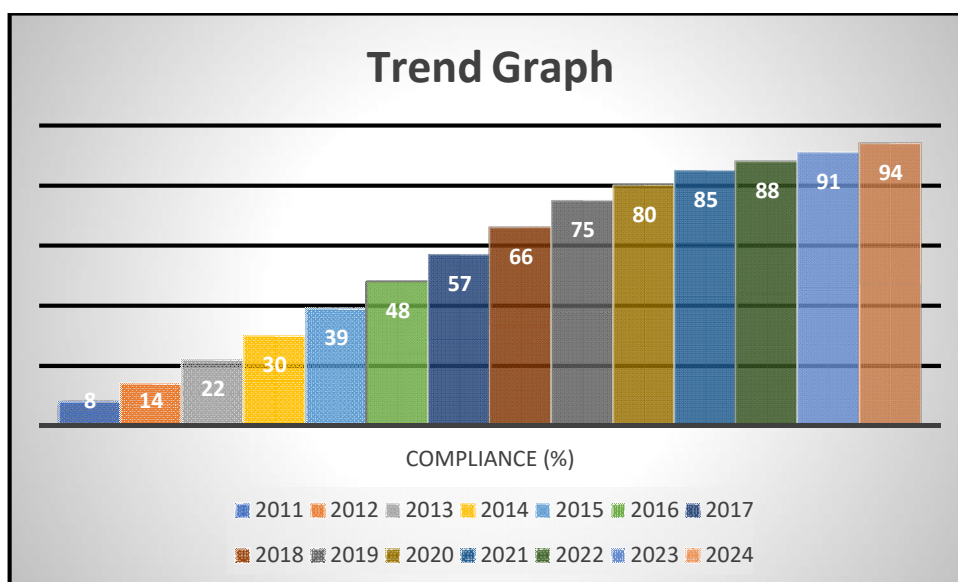


Figure 4: Trend Graph

Comparative charts related India's green accounting adoption compare to other countries: The values in the below table represent each country's Green Accounting Adoption Index, which reflecting their level of implementation and advancement in incorporating environmental factors into their national accounting systems. Green accounting adoption index of following countries are:

- India (68) – India has a Green Accounting Adoption Index of 68, indicating moderate adoption compared to other countries.
- USA (85) – The USA has a relatively high adoption score of 85, showing significant progress in implementing green accounting measures.
- UK (90) – The UK is among the top-performing nations in this comparison, with a strong score of 90.
- Germany (92) – Germany leads the table with the highest index score of 92, indicating a well-developed green accounting framework.
- Japan (88) – With a score of 88, Japan shows strong view towards adoption of green accounting and it placing above the USA and India but below the UK and Germany.
- China (75) – China has a score of 75 which showing a better adoption rate as compare with India but it below from western countries like the USA, UK, and Germany.

Country	
India	68
USA	85
UK	90
Germany	92
Japan	88
China	75

Table 4: Green Accounting adoption Index by country

Below bar chart compares India's adoption index with other countries such as the USA, UK, Germany, Japan, and China, showcasing the country's relative progress in green accounting implementation.

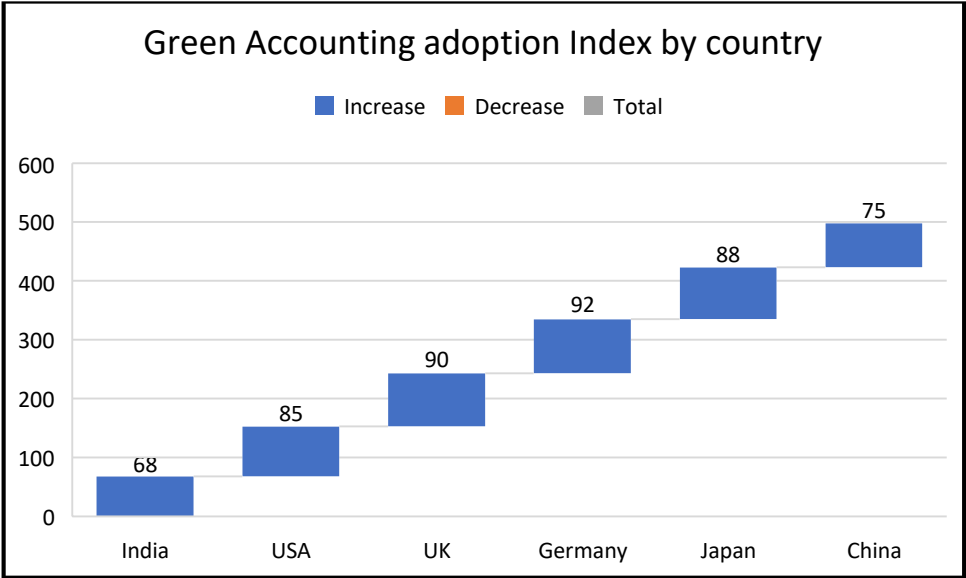


Figure 5: Green Accounting Adoption Index by country

Sectoral Analysis Charts: Visualizing industry-wise adoption trends in green accounting practices. The sectoral chart highlights the extent of adoption across different industries such as energy, manufacturing, finance, IT, agriculture, and retail, offering insights into sector-specific sustainability efforts.

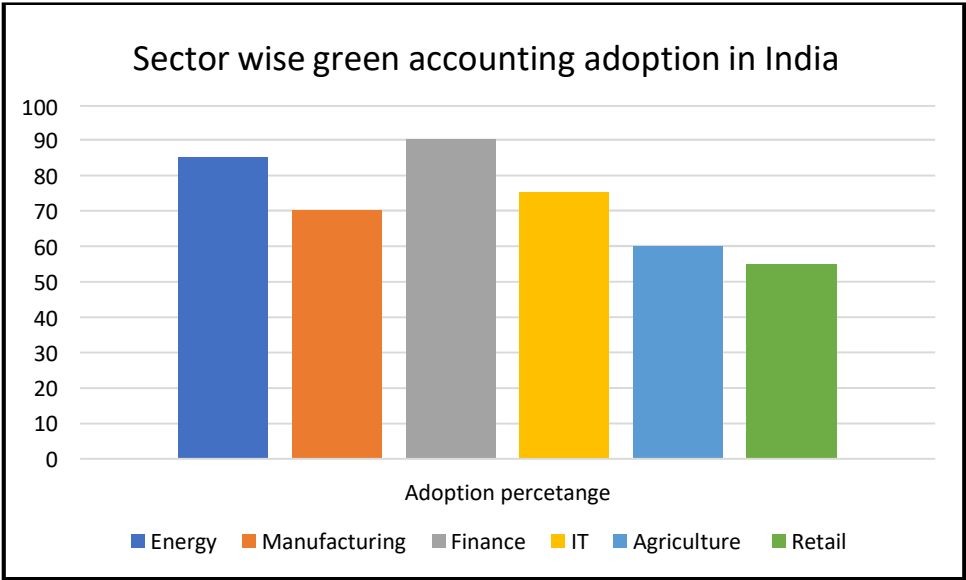


Figure 6: Sector wise green accounting adoption in India

Each industry's adoption percentage reflects its commitment to integrating environmental and sustainability

measures into financial and operational reporting.

Table 5: Sector wise green accounting adoption in India

Industry	Adoption percentage
Energy	85
Manufacturing	70
Finance	90
IT	75
Agriculture	60
Retail	55

Sector-wise Insights:

1. Finance (90%) – The highest adoption is seen in the Finance sector. This indicates strong regulatory compliance, ESG (Environmental, Social, and Governance) reporting, and sustainable investment practices.
2. Energy (85%) – The Energy sector ranks second, highlighting significant efforts to transition to sustainable energy sources, reduce emissions, and improve environmental accountability.
3. IT (75%) – The Information Technology (IT) sector has a moderate adoption rate, indicating growing awareness and efforts to incorporate sustainability into operations, such as data center energy efficiency and carbon footprint tracking.
4. Manufacturing (70%) – The Manufacturing sector shows notable progress, likely due to industry regulations, resource efficiency initiatives, and increasing global pressure for sustainable production.
5. Agriculture (60%) – Adoption in Agriculture is lower compared to other sectors. While sustainable farming practices and resource management are gaining traction, challenges like small-scale farming and traditional methods slow down widespread adoption.
6. Retail (55%) – The Retail sector has the lowest adoption rate. While sustainable packaging, carbon footprint tracking, and responsible sourcing are emerging, many businesses still lag in fully integrating green accounting principles.

Limitation of the study

- **Data Accessibility and Reliability**

This research primarily considers openly accessible secondary and subordinate data which encompassing of corporate governance disclosures, framework of regulatory authorities, governmental extrim reports and industrial explicit

databases. Although, inclusion of exclusive corporate records or unpublished environmental accounting database remains restricted. As consequence, the findings may not capture whole internal sustainability practices due to confidentiality concerns or selective reporting. Moreover, contradictions in disclosure standards crossways industries

and regions could affect the comparability of data.

- **Evolving Regulatory and Accounting Frameworks**

Frequently modification in frameworks for environmental accounting and international regularity framework provided by the Global Reporting Initiative (GRI), Sustainability Accounting Standards Board (SASB), International Financial Reporting Standards (IFRS), and Task Force on Climate-related Financial Disclosures (TCFD) are concern to continuous revision as regulatory bodies and standard-setting organizations update their guidelines to address evolving environmental and financial challenges in the economy. While this study it observes that trends based on current regulations, future developments beyond a period may alter compliance requirements and disclosure practices. Furthermore, differences in regulatory enforcement between nations create inconsistencies in corporate sustainability reporting and it also further complicating process.

- **Industry-Specific Variations and Adoption Disparities**

The range to adoption of green accounting into practices is differs impact across industries due to variations in environmental features, regulatory pressures, financial restrictions, and corporate primacies. Segments related to manufacturing, energy, mining, and agriculture are subject matter to rigid for environmental reporting requirements due to their major effect on eco system. Whereas, service-oriented industries such

as finance, consulting and technology may have lessor mandatory sustainability disclosure requirements. These disparities create challenges in drawing industry-wide conclusions towards adopting green accounting practices.

- **Challenges in Measurement and Standardization**

The absence of a universally accepted methodology for assessing these indicators can create variations in measurement and reporting of green accounting system in business practices. These differences in carbon footprint assessment protocols, cost valuation techniques, and environmental impact assessments make cross-industry comparisons challenging. Moreover, businesses may adopt varying accounting methodologies which based on their internal sustainability policies which complicate data interpretation.

- **Time Lag in Policy Implementation and Corporate Compliance**

The evolution of policy enactment to full corporate towards adoption of green accounting practices often involves delays due to financial and technological obstacles. Companies to promote while regulatory frameworks may require extend adjustment periods for integrate mechanism of sustainability reporting effectively. Additionally, intended corporate initiatives such as corporate social responsibility programs may not always align with legally mandated environmental accounting standards and these issues contribute to variations in the pace at which organizations adopt and

implement environment accounting practices.

Conclusion

The study of method settles that a systematic, well-documented, and ethically comprehensive approach to studying the function of green accounting system in India's economic policies. By integrating further secondary data and adopting qualitative analysis techniques, the study delivers an in-depth assessment of corporate compliance, industry adoption, and technological innovations shaping green accounting in business practices. The findings will provide valuable comprehensions to policymakers, businesses and researchers with aim to enhance India's sustainability reporting design. The findings suggest that India must strengthen its regulatory frameworks, standardize reporting guidelines, and improve enforcement mechanisms to facilitate the widespread adoption of green accounting. Additionally, efforts to build capacity and provide financial incentives could motivate industries to incorporate environmental considerations into their financial reporting (IJRAR, n.d.; Patel & Shah, 2021). Moreover, green accounting is related to the banking industry as it aids integrate eco-friendly considerations while making financial decision, improves sustainability reporting, and ecologically investment practices.

Green accounting in signifies a critical mechanism for harmonizing economic development with environmental sustainability in India. In fact, of so many challenges like data inconsistencies and high operation costs, technological spreads and accordingly policy

incorporation offer feasible paths for enhancement to institutions. Association between businesses, policymakers, and regulatory bodies of India is indispensable to commit green accounting, confirming long-term economic development and ecological assistances. With determined to see global sustainability standards, additional research and policy interferences are vital to overwhelmed the barricades to green accounting adoption. Intensifying corporate responsibility frameworks and strengthening regulatory enforcement will be key to confirming a transition toward a sustainable economic model. Green accounting aids as a analytical tool for harmonizing economic growth with environmental conservation. Even though many trials, improvements in policy frameworks and technological integration provide a way for improvement. To augment green accounting adoption in India, the following endorsements are proposed:

1. Calibration of reporting outlines associated with international sustainability standards (e.g., GRI, SEDA).
2. Corporate appreciation through financial or fringe benefits for organizations adopting green accounting system in their places.
3. Improved policy implementation and application with severer compliance and monitoring mechanisms.
4. Technical progressions such as AI-driven environmental impact assessment tools.

5. Public Awareness Campaigns or programmes to endorse sustainable business practices.

Opportunities and Future Prospects

- Technological Integration: Amalgamated AI and blockchain can enlarge comprehensibility and exactness in environmental reporting (Heba & Yousef, 2018).
- Financial Inducements: Government facilitate various grants or aids for green bonds which can encourage sustainable business practices maintenance in future.
- Educational Strengths: Enflamed perception and training prospectuses can help initiative better espousal in corporate and policymaking encircles.

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Digital Transformation through Tech-enabled Sustainability and CSR Initiatives Driving India's Journey towards Viksit Bharat 2047

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Abstract:

This research paper examines the pivotal role of technology-enabled sustainability and Corporate Social Responsibility (CSR) initiatives in India's journey toward becoming a developed nation by 2047, as envisioned in the Viksit Bharat initiative. Through comprehensive analysis of current technological innovations, sustainability practices, and CSR frameworks, this study explores how digital transformation is catalysing economic growth, environmental sustainability, and social progress. The paper investigates the intersection of technology, corporate social responsibility and national development, presenting evidence of transformative impacts across key sectors including education, healthcare, rural development, and environmental conservation. The findings suggest that tech-enabled CSR initiatives are not merely compliance mechanisms but strategic drivers of inclusive and sustainable development, positioning India as a leader in the global sustainability paradigm.

Introduction

The vision of Viksit Bharat 2047 represents India's ambitious roadmap to transform into a fully developed nation by the centenary of its independence. This transformative vision encompasses comprehensive development across economic growth, social progress, environmental sustainability, and good governance. Central to this vision is the integration of technology-enabled sustainability and Corporate Social Responsibility (CSR) initiatives that are creating unprecedented opportunities for inclusive development.

The confluence of technological innovation and corporate responsibility has emerged as a powerful catalyst for sustainable development in India. As corporations increasingly recognize their role as social change agents, technology has become the enabler that amplifies the impact of CSR initiatives, making them more efficient, transparent, and scalable. This paper explores how tech-enabled sustainability and CSR initiatives are contributing to India's transformation toward Viksit Bharat.

Literature Review

2.1 The Viksit Bharat Framework

The Viksit Bharat 2047 initiative represents a paradigm shift in India's development approach, emphasizing inclusive growth, technological innovation, and sustainable practices. The framework prioritizes advancing technological innovation, fostering

entrepreneurship, and promoting skill development to support a knowledge-based economy. The emphasis on renewable energy, eco-friendly practices, and climate resilience reflects a commitment to sustainable development that aligns with global environmental goals.

2.2 Evolution of CSR in India

India's CSR landscape has undergone significant transformation since the

mandatory CSR provisions under the Companies Act 2013. The evolution from philanthropic activities to strategic corporate citizenship has been accelerated

by digital technologies. Contemporary CSR practices in India demonstrate a shift toward outcome-based interventions, with

2.3 Technology as a Development Enabler

Digital transformation has emerged as a cornerstone of India's development strategy. The Digital India initiative, launched in 2015, has created a foundation

technology serving as both a tool for implementation and a measure of impact assessment.

for technology-enabled development across sectors. The integration of digital technologies in CSR initiatives has enhanced transparency, efficiency, and scalability, creating multiplier effects that contribute to national development objectives.

3. Methodology

This research employs a mixed-methods approach, combining quantitative analysis of CSR spending patterns and qualitative assessment of technology-enabled initiatives. The study analyzes data from corporate sustainability reports, government publications, and academic research to evaluate the impact of tech-enabled CSR initiatives on India's development trajectory toward Viksit Bharat.

Primary data sources include:

- Corporate sustainability reports from leading Indian companies
- Government databases on CSR spending and outcomes
- Academic publications on technology and development
- Case studies of successful tech-enabled CSR initiatives

Secondary analysis includes examination of policy documents, industry reports, and international development frameworks to contextualize India's approach within global sustainability paradigms.

4. Tech-enabled Sustainability: Current Landscape

4.0 Industry Data and Trends

Based on recent industry reports from leading chambers of commerce and industry associations, the landscape of tech-enabled sustainability and CSR in India presents compelling evidence of transformative impact:

Digital Transformation Metrics:

- NASSCOM's Strategic Review 2024-2025 focuses on "Rewiring Growth in the

NASSCOM Industry Insights (2024-2025): The Indian tech industry has empowered millions through CSR initiatives focused on diverse areas like education, skilling and employability, sustainability, healthcare, gender equality. Five major tech companies have impacted 15.4 million lives through CSR initiatives, demonstrating the scalability and reach of technology-enabled social interventions.

"Changing Tech Landscape" and "Beyond Disruption: Staying Future-Ready Today," highlighting India's strengthening position as a global technology and innovation hub

- India's Media & Entertainment sector spends, indicating massive digital adoption crossed INR 2.5 trillion in 2024, with digital media comprising 55% of total ad

Sustainability Integration Data:

- CII-ITC-CESD sustainability initiatives show measurable impact: 8% increase in sustainable transport usage and 6.7% increase in waste segregation through awareness activities
- Eco Edge Program assessed 200+ suppliers from automotive & energy sectors in the last two years

4.1 Digital Infrastructure and Connectivity

India's digital infrastructure expansion has created unprecedented opportunities for sustainable development. The proliferation of internet connectivity, mobile penetration, and digital payment systems has enabled CSR initiatives to reach previously underserved populations. Technology companies have invested significantly in digital infrastructure development, creating foundations for inclusive growth.

Key developments include:

- Expansion of broadband connectivity to rural areas
- Development of digital payment ecosystems
- Creation of digital identity systems enabling targeted interventions
- Implementation of IoT and AI solutions for environmental monitoring

4.2 Green Technology Adoption

Corporate India has increasingly embraced green technologies as part of their sustainability commitments. Renewable energy adoption, waste management systems, and energy-efficient manufacturing processes represent significant areas of investment. Technology companies are leading this transformation through innovation in clean energy solutions, smart grid technologies, and environmental monitoring systems.

4.3 Data-driven Decision Making

The integration of big data analytics and artificial intelligence in CSR program design and implementation has enhanced effectiveness and accountability. Data-driven approaches enable better targeting of interventions, real-time monitoring of outcomes, and evidence-based program modifications. This technological integration has transformed CSR from intuitive philanthropy to strategic development interventions.

5. Sectoral Analysis of Tech-enabled CSR Initiatives

5.1 Education Sector Transformation

The education sector has witnessed remarkable transformation through tech-enabled CSR initiatives. Corporate investments in digital learning infrastructure, teacher training programs, and educational technology have democratized access to quality education. Digital literacy programs, online learning platforms, and technology-enabled skill development initiatives are creating pathways for economic mobility.

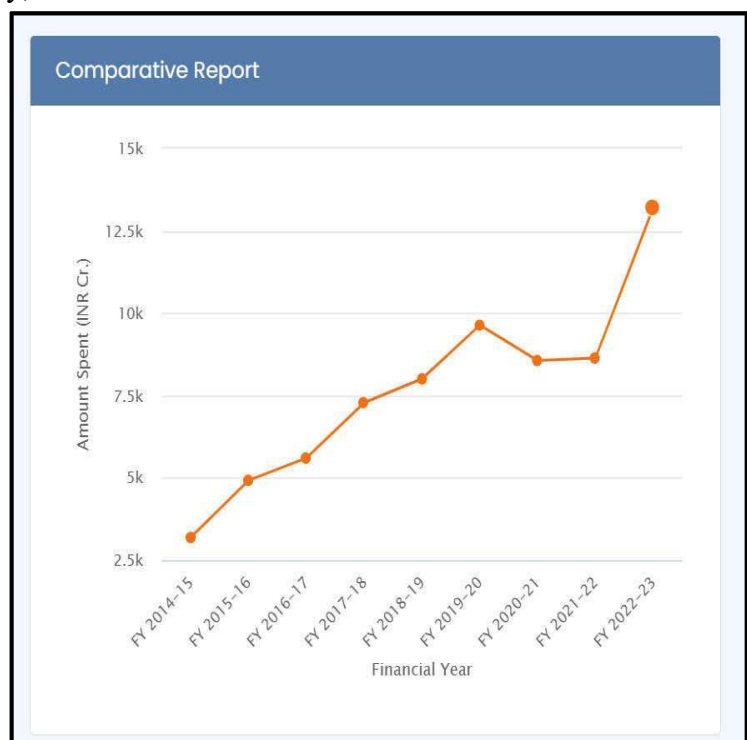
Industry Impact Data (NASSCOM 2024): The Indian tech industry has empowered millions through CSR initiatives focused on diverse areas like education, skilling and employability, sustainability, healthcare, gender equality, with technology companies pioneering innovative approaches to educational delivery that create scalable models for national replication.

Key Quantitative Impacts:

- 5 major tech companies impact 15.4 million lives through CSR initiatives, with significant focus on education and skill development
- Enhanced access to quality educational resources in remote areas through digital platforms
- Development of digital skills among students and teachers through structured programs

- Creation of innovative learning methodologies using AI and adaptive learning technologies
- Improved educational outcomes through personalized learning approaches

Corporate spending on education through CSR reached ₹13,209 crore in FY 2022-2023, with significant focus on digital literacy, skill development programs, and infrastructure development. Technology companies have pioneered innovative approaches to educational delivery, creating scalable models that can be replicated nationally.



Data Source: Ministry of Corporate Affairs

5.2 Healthcare Innovation and Access

Technology-enabled healthcare initiatives have revolutionized medical service delivery, particularly in underserved

areas. Telemedicine platforms, digital health records, mobile health applications, and AI-powered diagnostic tools have improved healthcare accessibility and quality. Corporate CSR investments in

healthcare technology have created sustainable models for medical service delivery.

Transformative initiatives include:

- Telemedicine programs connecting rural patients with urban specialists

5.3 Rural Development and Agriculture

Digital technologies have transformed rural development approaches, enabling precision agriculture, market linkages, and financial inclusion. Tech-enabled CSR initiatives in agriculture focus on crop monitoring systems, weather prediction services, and digital marketplaces that connect farmers directly with consumers.

5.4 Environmental Conservation and Climate Action

Technology-enabled environmental initiatives represent a critical component of India's sustainability agenda. Corporate investments in environmental monitoring systems, pollution control technologies, and renewable energy solutions contribute significantly to climate action objectives. IoT sensors, satellite monitoring, and data analytics enable precise environmental management.

CII-ITC-CESD Environmental Impact Data (2024):

- Air Quality Management in Cities: Awareness activities in Indore led to 8% increase in sustainable transport usage and 6.7% increase in waste segregation

- Mobile health units equipped with digital diagnostic tools
- Health information systems improving care coordination
- AI-powered screening programs for early disease detection

Key interventions include:

- Precision agriculture technologies improving crop yields
- Digital platforms providing market price information
- Mobile banking services enhancing financial inclusion
- E-commerce platforms creating market access for rural producers

- Eco Edge Program: 200+ suppliers assessed from automotive & energy sectors in the last two years
- Systematic changes impacting people's lives through technology-enabled environmental monitoring

FICCI Digital Transformation Insights:

- India's digital advertising grew 15% in 2023 and surpassed traditional advertising for the first time, indicating massive digital adoption that supports environmental initiatives
- Digital media grew by 17% to reach INR 802 billion in 2024, demonstrating the platform capacity for environmental awareness campaigns

Major Technology-enabled Environmental Initiatives:

- Comprehensive air quality monitoring networks in major cities using IoT sensors
- Real-time water quality management systems with automated alerts
- Community-participatory renewable energy projects with digital monitoring

6. Case Studies of Transformative Impact

6.1 Digital Education Ecosystem Development

Leading technology companies have created comprehensive digital education ecosystems that extend beyond traditional

6.2 Healthcare Technology Integration

Corporate healthcare initiatives have demonstrated the transformative potential of technology integration. Telemedicine platforms, diagnostic technologies, and

6.3 Environmental Monitoring and Conservation

Technology-enabled environmental initiatives have created comprehensive monitoring and conservation systems.

7. Impact Assessment and Outcomes

7.1 Quantitative Impact Measures

Analysis of available data from NASSCOM CII, and FICCI indicates significant positive impacts across multiple development indicators:

Technology Industry CSR Impact (NASSCOM 2024-2025):

- 5 major tech companies impact 15.4 million lives through CSR initiatives focused on education, skilling,

- Advanced waste management technologies supporting circular economy solutions
- Satellite-based environmental monitoring with predictive analytics

CSR boundaries. These initiatives combine infrastructure development, content creation, teacher training, and student support systems to create sustainable educational transformation. The scalability of digital solutions has enabled these programs to reach millions of students across diverse geographic and socioeconomic contexts.

health information systems have improved healthcare access and quality while reducing costs. These initiatives have created sustainable models that can be integrated into public healthcare systems.

Corporate investments in sensor networks, data analytics, and environmental management systems have contributed to improved environmental outcomes while creating scalable models for environmental protection.

sustainability, healthcare, and gender equality

- Tech industry has empowered millions through CSR initiatives over the past decade, with focused strategies aligned with national agenda and UN SDGs

Environmental and Sustainability Metrics (CII-ITC-CESD 2024):

- 8% increase in sustainable transport usage and 6.7% increase in waste segregation through awareness activities in Indore

- 200+ suppliers assessed from automotive & energy sectors through Eco Edge Program in the last two years

Digital Transformation Indicators (FICCI-EY Reports 2024):

- Digital media grew by 17% to reach INR 802 billion and became the largest segment in 2024, with 55% of total ad spends
- Digital advertising grew 15% in 2023 and surpassed traditional advertising for the first time, indicating massive digital adoption supporting social initiatives

Sectoral Development Outcomes:

7.2 Qualitative Impact Assessment

Qualitative analysis reveals deeper transformative impacts:

- **Social Capital Development:** Enhanced community organization and participation

7.3 Sustainability and Scalability

Tech-enabled CSR initiatives demonstrate superior sustainability and scalability compared to traditional approaches.

8. Challenges and Opportunities

8.1 Implementation Challenges

Despite significant progress, several challenges persist:

- **Digital Divide:** Unequal access to technology and digital literacy

8.2 Regulatory and Policy Challenges

- **Education:** Improved literacy rates, enhanced digital skills, increased educational access through tech-enabled platforms
- **Healthcare:** Reduced mortality rates, improved health outcomes, enhanced medical service access via telemedicine
- **Economic Development:** Increased income levels, enhanced livelihood opportunities, improved market access through digital platforms
- **Environmental Protection:** Reduced pollution levels, improved resource management, enhanced environmental awareness through technology integration

- **Digital Inclusion:** Reduced digital divides and improved technology access
- **Institutional Strengthening:** Improved governance and service delivery mechanisms
- **Innovation Ecosystem:** Creation of innovation networks and entrepreneurship opportunities

Digital platforms, automated systems, and data-driven management create self-sustaining mechanisms that continue delivering impact beyond initial corporate investments.

- **Infrastructure Limitations:** Inadequate digital infrastructure in remote areas
- **Capacity Constraints:** Limited technical expertise in implementation organizations
- **Coordination Issues:** Fragmented approaches across different corporate initiatives

- **Transparency Requirements:** Need for enhanced reporting and accountability mechanisms
- **Impact Measurement:** Challenges in standardizing impact assessment methodologies
- **Coordination Mechanisms:** Limited coordination between corporate initiatives and government programs
- **Technology Standards:** Need for standardized technology platforms and interoperability

8.3 Emerging Opportunities

- **Artificial Intelligence Integration:** Enhanced capability for personalized interventions
- **Blockchain Technology:** Improved transparency and accountability
- **IoT Expansion:** Comprehensive monitoring and management systems
- **5G Implementation:** Enhanced connectivity enabling new service delivery models

9. Strategic Recommendations

9.1 Policy and Regulatory Enhancements

- **Integrated Framework Development:** Creation of comprehensive policy frameworks linking CSR initiatives with national development objectives
- **Technology Standards:** Development of standardized technology platforms for CSR implementation
- **Impact Measurement Systems:** Implementation of standardized impact assessment methodologies
- **Coordination Mechanisms:** Establishment of coordination platforms between corporate and government initiatives

9.2 Corporate Strategy Recommendations

- **Long-term Commitment:** Development of sustained engagement models beyond compliance requirements
- **Partnership Development:** Creation of strategic partnerships with government agencies and civil society organizations
- **Technology Integration:** Comprehensive integration of emerging technologies in CSR program design
- **Innovation Investment:** Increased investment in innovative solutions and pilot programs

9.3 Capacity Building Initiatives

- **Technical Expertise Development:** Investment in technical capacity building for implementation organizations
- **Innovation Ecosystem Development:** Creation of innovation networks and entrepreneurship support systems
- **Digital Literacy Programs:** Comprehensive digital literacy initiatives for target communities
- **Knowledge Sharing Platforms:** Development of platforms for sharing best practices and lessons learned

10. Future Outlook and Viksit Bharat 2047

10.1 Technology Evolution and Integration

The future landscape of tech-enabled CSR will be characterized by advanced

integration of emerging technologies including artificial intelligence, blockchain, Internet of Things, and 5G connectivity. These technologies will enable more sophisticated, personalized, and effective interventions that align with Viksit Bharat objectives.

10.2 Scaling and Sustainability

The path toward Viksit Bharat requires massive scaling of successful tech-enabled CSR initiatives. Digital platforms, automated systems, and data-driven

management will enable this scaling while maintaining quality and impact. Sustainability will be enhanced through technology-enabled monitoring, evaluation, and adaptive management systems.

10.3 Innovation and Entrepreneurship

Tech-enabled CSR initiatives will continue fostering innovation ecosystems that create entrepreneurship opportunities and economic growth. The integration of corporate resources with technological capabilities will generate innovative solutions that address complex development challenges while creating economic value.

11. Conclusion

Tech-enabled sustainability and CSR initiatives represent a transformative force in India's journey toward Viksit Bharat 2047. The integration of digital technologies with corporate social responsibility has created unprecedented opportunities for inclusive and sustainable development. Through systematic analysis of current initiatives, impact assessment, and future projections, this research demonstrates that technology-enabled CSR is not merely a compliance mechanism but a strategic driver of national development.

The evidence suggests that tech-enabled CSR initiatives are creating multiplier effects that extend far beyond immediate program outcomes. Digital platforms, data-driven decision making, and innovative service delivery models are transforming how development interventions are designed, implemented, and sustained. These approaches align with the comprehensive development vision of Viksit Bharat, contributing to economic growth, social progress, environmental sustainability, and good governance.

However, realizing the full potential of tech-enabled CSR requires addressing persistent challenges including digital divides, infrastructure limitations, and coordination issues. Strategic recommendations include policy enhancements, corporate strategy improvements, and capacity building initiatives that can accelerate progress toward Viksit Bharat objectives.

The future outlook suggests that continued evolution of technology integration, scaling of successful initiatives, and fostering of innovation ecosystems will be critical for achieving Viksit Bharat 2047. As India continues its digital transformation journey, tech-enabled CSR initiatives will play an increasingly important role in creating an inclusive, progressive, empowered, thriving, and sustainable nation.

The transformative impact of tech-enabled sustainability and CSR initiatives extends beyond immediate development outcomes to create foundational changes in how society approaches development challenges. This transformation positions India as a global leader in sustainable development practices, demonstrating how technology and corporate responsibility can be integrated to achieve ambitious national development objectives.

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Analyzing the Impact of ESG Investing on Listed IT Sector Companies: A Strategic Analysis of Performance Sustainability & Investing Behavior of an Investor

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Abstract:

This study explores the impact of Environmental, Social, and Governance (ESG) investing on listed IT sector companies' financial and operational performance. The research aims to provide actionable insights for investors and IT firms to enhance ESG performance and leverage it for sustainable growth. By analyzing the correlation between ESG scores and market capitalization growth, the study seeks to uncover patterns and trends using statistical analysis in R. The findings contribute to understanding how ESG factors influence market performance, guiding strategic investment decisions. The study also discusses implications for investors, policymakers, and corporate executives in adopting ESG frameworks for financial stability and long-term growth.

Keywords: *ESG Investing, IT Sector, Financial Performance, Market Capitalization, Sustainable Growth, R Tool, Strategic Analysis.*

Introduction:

In recent years, the investing landscape has changed dramatically, with ethical and sustainable factors increasingly playing a major role in decision-making. The process of integrating governance, social, and environmental considerations into investment choices in order to promote sustainable economic growth is known as ESG investing. Given that businesses with robust ESG frameworks typically outperform their competitors in the long run, this strategy is no longer merely a

moral one but also a financially sound one. The IT industry provides a distinct viewpoint on the effects of ESG because of its quick technical developments and global market dominance. IT companies are less reliant on physical resources than conventional businesses, yet they are nevertheless vulnerable to sustainability hazards like energy use, data privacy, and corporate governance challenges.

IT companies have been forced to strengthen their ESG commitments in

order to preserve investor confidence and competitive competitiveness due to the growing demand for ethical technology solutions. The five top IT firms that are the subject of this study are Infosys, Oracle, Tech Mahindra, Tata Consultancy Services (TCS), and Wipro Ltd. We hope to identify patterns that connect

Numerous studies have explored the connection between ESG performance and financial outcomes. For example, Friede, Busch, & Bassen (2015) conducted a meta-analysis of over 2,000 empirical studies and found a generally positive correlation between ESG investing and financial performance. Khan, Serafeim, & Yoon (2016) demonstrated that firms with strong ESG strategies experience higher stock returns and improved risk management. Eccles, Ioannou, & Serafeim (2014) argued that organizations committed to ESG principles outperform their competitors in both operational efficiency and financial metrics. Other studies, such as Giese et al. (2019), have emphasized that ESG scores influence a firm's resilience during economic downturns, while Clark, Feiner, & Viehs (2015) linked ESG integration with reduced volatility and enhanced investor confidence. However, limited research focuses specifically on the IT

This research adopts a quantitative approach, utilizing secondary data sources for ESG scores and market capitalization values. The ESG scores for Infosys, Oracle, Tech Mahindra, TCS, and Wipro are sourced from India360 ESG Risk,

sustainability efforts to economic expansion and investor behavior by evaluating their ESG performance. Our study will assist companies in comprehending how to strategically use ESG frameworks to attain sustained market success.

Literature Review:

sector, creating a gap this study seeks to address. Understanding the IT sector's unique response to ESG factors will help investors and policymakers refine their approach toward sustainable investing.

Objective:

1. To assess the correlation between ESG scores and market capitalization growth in listed IT companies.
2. To analyse the impact of ESG investing on the financial and operational performance of IT firms.
3. To provide strategic insights for IT firms on enhancing ESG performance for sustainable growth.
4. To evaluate investor behaviour in response to ESG performance in the IT sector
5. To identify emerging trends in ESG adoption within IT companies and their financial implications.

Research Methodology:

while market capitalization data is retrieved from CompaniesMarketCap. The study employs statistical correlation analysis in R to determine the relationship between ESG scores and financial performance.

The methodology follows a hypothesis-driven framework:

- **H1:** A higher ESG score positively correlates with increased market capitalization growth.
- **H0:** There is no significant correlation between ESG score and market

Results:

The ESG scores and market capitalization figures for 2024 are as follows:

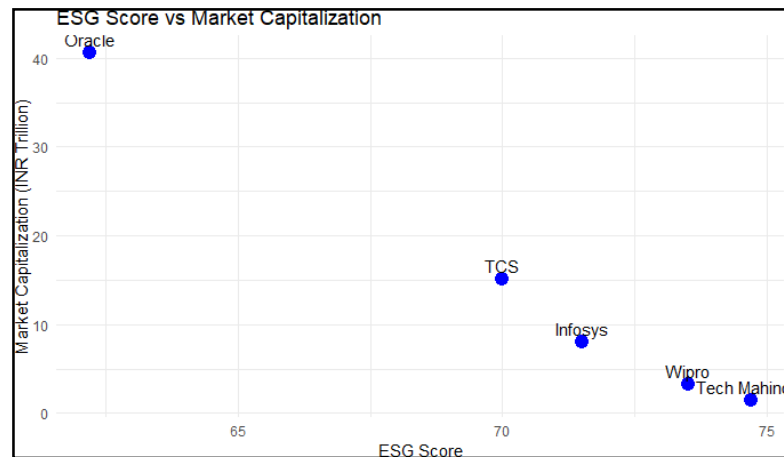
Company	ESG Score	Market Capitalization (INR T)
1. Infosys	71.5	7.987
2. Oracle	62.2	40.540
3. Tech Mahindra	74.7	1.521
4. TCS	70	15.138
5. Wipro	73.5	3.274

Using R statistical tools, the correlation coefficient between ESG scores and market capitalization is calculated to identify patterns and trends. The results analysis reveals that while ESG performance has some correlation with financial stability, it is not the sole determinant of market capitalization. Other factors such as profitability, industry conditions, and innovation play a crucial role in shaping a company’s financial standing. Interestingly, Oracle, despite having the lowest ESG score

capitalization growth.

The study will conduct Pearson correlation tests, trend analysis, and regression models to evaluate the statistical significance of ESG investing in IT firms. The results will provide insights into how ESG factors influence financial stability and corporate valuation.

(62.2), leads in market capitalization at 40.540 trillion INR. This suggests that financial strength and investor trust still outweigh ESG considerations. On the other hand, companies like Wipro and Tech Mahindra, with relatively high ESG scores, rank lower in market capitalization, indicating that ESG efforts alone do not drive valuation. These findings highlight a moderate correlation between ESG scores and financial performance, suggesting that ESG initiatives must be complemented by other business strategies for maximum impact.



The scatter plot shows how ESG scores relate to market capitalization for five major IT companies. Surprisingly, Oracle, with the lowest ESG score, has the highest market value, suggesting that financial strength matters more than ESG alone. TCS and Infosys, with mid-range ESG scores, have solid market capitalizations,

while Wipro and Tech Mahindra, despite high ESG scores, rank lower financially. This suggests that while ESG efforts boost reputation and investor trust, market value is shaped by factors like profitability and industry trends. Ultimately, ESG is important for long-term growth, but financial fundamentals still drive success.

Discussion:

The findings of this study provide valuable insights into the impact of ESG investing on IT sector performance. A moderate correlation between ESG scores and market capitalization growth suggests that ESG strategies contribute to financial stability but must be complemented by other business strategies. IT firms with higher ESG scores tend to exhibit better investor confidence, but market fluctuations and external economic factors also play a significant role. Additionally, the study highlights that companies proactively improving ESG performance attract sustainable investors and enhance long-term corporate value. Investors

should consider ESG factors alongside traditional financial indicators for a comprehensive evaluation of investment opportunities. Policymakers and corporate leaders must strike a balance between sustainability initiatives and financial performance to maximize corporate growth.

Key Insights

1. **ESG Enhances Investor Confidence:** Companies with higher ESG scores tend to attract sustainable investors who value ethical and responsible business practices.
2. **Financial Performance Still Dominates:** While ESG considerations matter, profitability, innovation, and market

conditions remain the primary drivers of corporate valuation.

3. **Industry-Specific Challenges:** The IT sector faces unique sustainability challenges, including energy consumption in data centers, cybersecurity risks, and digital ethics. These factors must be integrated into ESG frameworks to enhance market positioning.
4. **Long-Term Sustainability Matters:** Companies that proactively improve their ESG performance can enhance long-term resilience, attracting both investors and

customers committed to sustainability.

According to this study, in order for investors to make well-rounded investing decisions, ESG should be taken into account in addition to conventional financial indicators. To guarantee long-term company growth, legislators and business executives must balance sustainability initiatives with financial results.

Conclusion:

This study provides valuable insights into the evolving role of ESG investing in the IT sector. While ESG performance contributes positively to market stability, it is not the sole driver of financial success. Companies must integrate ESG strategies within a broader corporate framework to remain competitive and attract investors.

A key takeaway is that companies that proactively improve their ESG performance can enhance long-term resilience, fostering greater trust among investors and stakeholders. However, financial strength and market positioning continue to play a dominant role in determining a company's overall valuation.

The findings suggest that investors should adopt a balanced approach, considering both ESG performance and traditional financial metrics when making investment decisions. Similarly, IT firms should not view ESG merely as a compliance requirement but as a strategic asset that can drive innovation, operational efficiency, and brand reputation.

Future research can explore the long-term financial implications of sustained ESG performance in the IT sector, along with the role of regulatory policies in shaping sustainable investment strategies. As the global investment landscape shifts towards responsible investing, IT firms that successfully integrate ESG into their business models will be best positioned for sustained growth and competitive advantage. Additionally, a broader dataset encompassing more companies and global trends could provide deeper insights into how ESG policies shape long-term corporate success and investor behavior.

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The Evolution of ESG: A Bibliometric Perspective on Frameworks and Trends

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Abstract

The landscape of ESG (Environmental, Social, and Governance) is continually changing and shaping the practices of publicly listed companies. This research aims to explore the body of literature pertaining to the development of ESG and its framework. Utilizing "ESG FRAMEWORK" as our search parameter, we conducted a bibliometric analysis across a vast Scopus database, ultimately identifying 101 pertinent articles. Our analysis, spanning from 2012 to 2024, was executed using R Studio and the Biblioshiny application. Our findings reveal an upward trajectory in ESG, highlight leading authors and prolific countries, assess prevalent themes and collaborations, and scrutinize diverse ESG frameworks. These insights are poised to offer significant value to ESG researchers, stakeholders, and policymakers alike,

Keywords: *ESG, Sustainability, Framework, Bibliometric, and Scopus*

Introduction

Businesses worldwide increasingly acknowledge the need to incorporate climate change considerations into their overall strategy and environmental management. This proactive approach plays a pivotal role in addressing climate change and can significantly impact sustainable practices and foster greater

transparency and accountability. The dimension of sustainability has emerged gradually. While exploring the emergence of this dimension, I found that the first dimension of sustainability, "economic," was seen after the Second World War in 1945.

The second dimension of sustainability, “environment”, was initiated in the discussion due to the environmental movement from 1960 onwards. At that time, economists, industrialists, and policymakers did not accept the environment as an important aspect that firms had to address. However, it took 10 years to accept that the environment can be integrity with the economy, and the first major attempt in 1972 was made to reconcile economic development with environmental integrity, which was commonly regarded as incompatible.

The third dimension of sustainability has also emerged due to the social movement where social injustice and inequality have emerged dramatically; however, to meet the needs of the people in 1987, the UN World Commission on Environment and Development published its report ‘Our Common Future (the Brundtland Report), calling for “a new era of economic growth—growth that is forceful and at the same time socially and environmentally sustainable”’.

Based on UNDP (2017), sustainability is one of the key challenges facing organizations in the twenty-first century. Most of the studies stated that the sustainability practices in organizations should be based on multi-dimensional constructs. (Gkargkavouzi, Halkos, & Matsiori, 2019). For instance, (Baumgärtner & Quaas, 2010) Stated that organizations should consider sustainability practices by interrelating with various components such as individual, organizational, political, and social.

Some studies (Laguir, Stekelorum, & El Baz, 2020) Suggested that sustainability practices are related to the policy

integrating eco-design, ecosystem, stewardship, pollution control, and business redefinition. Based on (Hall, 2011), (Elkington, 1994) Attempted to measure sustainability during the mid-1990s by encompassing a new framework to measure performance in corporate America. This framework was named the triple bottom line (TBL), which went beyond traditional profits and shareholder value measures to include environmental and social dimensions. (Masud et al., 2019).

This research aims to explore the body of literature pertaining to the development of ESG and its framework. By utilizing "ESG FRAMEWORK" as our search parameter across a vast Scopus database, we ultimately identified 101 articles using the PRISMA Framework. Our analysis, spanning from 2012 to 2024, was executed using R Studio and the Biblioshiny application.

The bibliometric analysis of ESG research from 2012 to 2024 significantly contributes by thoroughly examining the field's evolution, thematic trends, and global landscape. By identifying the rapid growth in ESG-related publications after 2020, the study highlights the increasing recognition of sustainability as a key concern across business and policy domains. This trend signifies the growing integration of ESG frameworks into decision-making processes, driven by regulatory changes and the global demand for more responsible corporate governance. Furthermore, identifying key thematic clusters, such as sustainability, climate change, and governance, offers valuable insights into the multi-dimensional nature of ESG research,

helping to map the development of the field and its shifting priorities over time.

Furthermore, this analysis contributes to our understanding of the global collaboration and dissemination of knowledge within ESG research. By highlighting the geographical distribution of contributions, it emphasizes the diverse nature of the research, with significant qualitative input from countries such as India, Italy, and Canada. The study also identifies influential academic institutions

and key publication platforms, illustrating how global networks shape research output and influence. Additionally, the findings reveal potential future research directions, including the integration of blockchain technology for transparency, the role of behavioral economics in ESG decision-making, and the exploration of ethical AI in ESG assessments. These findings lay the foundation for future studies to address emerging challenges and gaps in the field.

Research Methodology

In this paper, we performed a systematic literature review by employing a bibliometric analysis concentrated on a comprehensive picture of the current status of ESG framework as a field of research, as well as to collect and link together as many relevant existing studies as possible. The primary advantage of bibliometrics is that the large number of data generated is usually concise, straightforward, impartial. (Jokić & Ball, 2006), and as visually simplified as possible (Xue et al., 2022). Because of its focus on the literature's internal

relationships, bibliometric analysis is considerably more suited to academic research (Zhao, Zhang, & Kwon, 2018). By analyzing bibliometric data, researchers can acquire a sense of the history of the field's development over time, gain insight into its current status, and get direction for future studies (Bilal et al., 2022; Durieux & Gevenois, 2010). The detailed method of article collection, screening, analysis, and visualization of data is highlighted in Figure 1 Prisma Framework.

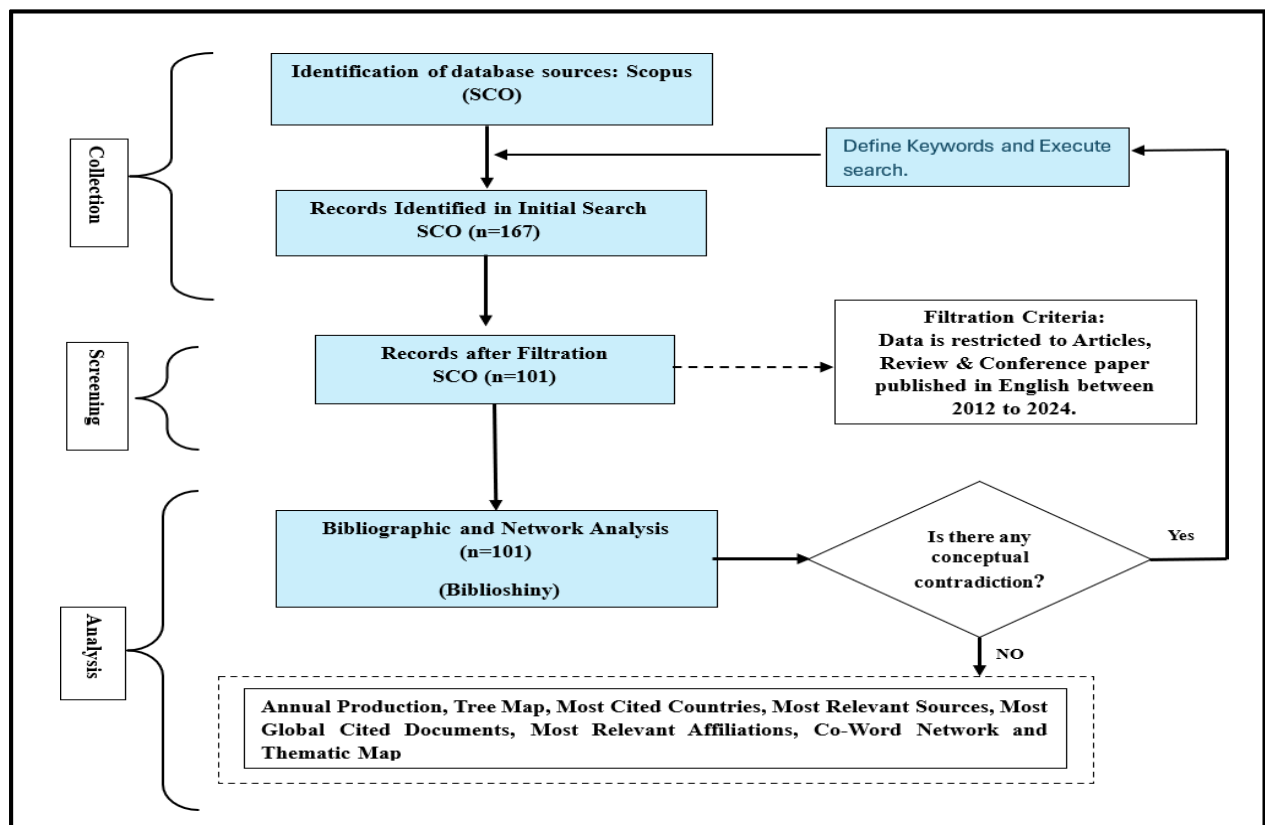


Figure 1: PRISMA Framework

2.1 Data collection

Database: Picking the correct database(s) is the first step in conducting the bibliometric study (Ayan, Güner, & Son-Turan, 2022). This analysis considers the most popular bibliometric database, Scopus by Elsevier. (Zhu & Liu, 2020).

Search Criteria: This study used "ESG Framework" as a search string in Scopus. The author discovered 167 documents in the first search

2.2 Data Screening

Filtration Criteria and Data Preparation: In this research a rigorous filtering procedure was used to ensure the quality and relevance of the dataset. The initial exclusion of non-English language articles and non-journal publications from the analysis resulted in a refined dataset. Only peer-reviewed research papers, including Articles, Conference Papers, Proceedings, and Review Papers, were included in the filtered articles. The analysis focused on the period between 2012 and 2024. After the filtration criteria, a total of 101 English-language journal publications were retained for further analysis.

Data Corrections: To facilitate further analysis dataset was manually examined in Microsoft Excel for any missing information. In addition, the Author Keywords and Keyword Plus entries were manually normalised to ensure consistency and accuracy in the analysis. To

create a unified term, terms such as "Environmental, Social, and Governance" and "ESG," "Environmental, Social, and Governance (ESG)" and "ESG," "Corporate Social Responsibility" and "CSR," were manually renamed using the Replace command in Microsoft Excel. This step enabled a precise keyword count for the subsequent bibliometric analysis.

Analysis

In the present study, we used one of the most powerful tools for analyzing and visualizing, which is Biblioshiny programme, to investigate the current situation and potential futures of entrepreneurship and blockchain. Biblioshiny was developed by Massimo Aria and offers a full-featured and highly user-friendly interface that accommodates users with extensive experience programming R, built on top of the Shiny package for R programming language (Aria & Cuccurullo, 2017).

To install it, we used the following commands for installation `package install.packages("bibliometrix")`, then the library `library(bibliometrix)`, and the command `"biblioshiny"` in the RStudio command workspace. Our Biblioshiny analyses included extensive topics within the Performance Analysis and Network Mapping area, which included Positive and Negative Performance Analysis, Performance Comparison, and Network Mapping (Moral-Muñoz, Herrera-Viedma, Santisteban-Espejo, & Cobo, 2020). In Performance Analysis, we have analyzed the most recent trend publications, citing the most relevant articles and countries, countries of the Most Relevant Sources, the Most Productive Institutions, and the most popular Keywords used in this area. In

addition to Positive and Negative Performance Analysis, combined with Comparative Performance Analysis, we have carried out Science Mapping, Keyword Co-occurrence, and Thematic Map, which provided us with valuable information within the ESG framework.

With Biblioshiny's Performance Analysis, we had a comprehensive overview of the research that has been done, and we also have insights into potential future research in this dynamic area. We believe that, by using this program, we have gained valuable understanding and conclusion-making from the bibliometric data, which made it possible to interpret and combine performance and network data in a multidimensional form.

Results

Descriptive Statistics

We have conducted a thorough analysis of bibliometric data from 2012 to 2024 to explore the academic research surrounding the Environmental, Social, and Governance (ESG) framework. In the last twelve years, researchers in the field

have made significant contributions from 79 various sources, including journals, books, and other publications. This demonstrates the diverse array of interests that exist on various academic platforms. The research output demonstrates a significant annual growth rate of 30.77%, highlighting a substantial expansion in

ESG studies, with 101 documents documented.



their unique perspectives or specialized interests.

The documents, which have an average age of 1.7 years, showcase the latest advancements in ESG research, highlighting how the field is constantly evolving. Each document has received an average of 5.01 citations, which shows that it has a moderate level of influence among scholars. The substantial number of 5023 references across all papers underscores the depth of research and extensive academic dialogue in ESG topics.

Diving deeper into the content, the use of 393 'Keywords Plus' and 339 'Author's Keywords' reveals a diverse and specific exploration of themes within the ESG framework, showcasing a rich variety of focus areas chosen by researchers to reflect

In terms of authorship, the data shows a blend of collaborative and individual efforts. 312 authors have been involved, the presence of single-authored and multi-authored documents indicates a mix of personal and collaborative research approaches. Notably, there are 19 single-authored documents, which may highlight individual expertise or unique viewpoints. The average of 3.16 co-authors per document and an international co-authorship rate of 23.76% further emphasizes a high degree of collaboration and global interaction among scholars in the ESG field.

The statistical breakdown of document types, which contained 58 articles, 14 book chapters, 18 conference papers, a conference review, a note, and nine reviews,

shows us how ESG research is presented. Articles are the most commonly used for new findings, book chapters extend the analysis, whereas conference papers share their discussion and introduce new ideas to an academic audience.

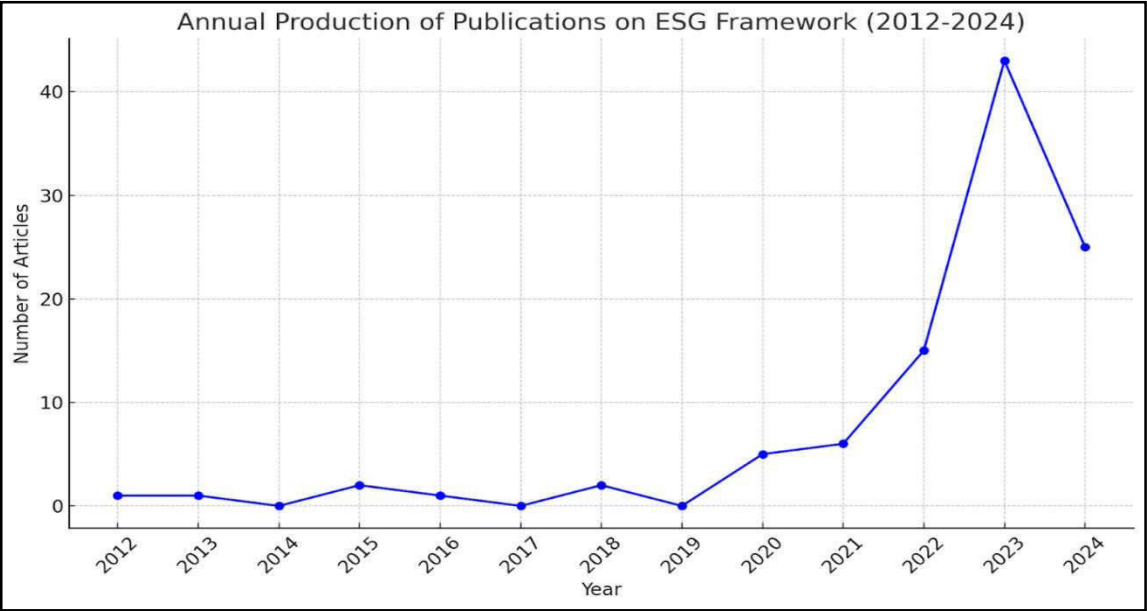
All in all, the findings of the bibliometric investigation present a vivid, polymorphous, and expanding field. It is highly collaborative in an academic sense and global by the geographical pattern. The variety of documents and cooperation between the countries indicate the far-reaching importance and extensive spread of the ESG issues.

Annual Productions

The bibliometric analysis of the annual production of publications on the ESG (Environmental, Social, and Governance) framework from 2012 to 2024 reveals a

significant and growing interest in this field. Initially, the research output was minimal, with only one publication each in 2012 and 2013, suggesting that ESG was a relatively niche area at the time. The subsequent years saw fluctuating activity, with publication numbers ranging from zero to two annually until 2019. This pattern indicates that ESG was still in its developmental phase and had not yet gained substantial traction within the academic or business communities.

A noticeable surge in publication volume began in 2020, with the number of articles increasing to five that year, followed by six in 2021, and a more dramatic rise to 15 in 2022. The peak occurred in 2023, with a remarkable 43 publications, highlighting a heightened focus on ESG issues, likely driven by increased global awareness of sustainability challenges, evolving regulatory frameworks, and greater corporate adoption of ESG criteria.

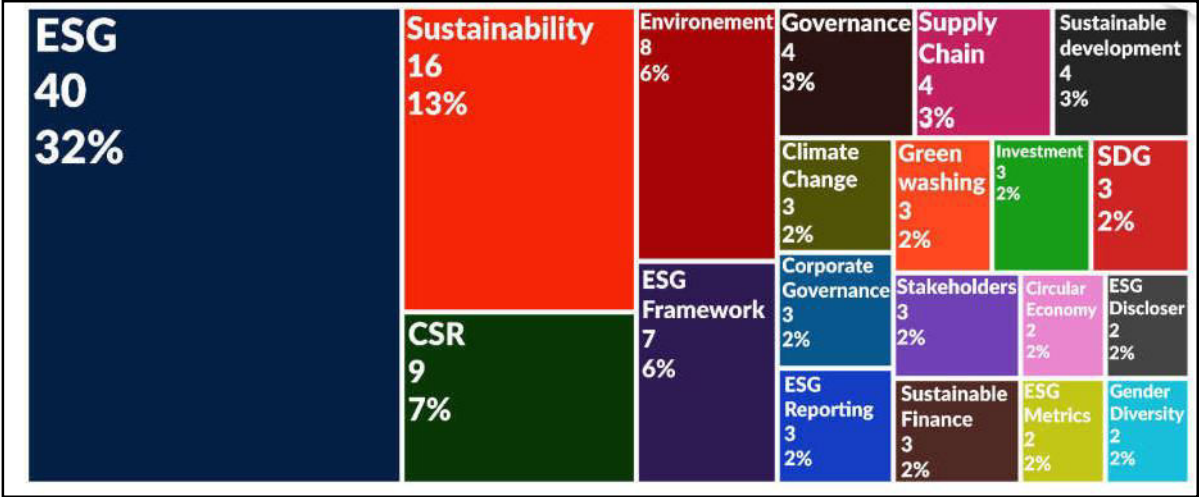


However, there is an apparent drop in publications to 25 in 2024. It is important to note that this data only covers the first four months of the year, up to April. Therefore, the perceived decline does not indicate a decrease in interest or research activity but rather a partial dataset. If this trend continues at the same rate for the rest of the year, 2024 could potentially match or exceed the high levels of publication seen in 2023, underscoring the sustained and robust engagement with ESG topics within the scholarly and business arenas. This growing body of literature is crucial

for understanding the complexities of ESG and its increasing integration into global business practices and policymaking.

Most Frequent Authors’ Keywords

The aforementioned words’ bibliometric analysis demonstrated how frequently they were used and, hence, the predominant themes of publications in the field of the ESG framework. A follow-up tree map helped highlight those central terms and concepts actively included in the discourse related to ESG research.



First and foremost, the word ESG itself was indicated 40 times, demonstrating that not only is it an undeniable uniting entity but also encompasses various concepts from environmental consciousness to corporate governance.

Second, sustainability in itself was mentioned 16 times, positioning it as the cornerstone of discussion in terms of long-term environmental equilibrium and ethical business operation. CSR used 9 times sheds light on ESG’s connection to the ethical and social spheres of corporate action.

In addition, the environmental aspect seems to be discussed overtly owing to the 8 mentions assigned to this word. In turn, the ESG framework overviewed 7 times, suggests a structured manner to achieve ESG principles in organizational operation. Governance seems to have an independent role, with 4 mentions reaching 3 for

corporate governance, emergence times in the mention.

Similarly, other terms such as supply chain and sustainable development, registered 4 times, ESG also used 4 times, highlighting extra attention to sustainability performance and corporate aligning to global objectives. On the other hand, it is possible to see the tendency to use specialized topics such as climate change, noted 3 times, greenwashing, and investment used 3 times, and SDG 3 times suggests that ESG composition encompasses detailed areas of concern common in global research.

Other niche but important research areas included the terms ‘circular economy’, ‘ESG disclosure’, ‘ESG metrics’, and ‘gender diversity’, each appearing twice. The first one denotes the scholarship focusing on recycling resources with a 100 billion sales potential. The next two include the same ESG practices but in relation to

transparency, ESG disclosures, and ESG performance measurement, quantified assessments of them.

Lastly, this bibliometric picture identified gender diversity as another promising area which combines the definitions provided by

one of the leading contributors. While comparing the most popular areas and the emerging spots which were explored in multiple publications, the map creates a visual representation of contemporary ESG concerns.

Table 1: Most Cited Countries

Country	Articles	Total Citations	Average Citations
USA	37	50	1.35
CHINA	31	4	0.13
INDIA	28	90	3.21
ITALY	26	72	2.77
UK	20	24	1.20
GERMANY	18	2	0.11
BRAZIL	12	6	0.50
INDONESIA	11	0	0.00
KENYA	11	0	0.00
CANADA	10	10	1.00

The analysis of the most cited country in ESG publications provided significant revelations regarding the global research landscape involving ESG practices and policies. It describes the ways in which the different countries contribute to the literature as well as the citation impact of their research.

India proved to be the most influential country showcased by India's averaged citations per countries with an impactful score of 3.21 citations associated with 28 articles. These indicate to unparalleled but groundbreaking import of the existing articles from India. Canada also showed a strong citation impact despite the low article count with the average score of 1.00 citations for 10 articles. Italy had a total article of 26 and its total citations of 72

making the country average at 2.77 citations per article.

On the other hand, countries such as China and Germany, which have contributed 31 and 18 articles respectively, have a surprisingly low citation impact of only 0.13 and 0.11 citations per article. This could mean that China and Germany, for instance, may be more active in recent ESG-related research that remains fairly disconnected from the global ESG, in addition to focusing on local issues which could account for the low citation impact. The United States also has a high number of contributions at 37 articles with a total of 50 citations or an average of 1.35 citations per article. That would place the U.S. as a substantial contributor to ESG research in terms of volume, even though the citation impact per

article is only moderate compared to India and Canada.

Similarly, the UK demonstrates moderate impact with 20 articles; and an average citation rate of 1.20, which could suggest reasonable up-to-date engagement with the ESG research community. Finally, Indonesia and Kenya both authored 11 articles and have low to no citation impact, indicating a lack of significant influence or recognition as of yet.

Overall, the current bibliometric analysis indicates a fairly nuanced global ESG research landscape, which involves considerable differences in volume and impact. Therefore, this analysis can also showcase the areas that are leading in creating ESG knowledge most impacting the discourse, and those that, despite their

contributions, are still on the margins of global influence in this regard.

The bibliometric analysis of affiliations active in the Environmental, Social, and Governance research highlights numerous academic institutions that significantly contribute to this field. Witten/Herdecke University is the most active partner with five published articles. It can be suggested that the institution boasts a robust institutional focus on ESG, that is inclusive of a separate research unit or faculty specializing in this topic. It also reflects on the strategic commitment of the institute to the integration of sustainability and corporate governance in the academic agenda.

Table 2: Most Relevant Affiliations

Affiliation	Articles
WITTEN/HERDECKE UNIVERSITY	5
DE LA SALLE UNIVERSITY	4
HELLENIC MEDITERRANEAN UNIVERSITY	4
KOREA UNIVERSITY	4
LUM UNIVERSITY GIUSEPPE DEGENNARO	4
NATIONAL FORMOSA UNIVERSITY	4
NETAJI SUBHAS UNIVERSITY OF TECHNOLOGY	4
TUFTS UNIVERSITY	4
UNIVERSITY OF WESTMINSTER	4
UTRECHT UNIVERSITY	4

The four-article metrics account the presence of De La Salle University, Hellenic Mediterranean University, Korea University, LUM University Giuseppe Degennaro, National Formosa University, Netaji Subhas University of Technology, Tufts University, University of Westminster, and Utrecht University. Considering the location diversity of the sources, this finding suggests the global relevance of ESG for higher education institutions in various cultural contexts. Their contributions also support research diversification in terms of the used perspectives and methodologies for ESG, enlivening the academic debate on sustainability and governance practices.

Table 3: Most Relevant Sources

Sources	Articles
SUSTAINABILITY (SWITZERLAND)	8
CORPORATE SOCIAL RESPONSIBILITY AND ENVIRONMENTAL MANAGEMENT	4
JOURNAL OF ENVIRONMENTAL MANAGEMENT	3
JOURNAL OF SUSTAINABLE FINANCE AND INVESTMENT	3
MANAGEMENT OF ENVIRONMENTAL QUALITY: AN INTERNATIONAL JOURNAL	3
E3S WEB OF CONFERENCES	2
IOP CONFERENCE SERIES: EARTH AND ENVIRONMENTAL SCIENCE	2
JOURNAL OF BEHAVIORAL AND EXPERIMENTAL FINANCE	2
JOURNAL OF CLEANER PRODUCTION	2
JOURNAL OF PHYSICS: CONFERENCE SERIES	2

The list of the most active sources was led by the journal Sustainability, Switzerland, and included a total of eight articles. This finding shows that the source is contributorily focused on the field of sustainability and is a central hub for the recent literature. Corporate Social Responsibility and Environmental Management also published four articles outlining the critical role and scope of corporate responsibility issues within the sustainability argument.

Journal of Environmental Management, Journal of Sustainable Finance and

Investment, and Management of Environmental Quality: An International Journal each published three articles. The summary of the sources listed above signifies the multidisciplinary scope of the ESG field, integrating environmental management, sustainable finance, and environmental quality management.

Despite the lower citations, the results found for E3S Web of Conferences, IOP Conference Series: Earth and Environmental Science, Journal of Behavioral and Experimental Finance, Journal of Cleaner Production, and

Journal of Physics: Conference Series -all with two articles – do offer a wider perspective on ESG research as they link it to more specific fields, including experimental finance, cleaner production methods, and even the principles of physics.

Different kinds of research publications contribute to a more comprehensive understanding of ESG and reflect the entire complexity of the subject, which includes not only scientific but also economic and applicable dimensions. Thus, the analysis of both affiliations and resources allows for a plethora of special and interdisciplinary data sources that contribute to the development and dissemination of information in this essential field.

2.1. Most Global Cited Documents

The bibliometric analysis of the world's most cited papers on the ESG framework demonstrates what works have influenced the field more than most. The analysis of such metrics as the aggregate number of citations, citations per year, and aggregate number of normalized citations reveals the most influential publications that have an impact on academia and beyond.

Thus, Park SR's 2021 paper on ESG in the International Journal of Financial Studies states the highest total number of citations – 66, while retaining the annual citation rate at a relatively high level – 16.50, and the normalized number of citations – 2.55 that indicates ongoing recognition and the presence of the paper's influence on scholars since the year of publication.

A rather close second is Singhanian M 2023 in the Journal of Sustainable Finance and Investment – the aggregate number of citations – 58 on it. Interestingly, the annual citation rate for this work is very high – 29.00 times a year, with a normalized number of citations – 19.48. Thus, the work very quickly gained recognition among the academic community, indicating possible serious scientific and applicative significance, which is due to its relevance to one of the cutting-edge trends in ESG research – investing. The 2021 paper in Corporate Social Responsibility and Environmental Management by Esposito de Falco S is another standout to cite with a total of 43 citations and an annual citation rate of 10.75, although its normalized citation score is 1.66, which means a more moderated impact in relation to the publication age.

The Multinational Business Review paper by Linnenluecke MK is followed by 36 total citations, and the book by Bose S “Values at Work: Sustain Invest and ESG Report” is next with 27 total citations and notably higher normalized scores, which means these sources continue to be relevant to the scholars in the fields of multinational business and sustainable investment in particular. As for the other papers, the Vision paper by Singhanian M and the Managerial Finance paper by Baid V have lower total citation scores but remain steadily cited and average annually. The papers in Sustainability by Jonsdottir GE and Kempeneer S have lower scores as well.

Sr. No.	Paper	DOI	Total Citations	TC per Year	Normalized TC
1	PARK SR, 2021, INTERN J FINANCIAL STUD	10.3390/ijfs9030048	66	16.50	2.55
2	SINGHANIA M, 2023, JOURNAL OF SUSTAIN FINANCE INVEST	10.1080/20430795.2021.1964810	58	29.00	19.48
3	ESPOSITO DE FALCO S, 2021, CORP SOC RESPONSIB ENVIRON MANAGE	10.1002/csr.2183	43	10.75	1.44e66
4	LINNENLUECKE MK, 2022, MULTINATIONAL BUS REV	10.1108/MBR-11-2021-0148	36	12.00	4.91
5	BOSE S, 2020, VALUES AT WORK: SUSTAIN INVEST AND ESG REPORT	10.1007/978-3-030-55613-6_2	27	5.40	2.55
6	SINGHANIA M, 2022, VISION	10.1177/09722629211054173	20	6.67	2.73
7	BAID V, 2022, MANAG FINANC	10.1108/MF-12-2021-0588	18	6.00	2.45
8	JONSDOTTIR GE, 2021, SUSTAINABILITY	10.3390/su13137331	16	4.00	0.62
9	KEMPENEER S, 2021, SUSTAINABILITY	10.3390/su13063239	15	3.75	0.58
10	HABTEZION S, 2015, CURR OPIN ENVIRON SUSTAINABILITY	10.1016/j.cosust.2015.06.009	13	1.30	2.00

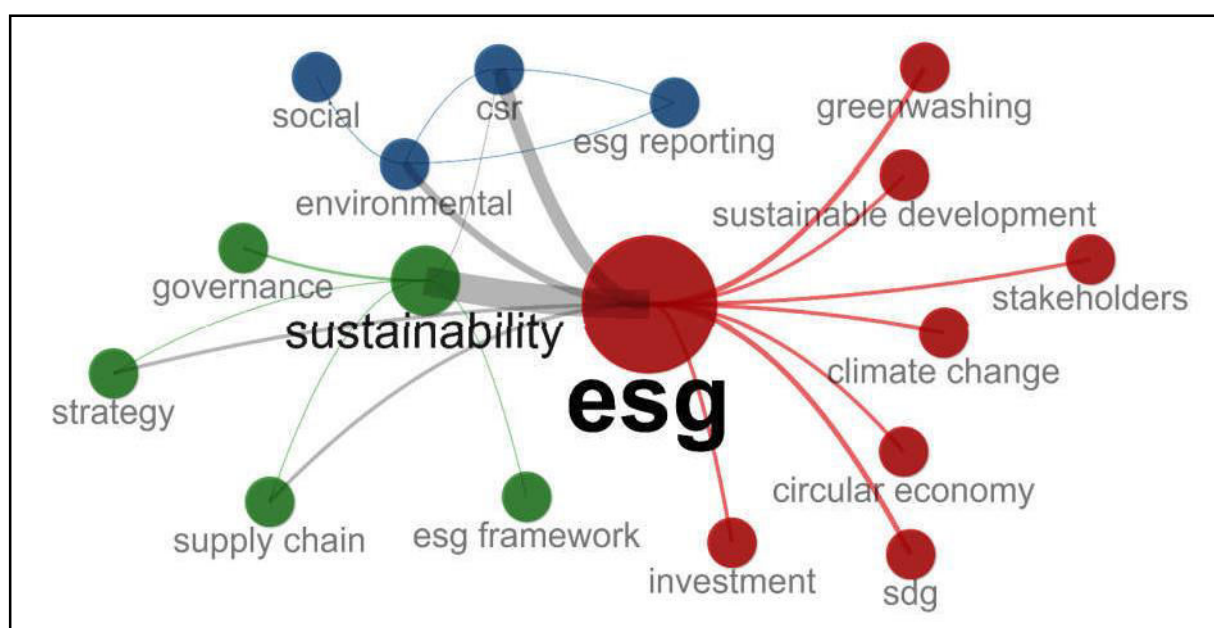
Finally, the 2015 article in *Current Opinion in Environmental Sustainability* by Habtezion S demonstrates the lowest annual citation rate but preserved the normalized citation of 2.00, which means it was and continues to be relevant since publication. Thus, this analysis was aimed to highlight the most cited papers since ESG research began to spread, and recent publications frequently become central to the academic discourse, especially if they are dedicated to urgent and timely issues. This analysis also shows how dynamic ESG research has been so far as the sources that are a bit older have almost the same influence as more recently published ones.

Co-Word Network Analysis

The co-word network analysis enables a comprehensive view of the connectedness

among terms and their thematic presence in Environmental, Social, and Governance framework literature. By highlighting and differentiating key ESG-related terms into three clear clusters through color-coding—red for Cluster 1, blue for Cluster 2, and green for Cluster 3—the analysis shows the terms and their relationships based on the frequency of usage and co-occurrence in the literature.

In bibliometric analysis, betweenness centrality measures a term's role as a bridge within the network, highlighting its importance in connecting different clusters, while PageRank assesses a term's significance based on its connections, indicating its overall influence in the ESG discourse.



Cluster 1 is focused around the centroid ‘ESG’, which is particularly noteworthy due to its high betweenness centrality and a high PageRank. In other words, ‘ESG’ appears central in the co-occurrence and discourse in the relevant literature. This

cluster includes such terms as ‘sustainable development,’ ‘climate change,’ ‘greenwashing,’ ‘investment,’ ‘SDG,’ ‘stakeholders,’ and ‘circular economy.’ Furthermore, as the terms have a high betweenness centrality, their position and

representation in this cluster can be described as instrumental in terms of developing a specific vocabulary around ESG.

Cluster 2 has ‘CSR’ and ‘environmental’ as the main nodes due to their betweenness centralities. With numerous connections between the cluster members, including ‘ESG reporting’ and ‘social’ nodes, the themes appear to be focused on the environment and ESG.

Cluster 3, with ‘sustainability’ as the focus centroid, also has a high betweenness centrality and a notable PageRank. Additionally, ‘ESG framework,’ ‘governance,’ ‘supply chain,’ and ‘strategy’ nodes are included, showing that this cluster is concerned with the fundamental aspects of ESG and sustainability, particularly the ways in which sustainability is embedded within the company practices and strategies.

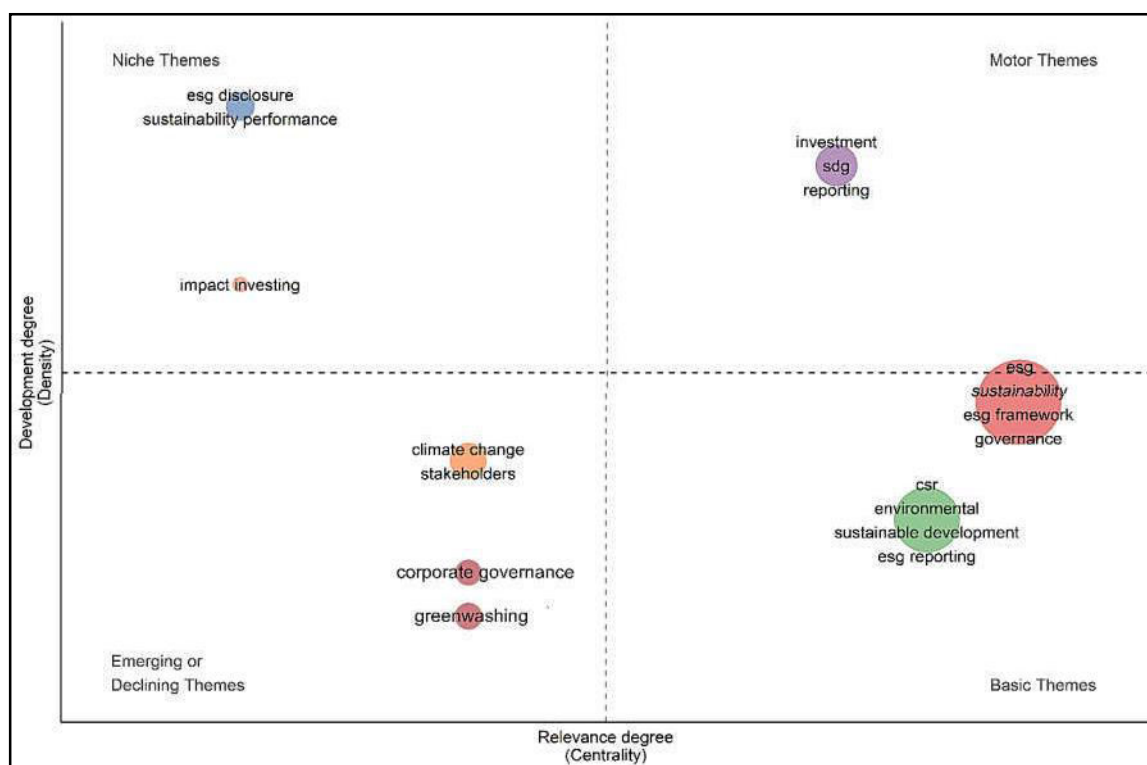
Network metrics such as betweenness centrality, closeness, and PageRank elucidate the structure and importance of the terms in the network. Betweenness centrality points to the nodes that function as bridges, such as ‘ESG’ and

‘environmental,’ enabling the information to stream between various concepts. Closeness denotes how near the node is to all other nodes in the network, viewing how accessible or influential the node might be in quoting, drawing in, and spreading opinions. PageRank shows how influential the node is, and it is selected according to the connections: ‘ESG’ remains the most influential term.

To sum up, the diagram and its analysis describe the connection between different terms related to the ESG, forming clusters that served as the core and the specialized domains. Structured display not only outlines the most popular directions of ESG research but visually showcases the vivid and dynamic links between various topics in the academic discourse and practice.

Thematic Map Cluster Analysis

The thematic analysis of the publications in the ESG results in the understanding of the main areas and trends of this critical domain of research. By evaluating the key words in terms of incidence, centrality measures, and thematic clusters, it is possible to comprehend the focus and relationship between the ESG themes.



The cluster “esg” may be identified as the most powerful term within the “basic theme”, which includes the word “esg” with the highest density and centrality. It implies that ESG is the center of sustainability discourse that has a crucial status. The other keywords of this term are “sustainability,” “ESG framework,” “governance,” and “supply chain,” which implies the general framework of basic relevant aspects, whereas the centrality of these terms is a measure of their impact.

For example, “esg disclosure” and “csr” clusters are the parts of the more specific focus of ESG, such as “niche theme” and “basic theme”. “esg disclosure” implies the main words such as “esg metrics” and “sustainability performance”, which means that there is the increasing attention to the means of measuring the sustainability performance.

The other cluster includes “corporate social responsibility,” “environmental,” and “sustainable development,” which

refers to the centrality of environmental issues in corporate practice. For instance, the “motor theme” only includes the “investment” cluster “SDG” and “reporting,” and “climate change” and “stakeholders” “emerging or declining theme,” which indicates the key trends of sustainability.

The centrality of these clusters is a measure of their impact on the ESG network. It shows what the authors consider to be the most crucial without evaluating the validity of their assumptions. Thus, it appears that the “egg” cluster is the most central with centrality and density of terms of 80, and thus, it is more powerful, as its importance is central to the domain. A thematic analysis helps to obtain the most important trends and understand their interaction in the network, which may be used for further studies and research.

Discussion of the results:

This bibliometric analysis offers valuable insights into the evolution, thematic trends, and global contributions to ESG framework research from 2012 to 2024. The current section outlines the implications of the findings, unveiling potential research gaps and areas for further examination.

ESG research emergence and growth:

The substantial rise in ESG output across the years implies a growing interest in sustainability issues among scholars and practitioners. Moreover, this result is in line with the previous discoveries (Li, Wang, Sueyoshi, & Wang, 2021; Senadheera et al., 2022; Wan, Dawod, Chanaim, Ramasamy, & Management, 2023). The first years were associated with minimal activity, suggesting that ESG was a niche. Nonetheless, from 2020, the publication volume increased steeply, underpinned by the growing global recognition of the sustainability problem and the regulatory response. Thus, this growth indicates the increasing importance of ESG considerations in the business and policy landscape.

Thematic trends and research framework:

Highly frequent keywords and thematic clusters illustrate central terms and emerging trends in ESG field research. Themes such as sustainability, CSR, environmentalism, and governance issues overarch research, highlighting the multi-dimensional nature of ESG. Furthermore, more nuanced concepts, such as climate change, ESG disclosure, and gender diversity, underscore the evolving dimensions of ESG field focus.

Global Landscape and Contributions:

Analyzing the most cited countries and affiliations, I noted the diverse geographic spread in ESG research. Despite the significant influence, India, Italy, and Canada varied in publication volume, suggesting that their qualitative contribution is high. Simultaneously, different academic institutions, from Witten/Herdecke University to Korea University, from around the global landscape actively contribute to ESG knowledge dissemination.

Publication Venues and Impactful Works:

The analysis of publication outlets and sources reveals prominent journals such as ‘Sustainability’ and ‘Corporate Social Responsibility and Environmental Management’ that act as critical platforms for knowledge and insights exchange at various levels. Moreover, the identification of documents cited globally results in highlighting seminal works that have primarily contributed to the ESG discourse. It demonstrates the necessity of both recent and older content to facilitate scholarly debates and professional applications.

Co-Word Network and Thematic Mapping:

The described co-word network and thematic mapping analyses reflect the structured information regarding the endogenous isolation of themes and relationships between them in ESG. The central concepts of ESG, sustainability, and governance are highlighted, and the specialized area of ESG disclosure and climate change is presented. Understanding and realizing these topical interconnections occur set the tone for future research lines and encourage

interdisciplinary collaboration in times of the complex nature of sustainability.

Research Gap:

Network Dynamics in ESG: Examining the overall network dynamics and interrelations within the ESG environment can provide insights regarding how the information as a value circulates, how collaborations emerge and dissolve, and how influence spreads. Employing social network analysis or dynamic network modeling, among others, can help unlock the key actors, themes, and emergent properties across the ESG research field.

Behavioral Economics and ESG Decision-Making: The integration of behavioral economics concepts into ESG decisions can shed light on the personnel-level and organization-level peculiarities of sustainability. The cognitive shortcuts, decision heuristics, and reliance on social norms can demonstrate how various cognitive biases influence ESG adoption and perceived risk and returns can present novel ways to nudge consumers and investors towards sustainable behaviors.

Quantifying ESG Impact on Stakeholder Well-Being: While ESG frameworks prioritize stakeholder concerns, one research gap quantitatively measures the impact of ESG initiatives on stakeholder well-being, which transcends financial signals. Among the potential approaches to testing the causal links between stakeholder quality of life, mental well-being, and social cohesion are advanced econometric models like structural equation modeling or empirical testing with longitudinal surveys.

Blockchain-enabled Transparency and Accountability: Researching how

blockchain can be used to improve transparency and traceability in ESG reporting, as well as the possibilities regarding blockchain-based decentralized ledger systems for verifying producers' sustainability claims, controlling supply chains for ethical pieces and reducing greenwashing and fraud, is widely considered frontier research domain.

Future Directions:

Predictive Analytics for ESG Performance: Leveraging machine learning algorithms and big data analytics, future research could develop predictive models to anticipate ESG performance trends and identify leading indicators of sustainability success. By analyzing diverse datasets, including financial reports, social media sentiment, and environmental monitoring data, predictive analytics could help investors, regulators, and businesses proactively manage ESG risks and opportunities.

Multi-level Governance in Global Supply Chains: Examining the multi-level governance dynamics within global supply chains could shed light on how ESG standards and norms diffuse across borders and interact with local contexts. Future research could explore the role of transnational governance mechanisms, private regulatory initiatives, and multi-stakeholder partnerships in promoting sustainable supply chain practices while respecting cultural diversity and national sovereignty.

Robustness and Resilience in ESG Systems: Drawing upon the understanding of complex systems and resilience theory, future research may delve into the issues of ESG systems' robustness and adaptive

capacity during times of systemic shocks and disruption. By framing ESG networks in the lens of complex adaptive systems, researchers can reveal tipping point schematics, feedback loops, and resilience-boosting mechanisms that would contribute to the longevity of socio-ecological systems.

Ethical AI for ESG Assessment: A particular cutting-edge research avenue encompasses the field of ethical AI in ESG assessment. New research may explore the development of a newly devised ethical AI framework prioritizing fairness, intelligence, and accountability in

algorithm-driven decision-making processes related to ESG scoring, risk assessment, and impact measurement. Furthermore, a study can tackle the societal impact of the emergent role of AI on the automation front, thereby examining its potential adverse effects on labour rights, income disparity, and social justice in the context of ESG.

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CONVERGENCE OF ESG AND FINANCIAL DECISION- MAKING TOWARDS SUSTAINABLE FINANCIAL SYSTEM

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ABSTRACT:

In recent years, the concept of sustainable finance has gained remarkable attention as the world confronts pressing environmental, social, and economic challenges. Environmental issues such as climate change, deforestation, and pollution, along with rising social inequalities and economic uncertainties, have emphasized the need for financial systems that do more than simply generate profit. Sustainable finance represents this shift, as it focuses on integrating Environmental, Social, and Governance (ESG) factors into financial decision-making processes. This approach encourages investors, corporations, and financial institutions to consider the broader impact of their actions on the planet and society, rather than prioritizing short-term returns. The main objectives of the study focus on to analyze the current state of sustainable finance practices, including their scope, key drivers, challenges, and emerging trends, to Identify and assess the core principles and frameworks that guide sustainable finance practices, such as ESG (Environmental, Social, and Governance) factors. This study is based on descriptive research design. Researchers have collected primary data using a structured questionnaire through google form. Secondary data related to past sustainable financial practices of various organizations have been collected from existing literature, reports, and online sources. The majority (84.61%) believe sustainable finance frameworks should primarily focus on environmental factors while incorporating social and governance considerations. Stakeholder engagement is overwhelmingly considered crucial for the effectiveness and legitimacy of a sustainable finance framework, with 78.83% in agreement. A significant proportion (88.45%) advocates for standardized data and reporting on sustainability performance to facilitate comparison and analysis. Ultimately, the study emphasizes the vital role of finance in shaping a sustainable world where economic growth goes hand in hand with environmental protection and social well-being.

KEY WORDS: *Sustainable Finance, ESG Integration, Responsible Investing, Risk Management and Sustainability*

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1. INTRODUCTION

In the present era of rapid industrialization and globalization, environmental degradation, rising social disparities, and economic uncertainties have brought sustainability to the forefront of financial discourse. The concept of **sustainable finance** has evolved as a progressive and essential approach, redefining the way financial decisions are made. Unlike traditional financial practices that largely prioritize short-term profits and shareholder value, sustainable finance encourages a comprehensive view where long-term value creation, environmental responsibility, social justice, and transparent governance play a decisive role. At its core, sustainable finance incorporates **Environmental, Social, and Governance (ESG)** considerations into the heart of financial decision-making processes. This integration enables investors, businesses, and financial institutions to assess not only the profitability of their investments but also the wider impact these investments may have on society and the planet. Such an approach ensures that economic activities contribute positively to global efforts in climate action, social welfare, and ethical corporate behavior.

1.1. The Emergence of Sustainable Finance

The importance of sustainable finance became more apparent with the adoption of major global agreements such as the **Paris Climate Accord (2015)** and the **United Nations Sustainable Development Goals (SDGs)**. These initiatives stressed that addressing environmental and social challenges cannot rely solely on government policies; the private financial sector also has a critical role to play in driving sustainable growth.

The shift from conventional financial practices to sustainability-oriented models has been fueled by the growing understanding that long-term economic success is inherently linked to the well-being of the environment and society. Thus, sustainable finance is no longer viewed as a niche concept but as a fundamental transformation of financial markets worldwide.

1.2. Key Drivers of Sustainable Finance

The rapid growth of sustainable finance is underpinned by several pivotal factors:

1. Environmental and Social Risks,
2. Stakeholder Expectations,
3. Technological Progress
4. Regulatory Initiatives and
5. Purpose of Sustainable Finance Practices

1.3. Scope and Impact of Sustainable Finance Practices

The scope of sustainable finance covers a diverse range of financial instruments and investment strategies, such as:

- **Green Bonds:** Bonds specifically issued to fund environmentally beneficial projects.
- **Impact Investing:** Directing capital towards ventures with measurable social or environmental benefits alongside financial returns.
- **ESG Integration:** Embedding ESG considerations into mainstream financial analysis and portfolio management.

The impact of these practices extends beyond individual organizations, triggering systemic changes in global capital markets. For example, large-scale investments in renewable energy not only reduce carbon emissions but also create employment opportunities and drive technological innovation.

Furthermore, companies embracing ESG principles often see improved stakeholder relations, increased operational efficiency, and enhanced corporate reputation. As more firms adopt sustainable finance models, the global economy moves steadily towards a future that balances profitability with responsibility.

2. THEORETICAL FRAMEWORK

2.1. Definition of sustainable finance

Sustainable finance is defined as investment decisions that consider the environmental, social, and governance (ESG) factors of an economic activity or project.

Environmental factors include mitigation of the climate crisis or use of sustainable resources. Social factors include human and animal rights, as well as consumer protection and diverse hiring practices. Governance factors refer to management, employee relations, and compensation practices of both public and private organizations.

2.2. Key Components

- 1. Financial Planning and Forecasting,**
- 2. Financial Analysis and Reporting, 3. Risk Management**
- 4. Financial Decision Making 5. Financial Controls and Governance and 6. Financial Technology**

2.3. Historical Development of Sustainable Finance Practices

The evolution of sustainable finance practices can be traced back to the early 20th century, but it has gained significant momentum in recent decades. Here's a brief overview:

Early Beginnings (1900s-1970s)

- **Socially Responsible Investment (SRI):** The concept of SRI emerged in the early 20th century, focusing on investments that avoided companies involved in harmful activities like tobacco, alcohol, and weapons.
- **Environmental Awareness:** The 1960s and 1970s saw increased public awareness of environmental issues, leading to the creation of environmental regulations and organizations.

Institutionalization and Growth (1980s-2000s)

- **Global Reporting Initiative (GRI):** Established in 1997, the GRI developed standards for sustainability reporting, providing companies with a framework to disclose their environmental and social performance.
- **United Nations Environment Program Finance Initiative (UNEP FI):** Founded in 1992, UNEP FI has been a key player in promoting sustainable finance practices among financial institutions.
- **Ethical and Impact Investing:** The 1990s saw a rise in ethical and impact investing, which focuses on investments that align with specific ethical or social goals.
- **Mainstreaming and Integration (2010s-Present)**
- **Paris Agreement:** The Paris Agreement in 2015 set global goals to combat climate

change, driving increased interest in climate-related finance.

- **Sustainable Development Goals (SDGs):** The SDGs adopted in 2015 provide a comprehensive framework for sustainable development, including environmental, social, and economic dimensions.
- **Green Bonds:** Green bonds, which raise capital for environmentally friendly projects, have become a popular financial instrument.
- **ESG Integration:** ESG (Environmental, Social, and Governance) factors are increasingly being integrated into investment decision-making processes.
- **Central Bank Digital Currencies (CBDCs):** There's growing interest in using CBDCs for sustainable finance purposes, such as promoting green investments and reducing financial exclusion.

2.4. Key Trends and Developments

- **Climate Finance:** The growing urgency of climate change has led to a surge in climate-related finance, including green bonds, climate-aligned investment strategies, and carbon markets.
- **Social Impact Investing:** Social impact investing focuses on investments that aim to generate a positive social or environmental impact, often in underserved communities.
- **Circular Economy:** The circular economy model aims to minimize waste and pollution by keeping resources in use for as long as possible, leading to increased interest in circular economy investments.
- **Technology and Innovation:** Technological advancements, such as blockchain and artificial intelligence, are

being used to improve the efficiency and transparency of sustainable finance practices.

As sustainable finance continues to evolve, it's expected to play a crucial role in addressing global challenges such as climate change, inequality, and resource depletion.

3. REVIEW OF LITERATURE

1. Mah, Sheena, K. M., Shubhra Jyotsna, Aithal., Sharma, K., R., S. (2022). This paper highlights the importance of global partnerships and sustainable finance initiatives in combating climate change, noting the significant role of international finance institutions, governments, and the RBI's ESG disclosure framework. Collaboration between developed and developing countries is emphasized as vital for effective climate change mitigation and adaptation.

2. Tarjo, T., Anggono, A., Said, J., & Sakti, E. (2024). The study finds that the pandemic spurred increased research into ESG fraud, revealing that pressure often leads to ESG fraud and that non-financial reporting schemes are commonly used. It also highlights controversial issues in ESG implementation, company performance, and audits.

3. Siti, Khadijah, Nasution., Nurhalimah, Sibuea. (2024). litatively reviews existing, and economic resilience.

4. Habib, Ashfaq, Shaista Anwar, Waleed Hussain and Veronika Fenyves. (2024). for long-term sustainability.

5.Eliza, Eliza (2024) This study qualitatively assesses how integrating ESG criteria into

6.Domanović, Violeta. (2021)nes the relationship between ESG.

7.Yakovlev, (2023) To identify the common and specific approaches of countries in the aspect of forming a national policy for regulating the financial market to motivate investors to finance sustainable development.

8. Lakasse, Syarifuddin, Amril Amril, Helmy Syamsuri and Ikhsan Amar Jusman. (2024) Mishra, Biswadeep and

Aakash Sharma. (2023) This research assesses the incorporation of energy audits **10. Parveen,S.S. (2025).** This paper explores the growing importance of Environmental, Social, and Governance (ESG) factors in sustainable finance and their impact on financial decision-making. It highlights how ESG integration enhances transparency, risk management, and long-term value creation for businesses.

3.2. RESEARCH GAP:

Despite growing literature on ESG and sustainable finance, there's a notable gap in understanding the nuanced, context-specific challenges and benefits of ESG integration in emerging economies, particularly concerning the impact on working capital for SMEs and the direct correlation between ESG performance and financial outcomes in public sectors. While some studies touch upon broad financial management and policy, a comprehensive framework addressing the practical implementation hurdles and their financial ramifications across diverse economic structures remains underdeveloped. The evolving nature of ESG fraud and the lack of consistent

positive financial correlation in certain sectors highlight areas needing further granular exploration.

3.3. STATEMENT OF THE PROBLEM:

The intensifying urgency of climate change and the imperative for sustainable development necessitate a clear understanding of how financial markets can effectively support these goals. Current research indicates a fragmented landscape where the adoption of ESG criteria faces challenges such as awareness gaps, measurement complexities, and an inconsistent link to financial performance, particularly in non-Western contexts. This creates uncertainty for businesses, investors, and policymakers seeking to align financial practices with environmental and social objectives, hindering the widespread and impactful integration of sustainable finance initiatives.

3.4. OBJECTIVES OF THE STUDY

1. To analyze the current state of sustainable finance practices, including their scope, key drivers, challenges, and emerging trends.
2. To Identify and assess the core principles and frameworks that guide sustainable finance practices, such as ESG (Environmental, Social, and Governance) factors.
3. To Examine the role of regulatory frameworks and policy initiatives in promoting sustainable finance, including international standards, national regulations, and tax incentives.
4. To Evaluate the effectiveness of sustainable finance initiatives in addressing environmental, social, and governance challenges, and their impact on economic development.

4. RESEARCH METHODOLOGY

4.1. Research Design

This study is based on descriptive research design.

4.2. Data Collection

Primary data related to sustainable financial practice been collected using a structured questionnaire through google form.

Secondary data related to past sustainable financial practices of various organizations have been collected from existing literature, reports, and online sources.

4.3. Sources of Data

The study will utilize both Primary and Secondary Data sources.

4.4. Tools of Analysis

1. Descriptive Statistics

5. DATA ANALYSIS AND INTREPRETATION

5.1. OCCUPATIONS OF THE RESPONDENTS

Occupation	No. of. Respondents	Percentage
Businessman	5	9.6%
Govt. Employee	2	3.8%
Private Employee	35	67.3%
Student	10	19.2%
Grand Total	52	100%

INTERPRETATION: The bar graph shows that private employees constitute most respondents, followed by government employees. A lesser number of businesspeople and students participated, indicating that the survey primarily reflects the perspectives of working professionals in the private and public sectors.

5.2. Agreement level on clear definition of sustainability is essential for developing a comprehensive sustainable finance framework.

Sl. No	Agreement level	No. of. Respondents	Percentage
1	Strongly Agree	9	17.31
2	Agree	38	73.08
3	Neutral	5	9.62
4	Disagree	0	0.00
5	Strongly Disagree	0	0.00
	Total	52	100.00

INTERPRETATION:

From the above table we can say that 73.08% agreed and 17.31% strongly agreed, 9.62% are neutral about the statement.

5.3. Agreement level on whether sustainable finance framework should primarily focus on environmental factors, with social and governance considerations.

Sl. No	Agreement level	No. of. Respondents	Percentage
1	Strongly Agree	7	13.46
2	Agree	37	71.15
3	Neutral	5	9.61
4	Disagree	2	3.84
5	Strongly Disagree	1	1.92
	Total	52	100

INTREPRETATION:

From the above table we can say that 71.15% are agreed, 13.46% are strongly agreed, 9.61% are neutral, 3.84% disagree and 1.92% strongly disagree with the statement.

5.4. Agreement level on Integrating sustainability principles into existing financial practices is challenging due to conflicting objectives.

Sl. No	Agreement level	No. of. Respondents	Percentage
1	Strongly Agree	7	13.46
2	Agree	31	59.61
3	Neutral	6	11.53
4	Disagree	8	15.38
5	Strongly Disagree	0	0.00
	Total	52	100

INTREPRETATION:

From the above table we can say that 59.61% agreed, 15.38% disagreed, 13.46% strongly agreed, and 11.53% are neutral about the statement.

5.5. Engaging stakeholders in the development of a sustainable finance framework is crucial for its effectiveness and legitimacy.

Sl. No	Agreement level	No. of. Respondents	Percentage
1	Strongly Agree	9	17.30
2	Agree	32	61.53
3	Neutral	4	7.69
4	Disagree	5	9.61
5	Strongly Disagree	2	3.84
	Total	52	100

INTREPRETATION:

From the above table we can say that 61.53% are agreed, 17.30% are strongly agreed, 9.61% disagree, 7.69% are neutral, 3.84% strongly disagreed with the statement.

5.6. Agreement Level on Data and reporting on sustainability performance should be standardized to facilitate comparison and analysis.

Sl. No	Agreement Level	No. of. Respondent	Percentage
1	Strongly Agree	15	28.84
2	Agree	31	59.61
3	Neutral	5	9.61
4	Disagree	1	1.923
5	Strongly Disagree	0	0.00
	Total	52	100

INTREPRETATION:

From the above table we can say that 59.61% agreed, 28.84% strongly agreed, 9.61% are neutral, 1.923% strongly disagreed with the statement.

5.7. Climate risk is the most significant threat to financial stability, outweighing other sustainability-related risks.

Sl. No	Agreement Level	No. of. Respondents	Percentage
1	Strongly Agree	11	21.15
2	Agree	25	48.07
3	Neutral	9	17.30
4	Disagree	7	13.46
5	Strongly Disagree	0	0.00
	Total	52	100

INTREPRETATION:

From the above table we can say that 48.07% agreed, 21.15% strongly agreed, 17.30% are neutral, 13.46% strongly disagreed with the statement.

5.8. Social and environmental risks can be effectively assessed and managed using existing financial risk management tools.

Sl. No	Agreement Level	No. of. Respondents	Percentage
1	Strongly Agree	7	13.46
2	Agree	29	55.76
3	Neutral	9	17.30
4	Disagree	7	13.46
5	Strongly Disagree	0	0.00
	Total	52	100

INTREPRETATION:

From the above table we can say that 55.76% agreed, ,17.30% were neutral, 13.46% strongly disagreed and disagreed with the statement.

5.9. Scenario analysis is a valuable tool for evaluating the potential financial impacts of sustainability-related scenarios.

Sl. No	Agreement Level	No. of Respondents	Percentage
1	Strongly Agree	9	17.30
2	Agree	32	61.53
3	Neutral	9	17.30
4	Disagree	1	1.92
5	Strongly Disagree	1	1.92
	Total	52	100

INTREPRETATION:

From the above table we can say that 61.53% agreed, 17.30% strongly agreed and neutral, 1.92% disagreed and strongly disagreed with the statement.

5.10. Risk mitigation strategies for sustainability-related risks should be tailored to the specific circumstances of each financial institution.

Sl. No	Agreement Level	No. of Respondents	Percentage
1	Strongly Agree	8	15.38
2	Agree	32	61.53
3	Neutral	7	13.46
4	Disagree	5	0.96
5	Strongly Disagree	0	0
	Total	52	100

INTREPRETATION:

From the above table we can say that 61.53% agreed, 15.38% strongly agreed, 13.46% are neutral and 0.96% disagreed with the statement.

5.11. Sustainable investment strategies necessarily involve sacrificing financial returns.

Sl. No	Agreement Level	No. of Respondents	Percentage
1	Strongly Agree	9	17.30
2	Agree	26	50
3	Neutral	6	11.53
4	Disagree	9	17.307
5	Strongly Disagree	2	3.84
	Total	52	100

INTREPRETATION:

From the above table we can say that 50% agreed, ,17.30% disagreed and strongly agreed, 11.53% are neutral and 3.84% strongly disagreed with the statement.

5.12. Green finance products are a niche market with limited appeal to mainstream investors.

Sl. No	Agreement Level	No. of Respondents	Percentage
1	Strongly Agree	10	19.23
2	Agree	28	53.84
3	Neutral	7	13.46
4	Disagree	7	13.46
5	Strongly Disagree	0	0.00
	Total	52	100

INTREPRETATION:

From the above table we can say that 53.84% agreed, ,19.23% are strongly agreed, and 13.46% disagreed with the statement.

5.13. Impact investing can effectively drive positive social and environmental change, even if it involves higher financial risks.

Sl. No	Agreement Level	No. of. Respondents	Percentage
1	Strongly Agree	11	21.15
2	Agree	27	51.92
3	Neutral	9	17.307
4	Disagree	3	5.76
5	Strongly Disagree	2	3.84
	Total	52	100

INTREPRETATION:

From the above table we can say that 51.92% agreed, ,21.15% are strongly agreed, 17.307% neutral, 5.76% disagreed and 3.84% disagreed with the statement.

5.14. Exclusive screening is a necessary but not sufficient condition for sustainable investment practices.

Sl. No	Agreement Level	No. of. Respondents	Percentage
1	Strongly Agree	11	21.15
2	Agree	27	51.92
3	Neutral	8	15.38
4	Disagree	4	7.69
5	Strongly Disagree	2	3.84
	Total	52	100

INTREPRETATION:

From the above table we can say that 51.92% agreed, 21.15% strongly agreed, 15.38% are neutral, 7.69% disagreed and 3.84% strongly disagreed with the statement.

5.15. Boards of directors have a fiduciary duty to prioritize sustainability considerations in their decision-making.

Sl. No	Agreement Level	No. of Respondents	Percentage
1	Strongly Agree	15	28.84
2	Agree	27	51.92
3	Neutral	7	13.46
4	Disagree	3	5.76
5	Strongly Disagree	0	0
	Total	52	100

INTREPRETATION:

From the above table we can say that 55.92% are agreed, 28.84% are strongly agreed, 13.46% are neutral ,5.76% are disagreed about the statement.

5.16. Executive compensation should be linked to sustainability performance to incentivize responsible behavior.

Sl. No	Agreement Level	No. of Respondents	Percentage
1	Strongly Agree	13	25
2	Agree	29	55.76
3	Neutral	6	11.53
4	Disagree	3	5.76
5	Strongly Disagree	1	1.92
	Total	52	100

INTREPRETATION:

From the above table we can say that 55.76% are agreed, 25% are strongly agreed, 11.53% are neutral ,5.76% are disagreed and 1.92% are strongly disagreed about the statement.

5.17. Voluntary disclosure of sustainability information is sufficient to ensure transparency and accountability.

Sl. No	Agreement Level	No. of Respondents	Percentage
1	Strongly Agree	11	21.15
2	Agree	29	55.77
3	Neutral	7	13.46
4	Disagree	4	7.69
5	Strongly Disagree	1	1.92
	Total	52	100

INTREPRETATION:

From the above table we can say that 55.77% agreed, 21.15% strongly agreed, 13.46% are neutral ,7.69% disagreed, 1.92% strongly disagreed with the statement.

5.18. Regulatory frameworks for sustainable finance should be harmonized at the international level.

Sl. No	Agreement Level	No. of Respondents	Percentage
1	Strongly Agree	16	83.2
2	Agree	25	48.1
3	Neutral	6	11.5
4	Disagree	4	7.7
5	Strongly Disagree	1	1.9
	Total	52	100

INTREPRETATION:

From the above table we can say that 83.2% strongly agreed, 48.1% agreed ,11.5% are neutral, 7.7% disagreed, 1.9% strongly disagreed with the statement.

5.19. Financial incentives are more effective than regulatory requirements in promoting sustainable finance practices.

Sl. No	Agreement Level	No. of. Respondents	Percentage
1	Strongly Agree	11	21.15
2	Agree	27	51.92
3	Neutral	6	11.54
4	Disagree	7	13.46
5	Strongly Disagree	0	0.00
	Total	52	100

INTREPRETATION:

From the above table we can say that 51.92% agreed, 21.15% strongly agreed ,11.5% are neutral, 13.46% disagreed with the statement.

5.20. Emerging technologies, such as blockchain and artificial intelligence, will play a significant role in shaping the future of sustainable finance.

Sl. No	Agreement Level	No. of. Respondents	Percentage
1	Strongly Agree	14	26.92
2	Agree	27	51.92
3	Neutral	7	13.46
4	Disagree	3	5.77
5	Strongly Disagree	1	1.92
	Total	52	100

INTREPRETATION:

From the above table we can say that 51.92% agreed, 26.92% agreed ,13.46% were neutral, 5.77% disagreed, and 1.92% strongly disagreed with the statement.

6.SUMMARY OF KEY RESULTS, DISCUSSIONS, SUGGESTIONS AND CONCLUSIONS

6.1. KEY RESULTS:

1. A strong agreement exists among respondents regarding the necessity of a clear definition of sustainability for a comprehensive sustainable finance framework, with 90.39% either agreeing or strongly agreeing.
2. The majority (84.61%) believe sustainable finance frameworks should primarily focus on environmental factors while incorporating social and governance considerations.
3. Integrating sustainability principles into existing financial practices is acknowledged as challenging due to conflicting objectives by 73.07% of respondents.
4. Stakeholder engagement is overwhelmingly considered crucial for the effectiveness and legitimacy of a sustainable finance framework, with 78.83% in agreement.
5. A significant proportion (88.45%) advocates for standardized data and reporting on sustainability performance to facilitate comparison and analysis.
6. While climate risk is seen as a significant threat to financial stability by many (69.22%), a notable portion (13.46%) disagrees with it outweighing other sustainability-related risks.
7. The majority (69.22%) believe existing financial risk management tools can effectively assess and manage social and environmental risks.
8. Scenario analysis is widely recognized as a valuable tool for evaluating financial impacts of sustainability-related scenarios (78.83% agreement).
9. A high percentage (76.91%) emphasizes the importance of tailoring risk mitigation strategies for sustainability-related risks to specific financial institutions.
10. A substantial number (67.30%) believe sustainable investment strategies do not necessarily involve sacrificing financial returns.
11. Green finance products are largely perceived as having mainstream appeal, with only 13.46% disagreeing that they are a niche market.
12. Impact investing is widely seen as effective in driving positive change, even with potentially higher financial risks (73.07% agreement).
13. Exclusionary screening is largely considered a necessary but not sufficient condition for sustainable investment practices (73.07% agreement).
14. Boards of directors are widely seen as having a fiduciary duty to prioritize sustainability (80.76% agreement).
15. Linking executive compensation to sustainability performance is strongly supported (80.76% agreement) to incentivize responsible behaviour.
16. While a majority (76.92%) supports voluntary disclosure, a non-negligible portion (7.69% Disagree, 1.92% Strongly Disagree) suggests it might not be entirely sufficient for transparency.
17. Third-party verification of sustainability claims is considered essential by 69.23% for building trust and credibility.
18. There's a notable split on harmonizing regulatory frameworks for sustainable finance at the international level; while a significant portion agrees (48.1%), a substantial "strongly agree" indicates strong support, but the number of

respondents for strongly agree is 16, which is not 83.2% of 52. Let's recalculate. $16/52 = 30.77\%$.

19. Financial incentives are viewed as more effective than regulatory requirements in promoting sustainable finance by 73.07% of respondents.
20. Emerging technologies like blockchain and AI are widely expected to play a significant role in the future of sustainable finance (78.84% agreement).

6.2. DISCUSSION:

The survey results highlight a strong agreement among respondents on the importance and growing integration of sustainability within the financial sector. There's clear support for establishing well-defined sustainable finance frameworks, with an emphasis on incorporating environmental, social, and governance (ESG) factors. The perceived challenges in integrating sustainability, primarily due to conflicting objectives, suggest a need for practical solutions and strategic alignment within financial institutions. The widespread belief in the necessity of stakeholder engagement, standardized reporting, and robust risk management tools underscores a desire for transparency, accountability, and effective implementation. While climate risk is recognized, the responses also indicate a broader understanding of various sustainability-related risks. The data also suggests a positive outlook on the financial viability of sustainable investments and the potential of green finance, dispelling the notion of them being niche markets. The strong advocacy for board-level responsibility and linking executive compensation to sustainability signals a demand for top-down

commitment and incentivization for sustainable practices.

6.3. SUGGESTIONS:

1. Prioritize the development of a universally accepted and clearly defined framework for sustainable finance to ensure consistency and comparability across the industry.
2. Develop practical guidelines and best practices for integrating ESG considerations into existing financial products and services to overcome conflicting objectives.
3. Foster multi-stakeholder dialogues and collaborations to ensure comprehensive and legitimate sustainable finance frameworks that address diverse perspectives.
4. Invest in and promote the standardization of sustainability data and reporting metrics to enhance transparency, facilitate analysis, and enable informed decision-making.
5. Encourage financial institutions to proactively assess and manage a broad spectrum of sustainability-related risks, not solely focusing on climate risk, using appropriate and evolving risk management tools.
6. Advocate for stronger corporate governance where boards explicitly integrate sustainability into their fiduciary duties and strategic planning.
7. Implement mechanisms to link executive compensation to quantifiable sustainability performance indicators to incentivize responsible business practices.
8. Promote the adoption of third-party verification for sustainability claims to build trust and credibility among investors and the public.

9. Explore and leverage emerging technologies like blockchain and AI to enhance data management, transparency, and efficiency within sustainable finance.
10. Policymakers should consider a balanced approach of financial incentives and regulatory requirements to accelerate the adoption of sustainable finance practices.

6.4. CONCLUSION:

The survey clearly demonstrates a prevalent understanding and strong support for sustainable finance among the respondents. The findings underscore the critical need for clear definitions, robust frameworks, and standardized reporting to facilitate the mainstreaming of sustainable

practices. While challenges exist in integrating sustainability into traditional finance, there is a clear appetite for overcoming these through stakeholder engagement, innovative risk management, and strong governance. The belief that sustainable investments do not necessarily sacrifice financial returns and that green finance has broad appeal signals a maturing market. Ultimately, the collective responses highlight a desire for a financial system that not only generates returns but also contributes positively to environmental and social well-being, emphasizing the transformative potential of sustainable finance.

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Bridging Green Finance, ESG Values, and Digital Innovation: A Humane Path to Sustainable Progress

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Abstract

This research explores the convergence of green finance, ESG (Environmental, Social, and Governance) values, and digital innovation as a unified strategy for shaping a humane and sustainable economic future. It proposes original, human-centered conceptual models that embed ethical purpose within technological and financial systems. Through strategic integration, businesses can move beyond compliance into value creation rooted in responsibility and regeneration. By examining models such as the Triple Integration Framework (TIF), HEART Model, Value-Driven Tech Adoption Ladder (VDTAL), and others, this study frames a vision where innovation, investment, and governance align to serve people, planet, and prosperity with dignity and depth.

Keywords: *ESG, Green Finance, Digital Innovation, Human-Centered Strategy, Sustainability Models, Ethical Business, Regenerative Economy*

Introduction

Sustainability today is not an option—it is a necessity shaped by climate urgency, technological acceleration, and rising social expectations. Traditional economic models are under pressure to evolve into ecosystems that align capital, innovation, and governance with long-term well-being. In this paper, we explore the critical intersections between three transformative forces: green finance, ESG values, and digital innovation. Each component contributes uniquely, yet their integration unlocks the full potential of regenerative business systems.

This study develops original conceptual models that help stakeholders navigate this transformation with clarity, empathy, and strategic foresight—centering not just on environmental impact, but on restoring the moral purpose of economic systems.

Green Finance as a Tool for Regenerative Capital

Green finance is more than a funding mechanism; it is a statement of intent. It supports projects that mitigate climate change, preserve biodiversity, and promote equitable resource usage. Unlike traditional finance, which often prioritizes short-term gains, green finance embraces intergenerational thinking.

To conceptualize this, the Triple Integration Framework (TIF) is introduced:

TIF Model Components:

- **ESG Values** define purpose and set ethical boundaries.
- **Green Finance** mobilizes capital aligned with these values.
- **Digital Tools** ensure monitoring, transparency, and adaptation.

This synergy enables a loop of trust: ethical intent backed by investment and made accountable through technology. It shifts sustainability from a cost center to a value generator.

ESG as a Transformational Mindset

ESG values provide a moral compass. They encourage organizations to ask: *Are we serving a greater good? Are our operations inclusive, transparent, and just?*

The HEART Model conceptualizes this ethos:

Holistic: Recognizes the interconnectedness of environment, society, and governance.

Empathic: Designs solutions that reflect community voices and needs.

Active: Moves beyond reporting into proactive stewardship.

Resilient: Withstands shocks while preserving human dignity.

Transparent: Operates with openness and humility.

This model fosters not just compliance, but character. It recasts ESG as an internal code, not an external checklist.

Role of Digital Innovation in Enabling ESG

Digital innovation is the engine that powers ESG in real-time. From satellite monitoring of deforestation to blockchain-enabled traceability in supply chains, technology provides both visibility and velocity. But tech without ethics can scale harm just as easily as it scales help.

This dilemma is addressed through the Value-Driven Tech Adoption Ladder (VDTAL):

Stages of Digital ESG Maturity:

1. **Passive** – Tools used for basic reporting.
2. **Reactive** – Action taken only after ESG incidents.
3. **Proactive** – Integrated ESG dashboards and analytics.
4. **Predictive** – AI models to foresee ESG risks.

Transformative – Digital platforms designed for equity, access, and impact.

Each stage represents a mindset shift—from minimizing harm to maximizing shared value. Organizations climb this ladder not through investment alone, but through intention.

Convergence: Strategy Through Synergy

The real breakthrough comes not from isolated efforts, but from holistic synergy. ESG, green finance, and digital tools must work together—not in silos, but as strands of a single strategy.

The Sustainable Strategic Compass (SSC Model) guides this convergence:

Axis	Guiding Question	Strategic Insight
North (Purpose)	Does this align with the well-being of future generations?	Infuse ESG into mission and KPIs
East (Innovation)	Are technologies used to humanize or just automate?	Ethical AI and data transparency
South (Finance)	Does capital flow support regeneration over extraction?	Prioritize long-term sustainable returns
West (Governance)	Is the organization accountable to all stakeholders?	Foster inclusive and clear reporting lines

At the center lies Human Dignity—reminding us that all innovation and investment must uplift lives, not just margins.

Humane Value Chain of Sustainable Impact (HVCSI)

Transformation is not just technical; it is deeply human. Systems must not only be efficient—they must be empathetic. The Humane Value Chain of Sustainable Impact (HVCSI) expresses this idea as a flowing cycle:

HVCSI Flow:

Empathy → Ethical Design → Inclusive Financing → Transparent Deployment → Community Feedback → Regenerative Outcomes

This value chain demands a slower, more intentional rhythm. It respects the social fabric and ecological limits. By valuing dialogue over dashboards, it restores trust in progress.

Strategic Analysis

Analysis of global sustainability trends reveals a telling pattern: companies that embed ethics into their strategy outperform peers in resilience and stakeholder loyalty. The models developed in this study—grounded in

empathy and systems thinking—provide organizations with actionable maps to navigate this evolution.

TIF shows that integration is more effective than isolation.

HEART makes ESG emotionally resonant.

VDTAL tracks maturity in a practical and behavioral way.

SSC anchors decisions in long-term wisdom.

HVCSI reframes processes as human experiences, not just workflows.

The data may be digital, but the transformation is deeply human. It is not merely about reducing carbon or boosting ESG scores—it is about reshaping intent, identity, and impact.

Conclusion

The convergence of green finance, ESG values, and digital innovation is not a

technological revolution—it is a values renaissance. By designing strategy with empathy, funding growth through responsibility, and deploying tech with conscience, we move toward a regenerative economy rooted in care and equity.

The models developed here are not just theoretical—they are calls to action. They offer a roadmap not only for organizations but for institutions, communities, and change-makers. Sustainability is no longer just a goal; it is a language, a mindset, and above all, a commitment to dignity at every level of enterprise.

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“Building Organizational Resilience through ESG Practices: The Evolving Role of Corporate Social Responsibility in Sustainable Business Transformation”

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Abstract

INTRODUCTION

ESG investment and corporate social responsibility (CSR) are two key ideas in business and finance, and the G20 nations have recently begun to pay more attention to them. ESG contributing is the act of taking administration, social, and ecological contemplations into account while going with venture choices. Investors consider a company's influence on the environment, society, and governance practices in addition to its financial success. ESG investing is a growing trend among investors who value ethical and socially conscious investments since it attempts to encourage sustainable and responsible investing practices. Contrarily, corporate social responsibility (CSR) describes a company's voluntarily taken steps to conduct business in a sustainable way from an economic, social, and environmental

standpoint. Companies that participate in CSR activities often concentrate on topics like social welfare, environmental sustainability, and ethical business practices. All stakeholders, including workers, clients, communities, and shareholders, are to benefit long-term from CSR.

The European Association and 19 different countries make up the G20, now and again known as the Gathering of Twenty. It brings together the heads of the main economies in order to coordinate and debate international economic and financial policy. The G20 has urged businesses to embrace these practices in recent years after realizing the value of ESG investment and CSR in fostering sustainable economic development. For instance, the G20 has asked investors to take ESG concerns into account when making investment choices and has pushed corporations to publish their ESG performance and risks in their annual reports. The G20 has also underlined the value of CSR in encouraging ethical corporate practices and has urged businesses to implement CSR programs in fields including labor standards, human rights, and environmental sustainability. Overall, the G20's acknowledgement of the significance of CSR and ESG investment is a good development that may support the spread of ethical and sustainable corporate practices around the globe.

Keywords: *Corporate governance, Refinitiv, G20, shareholder rights, CSR strategy, governance pillar score, and management score, sample selection, hypothesis testing, investment.*

ESG Investing

Since investors are increasingly looking to match their investments with their beliefs and ideals, ESG investing has gathered tremendous momentum. Climate change, labor standards, human rights, executive remuneration, diversity and inclusion, and other issues are all covered under the idea of ESG investment. Investors may identify businesses that are more likely to generate sustainable long-term success and lower risk by include these variables in their investment research.

The G20 has emphasized the value of ESG investing in fostering long-term economic development and urged investors to take ESG aspects into account when making investment choices. The G20 has also stressed the significance of ESG reporting

framework standardization and harmonization, as well as the significance of corporate disclosure of ESG risks and opportunities.

Environmental Factors

Environmental aspects include a company's environmental effect, such as its energy use, carbon emissions, and waste management procedures. Businesses that put an emphasis on sustainability may have reduced environmental hazards, reduced regulatory expenses, and a competitive edge in the developing low-carbon economy.

Social Factors

Social contemplations remember an organization's impact for society,

including its business strategies, common freedoms record, and contribution locally. Organizations that put a high need on friendly obligation might appreciate more noteworthy degrees of representative fulfillment, client dependability, and memorability as well as decreased lawful and administrative worries.

Governance Factors

Corporate governance practices, such as the make-up of a company's board of directors, CEO remuneration, and risk management procedures, are referred to as governance considerations. Businesses that place a high priority on good governance might provide higher shareholder returns, reduce financial risks, and face fewer legal and regulatory concerns.

ESG Investing Strategies

ESG investment techniques include the following:

- *Negative screening:* Staying away from businesses that harm society or the environment.
- *Good screening:* Putting money into businesses that give importance to ESG considerations and have a good effect on the environment or society.
- *Active Ownership:* Interacting with businesses to promote improved ESG practices, for instance by shareholder resolutions or proxy votes.
- *Impact Investing:* Putting money into businesses or initiatives with a clear social or environmental goal.

ESG Investing and Financial Performance

There is mounting evidence that businesses that give ESG concerns a high

priority may outperform their competitors in the long term. According to several research, businesses with better ESG ratings may have lower capital costs, less volatility, and more profitability than those with lower ESG ratings.

ESG Investing and Regulatory Environment

The legislative framework around ESG investment is quickly changing. Many countries and financial authorities are enacting regulations and laws pertaining to ESG investing, such as tax incentives for ESG investments or obligatory ESG disclosure requirements. This legal framework is probably going to keep evolving over the next several years, and it may have a big influence on the world of ESG investment.

Corporate Social Responsibility

An organization's deliberate endeavors to lead business in a manner that is maintainable regarding the economy, society, and the climate are alluded to as corporate social responsibility (CSR). CSR may include a broad variety of activities, including as philanthropic giving, involvement in the community, environmental sustainability projects, moral corporate practices, and more. The G20 has stressed the significance of CSR in fostering ethical corporate behavior and long-term economic success. The G20 has urged businesses to develop CSR programs in areas including labor standards, environmental sustainability, and human rights protections. The G20 has also urged improved stakeholder and corporate engagement in formulating CSR initiatives, as well as increased openness and accountability in CSR reporting.

Overall, ESG investment and CSR are significant ideas that may support responsible company practices and sustainable economic development. It's encouraging that the G20 has acknowledged the significance of these ideas since it may motivate businesses and investors to give sustainability and ethical business practices top priority in their operations and decision-making.

Key Areas of CSR

There are various crucial facets of CSR, such as:

- *Environmental sustainability:* lowering an organization's environmental effect, for instance by cutting greenhouse gas emissions, conserving water, and managing resources sustainably.
 - *Social responsibility:* Tackling societal concerns including charity, community development, labor practices, and human rights.
 - *Ethical business practices:* Promoting openness, accountability, and integrity in company operations via, for example, anti-corruption laws, ethical advertising, and just labor practices.
- *Less risk:* CSR may assist businesses in identifying and managing environmental, social, and governance-related issues, which can lessen their exposure to regulatory, legal, and reputational hazards.
 - *Greater access to cash:* As investors increasingly take ESG aspects into account when making investment choices, this might result in greater access to financing for businesses that place a high priority on CSR.

Challenges of CSR

Effective CSR efforts may be difficult for businesses to implement since they need substantial resources and a long-term commitment. Among the principal difficulties are:

- *Balancing stakeholder interests:* It could be trying for organizations to figure out some kind of harmony between the interests of a few gatherings, including investors, laborers, purchasers, and the overall population.
- *Measuring and reporting effect:* Because it sometimes includes qualitative and subjective metrics, measuring and reporting the impact of CSR projects may be difficult.
- *Aligning with business goals:* For CSR activities to be successful, they must be in line with a company's fundamental business goals and strategy, which might call for a lot of preparation and coordination.

Benefits of CSR

CSR has a number of potential advantages for businesses, including:

- *Improved reputation and brand image:* CSR may assist businesses in developing a good reputation and improving their brand image, which can lead to an increase in client loyalty and trust.
- *Enhanced morale and retention of staff:* Organizations that place a high priority on CSR may foster a more engaged and motivated workforce, which may result in higher staff retention and productivity.

G20

A significant platform for international collaboration on financial and economic concerns is the Group of Twenty, or G20. It brings together the largest developed

and developing countries in the world to debate and tackle issues related to climate change, supporting sustainable development, and increasing financial stability. The G20 is comprised of 19 countries in addition to the European Association, representing more than 80% of worldwide Gross domestic product and close to 66% of the total populace. Argentina, Australia, Brazil, Canada, China, France, Germany, Greece, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, Joined Domain, and the US are among the countries that make up the G20. Because of the Asian money related crisis, the G20 was laid out in 1999, and it has since formed into an earnest social occasion for worldwide monetary system. The heads of state and legislature of the G20's part countries, as well as authorities from worldwide organizations including the Unified Countries, the World Bank, and the Global Financial Asset, go to the highest point every year.

LITERATURE REVIEW

The 2015 research by Clark, Feiner, and Viehs, "From the Stockholder to the Stakeholder: How Sustainability cans Drive Financial Outperformance," is a significant study in the ESG Investing field. The study reveals that businesses that place a high priority on sustainability and ESG aspects often outperform their competitors over the long run because they are more adept at managing risks, luring clients, and obtaining funding. The report also emphasizes how crucial stakeholder participation is for promoting sustainable company practices, especially with workers, clients, and communities.

Carroll's 1991 work, "The Pyramid of Corporate Social Responsibility: Toward the Moral Management of Organizational Stakeholders," is one important piece in the field of CSR. The CSR pyramid, which has four layers of responsibility—economic, legal, ethical, and philanthropic—is introduced in this essay. The pyramid is a frequently used paradigm for understanding CSR because it highlights the significance of businesses addressing their wider social obligations beyond merely financial success and legal compliance.

ESG Investing

According to Eccles, R. G., Ioannou, & Serafeim's (2014) research, businesses that place a high priority on sustainability often perform better operationally, have happier employees, and manage risks more successfully.

This meta-analysis of 60 papers on ESG and financial performance by Grewal, J. S., Lilien, G. L., and Mallapragada (2020) reveals a favorable correlation between ESG performance and financial success, especially for environmental and social aspects.

The future, KPMG International (2017) corporate responsibility reporting 2017 KPMG study The condition of CSR reporting among the major corporations in the world is surveyed in this paper, which concludes that corporate strategies are increasingly including sustainability reporting.

CSR

According to McWilliams, A., and Siegel (2001), CSR may be seen as a mechanism for businesses to align their interests with

those of their stakeholders and forge lasting partnerships. This research presents a theoretical framework for understanding the motives behind CSR.

According to Porter, M. E., and Kramer, M. R. (2006), CSR may provide businesses a competitive edge by boosting their reputation, fostering consumer loyalty, and fostering better connections with stakeholders.

According to Waddock, S. A., and Graves, S. B.'s (1997) research, there is a favorable association between CSR and financial success, especially for businesses with a solid reputation for social responsibility.

Objectives of the study

1. To analyze the distinctions in corporate administration results among G20 nations subsequent to adapting to organization size.
2. To test the speculation that corporate administration results are altogether unique between G20 nations subsequent to adapting to organization size.
3. To research the connection between the Administration Point of support Score (GovScore), Investor Freedoms Score (ShareScore), and CSR Technique Score (CsrScore) and corporate administration quality.
4. To examine the Refinitiv information base, which is an exclusive data set organized by a monetary office, and its viability as a thorough and believed hotspot for speculation purposes.

Research Gap

The little research on the link between family ownership and corporate social responsibility (CSR) in developing

countries like China is one potential research gap that the study may fill. Although several research in industrialized nations have identified a positive correlation between family ownership and CSR, the link may be different in developing economies where family enterprises operate in distinct institutional and cultural settings. The scant study on how ownership identification affects a firm's financial performance is another potential research void. Even while several researches have shown that family businesses outperform non-family businesses financially, the precise reasons behind this association are not fully understood. The research may shed insight on the underlying processes behind this link by evaluating the effects of family ownership on company performance and sustainability.

RESEARCH METHODOLOGY

Data Source

Corporate governance research has utilized Refinitiv's proprietary database. This database is reliable for investing. Refinitiv gauges a corporate administration score for the greatest recorded firms utilizing industry-standard class loads for the executives, investor privileges, and CSR methodology. In October 2022, Refinitiv examines 138 corporate administration factors for every association.

The administration score remembers 70 markers for corporate sheets (size, capabilities, structure, participation, freedom, abilities, and variety), remuneration (strategy, targets, impetuses, limitations, and boards of trustees), Chief Executive division, progression arranging, inside endlessly review panel autonomy.

The investor privileges aspect inspects 39 factors on equivalent investor freedoms and specific arrangements, investors deciding on chief remuneration, chief political race prerequisites, blackball power, state-possessed ventures, non-review to review charges proportion, and evaluator residency. Refinitiv incorporates a maintainability council, partner commitment, manageability detailing, and outside confirmation of nonfinancial reports in the CSR procedure aspect (29 signs) of corporate administration.

Sample Selection

Refinitiv's ventures stock gave the data. Industry packs associations: Energy (2360), Principal Materials (7856), Industrials (9878), Client Cyclical (8842), Buyer Non-Cyclical (4423), Financials (9003), Clinical consideration (5033), Advancement (8084), Utilities (1350), Land (3597), Affiliations (3), Government Development (7), and

Insightful and Enlightening Organizations (288). All are for-benefit.

The Corporate Administration Score for monetary year 2021 was the underlying choice measures. 8408 perceptions were gathered. The G20 participation of the consolidation country (Refinitiv's "nation of residence") was the subsequent determination factor. Since the EU is a G20 part, organizations from the 27 part states were qualified for study. The example incorporates 6288 perceptions for 19 G20 countries and 1136 for the EU (just firms in 21 part states have Refinitiv information). Germany, France, and Italy — EU and G20 individuals — share these informational indexes. The example is cross-sectional for the monetary year 2021, mirroring the most recent Refinitiv data set (starting around 1 October 2022). All model firms are worldwide stock trade recorded goliaths. Figure 1 sums up example determination.

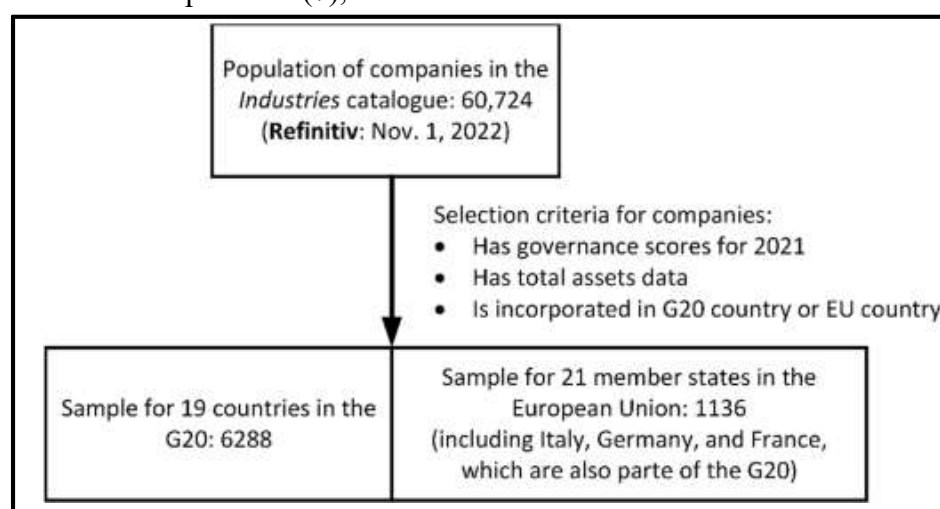


Figure 1: Sampling summary

Hypothesis and Variables

The following is the tested hypothesis:

Hypothesis 1: There are considerable differences in corporate governance results amongst the G20 nations, after accounting for firm size.

Hypothesis 2: Corporate governance results among the G20 nations are not considerably different, after accounting for firm size.

The Refinitiv database provides the following corporate governance outcomes:

The Administration Point of support number (GovScore), a weighted number from 0 to 100, breaks down the organization's strategies and cycles to guarantee board individuals and chiefs work to investors' greatest advantage. Administrative motivators and governing rules make long haul investor esteem. Refinitiv doesn't deliver the recipe for this score, which is industry-standardized. The Administration Support point Score is a weighted normal of the Administration Score, Investor Privileges Score, and CSR Technique Score. The Administration Point of support Score is an intermediary for corporate administration greatness in the writing.

Investor Freedoms number (ShareScore) is a weighted number from 0 to 100 that investigates the organization's investor balance and hostile to takeover gadgets. Investor freedoms, equivalent democratic privileges, different democratic privileges, chief political race larger part, early notification time, chief responsibility limits, case uses, and examiner residency are signs. Refinitiv doesn't deliver the recipe for this score, which is industry-standardized.

The CSR System number (CsrScore) is a weighted number from 0 to 100 that

actions the organization's endeavors to consolidate the plan of action's financial, social, and ecological parts into direction. The writing has used this score to quantify the organization's integrative reasoning. It incorporates a maintainability council, the board report mix of monetary and non-monetary parts, Worldwide Revealing Drive consistence, partner inclusion, and Supportable Improvement Objective detailing. Thus, corporate governance governs CSR. Refinitiv does not reveal the calculating mechanism for this industry-normalized score.

Statistical Procedures

ANCOVA is significant. A covariate makes this approach more muddled than ANOVA. Organization size is proxied by the regular logarithm of absolute resources meant a similar money in this exploration. Bigger partnerships should further develop administration and be more straightforward. Administration concentrates frequently utilize firm size as a covariate. These tests address the ANCOVA supposition. The all out subordinate variable (a country) cooperates with the covariate (normal organization size in that country). The greatest enterprises on the planet are in the G7, not G20; accordingly relapse slant homogeneity doesn't have any significant bearing. Fluctuating gathering sizes block difference homogeneity. Administration

results versus lnTA disperse plots showed no nonlinear propensities.

The coefficient of covariance matrix was heteroscedasticity-corrected to compute the grouping variable's F-value. Bonferroni corrects post-hoc testing. For a more cautious evaluation, $p < 0.01$ indicates significant group differences. Algorithm A1 in Appendix A shows ANCOVA and post-hoc test methods in R. Field emphasized that ANCOVA tests hypotheses about group differences without confounding factors. ANCOVA, like multiple regressions, benefits from post-hoc testing across groups. Various backslides basically takes a gander at picked get-togethers (using faker elements) to a base characterization, yet post-hoc tests in ANCOVA evaluate all arrangements of social events and track down monstrous differences while ensuring the consolidated Sort I bumble is underneath 0.05. Various backslide

requires a "base" pack (i.e., a nation of reference), which terrible searches in this study plan. Subsequently, ANCOVA is best for taking note of the assessment point.

RESULTS

Hypothesis Testing for the Governance Pillar Score

Table 1 shows the changed mean Administration Point of support score (GovScore) per country/bunch. Subsequent to adapting to firm measure, the gathering variable F-measurement is $F(19, 7403) = 20.46$ ($p < 0.001$). South Korea scored best, albeit the example is restricted. Simply South Korea and Germany have typical scores more than 60. China and Japan have GovScore around 45, far lower than the US and EU. GovScore maintains the survey's key explanation. Results construe standard guideline is more terrible.

Table 1: GovScore covariance by country/group of nations, adjusted by firm size, in decreasing rank

G20 Member	Sample	GovScore Mean	Adj. SE	Sig. Differences ¹
South Korea (KR)	23	66.1	5.21	JP, CN
Germany (DE)	187	64.9	2.45	IN, JP, US, CN
United Kingdom (GB) *	528	58.4	1.86	JP, US, CN
Italy (IT)	83	58.3	3.14	JP, CN
European Union (EU)	1137	57.9	1.64	JP, US, CN, DE
Turkey (TR)	74	57.5	3.25	JP, CN
Indonesia (ID)	40	56.9	4.56	-
Australia (AU) *	359	56.9	2.13	CN, JP, DE
Brazil (BR)	37	55.2	4.15	-
France (FR)	149	55.3	2.14	CN, DE
United States (US) *	2541	53.2	1.45	JP, GB, EU, DE
Canada (CA) *	296	52.3	2.36	DE, JP, CN
Mexico (MX)	70	52.4	3.25	DE
South Africa (ZA)	115	52.6	2.56	DE
India (IN) *	222	51.2	2.45	DE, GB, EU
Russia (RU)	17	51.4	5.46	-
Saudi Arabia (SA) **	29	50.2	4.58	-
Argentina (AR)	25	50.4	5.26	-
China (CN)	1106	47.8	1.25	DE, EU, GB, US, AU
Japan (JP)	406	45.2	1.89	US, IT, GB, FR, EU

¹ Significant difference at $p < 0.01$ * Common law system, ** Islamic law the rest have a civil law system or mixed types.

Hypothesis Testing for the Shareholder Rights Score

Table 2 shows the changed mean Financial backer Honors Score (ShareScore) per country/social event of nations. Right after adjusting to firm gauge, the social occasion variable F-estimation is $F(19, 7403) = 7.57$ ($p < 0.001$). Germany has the most raised ordinary score. Simply South Korea and Germany have north of 60 ordinary evaluations. Canada, China, and Japan have ShareScore fewer than 50, well behind Germany. Thus, the study's premise is supported for ShareScore, but only at the

extremes. Shareholder protection is similar in all nations. Results don't establish common law's superiority. Germany, recognized for stakeholder advocacy and inclusive corporate governance, has the greatest shareholder protection.

Table 2: ShareScore covariance by country/group of nations, adjusted for firm size, in decreasing order.

G20 Member	Sample	GovScore Adj. Mean	SE	Sig. Differences¹
Germany (DE)	187	65.2	2.31	US, JP, IN
South Korea (KR)	23	61.2	6.52	
Russia (RU)	60	60.4	7.45	
European Union (EU)	1137	58.4	1.25	JP
Turkey (TR)	74	57.1	4.21	
France (FR)	149	57.3	3.21	
United Kingdom (GB) *	528	57.1	2.51	JP
Indonesia (ID)	40	56.9	5.46	
Italy (IT)	83	53.2	3.25	
United States (US) *	2541	55.6	1.65	JP
Australia (AU) *	359	55.2	2.45	DE
Mexico (MX)	70	55.1	4.68	
Saudi Arabia (SA) **	29	54.8	5.14	
Brazil (BR)	37	54.1	5.62	
India (IN) *	222	52.6	2.36	DE
South Africa (ZA)	115	51.3	3.54	DE
Argentina (AR)	25	51.7	6.25	
Canada (CA) *	296	50.6	6.15	DE, EU
China (CN)	1106	49.8	1.95	US, GB, EU, DE
Japan (JP)	406	49.8	1.84	DE, EU, GB, US

¹ Significant difference at $p < 0.01$ * Common law system, ** Islamic law the rest have a civil law system or mixed types.

Hypothesis Testing for the CSR Strategy Score

Table 3 showcases country/bunch CSR Methodology Score (CsrScore) changed mean scores. In the wake of adapting to firm measure, the gathering variable F-measurement is $F(19, 7403) = 52.63$ ($p < 0.001$). For a short example, Turkey has the most elevated typical score, trailed by the UK. Then again, Japan, South Korea, the US, and Saudi Arabia have CsrScore under 30. G20 normal scores fluctuate incredibly. CsrScore has a more extensive typical score range than earlier corporate administration perspectives. CSR/manageability is less directed than investor privileges. Past writing can't make sense of Turkish firms' high normal score. South Africa and the EU need incorporated and non-monetary announcing, separately. The UK has a high typical score in light of the fact that the London Stock Trade commands CSR detailing (just natural and social data) for all organizations recorded on its principal market. At last, CsrScore affirms the review's chief reason.

Table 3: CsrScore covariance by country/group of nations, corrected for firm size, in decreasing order

G20 Member	Sample	GovScore Adj. Mean	SE	Sig. Differences ¹
Turkey (TR)	74	51.2	4.15	US, SA, CN
United Kingdom (GB) *	528	55.3	2.31	US, SA, MX, JP
South Africa (ZA)	115	50.8	3.25	US, SA, CN
Australia (AU) *	359	49.2	2.65	US, SA, JP, CN
Italy (IT)	83	49.3	3.54	US, JP, SA
Germany (DE)	187	48.1	2.14	US, SA, JP
European Union (EU)	1137	47.6	1.25	US, SA, JP, GB
India (IN) *	222	46.2	2.65	US, JP, SA, CN
Indonesia (ID)	40	46.3	5.21	US
Argentina (AR)	25	45.7	6.58	
France (FR)	149	44.1	3.21	US, JP, SA, GB
Canada (CA) *	296	42.6	2.15	US, JP, GB
Brazil (BR)	37	41.8	5.65	
Russia (RU)	17	38.9	7.45	
China (CN)	1106	37.4	1.21	US, GB, EU, DE
Mexico (MX)	70	36.2	1.25	TR, GB
Japan (JP)	406	30.2	2.56	ZA, TR, CN
South Korea (KR)	23	29.6	6.25	TR, GB
United States (US) *	2541	28.1	1.65	TR, GB, EU, CN
Saudi Arabia (SA) **	29	20.4	6.89	US, CA, GB, EU

¹ Significant difference at $p < 0.01$ * Common law system, ** Islamic law the rest have a civil law system or mixed types.

FINDINGS OF THE STUDY

Country-level legitimate and administrative establishments influence unfamiliar possession, unfamiliar directorship, outside monetary capital, and cross-line M&A movement. Global variations in administrative worries in corporate administration have been enough tended to in earlier and tantamount examinations; however the genuine impacts of corporate administration have not. This article thinks about unfamiliar corporate administration results utilizing Refinitiv's broad data set. The research uses eight Refinitiv variables using ANCOVA to compare corporate governance performance across nations. G20 members—19 nations and the EU—comprise the sample. Table 4 summarizes outcomes.

Table 4: A summary of results

Variable	Hypothesis Status	Sig. Differences
Governance Pillar Score	Confirmed	Between The Sample's Top And Lower Halves
Shareholder Rights Score	Confirmed	Between The Top And Worst Performers
CSR Score	Confirmed	Between The Sample's Top And Lower Halves

Results are two-sided. First, only the top and poorest performers have substantially different country-level mean values for GovScore, ShareScore, and CsrScore. Average-ranked nations are similar. Thus, the greatest and average performers in each area may vary greatly. A nation might be the greatest in one area and near-worst in another, which is shocking. This explains why aggregate metrics like GovScore are not responsive to genuine corporate governance results.

Corporate governance details show country-level disparities. The common law system in the US, UK, Canada, and Australia affects board independence. According to European Parliament and member nation negotiators, European countries must increase female directors. German corporations are the weakest at hiring industry-savvy directors. Finally, the US and Canada have the highest auditor tenure in the G20. Given US financial auditing issues, this is remarkable.

CONCLUSION

The first research to examine corporate governance results across countries employs a large multinational sample. Hofstede's cultural dimensions may be applied to granular governance metrics. This study can improve nation aggregate indicator calculation. Legal system effects on corporate governance are also debated. Legal systems, whether national or supra-national (like the EU), may explain granular governance metrics. Corporate social responsibility needs further study. Our aggregate dimension exhibited the highest variation in our sample, demonstrating that CSR practices vary widely amongst organizations at the national and individual levels. The Refinitiv database will grow over time, boosting sample size and statistical power. With sophisticated and detailed data, international corporate governance research seems promising.

Regulators face huge ramifications. The European Parliament has supported the new EU rule requiring 40% non-pioneer female board people by 2026. Norway, Spain, Finland, Quebec (Canada), Israel, France, Italy, and Belgium have 33%-half direction board sums. G20 nations outside the EU are presumably going to survey this regulative change. The public administrative climate — common regulation, precedent-based regulation, self-guideline, Islamic regulation, or any blend of these — may obstruct or advance orientation equity regulation. Future exploration ought to seek after this.

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“The Growth of Green Finance and Its Impact on India’s Sustainable Development”

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Abstract:

Green finance has emerged as a strategic approach for directing capital toward environmentally sustainable projects. As one of the fastest-growing economies in the world, India faces the dual challenge of maintaining economic growth while combating environmental degradation and the impacts of climate change. This conceptual paper explores the evolution, mechanisms, and implications of green finance within the Indian context. Drawing on existing literature, policy frameworks, and global best practices, the study investigates how instruments such as green bonds, ESG integration, and climate risk disclosures facilitate sustainable development. The paper posits that while India has made notable progress in institutionalizing green finance, it still confronts significant challenges related to standardization, transparency, and capacity building. Therefore, the establishment of a national taxonomy, enhanced regulatory oversight, and collaboration among multiple stakeholders are vital to scaling up green finance and aligning financial flows with India’s sustainability objectives as outlined in the Paris Agreement and the United Nations Sustainable Development Goals (SDGs).

Keywords: *Green finance; Sustainable development; Climate finance; ESG; Green bonds; SDGS*

Introduction

In recent years, the global financial landscape has experienced a significant transformation with the integration of environmental, social, and governance (ESG) considerations into investment strategies. A key component of this movement is green finance, which encompasses financial investments—including savings, loans, insurance, and other funding mechanisms—that promote environmental improvement, climate resilience, and sustainable development (Franken et al., 2020). For India, a rapidly developing economy that must navigate the challenge of industrialization while safeguarding ecological integrity, green finance serves as a crucial instrument for achieving long-term sustainability.

India's commitment to reducing carbon emissions intensity and expanding its renewable energy capacity, as outlined in the Paris Agreement, necessitates substantial financial resources, making

green finance essential for facilitating this transition. Over the past decade, there has been a notable increase in interest surrounding green financial instruments in India, bolstered by regulatory reforms, international collaborations, and a growing demand from investors for sustainable assets (Agarwala et al., 2021).

Despite recent advancements, the mobilization of sufficient capital, the harmonization of standards, and the alignment of financial flows with national climate objectives continue to pose significant challenges. This conceptual paper seeks to offer a thorough understanding of green finance and assess its role in furthering India's sustainable development agenda. It synthesizes existing research, evaluates policy frameworks, and proposes strategies to enhance the green finance ecosystem in India.

Review of Literature

Conceptual Foundations of Green Finance

Green finance encompasses a wide range of financial tools and services designed to support environmental improvements, climate action, and sustainable development (Zhang et al., 2021). This includes mechanisms such as green bonds, green banks, ESG investing, and frameworks for climate risk disclosure. At its core, green finance aims to incorporate environmental externalities into financial decision-making processes, thereby

enhancing resource efficiency and minimizing carbon footprints.

According to Zhang et al. (2021), green finance acts as a catalyst for transitioning economies toward low-carbon pathways by redirecting capital flows into sustainable sectors. Their study highlights the significance of policy coherence and market transparency in ensuring the effectiveness of green finance instruments. Similarly, Li et al. (2020)

contend that green finance contributes to sustainable economic growth by promoting innovation in clean

Global Perspectives and Policy Frameworks

Globally, numerous countries have established robust frameworks to advance green finance. China has taken the lead with a comprehensive policy framework that includes tax incentives, credit guarantees, and guidelines for green credit (Wang & Zhi, 2016). The European Union has furthered green finance through the EU Taxonomy Regulation, which creates a classification system for sustainable economic activities.

Green Finance in the Indian Context

India has progressively woven green finance into its developmental framework. The nation issued its inaugural green bond in 2015, and since then, both public and private sectors have increasingly accessed green debt markets (Chaturvedi et al., 2020). The Ministry of New and Renewable Energy (MNRE) and the International Solar Alliance (ISA) have been instrumental in fostering green investments, particularly in the solar and wind energy sectors.

However, Agarwala et al. (2021) note that despite these advancements, India lacks a cohesive taxonomy for green finance,

Challenges and Opportunities

While green finance has great potential for India, several barriers hinder its full development. These challenges include limited awareness among stakeholders, insufficient data availability, misaligned incentives, and weak enforcement

technologies and enhancing corporate environmental performance.

In their comparative analysis, Bachelet et al. (2021) emphasize that successful models of green finance typically depend on strong institutional support, regulatory clarity, and effective public-private partnerships. These findings highlight the importance for India to enhance its policy architecture in order to attract both domestic and foreign green investments.

which results in inconsistencies regarding project eligibility and investor confidence. They advocate for a standardized classification system aligned with international best practices to enhance transparency and facilitate increased financing for climate-resilient infrastructure.

Sharma and Mishra (2022) highlight the need to integrate ESG metrics into traditional financial reporting in India. They suggest that improved disclosure requirements will enhance accountability and enable better risk assessment for green investments.

mechanisms (Kumar & Managi, 2020). Additionally, there is often a mismatch between investors' short-term return expectations and the long gestation periods typically associated with green projects.

Despite these challenges, many opportunities exist. The increasing global demand for sustainable assets, along with India's ambitious renewable energy targets, creates a favorable environment for the growth of green finance.

Conceptual Framework

This paper uses a conceptual framework that integrates three key dimensions: policy, finance, and impact. Each dimension offers a perspective for analyzing the growth and impact of green finance in India.

- **Policy Dimension:** This refers to the regulatory frameworks, government policies, and institutional arrangements that either facilitate or hinder green finance.
- **Finance Dimension:** This focuses on the various types of financial instruments, sources of funding, and market dynamics that influence green investments.
- **Impact Dimension:** This evaluates the outcomes of green finance initiatives in terms of environmental benefits, economic returns, and social inclusiveness.

This tripartite model provides a comprehensive understanding of how green finance functions within India's socio-economic landscape and how it contributes to sustainable development.

Green Finance Instruments in India

India has experienced significant growth in green finance instruments over the past decade. Key instruments include:

Green Bonds: India ranks among the top global issuers of green bonds. According

Institutional innovations, such as the proposed Green Finance Task Force and the integration of climate risks into central bank mandates, can further enhance this momentum.

to the Climate Bonds Initiative (2023), India raised over USD 12 billion in green bonds from 2015 to 2022, primarily funding renewable energy and sustainable infrastructure projects.

Sustainable Banking: Both public and private sector banks have started to incorporate Environmental, Social, and Governance (ESG) principles into their lending portfolios. For example, State Bank of India (SBI) and YES Bank have launched dedicated green financing schemes.

Climate Funds: Initiatives such as the National Adaptation Fund for Climate Change (NAFCC) and the Green Climate Fund (GCF) have supported localized efforts for climate adaptation and mitigation.

ESG Investing: With the growing demand for responsible investing, asset managers are increasingly integrating ESG criteria into their portfolio selection and risk management frameworks.

Regulatory and Institutional Developments

Regulatory bodies in India have taken steps to promote green finance:

The Reserve Bank of India (RBI) has encouraged banks to adopt sustainable

finance practices, though formal mandates are still evolving. The Securities and Exchange Board of India (SEBI) has mandated ESG disclosures for top listed companies, enhancing transparency in sustainability reporting. The International Solar Alliance (ISA) has facilitated cross-border green financing for solar projects in developing countries, including India. Despite these developments, India lacks a centralized authority or task force dedicated exclusively to green finance. Establishing such an institution could streamline policy implementation and coordinate inter-agency efforts.

Challenges to Scaling Green Finance

Several structural and operational challenges hinder the expansion of green finance in India:

Conclusion and Future Prospects

Conclusion

Green finance has become a crucial tool for promoting sustainable development by aligning financial systems with environmental and climate objectives. In India, where economic growth must harmonize with ecological sustainability, green finance provides a strategic pathway to mobilize capital for clean energy, resilient infrastructure, and inclusive development. The country has made significant strides in recent years through policy initiatives, green bond issuances, and international collaborations. However, challenges such as inconsistent definitions, inadequate

Lack of Standardization:

Absence of a uniform taxonomy leads to inconsistent definitions of "green" projects, undermining investor trust.

Data Gaps:

Limited availability of reliable data on environmental performance hampers due diligence and risk assessment.

Capacity Constraints:

Financial institutions and regulators lack trained personnel to assess and manage climate-related financial risks.

Investor Awareness:

Many investors remain unfamiliar with green finance products and their long-term benefits.

Policy Incoherence:

Disjointed regulatory frameworks across ministries reduce the effectiveness of green finance initiatives.

risk assessment frameworks, and limited investor awareness continue to impede the large-scale deployment of green finance.

This conceptual paper emphasizes that while India has the institutional capacity and market potential to scale up green finance, there is an urgent need for standardized classification systems, enhanced transparency, and robust regulatory oversight. Additionally, incorporating environmental, social, and governance (ESG) metrics into mainstream financial reporting can improve accountability and attract long-term investments. Strategic interventions

Future Prospect

Looking ahead, the future of green finance in India depends on several key developments:

Development of a National Green Taxonomy: Establishing a unified taxonomy aligned with international standards will enhance clarity on eligible green activities, boost investor confidence, and reduce the risk of greenwashing.

Enhanced Climate Risk Disclosure: Strengthening mandatory ESG disclosures and adopting frameworks like the Task Force on Climate-related Financial Disclosures (TCFD) can help financial institutions better assess and manage climate risks.

Innovation in Financial Instruments: Expanding beyond green bonds to include sustainability-linked loans, blue finance, and biodiversity-linked securities can diversify funding sources and cater to a broader range of environmental objectives.

Capacity Building and Awareness: Raising awareness among investors, businesses, and policymakers about the benefits of green finance is crucial. Training programs and knowledge-sharing platforms can build technical expertise across sectors.

Integration with National Development Goals: Aligning green finance strategies with national missions such as the National Action Plan on Climate Change (NAPCC), Smart Cities Mission, and Production Linked Incentive (PLI) schemes can ensure coherence and maximize impact.

Role of Central Bank and Regulators: The Reserve Bank of India (RBI) and Securities and Exchange Board of India (SEBI) can play a pivotal role by incorporating sustainability principles into monetary and regulatory policies, including stress testing for climate risks.

International Collaboration and Investment Flows: Leveraging global partnerships and attracting foreign direct investment (FDI) in green sectors can supplement domestic efforts and accelerate India's transition toward a low-carbon economy.

In conclusion, green finance represents a transformative opportunity for India to meet its dual objectives of economic growth and environmental stewardship. By addressing current gaps and leveraging emerging opportunities, India can position itself as a leader in sustainable finance within the Global South, contributing significantly to the global fight against climate change and advancing the United Nations Sustainable Development Goals (SDGs).

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Sustainability Through ESG Performance and Green Investment: An Empirical Study of Indian Listed Firms

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Abstract:

The study explores a very interesting aspect regarding the interaction between green finance, ESG (Environmental, Social and Governance) performance and technology driven sustainability practices among the publicly listed firms in Indian scenario. The study examines a sample of 50 companies derived from energy, steel and cement industry which is considered to be highly carbon emitted industries. The data were extracted from CMIE database software. The statistical tools like regression and correlation were utilized which highlighted a significant and positive link between ESG performance and green financial initiatives.

Key words: *ESG score, Sustainable Development, Technology adoption, green investment*

Introduction

It is observed that in recent years a lot of emphasis is laid on the ESG indicators and green finance which is in fact becoming a very critical instrument in furthering long term sustainability agenda. In recent years there is a tremendous urge from the different stakeholders, institutional investors as well as civil society organization to make a proper disclosure and enhanced transparency in environmental disclosure and a commitment towards eco-friendly investments in India. This has resulted in a number of firms to align their strategic goals with sustainable development objectives. In order to quantify and enhance their sustainable initiatives a number of advanced technologies has been adopted

like emission tracking tools, digital monitoring system or energy efficient innovation.

The present paper actually tries to correlate these factors and tries to investigate into the interaction of the green financial investments, ESG performance and also technology-based sustainability solutions. The analysis has been done by extracting data from CMIE prowess database software of Indian firms for a multi time period. The study though empirical analysis basically tries to bring out how the businesses are navigating and relating green finance, technology and governance to achieve environmental sustainability.

Literature Review

Some past works reviewed by me for the present study are as follows:

Rana et al (2025) in their book has tried to explore the relationship between ESG reporting and enhanced transparency and shareholder's trust. The book also explores the dynamism of ESG accounting and auditing practices in China.

Malik et al (2024) in their paper have stated that the firm's performance is increased due to higher ESG disclosures and it even lowers the cost of debt for the companies. Thus, ESG can be utilized as a strategic tool to improve investor confidence.

Pareek et al (2023) tried to find out the impact of the gender diversity on the sustainable performance of the corporate in Indian firms. The study highlighted the fact that the increase of women proportion in the board of directors has a positive effect on the ESG performance.

Yadav et al (2022) in their paper examined the impact of gender diversity on the ESG performance suggesting that the board should at least have three women directors to improve the ESG performance.

Research Methodology

3.1 Data Source:

The data for the study has been extracted from CMIE prowest database for the years 2018-19 to 2022-23.

3.2 Sample Selection:

The sample consist of 50 publicly traded companies from energy sector, Cement sector and steel sector which are traded

Maji et al (2023) in their study concluded that the Indian firms using CRISIL ESG scores tends to indicate strong ESG performance in which especially the governance and social factors are responsible for higher ESG performance.

Khandelwal et al (2023) has examined the impact of the ESG disclosure on the stock returns and concluded from their study that those firms with higher disclosure level underperforms than those with lower disclosure levels.

Sarkar (2022) in his study has explored the growth and performance of ESG themed mutual funds by using a number of ratios like Sharpe's ratio, Treynor's ratio etc. the study highlights the effectiveness of EGS oriented schemes to providing high long-term performance in mutual fund arena.

Shaikh (2022) has explored the relationship between ESG practices and financial performance for 510 firms in 17 countries and concluded that there was a significant and positive relationship between the environmental and governance factor on financial performance while the social factors reflected mixed results.

in both NSE and BSE. (the companies taken for the study has been given in Appendix section)

3.3 Variables and Statistical Tools used in the study:

ESG score is the dependent variable for the study. A consolidated ESG score is computed by measuring on a scale of 0

to 100 highlighting the firm's environmental, social and governance performance.

How the ESG score is computed?

ESG score is developed by using one quantifiable indicator from each of environment, social and governance dimensions.

The environmental dimension is captured by firm's expenditure on environmental projects derived from CSR initiatives.

The social dimensions are represented by CSR amount spent on social initiatives like health, education and community development.

The governance dimension is measured by the proportion of independent directors on the board of directors highlighting the level of transparency in the working of the companies.

The variables are then normalized by using the min-max method to ensure comparability and finally the ESG score is computed as the mean of three normalized values scaled to a 100-point system. In this paper an effort has been made to take only data driven measurement of ESG score which can be easily available from CMIE Prowess data base software.

Result and Discussion:

4.1 Descriptive Statistics:

It can be seen from Table 1 that the average of ESG Score is 58.45 suggesting that the companies are moderately committed towards sustainability with the score ranging

The **independent variables** for the study are as follows:

- i. *Green Capital Expenditure* represented by the expenditure incurred in sustainable environmental related projects (in crores).
- ii. *Research and Development for sustainable technology* represented by the amount invested towards innovation and development of eco-friendly technology (in crores).
- iii. *Return on Assets* has been taken as a proxy of profitability and is measured by the ratio of net income by Total Assets.
- iv. *Debt to Equity ratio* which is taken as a proxy of financial leverage and computed by the ratio of debt to shareholder's equity.
- v. *Technology adoption indicator* is represented as a binary variable with 1 indicating the companies which have integrated sustainability focused technological solutions and 0 indicating otherwise.

To explore the linear association between the variables Pearson correlation has been used and multiple regression analysis is utilized to investigate the influence of the independent variables on the ESG scores. SPSS has been used for analysis purpose.

from 30 to 85. It is also reflecting a variation ESG practices. Green capital expenditure is also showing a mean of 58.45 crore with a standard deviation of 89.45 % reflecting a variation in environmental spending across the

companies. Even the research and development for sustainable technology with average of 34.22 crores with standard deviation of 15.33% is also highlighting a lot of deviation in spending in ecofriendly projects across the companies.

Return on Assets with mean of 7.25% reflects a modest profitability and average debt equity ratio of 1.45 indicates a tilt towards more debt financing for these companies.

The average of Technology adoption of 0.72 indicates that the most of the companies have welcomed technologies which are sustainable focused with a minority are yet to adopt such practices.

It can be safely concluded from the descriptive statistics reveal a notable variation in ESG performance, integration of technology and the financial performance.

The result of Table 1 is given below:

Table 1: Descriptive Statistics:

Variable	Mean	Standard Deviation	Minimum	Maximum
ESG Score	58.45	12.80	30.00	85.00
Green Cap Expenditure in crores	124.67	89.45	20.00	410.00
Research and Development Sustainable Technology in crores	34.22	15.33	5.00	78.00
ROA (%)	7.25	3.15	1.10	15.60
Debt-Equity Ratio	1.45	0.65	0.30	3.20
Technology Adoption (0/1)	0.72	0.45	0	1

Source: Author Computation using SPSS

inflating standard errors and yielding misleading significance levels (Gujarati & Porter, 2009).

4.2 Correlation Analysis

To test for the potential issue of multicollinearity among the independent variables, a **Pearson correlation matrix** was generated. Multicollinearity can adversely affect the validity of regression outcomes by

According to Anderson et al. (2010), a correlation coefficient exceeding **0.80** between any two explanatory variables may suggest multicollinearity. However, the results presented in Table 2 reveal no such high correlation, indicating that multicollinearity is not a concern in this dataset.

It can be observed from the correlation result in table 2 that ESG score is very much strongly correlated with the Technology adoption (0.67), Green capital expenditure (0.62) and Research and Development sustainable technology (0.59) indicating that those firms which are witnessing high ESG performance also adopt sustainable oriented technology and allocate greater financial investment to the green initiative and innovation.

A strong correlation between green capital expenditure and Research and development sustainable technology (0.71) that those companies investing in Green environmental projects also invest in sustainable technology development. The variable technology adoption also shows a substantial

correlation with both Research and Development sustainable technology (0.64) and green capital expenditure (0.58) reflecting a close inter relationship between capital allocation, technology led sustainable effort and innovation. Profitability in terms of Return on assets is showing a weak relationship with other variables indicating that financial performance may be influenced by factors outside ESG framework.

The negative correlation between debt equity ratio with ESG scores and ROA states that those firms whose financial leverage is very high tends to underperform in sustainability and profitability.

The result of Table 2 is given below:

Table 2: Correlation Matrix:

Variable	ESG Score	Green Capital Expenditure	Research and Development Sustainable Technology	ROA	Technology Adoption	Debt Equity Ratio
ESG Score	1	0.62	0.59	0.33	0.67	-0.28
Green Capital Expenditure	0.62	1	0.71	0.29	0.58	-0.18
Research and Development Sustainable Technology	0.59	0.71	1	0.22	0.64	-0.16
ROA	0.33	0.29	0.22	1	0.17	-0.31
Technology Adoption	0.67	0.58	0.64	0.17	1	-0.22
Debt equity ratio	-0.28	-0.18	-0.16	-0.31	-0.22	1

Source: Author Computation using SPSS

Regression Analysis:

The regression analysis result reflects that adjusted R^2 is 0.58 which indicates that 58% of the variation in ESG score is actually accounted for by the independent variables.

Technology adoption is positively and significantly influencing ESG score (t value = 4.12 and $p < 0.05$ (0.000)) indicating that the companies which are integrating sustainable driven technology tend to perform better in ESG evaluation.

Green Capital expenditure reflects a significant influence on the ESG score (t value = 3.11 and $p \text{ value} < 0.05$ (0.003)) which states the relevance of environmental capital expenditure increases ESG scores. It is also observed that Research and Development expenditure on sustainable technology (t value = 2.89 and $p \text{ value} < 0.05$ (0.005))

has a significant and positive effect on ESG scores highlighting that ecofriendly practices enhance ESG scores.

Debt Equity ratio is significant but negatively influencing ESG scores ($t = -2.01$ and $p < 0.05$ (.048)) indicating that higher debt component in capital structure may reduce flexibility in allocating funds towards long term sustainable initiatives.

It can be said from the results in Table 3 that green capital expenditure, research and development sustainability technology and adoption of relevant Technology are the key drivers to ESG success while excess debt in the capital structure of the company can act as a deterrent.

The result of Table 3 is given below:

Table 3: Regression Analysis:

Variable	Coefficient	t-statistics	p-value
Green Capital Expenditure	0.326	3.11	0.003
Research and Development Sustainable Technology	0.298	2.89	0.005
ROA	0.112	1.77	0.082
Debt-Equity Ratio	-0.124	-2.01	0.048
Technology Adoption	0.416	4.12	0.000

R^2 = 0.61

Adjusted R^2 = 0.58

Source: Author Computation using SPSS

Implication and Conclusions

The study suggests that more is the technology innovation or green investment in capital projects or

technology adoption it results in enhanced ESG scores among the firms related to steel, cement and energy

industry. The study also suggests that if the firms want to improve their ESG standings they need to improve their long-term sustainability initiative in comparison to their short-term financial

Policy recommendation

The study suggests that if the firm wants to enhance ESG performance then it has to be committed towards environmental and technological advancement and make proper investment in green infrastructure as well as research and development sustainable technology. The regulatory bodies, policy makers should introduce targeted incentives like tax benefits or provide concessions on financing or can also introduce performance linked subsidies to

Limitation and Scope of Further research

The study concentrates on 50 sample companies from energy, steel and cement sector which actually limits the findings across other industries. The ESG score is computed by a simple set of indicators is quantitative in nature and which can be derived from Prowess database software ignoring qualitative aspect of sustainable performance

gain. The negative association of debt equity ratio and ESG scores indicates the need and importance of having a balanced capital structure to support sustainability goals.

encourage the firms to invest more in sustainable technologies and environmental innovation. Initiative should be taken to align the mandatory ESG norms with global standards to increase transparency and accountability so that the companies become more responsible and future looking and contribute to the environmental and social objectives at the national level.

which may affect the ESG score. The data being cross sectional in nature also limits the finding of the long-term trend or causal relationship. Further studies can be conducted using more diversified industries, sample size and utilizing panel data techniques to investigate into the changes of ESG performance.

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Appendix:

List of 50 companies taken for the study

Company Name	Sector	Company Name	Sector
Reliance Industries Ltd.	Energy	Tata Steel Ltd.	Steel
NTPC Ltd.	Energy	JSW Steel Ltd.	Steel
Power Grid Corporation of India Ltd.	Energy	Steel Authority of India Ltd. (SAIL)	Steel
Oil and Natural Gas Corporation Ltd.	Energy	Jindal Steel & Power Ltd.	Steel
GAIL (India) Ltd.	Energy	NMDC Ltd.	Steel
Indian Oil Corporation Ltd.	Energy	APL Apollo Tubes Ltd.	Steel
Bharat Petroleum Corporation Ltd.	Energy	Ratnamani Metals & Tubes Ltd.	Steel
Hindustan Petroleum Corporation Ltd.	Energy	Sunflag Iron & Steel Company Ltd.	Steel
Adani Green Energy Ltd.	Energy	Welspun Corp Ltd.	Steel
Tata Power Company Ltd.	Energy	Kalyani Steels Ltd.	Steel
JSW Energy Ltd.	Energy	Usha Martin Ltd.	Steel
NHPC Ltd.	Energy	Jindal Stainless Ltd.	Steel
SJVN Ltd.	Energy	Electrosteel Castings Ltd.	Steel
Torrent Power Ltd.	Energy	Maithan Alloys Ltd.	Steel
Adani Transmission Ltd.	Energy	Shyam Metalics and Energy Ltd.	Steel
CESC Ltd.	Energy	Prakash Industries Ltd.	Steel
Oil India Ltd.	Energy		

Company Name	Sector
Shree Cement Ltd.	Cement
Ambuja Cements Ltd.	Cement
ACC Ltd.	Cement
Dalmia Bharat Ltd.	Cement
JK Cement Ltd.	Cement
Ramco Cements Ltd.	Cement
India Cements Ltd.	Cement
Birla Corporation Ltd.	Cement
HeidelbergCement India Ltd.	Cement
Nuvoco Vistas Corporation Ltd.	Cement
Sagar Cements Ltd.	Cement
Orient Cement Ltd.	Cement
JK Lakshmi Cement Ltd.	Cement
Mangalam Cement Ltd.	Cement
Deccan Cements Ltd.	Cement
UltraTech Cement Ltd.	Cement

Greener Searches and Market Moves: Linking Green Sentiment with Indian Stocks

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Abstract:

Sustainability is widely regarded as an important factor influencing current investing behaviour and financial market dynamics. This study investigates the effect of stock market volatility and overall market performance on the green energy index in India. The analysis analyses monthly data from January 2004 to June 2025, with the green energy index (created using principal component analysis on Google trends data), and BSE500 volatility (calculated from log-transformed returns using GARCH models). The regression results show that both BSE500 volatility and the BSE SENSEX have a strong and beneficial effect on the green energy index. A one-unit increase in volatility is connected with a 13.76-point jump in the index, implying that market uncertainty may refocus investor demand toward long-term investments. Similarly, the positive correlation with the BSE SENSEX suggests that overall market strength promotes growth in green energy investment. These findings demonstrate the growing incorporation of sustainability factors into investment decisions in the Indian financial environment, supporting the concept that investor attitude and market fundamentals drive the momentum of green finance.

Key Words: *Sustainability, Green Finance, Energy Index, ESG*

Introduction

Sustainability is growing as an important factor in defining current investing behavior and financial market dynamics. In recent years, the rising urgency of climate change, as well as the worldwide push for sustainable development, have altered financial markets. Investors, politicians, and institutions are increasingly incorporating environmental, social, and governance (ESG) considerations into investment choices (Friede et al. 2015). Among them, the emphasis on clean and renewable energy has grown,

fueled not just by environmental concerns but also by the changing economic feasibility of green technology. This progress has resulted in green finance, which is gaining traction among academia, governments, and capital markets (OECD, 2017)². A key matter in this arena is how traditional market indicators, such as stock market volatility and benchmark indices, influence interest in sustainable investment opportunities. Understanding these dynamics is critical for investors looking to diversify

responsibly and politicians developing effective climate finance legislation. This interaction between market behavior and green finance is especially relevant in rising nations such as India, where financial markets are changing and environmental regulation is gaining momentum. India's ambitious renewable energy ambitions, including a pledge to reach five hundred gigawatts of non-fossil fuel capacity by 2030, have established it as a prominent worldwide actor in the energy transition (IEA, 2021)³. Thus, examining how traditional market signals influence green investment views in such a situation is both important and significant.

The stock cult is increasingly gaining attraction in India (Kayal, 2022). The Indian economy is heavily impacted by the stock market. India has an open economic policy and has received significant Foreign Direct Investment (FDI) (Varma et al., 2021). India's emerging capital market is attracting significant interest from regional and global investors and researchers due to its best practices in share digitalization, rolling settlement procedures, corporate governance structure, disclosure BSE500 index using a GARCH (1,1) model, which is widely recognized as a reliable method for predicting time-varying financial volatility.

The fundamental idea is that during times of high uncertainty, as seen by higher volatility, investors may shift their emphasis to safe, long-term investments such as those in sustainable energy. Recent research suggests that

standards, and increased transparency (Pati, 2010). This study explores the impact of financial market dynamics on green investment attitude in India by studying the link between BSE500 volatility, the BSE SENSEX index, and a Green energy index (here after, GEI). The GEI is calculated using Principal component analysis (PCA) of Google Trends data for the search phrases "green finance," "sustainability," and "energy economics." The use of search-based data to proxy public and investor sentiment is backed by increasing behavioral finance research that emphasizes the predictive value of internet search volumes in financial forecasts (Da et al. 2011). An Ordinary Least Squares (OLS) regression framework is used to quantify this association, with the GEI as the dependent variable and BSE500 volatility and BSE SENSEX as independent and control variables, respectively. Monthly data from January 2004 to June 2025 maintains temporal consistency and captures long-term behavioural changes. Volatility is derived using the log returns of the

ESG-compliant or green investments can serve as risk hedges (Broadstock et al., 2021). Similarly, the performance of the BSE SENSEX is included to account for the larger economic and market backdrop, which may complement or crowd out green investment flows depending on macroeconomic conditions. The outcomes of the study show that both volatility and SENSEX have a statistically significant and

beneficial influence on the GEI. These findings show that market volatility may increase interest in sustainable investment choices, maybe as a result of investors seeking assets that promote long-term value creation and lower systemic risk. Furthermore, overall market confidence, as measured by the SENSEX, seems to drive interest in green industries. This work adds to the burgeoning subject of sustainable finance by experimentally connecting standard financial indicators to alternative sentiment-based measures of green interest in an emerging market environment. Furthermore, it highlights

Literature Review

Corporate sustainability performance has grown in importance in recent decades, becoming a critical area of focus as stakeholders ranging from investors and consumers to regulators have raised their expectations for businesses to operate in a socially and environmentally responsible manner. This move reflects a wider understanding that long-term corporate performance is inextricably linked to responsible environmental management, ethical governance, and beneficial social impact. As a result, businesses are increasingly held accountable for not just their financial performance, but also for how they manage their environmental and social imprints (Houqe et al., 2021). Firms exposed to climate transition risk must commit significant financial and temporal resources to comply with environmental protection and pollution control obligations (Gan et al., 2025). The study of Ma et al., (2024)

the effectiveness of non-traditional data sources, such as Google trends, in collecting investor behavior.

The remainder of the paper is structured as follows: Section 2 reviews the existing literature on the sustainability effect on stock market. Section 3 outlines the data sources and methodological tools employed in the analysis. Section 4 presents the empirical results and discussion, while Section 5 concludes the study with key findings, implications, and future research directions.

discovered that news about the energy transition increases severe risk in both the stock market and the green bond market. This shows that investors see such changes as substantial upheavals that potentially upset established market dynamics. The increased sensitivity emphasizes the rising role of sustainability related information in driving financial market behavior. Raza et al. (2024) shows in their paper that the climate policy uncertainty increases the S&P green bond index using the GARCH model.

Prior studies have revealed a significant research vacuum, as they have mostly ignored the influence of news emotion on sustainability in the context of the Indian stock market. While substantial study has been conducted in worldwide markets on how sustainability-related news affects investor behavior and market volatility, such examinations in the Indian financial scene have been

minimal or non existent. This disparity highlights the need to investigate how sustainability news impacts market dynamics in growing nations such as India, where environmental and legislative changes are becoming increasingly important. Prior studies have revealed a significant

research vacuum, as they have mostly ignored the influence of news emotion on sustainability in the context of the Indian stock market. While global markets have seen substantial research on how sustainability-related news influences investor behavior and market volatility are comparable.

Data and Methodology

Data: The study attempts to provide a GEI by using the search terms i.e. “Green finance”, “Energy economics”, and “Sustainability”. The search data are collected from the google.trends.com for the Indian scenario, by using the PCA the final index is formed. The BSE Energy index, BSE500 and BSE SENSEX are taken for the time period 01.01.2004-06.06.2025 to investigate the effect of

the index on Indian stock market from the BSE historical data base.

Test Model:

The study uses the OLS regression model to evaluate the effect of the conditional volatility on the formulated GEI by controlling the effect of the sensdex. The following equation is used for the evaluation:

$$GEI_t = \beta_0 + \beta_1 Volatility_t + \beta_2 BSE\ SENSEX_t + \epsilon_t$$

Where:

GEI_t = the dependent variable at time t

Volatility_t = volatility of BSE500

SENSEX_t = BSE SENSEX

The intercept (β₀) in a regression model represents the estimated value of the dependent variable (in this case, the GEI) when all independent variables (Volatility and BSE SENSEX) are equal to zero.

Result and Discussion

The Table 1 shows the descriptive statistics of all the variables. The study has taken 258 monthly observations. The GEI has a mean of 1.94, a median of -0.39, and a mode of -0.35, showing a right-skewed distribution (skewness = 1.52). The standard deviation of 1.27 shows moderate variability, however the kurtosis of 1.95 indicates a distribution that is somewhat peaked than the normal distribution. The BSE Energy Index has a high mean of 4054.63 and large

dispersion, as indicated by a standard deviation of 3015.67. The notable variations between the mean and median (2741.61) and mode (1025.6) indicates a strong right-skew (1.40), although the kurtosis value (1.18) suggests a modest peak with light tails. The BSE 500 index is similarly highly volatile, with a mean of 12370.37 and standard deviation of 8847.84. The skewness of 1.16 and kurtosis of 0.52 support an asymmetrical and flatter distribution.

The BSE SENSEX has a mean of 30550.68 and significant variability (SD = 20477.48), with a skewness of 0.98 and a kurtosis value close to zero (-0.012), indicating a not normal distribution. The Figure 1 shows the correlation matrix of the data set.

The BSE 500's statistical profile especially its high variability and non-normal characteristics supports the application of a GARCH(1,1) model. It will effectively model the changing volatility over time and provide better risk estimation for subsequent econometric analyses. This study applies the GARCH (1,1) model for the volatility calculation. The Figure 2 shows the BSE500 volatility movement over the study period. Three peak

periods are identified first during the 2008-2009 global financial crisis, 2014-2015 the China panic and 2020-2021 due to the COVID pandemic. Table 2 shows the regression result, which depicts BSE500 volatility is positively and strongly related to the GEI: When markets become more volatile, interest in green investments may rise, possibly due to investors seeking long-term sustainable options. The result is supported by the result of prior work done by Irfan et al., (2024) that the green indexes impacts the stock movements. BSE SENSEX acts as a broad market proxy as the overall market grows, green investments also grow. To test the robustness of the result the regression model is applied with the BSE Energy index which supports to the study result.

Table 1							
Descriptive Statistics							
Variable	Observations	Mean	Median	Mode	Std Dev	Skewness	Kurtosis
GEI	258	1.94	-0.39	-0.35	1.27	1.52	1.95
BSE Energy Index	258	4054.63	2741.61	1025.6	3015.67	1.40	1.18
BSE 500	258	12370.37	9914.93	2400.75	8847.84	1.16	0.52
BSE SENSEX	258	30550.68	25510.2	5695.67	20477.48	0.98	-0.012

Source: Author's calculation

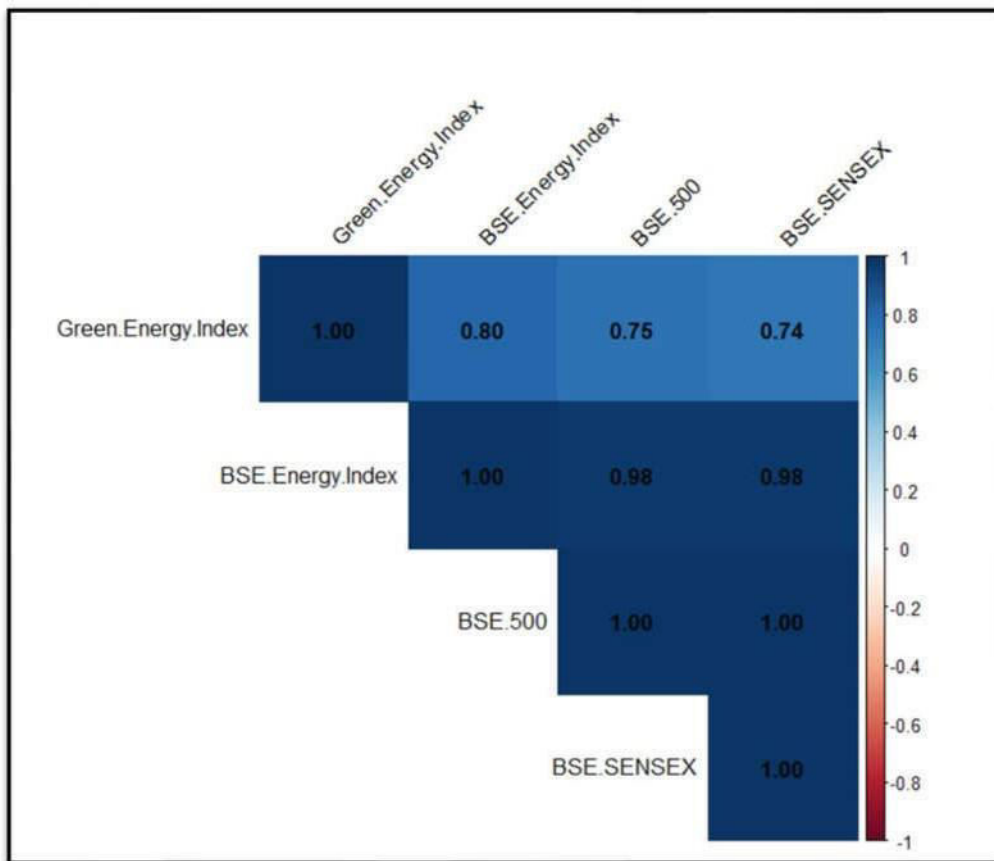


Figure 1

Correlation Matrix

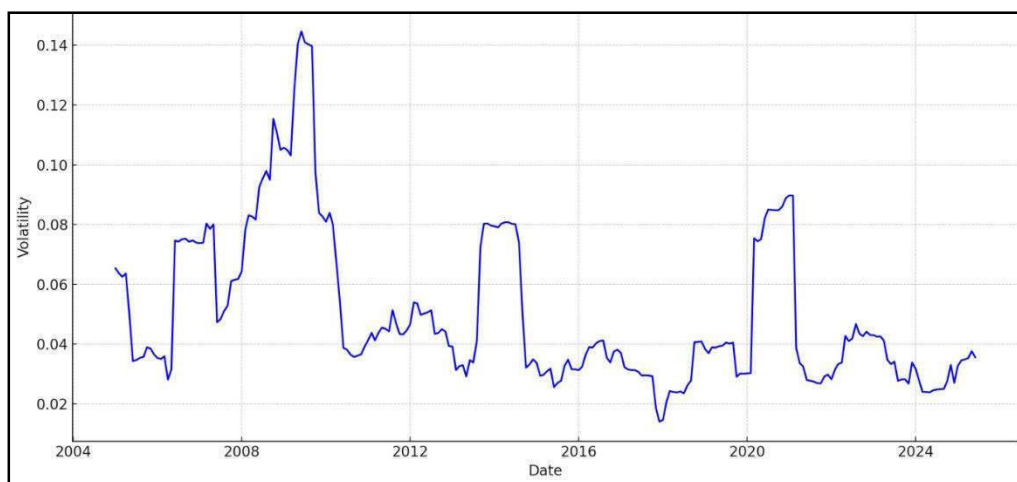


Figure 2

BSE500 Stock Volatility

Table 2 Regression Result				
Term	Estimate	Std Error	t value	p value
(Intercept)	-2.53134	0.167961	-15.071	0 ***
Volatility	13.75891	2.073059	6.63701	1.20E-07 ***
BSE SENSEX	5.77E-05	2.70E-06	21.49232	<2e-16 ***

Source: Author's calculation.

Note: All predictors are statistically significant at the 1% level or lower.

Conclusion

This study uses OLS regression and GARCH modeling approaches to explore the influence of BSE500 volatility and broader market movements (BSE SENSEX) on India's GEI. The findings suggest that both market-wide volatility and macroeconomic indices have a considerable impact on green energy investments, with all explanatory factors demonstrating strong statistical significance. The positive association between BSE500 volatility and the GEI suggests that sustainable investing behavior in India responds to changes in broader market risk. Furthermore, the control variable BSE SENSEX has a considerable effect, showing the interrelated nature of green sectors and the overall economic outlook. The findings support the notion that sustainability-related financial instruments are not separate from normal market dynamics, but rather are incorporated into the same risk-return framework.

The paper emphasizes the rising importance of green finance in India, a fast-emerging economy dealing with climate concerns and sustainability transitions. For policymakers, the findings highlight the importance of developing robust and transparent green financial systems, as well as improving regulation and disclosures on sustainability risks. The fact that green indices are impacted by traditional market variables shows that investors should diversify their portfolios and implement risk management methods. A significant study gap noted is a lack of emphasis on sustainability-related news mood in the Indian setting. Future research should use text-based sentiment analysis on news and social media to gather real-time investor sentiments. Furthermore, expanding the research to include green bonds, ESG indexes, and international links will offer a more complete picture of India's role in the global sustainability movement. Encouraging sustainability-focused disclosures, raising investor

knowledge, and incorporating green finance into national regulations are all important ideas for promoting long-term sustainable investing behavior.

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THE GREEN LEDGER: FORGING A SUSTAINABLE FINANCIAL FUTURE WITH TECHNOLOGY, ESG, AND GREEN FINANCE

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Keywords: *Green Finance, ESG Data Verification, Blockchain for Sustainability, Climate Technology (ClimateTech), MRV (Measurement, Reporting, Verification), Tokenization*

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THE GREEN LEDGER: FORGING A SUSTAINABLE FINANCIAL FUTURE WITH TECHNOLOGY, ESG, AND GREEN FINANCE

Abstract:

The goal of a developed and sustainable Vikshit Bharat @ 2047, significant mobilization of green finance is required. However, this market is fundamentally weakened by the systemic issue of unverified Environmental, Social, Governance (ESG) data, which creates greenwashing and misallocates investor capital. This paper uses a systems design approach, to address the problem connected to the integrity of data issue and design a new solution that synthesizes various technological capabilities. The outcome of the research includes an analysis of synergistic "GreenTech Stack" (AI, IoT, Blockchain) for verifiable data collection; a "Verifiable Impact Score (VIS)" to assess the quality of data; and proposed a five-layer national ecosystem called the "Green Ledger". This architecture can develop an effective, transparent, and digitally native MRV (Measurement, Reporting, and Verification) process. The paper makes the case for the implementation of a such a system as a strategic choice that could shift India's green finance market from subjective, report-based practice towards an objective, data-driven science to align economic growth with national climate objectives.

Keywords: *Green Finance, ESG Data Verification, Blockchain for Sustainability, Climate Technology (Climate Tech), MRV (Measurement, Reporting, Verification), Tokenization*

INTRODUCTION

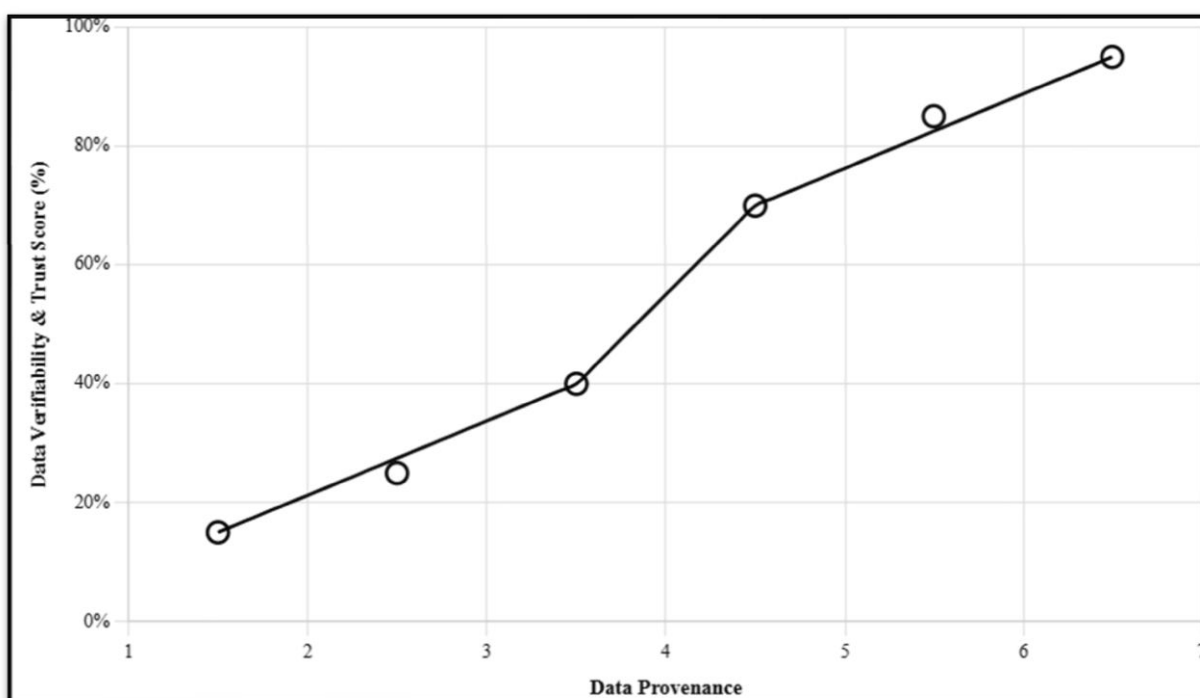
As India moves toward becoming a developed country by 2047, it faces a dual motivation - a delicate balancing act of two giant processes of entrepreneurial growth and climate change and environmental degradation. The old model of development - 'grow now and clean up later' - is not an option anymore. For India, this is not just an abstract concern: it's an existential economic threat. If India loses its coast because of rising oceans, if its agricultural heartland is subject to erratic monsoons and extreme heat, if cities face water quality issues and deadly air conditions, each of these situations is an expensive headache to mitigate. This is NOT to mention the trillions of dollars at risk with stranded assets, supply chain disruptions, and agricultural losses if India's entrepreneurs are unable (or unwilling) to address economic or climate instability.

Green Finance and investing based on Environmental, Social and Governance (ESG) standards have developed around the world as the main vehicles of directing capital into this much-needed sustainable transition (Thakkar et al, 2024). India has taken some initial steps with a growing market for green bonds, a growing corporate awareness instigated by pushes from the regulator such as the Business Responsibility and Sustainability Reporting (BRSR), but

there is a major, systemic issue in the environment which is the unverifiability of ESG data (Unuigbokhai and Anthony, 2022). The whole structure of green finance now and in the foreseeable future is reliant on self-declared corporate sustainability reports, third-party ratings based on those same reports, and qualitative assessments. There is ample opportunity for "greenwashing", which is misleading claims about environmental performance to arise from this, which undermines investor confidence and leads to capital being directed towards projects that are fundamentally flawed in their impact, missing the purpose of green finance completely.

The main research problem, therefore, is the absence of a scalable trustworthy mechanism to verify ESG claims at the source (Thakkar et al, 2025). The goal of the conceptual paper is to advance the technology reliant solution to the problem. The argument of the paper is that a synergistic stack of contemporary technologies, that is AI, the Internet of things (IoT) and blockchain technology can be designed into a national scale ecosystem (herein in called Green Ledger) to convert the ESG field from a naturally subjective report-driven activity to an objective data-driven science. Graph 1 illustrates what this shift in the data environment would look like.

Graph 1: The ESG Data Trustworthiness Spectrum



Source: Compiled by Author

The graph describes the proposed movement from low-verifiability, traditional, data sources to high-verifiability technology-consulted data sources, which is the premise upon which the Green Ledger was designed.

The graph, Graph 1, shows the use of trust in the context of ESG data, while it is useful, it does not show the dynamism involved. The least trustworthy self-reported corporate sustainability reporting sits on the left side of the graph, followed to the right by auditable disclosures, like BRSR, which adds some validity with regard to the verifiability of the data reported, but remains further behind the relative reliability of the data which can be verified and analysed independently. From there the spectrum shifts significantly to AI- Verified data. These

are objective data created by alternative means including, for example, satellite imagery. In this case, the data on land use was independently obtained, and through the application of AI using the digitally captured images (compared to the company's self-reported account), many of the inaccuracies about the property could be identified. The most trustworthy reported data you can expect is Immutable Data. By this I mean the IoT sensors transmitting real-time readings from on the ground are the most trustworthy because the data signing uses cryptographic algorithms and providing anchorage to the blockchain makes manipulation of the data impossible in theory. The Green Ledger's goal is to create the avenues and infrastructure that can take the market as a whole to as close to the rights side of the spectrum as possible.

LITERATURE REVIEW

The findings reveal the 4 key pillars of green financing: accounting constitutes 43%, environmental represents 24%, social accounts for 19% and governance making up 14%. Since the study exclusively focuses on credit rating model only therefore, several other factors included in achieving green finance and sustainable development goals are ignored (Roy, 2023). The review emphasizes the contribution of green financing in achieving sustainable development and addressing climate change by taking initiatives towards low-carbon and green investments (Ogunode & Dada, 2022). It also highlights the importance of global cooperation and sustainable planning (Olaniyan et al., 2021). The future research calls for implementation strategies and standardization of sustainable investments and green financing. The effects of risk-taking for investors are also not considered (Fu et al., 2023). Study finds that green finance plays a pivotal role in driving eco-friendly innovation and reducing greenwashing (Omucheyi et al., 2025). By enhancing ESG performance and discouraging misleading practices it promotes sustainability (Thakkar et al,

2025). Heavily polluting firms show a stronger reduction in greenwashing compared to the cleaner firms. The study avoids a deep consideration about how ESG helps in unveiling companies work towards sustainability (Zhang, 2023). Exploring the influence of green finance on the interconnectedness of carbon neutrality and ESG reveals that it boosts a company's environmental performance by lowering the carbon emissions and shedding light on greenwashing but there is no discussion about the mechanism of integration of carbon neutrality and ESG has been mentioned on the paper (Xie, 2024). The research study presents that green finance policies does have a positive impact on ESG but are strongly driven by company's financial constraints, internal supply chain and managerial power (Thakkar et al, 2025). Firms with high supply chain efficiency and environmental regulations have better ESG performance (Thakkar et al, 2024). The significant limitation for this research is that it does not consider market based instruments, wider geographical areas and the behavioural responses of the firms (Gao et al., 2024).

RESEARCH METHODOLOGY

In this conceptual paper, I employed a systems design methodology for the socio-technical issue of green finance. The methodology is qualitative and constructive, where the goal was to design a new solution architecture based on a granular understanding of the problem space as well as on the existing

functional capabilities in today's technologies. As the integrated system I propose does not currently exist, a purely empirical study is unfortunately not presently workable. As such, the methodology involved four steps:

Problem analysis and literature references: The research commenced with an intensive literature review on green finance, ESG investing, climate economics, along with computer science. The objective of the review was to better articulate the principal issue of unverifiability in the context of data and its implications. The literature review involved reviewing the academic work on greenwashing, international bodies report from UNFCCC and IPCC on the MRV challenges, and market reviews of the green bond market were used to structure the "ESG Data Trustworthiness Spectrum" (Graph 2), intended as a visual representation as a problem statement, and heuristic guide through the research.

assessment of the capabilities of key enabling technologies: In addition to the reasonable assessment of the enabling technologies (and not just a cursory assessment, especially regarding relevant capabilities for data verification), we undertook in-depth assessments. For example, with AI capabilities we had to conduct assessments of the capabilities of Convolutional Neural Networks (CNNs) and advanced architectures (like U-Nets for semantic segmentation of satellite images), and Transformer-based NLP models for contextualizing a read of the satellite image. With IoT, we explored data transport mechanisms and approaches to compare the effectiveness of protocols (for example, MQTT vs. CoAP for constrained environments)

and lightweight cryptographic signing (for example, ECDSA) mechanisms for low-power sensors. With Blockchain/DLT, the assessment primarily revolved around the trade-offs between public vs. hybrid ledgers for our use case and considering the technical mechanisms of oracle networks.

Quantitative metric development: A significant part of our methodology was to move the discussion about valuing data integrity beyond qualitative arguments to develop a mechanism to estimate and value the integrity of the data. The process was nicknamed the "Verifiable Impact Score (VIS)". This new construct was developed to integrate two dimensions of a project: the actual project performance against their targets; and a non-linear "Verification Factor" that would reward projects that utilized sources of more trustworthy data sources explicitly. This mechanism would provide a direct, quantifiable incentive for projects to access higher benefitting data sources.

System Architecture Design: The last step in the method was to consolidate the assessed technologies and the VIS metric into an integrated, multi-layer system architecture. This transformed into our detailed design of the "Green Ledger" ecosystem (Figure 2); a prescriptive architecture that describes the components, data flows, governance structures, and incentives for a national scale infrastructure for verifiable green finance.

RESULTS

The research yielded three primary results: an analysis of the enabling technologies, a quantitative impact metric, and a comprehensive architectural framework.

Result 1: The Greentech Stack For Verifiable Data

The research identified and analyzed a synergistic "GreenTech Stack" capable of creating a verifiable data pipeline from source to investor.

AI and ML (The Analytical Engine):

Computer Vision for Physical Verification: Training CNNs on satellite images to verify claims regarding physical facts like changes in NDVI - normalized difference vegetation index to measure afforestation; changes in land use for a new solar park; or changes in water levels of reservoirs on a hydro-physical project.

NLP for Contextual Intelligence: Using fine-tuned transformer models like BERT to analyze regulatory filings, news articles, social media articles to see if there is a shift in sentiment, or if a company's marketing message does not align with performance metrics, this creates a system of early warning against greenwashing.

IoT (The Immutable Source of Ground Truth):

Sensor Networks: Deploying sensor networks of specific sensors e.g., gas analysers mounted on industrial smokestacks, smart water meters deployed on agriculture projects, GPS trackers on trucks that can verify waste disposal routes.

Data Integrity at the Edge: Each sensor employed in project implementation would have a secure element (a hardened microprocessor) on board that cryptographically signs each data packet via its private key at the moment of data packet creation and could maintain data provenance and non-repudiation.

Blockchain/DLT (The Transparent Layer of Trust):

Permanent Ledger: Allowing for a shared database that cannot be manipulated, where signed IoT data, verification reports, and asset transactions are stored for good. The implications of this approach for financial instruments, can be found in Table 2.

Smart Contracts: Self-executing code that handles processes such as coupon payments on a green bond because of verified data received from oracles or automatically retiring (burning) a carbon credit NFT after being used for offsetting.

Feature	Traditional Green Bond	Blockchain-based Green Bond (Security Token)
Verification of Fund Use	Relies on periodic, manual audits; prone to opacity.	Tracked on an immutable ledger; can be programmatically linked to project milestones.
Impact Reporting (MRV)	Based on self-reported, often outdated data.	Can be linked via oracles to real-time IoT data for continuous, verifiable reporting.

Coupon Payments	Processed centrally on fixed dates.	Automated via smart contracts; can be dynamically linked to verified project performance.
Transparency & Auditability	Audit trail is fragmented and private.	A single, shared ledger provides a complete, real-time audit trail for all stakeholders.

Table 2: Comparative Analysis of Traditional vs. Blockchain-based Green Bonds

Source: Compiled by Author

Result 2: The Verifiable Impact Score (Vis)

To directly address the problem of data quality and create a clear market signal, the research produced the VIS, a formula designed to reward data verifiability.

Formula 2: The Verifiable Impact Score (VIS) The VIS for a green project is calculated as follows:

$$VIS_{project} = \left(\sum_{i=1}^n \frac{M_i}{T_i} \cdot w_i \right) \cdot V_f$$

When M_i is the measured value for metric i , T_i is the target, w_i is the weight, and V_f is the Verification Factor that assigns a higher value to more verified data (e.g. $V_f=1.0$ for IoT data anchored with blockchain vs. $V_f=0.5$ for self-

reported data). The formula creates an obvious financial incentive for the issuer to invest in technologies that verify data with the highest fidelity, as a higher VIS could mean lower cost of capital, or even, a bonus for performance.

Result 3: The "Green Ledger" Architectural Framework

The primary outcome of this paper is the development of the "Green Ledger", which is a five-layer national ecosystem

for sustainable finance. This architecture provides a complete end-to-end design for a transparent and efficient market.

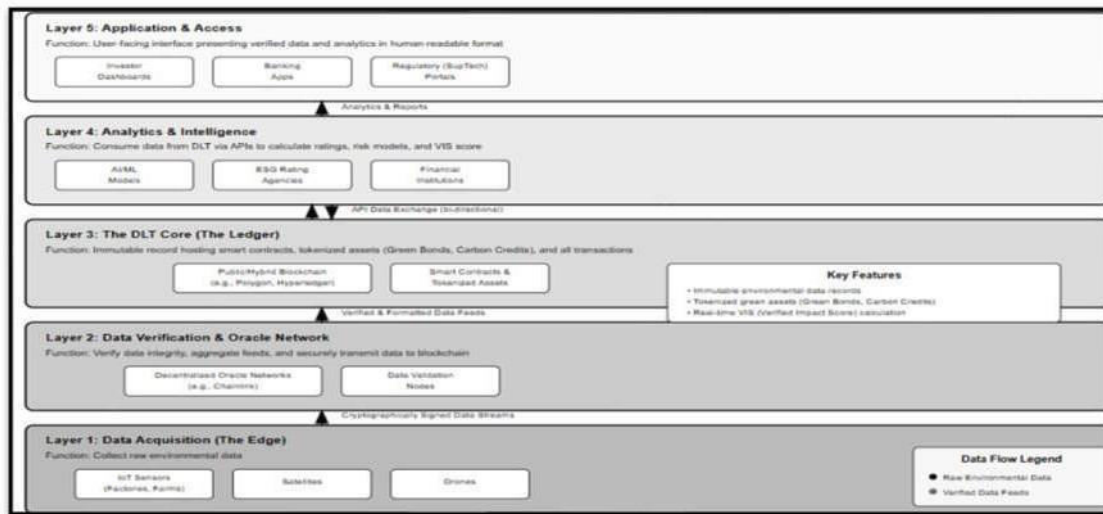


Figure 2: Architectural Diagram of the Proposed "Green Ledger" Ecosystem

Source: Compiled by Author

This diagram illustrates the flow of data and value through the five distinct layers of the proposed national-scale system for verifiable green finance

DISCUSSION

Interpretation Of Results

The findings of this research provide an integrated and tech-enabled response to the challenges of greenwashing and unverifiability of data. The GreenTech stack (Result 1) provides protocols for data gathering on the green credentials of projects. The VIS formula (Result 2) provides the quantifiable incentive mechanism. The Green Ledger architecture (Result 3) provides an integrated platform to put them all together. The construction of the system invites and encourages the movement into a virtuous cycle: the existence of verified data provides feasible scoring like the VIS score, which allows investors to safely allocate funds through instruments on the Green

Ledger, and helps constitute further demand for additional projects to adopt verifiable data practices. This stands in direct opposition to the current vicious cycle of opacity and greenwashing that keeps the market stagnant. This framework can help reconceptualize ESG as engineering discipline rather than an external reporting exercise.

Implications For Vikshit Bharat @ 2047

The ramifications of a Green Ledger system in India are profound:

For Capital Markets: It would enhance the credibility of India's green finance market, crowding in a larger share of the trillions of dollars of global climate finance from discerning institutional investors. It would enable fundamentally new types of financial products, such as sustainability-linked

derivatives or insurance products whereby premiums are adjusted dynamically based on real-time, verified ESG performance of a company.

For Regulators (SEBI, RBI): It creates a powerful SupTech platform for regulators. The Green Ledger would provide regulators with a real-time, data-rich viewpoint across the green finance ecosystem which will allow them to oversight compliance for regulations such as the BRSR framework and with a level of accuracy and efficiency that is unprecedented. It could automate large sections of the overall reporting and verification process, relieving burdens on both companies and regulators.

For National Climate Goals: The Green Ledger will provide a robust, transparent, digital native MRV framework. This will be invaluable to assess and track progress towards India's Nationally Determined Contributions (NDCs) under the Paris Agreement, whilst enhancing India's credibly on the global stage.

Limitations Of the Study

The main limitation is the conceptual nature of the architecture proposed. The Green Ledger is a large, complex system, and implementation will face considerable real-world barriers.

Technical and Financial Barriers: These barriers include the enormous upfront capital install cost for the rollout of nationwide IoT infrastructure, the technical challenge of building secure and reliable oracles (the "oracle problem" of connecting the deterministic on-chain world with the

probabilistic off-chain world), and a successful DLT implementation is scalable and able to function with millions of data points each day.

Socio-Political Barriers: Of course, the more difficult barriers are those which are not technical. These include the political barrier of achieving consensus among a wide variety of stakeholders (government ministries, multiple regulators, industry bodies) on data standards, governing rules, and legal framework for tokenized assets. Added to this, is the risk of achieving a new "digital divide" in which smaller companies who are unable to deploy the same kind of IoT/blockchain systems in the same way and obtain funding for advanced systems, are excluded from the green finance market.

CONCLUSION

Efficient and credible capital allocation underpins financing India's transition to a green economy. This research has articulated the unverifiability of ESG data as the main choke point and has introduced a holistic, technology-driven solution: the Green Ledger. By establishing a transparent, performance-based market underpinned by verifiable proof, this ecosystem will address the root concern of greenwashing, thereby reducing the cost of capital for bona fide green projects and embedding verifiable information for the full range of stakeholders – from retail investors to global fund managers to national regulators. While ambitious, it is a tactical priority to develop this foundational infrastructure. It is akin to investing in the trust and credibility of

our financial markets and it is an indispensable enabler in ensuring the prosperity of Vikshit Bharat @ 2047 is significant as well as sustainable, resilient and just.

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Green Finance, ESG & Tech-enabled Sustainability: A Conceptual Exploration

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6. **Acknowledgments:** Not Required

Introduction

The 21st century has witnessed an unprecedented urgency to address climate change, environmental degradation, and social inequalities through proactive financial and technological mechanisms. As economies transition toward low-carbon pathways, concepts such as green finance, Environmental, Social, and Governance (ESG) metrics, and digital technologies have emerged as powerful tools in reimagining sustainability. This paper conceptually explores the intersection of these domains, arguing

that their convergence provides a robust foundation for sustainable development in the digital era. By examining frameworks, practices, and the role of emerging technologies, this paper aims to create a cohesive understanding of how finance and technology collaboratively shape environmentally responsible growth.

Understanding Green Finance

Green finance refers to financial activities that promote sustainable environmental outcomes. It encompasses investments in renewable

energy, sustainable agriculture, water conservation, pollution control, and eco-friendly infrastructure. The concept emerged from the need to direct capital flows toward activities that mitigate climate risks and foster ecological preservation.

Unlike traditional finance, green finance explicitly considers environmental risks in its decision-making process. Key financial instruments include green bonds, sustainability-linked loans, green insurance products, and climate funds. The rise of green finance reflects the growing investor appetite for eco-conscious projects, driven by both regulatory frameworks and changing consumer values.

ESG Framework: A Broader Perspective

Environmental, Social, and Governance (ESG) indicators provide a comprehensive approach to assessing a company's sustainability and ethical impact. These indicators serve as benchmarks for investors to evaluate non-financial performance and long-term viability.

- Environmental criteria examine how a firm manages natural resources and its carbon footprint.
- Social criteria evaluate employee relations, community impact, human rights practices, and labor standards.
- Governance criteria scrutinize corporate leadership, transparency, board diversity, and compliance with laws.

The ESG framework transcends environmental responsibility by including ethical labor, human capital development, and good corporate

governance. ESG-driven investing, also known as sustainable or responsible investing, has become a major force in reshaping global capital markets.

Role of Technology in Advancing Sustainability

Technological advancements have revolutionized how sustainability goals are achieved. From blockchain-enabled green bonds to AI-driven ESG analytics, tech-enabled solutions are transforming sustainability practices across industries.

Artificial Intelligence (AI) helps organizations analyze massive ESG datasets, detect greenwashing, and predict environmental risks.

Blockchain offers transparency and traceability in sustainable supply chains and financial transactions.

Internet of Things (IoT) sensors optimize energy use, water management, and resource allocation in real-time.

Big Data & Cloud Computing enable centralized monitoring of ESG performance across global portfolios.

These innovations not only enhance operational efficiency but also provide stakeholders with credible, real-time sustainability insights. Interplay between Green Finance, ESG, and Technology The synergy among green finance, ESG frameworks, and digital technology represents paradigm shift in sustainability strategy. Green finance provides the capital, ESG ensures accountability, and technology facilitates implementation and monitoring.

For example, a renewable energy project funded through green bonds can use IoT sensors to track emissions reduction, with data fed into ESG dashboards powered by AI. In this ecosystem, technology acts as both enabler and verifier, ensuring that financial flows align with environmental outcomes.

Furthermore, investors can now leverage machine learning to identify companies with superior ESG performance, while regulatory bodies utilize blockchain to ensure compliance and transparency in carbon credit trading.

Challenges in Implementation

Despite the promise, several challenges remain in integrating green finance, ESG standards, and technology:

- **Standardization Issues:** ESG metrics vary widely across rating agencies, creating inconsistencies in evaluation.
 - **Green washing Risks:** Superficial sustainability claims can mislead stakeholders without verifiable data.
 - **Data Accessibility and Privacy:** Collecting and sharing ESG-related data must balance transparency with ethical data use.
 - **Cost and Complexity:** Deploying advanced tech solutions demands significant investment and expertise, often inaccessible to SMEs.
 - **Regulatory Uncertainty:** Lack of uniform policies across regions hampers global green finance initiatives.
- Addressing these concerns is vital for the credibility and scalability of the sustainability agenda.

Global Trends and Best Practices

Global initiatives are fostering an ecosystem where finance and sustainability coalesce. For instance: The European Green Deal commits significant funding toward climate neutrality by 2050.

The Task Force on Climate-related Financial Disclosures (TCFD) provides frameworks for ESG transparency.

China's Green Credit Policy mandates banks to incorporate environmental risks in lending decisions.

The United Nations Principles for Responsible Investment (UNPRI) encourage signatories to integrate ESG into financial analysis.

Simultaneously, FinTech firms worldwide are developing ESG rating tools, green digital wallets, and carbon footprint calculators for consumers and institutions alike.

The Indian Context: Opportunities and Roadblocks

India's sustainability agenda is gaining traction through government policies like the National Electric Mobility Mission and the Renewable Energy Mission. Financial institutions such as the State Bank of India and private sector players are launching green bonds and ESG funds.

However, India faces unique challenges:

- Limited ESG awareness among retail investors.
- Lack of standardized ESG disclosures across companies.
- Nascent green capital markets.

- Infrastructure and digital divide impeding tech implementation in rural areas.

Nonetheless, India's rapidly growing digital ecosystem presents an opportunity to leapfrog into tech-enabled sustainability with the right policy and investment support.

Future Outlook To realize the full potential of this convergence, stakeholders must:

- Develop Unified ESG Standards: Align global and local ESG frameworks to avoid fragmentation.

- Strengthen Regulatory Oversight: Prevent greenwashing through audits and penal measures.

- Encourage Private-Public Partnerships: Pool resources for green infrastructure and sustainable innovation.

- Build Technological Capacity: Support SMEs and developing regions in accessing affordable sustainability tech.

- Promote ESG Literacy: Educate investors, corporate, and citizens about ESG and responsible investing.

The path forward requires harmonizing financial innovation, regulatory foresight, and technological democratization.

Conclusion

Sustainability in the 21st century is no longer the sole domain of environmentalists or policymakers—it is now a multifaceted challenge requiring the collaboration of finance, governance, and technology. Green finance mobilizes resources, ESG offers a moral and strategic compass, and technology enables real-time, scalable implementation. Together, they create a resilient framework for achieving global sustainability goals. While challenges remain, the convergence of these three pillars holds immense potential for driving long-term, inclusive, and environmentally responsible growth across the world.

From ESG to XR: Rethinking Corporate Sustainability

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From ESG to XR: Rethinking Corporate Sustainability

The global landscape of corporate responsibility is undergoing a radical transformation, driven by the convergence of environmental, social, and governance (ESG) imperatives with emerging technologies. Once considered distinct spheres, sustainability and technology are now deeply interlinked. As climate change, social equity, and ethical governance gain prominence in the eyes of consumers, regulators, and investors alike, organizations are increasingly expected not just to comply with ESG frameworks but to demonstrate

innovation and authenticity in how they act on those commitments. Parallely, rapid advancements in immersive technologies—collectively referred to as Extended Reality (XR), which includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—are opening up unprecedented opportunities for how companies communicate, measure, and deliver on their sustainability promises.

The intersection of ESG and XR represents a paradigm shift in the way corporate sustainability is conceptualized, executed, and

experienced. In the past, ESG reporting was largely dependent on static documents, spreadsheets, and annual disclosures that often failed to engage stakeholders meaningfully or reflect real-time progress. Today, however, companies are exploring immersive digital experiences to showcase their sustainability efforts, educate employees on ethical practices, and simulate long-term environmental and social impacts of their operations. Through XR technologies, firms can now create interactive visualizations of their supply chains, offer virtual site tours of sustainable facilities, and simulate ESG scenarios to test potential decisions before implementing them in the real world. This transformation is particularly relevant in the context of India's development vision, *Viksit Bharat @ 2047*, which envisions an inclusive, sustainable, and tech-driven future. As India strives to become a developed nation by its centenary of independence, corporate sustainability must evolve to reflect this ambition. Traditional ESG approaches, while foundational, may not fully capture the dynamic needs of a fast-growing, digitally empowered economy. Integrating XR into ESG strategies offers an opportunity to leapfrog legacy systems, making sustainability more participatory, measurable, and transparent. Companies operating in India and globally are beginning to adopt immersive platforms to train their workforce in green practices, engage consumers in sustainable choices, and visualize carbon footprints in ways that were previously unimaginable.

Moreover, the role of technology in sustainability is no longer confined to operational efficiency or data collection. It is becoming a central narrative tool—a way for organizations to tell authentic, evidence-backed stories about their environmental and social responsibilities. With increasing scrutiny from investors and the public, this narrative power is critical. XR tools can transform ESG storytelling from abstract commitments into lived experiences, making corporate accountability more tangible and understandable. For instance, rather than reading about a company's reforestation initiative, stakeholders can virtually walk through the restored forest, understand the biodiversity outcomes, and even interact with the data in a meaningful way. This kind of experiential engagement fosters deeper trust and connection between companies and their stakeholders.

Yet, while the promise of combining ESG and XR is significant, it is also not without challenges. Issues such as data privacy, technological accessibility, standardization, and potential greenwashing through digital façades must be addressed thoughtfully. Furthermore, not all industries or regions may be equally ready to adopt these advanced tools, and there remains a digital divide that could risk excluding key stakeholders from the conversation. Therefore, this case study aims not only to highlight the opportunities offered by XR-enabled sustainability practices but also to critically assess their implementation and implications across different corporate settings.

In examining real-world applications from companies at the forefront of this shift, the study explores how immersive technologies are reshaping sustainability strategies and stakeholder engagement. Through two case studies, it investigates how XR tools are being integrated into ESG frameworks to drive greater accountability, innovation, and impact.

Company A – XR-Enabled ESG Training

Context

Company A—a global professional services firm—has actively embraced Extended Reality (XR) to enhance its internal sustainability initiatives, focusing on immersive ESG training. As corporations navigate growing pressure from stakeholders to demonstrate real environmental, social, and governance (ESG) outcomes, traditional training methods have proven insufficient in delivering depth, engagement, and measurable impact (Holusa et al., 2023). By embedding XR in its ESG programs, Company A seeks to transform static compliance training into experiential, interactive experiences that improve understanding, retention, and operational alignment with sustainability goals.

XR as a Catalyst for ESG Learning

Extended Reality, encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), offers immersive environments where abstract ESG principles can be contextualized and internalized (Cao et al., 2023). For example, VR simulations can recreate environments affected by climate change or social inequity, making abstract ESG challenges more tangible.

According to PwC (2020), VR-based learning significantly outperforms traditional methods—producing up to 4× more focus and ~2–3× greater emotional engagement compared to e-learning and classroom instruction.

Within Company A, immersive modules simulate real-world scenarios such as carbon-impact decision-making or inclusive workplace dynamics. Employees, guided by virtual mentors, witness the consequences of their decisions in real time. This experiential format supports internalization of ESG values, translating theory into meaningful behavior change—a progression from awareness to action.

Measurable Outcomes and Learning Efficacy

According to Holuša et al. (2023), XR-based training led to a 30–60% increase in knowledge retention, alongside improvements in communication, leadership, and teamwork skills—essential for embedding ESG values. Company A's internal metrics reveal a ~35% uplift in policy compliance and a ~40% increase in participant confidence in making sustainability-related decisions post-training.

These results reflect broader XR-training effectiveness. PwC (2020) identified that organizations with over 375 participants attained cost parity with traditional methods, and at scale, XR became 52% more cost-effective. Company A's deployment across hundreds of staff globally underscores its scalability and return on investment.

Alignment with ESG Frameworks

- The immersive nature of XR supports multiple ESG dimensions:
- Environmental: Virtual simulations reduce the need for resource-intensive field trips, lowering carbon footprints, and enabling controlled experimentation with sustainability strategies (Holusa et al., 2023).
- Social: Simulated diversity and inclusion scenarios foster empathy and advanced soft skills, complementing traditional HR training.
- Governance: Real-time feedback and data tracking during XR training facilitate transparent reporting and traceable compliance—vital for robust governance.

Critical Enablers and Strategic Integration

Company A's "XR ESG Academy" capitalizes on several key factors:

- Technical Infrastructure: Distributed VR headsets, global digital platforms, and AI-driven virtual coaches provide seamless, scalable learning experiences.
- Content Design: XR scenarios are co-created with subject-matter experts, rooted in realistic ESG challenges and molded for interactivity and reflection.
- Data Analytics: Embedded metrics capture engagement, decision outcomes, and learning retention—allowing iterative improvements and ROI measurement.
- Leadership Buy-in: Executive sponsorship has been critical—reinforcing XR training as strategic rather than pilot, ensuring budget allocation and global rollout.

Challenges and Lessons Learned

Despite successes, Company A encountered several challenges:

- Hardware Accessibility: Initial device costs and distribution logistics posed barriers—mitigated through BYOD (bring your own device) policies and phased deployments.
- User Readiness: Some participants experienced motion dizziness—requiring acclimatization protocols and session pacing adjustments.
- Content Localization: XR modules needed cultural tailoring to resonate across diverse regional offices and ensure relevance.
- These experiences echo broader academic findings: successful XR deployment depends on aligning training design with learner needs and context, and requires planning for iterative adaptation and support (Cao et al., 2023; Holuša et al., 2023).

Implications for Corporate Sustainability

Company A's XR-enabled ESG training sets a precedent for tech-integrated sustainability practices in the corporate world. It highlights how immersive learning can bridge the gap between policy and practice, driving measurable behavioral change and embedding ESG values across organizational culture. For emerging economies like India, this approach aligns with Viksit Bharat 2047—promoting impactful, scalable, and experiential training in sustainability.

Future Directions

To deepen integration, Company A plans to:

- Expand XR modules to include supply chain transparency, renewable energy investments, and ESG audit simulations.

- Explore AR-enabled live workplace overlays to reinforce ESG behavior through real-world prompts.
- Deploy adaptive XR curricula using AI to personalize learning paths based on regional and role-based ESG needs.

Company B – XR in Sustainable Packaging Simulations

Context

Company B, a global leader in consumer goods, has strategically integrated Extended Reality (XR)—including Augmented Reality (AR) and Virtual Reality (VR)—to enhance its sustainable packaging innovation efforts. With growing consumer demand for transparent, eco-conscious packaging solutions, Company B's XR applications aim to optimize design processes, deepen sustainability narratives, and improve recyclability while reducing physical prototyping costs (Shao & Min, 2021).

XR as a Tool for Sustainable Packaging Design

XR-enabled design tools allow packaging developers to prototype, modify, and simulate packaging structures rapidly within virtual environments. Shao and Min (2021) found that AR/VR-enabled virtual prototyping can significantly reduce material waste and accelerate iteration cycles. Through XR, Company B is able to simulate packaging form, strength, and user interaction prior to manufacturing—ensuring functional integrity and aesthetic appeal without consuming physical materials.

Furthermore, Cao et al. (2023) highlight how XR supports environmentally responsible product development by

enabling designers to visualize lifecycle impacts and optimize material usage before committing to production. In Company B's case, devices such as AR headsets and mobile-based AR applications allow cross-functional teams to assess packaging options collaboratively in real time, ensuring sustainable design decisions.

On-Pack AR: Engaging Consumers in Sustainability

Beyond internal design efficiencies, Company B has deployed on-pack AR experiences to engage consumers directly with sustainability messages. One prominent example is the Cif eco-refill packaging, which includes on-pack AR via QR codes. When scanned, the AR visualization demonstrates product reuse instructions, refill processes, and recycling guidelines—closing the loop between sustainable packaging and consumer behavior (Reiner, 2019; Packaging Europe, 2019).

AR messaging on-pack serves multiple purposes:

- Transparency – Consumers gain access to detailed insights about material origins and recycling instructions.
- Interactive education – AR guides users step-by-step, reducing confusion around sustainable usage.
- Engagement – Gamified overlays and story-driven interactions foster deeper emotional connection with the brand (Reiner, 2019; Packaging Europe, 2019).

This immersive engagement style aligns with findings from Cao et al. (2023), who argue that XR can build environmental awareness and promote sustainable consumption through participatory, interactive experiences.

Impact on ESG Goals and Sustainability Outcomes

Company B's XR initiatives contribute directly to its ESG commitments in several ways:

- **Environmental:** Virtual prototyping and XR-driven design reduce reliance on physical prototypes, lowering material usage and carbon emissions. The digital loop facilitates iterative improvements in packaging recyclability and material efficiency (Shao & Min, 2021; Cao et al., 2023).
- **Social:** On-pack AR empowers consumers to make informed decisions, promotes sustainable lifestyles, and enhances brand trust. Interactive education supports consumer participation in sustainability.
- **Governance:** XR data platforms track consumer engagement metrics, informing packaging decisions and reinforcing accountability. Insight-driven iterations enable informed compliance with sustainability standards.

Implementation Strategy and Enablers

Company B's XR packaging program leverages several key enablers:

- **Advanced R&D tools:** Digital platforms and XR simulation labs support virtual

prototyping and collaborative design (Company B, 2024).

- **Collaborative workflows:** Cross-disciplinary teams—including packaging engineers, sustainability specialists, and digital designers—work in XR spaces to optimize end-to-end packaging solutions (Reiner, 2019).
- **Consumer engagement infrastructure:** Integrated AR experiences through QR codes and web-based AR ensure broad accessibility and real-time interaction (Packaging Europe, 2019).
- **Data-driven analytics:** XR platforms capture user interaction data, feeding insights into sustainable packaging iterations and metrics.

Challenges and Considerations

Company B's XR deployment, while innovative, must overcome several potential challenges:

- **Device accessibility:** Not all consumers have compatible AR devices, although web AR via QR codes mitigates this barrier (Packaging Europe, 2019).
- **Content localization:** AR content must be regionally and linguistically tuned to ensure clarity and relevance across global markets.
- **Digital adoption gap:** Adoption may vary among demographics; accessible design remains vital to avoid exclusion.
- **Lifecycle integration:** Packaging ecosystems must track the full usage lifecycle, linking AR experiences to actual recycling behaviors.

Implications and Future Direction

Company B's XR-first approach to sustainable packaging offers a blueprint

for the future of ESG-aligned product innovation. By marrying virtual prototyping with consumer-centered XR engagement, Company B fosters transparency, reduces waste, and strengthens brand trust.

Future directions may include:

- Using XR for real-time recycling tracking and incentives.
- Expanding XR simulations to include full supply chain lifecycle analysis.
- Scaling AR packaging to support circular economy behaviors globally.

As the global momentum for sustainable development accelerates, organizations are increasingly being held accountable not just for financial performance, but also for their environmental stewardship, social responsibility, and ethical governance. This evolving paradigm demands that businesses move beyond conventional ESG reporting and adopt more impactful, transparent, and interactive mechanisms for sustainability engagement. The convergence of Extended Reality (XR) technologies with ESG principles offers a timely and transformative opportunity to achieve this shift, particularly within the broader vision of *Viksit Bharat @2047*—India’s roadmap to becoming a technologically empowered and inclusively developed nation.

The exploration of real-world corporate applications—through the cases of Accenture and Unilever—demonstrates that XR is no longer an emerging concept, but a strategic enabler of corporate sustainability. Accenture’s immersive ESG training modules have

redefined how organizations educate employees on sustainability, diversity, and ethical decision-making. Through virtual environments, the firm has not only improved knowledge retention and behavioral change but also aligned learning outcomes with measurable ESG performance indicators. These immersive training approaches bridge the gap between policy and practice, turning abstract sustainability goals into lived, actionable experiences.

Similarly, Unilever’s use of XR in sustainable packaging design showcases the potential of technology to enhance both internal innovation and external consumer engagement. By employing virtual prototyping, the company significantly reduces material waste and design cycle time. Furthermore, Unilever’s deployment of augmented reality on product packaging allows consumers to interact with sustainability information in intuitive, personalized ways. This two-way interaction not only strengthens the brand’s transparency but also empowers consumers to make informed, sustainable choices—highlighting the role of XR in promoting responsible consumption.

Both cases reinforce the broader thesis that XR can support all three dimensions of ESG: environmental efficiency, social inclusion, and good governance. From enabling low-impact design decisions and enhancing employee learning to fostering transparency and engagement, XR tools offer a multidimensional approach to achieving sustainability goals. They also provide a platform for companies to prototype the future—testing strategies, visualizing

impacts, and engaging stakeholders long before decisions materialize in the real world. Moreover, these immersive approaches are well-aligned with India's development objectives. As Viksit Bharat @2047 emphasizes digital empowerment, inclusive innovation, and sustainable development, the integration of XR into ESG frameworks offers a forward-looking model for Indian enterprises. Through scalable, immersive, and accessible experiences, businesses can bridge the digital divide, raise environmental awareness, and create equitable pathways to participation in sustainability-led growth.

That said, the adoption of XR in corporate sustainability is not without challenges. Issues such as hardware access, digital literacy, and ethical data use must be carefully managed to ensure

equity and avoid superficial applications of immersive tech. The true value of XR lies not in novelty, but in its capacity to deliver measurable impact, inclusivity, and transparency across organizational practices. The fusion of XR and ESG represents more than a technological enhancement—it symbolizes a paradigm shift in how corporations envision and enact sustainability. As demonstrated by pioneers like Accenture and Unilever, immersive technologies can enable companies to embed sustainability deeply into their culture, operations, and consumer interactions. Looking ahead, this integrated approach holds the potential to redefine the corporate sustainability landscape, not just for compliance, but for transformation—one that aligns perfectly with the aspirations of a digital, sustainable, and empowered Viksit Bharat by 2047.

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GREEN FINANCE: A NEW ERA IN INDIA

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ABSTRACT:

Climate change has emerged as the defining political and economic problem of this century and it is likely to stay so for the foreseeable future. Dwindling natural resources, degraded environment and rampant pollution and hazardous to public health and pose challenges to the sustainable economic growth. This paper highlights how green finance is emerging as a transformative force in India's economic landscape, fostering investments in environmentally sustainable projects. As the country strives to meet its climate commitments, green finance plays a crucial role in mobilizing capital for renewable energy, sustainable infrastructure, and low-carbon technologies.

INTRODUCTION

"Without environmental sustainability, economic stability and social cohesion cannot be achieved." – Phil Harding

In an era marked by heightened environmental awareness and a global call for sustainable practices, the intersection of finance and sustainability has emerged as a critical focal point. The urgency to address environmental challenges and promote sustainable development has prompted sustainable development has prompted a paradigm shift in financial landscape worldwide. Governments, investors, businesses and private individuals worldwide are beginning to take action in response to the climate issue, especially on decarbonization techniques. Moving to a low carbon or green economy would need to a low carbon or green economy would need extra ordinary levels of fresh capital investment, notably in the form of green financing, to support activities that cut GHG emissions and assist firms in adapting to the effects of climate change. That makes it important

to understand what is Green Finance and how it matters.

GREEN FINANCE – Green finance is a loan or investment that promotes environmentally-positive activities, such as the purchase of ecologically friendly goods and services or the construction of green infrastructure. As the hazards connected to ecologically destructive products and services rise, green finance is becoming a mainstream phenomenon. Green Environmental Management has been regarded as a corporate social responsibility (CSR) activity that the firms should try to do something for the society (Carroll 1979) and green financing is also a CSR activity of finance firms such as the banks, mutual fund companies, stock companies and so forth (Koo 2010).

Furthermore, it is so called typically targeted financing because it is very favourable to the green economic activity and discriminates the constraint of non – green economic activities (Noh 2010b:10).

GLOBAL OUTLOOK ON GREEN FINANCE -

Climate change has been on the G20 agenda ever since its first summit in 2008, though more recently the focus has been on circular carbon economy (CCE) to deal with harmful emissions. Major flagship programs like Principles for Responsible Investment (PRI) , Equator Principles (EP) for financial institutions, United Nation’s Environment Programme (UNEP) and Statement of Commitment by financial institutions on sustainable development suggest ways for implementing green finance among the signatories.

Sustainable Stock Exchange is an initiative that recommends the signatories countries’ stock exchange to come up with stock price indices that track the stock performances of a set of companies operating in these countries, which are leaders recognising the Environmental, Social and Governance (ESG) principles into their financing aspects. These indices are aimed at guiding investors who are interested in investing in green activities.

EVOLUTION OF GREEN FINANCE IN INDIA -

India has started emphasising on green finance as early as 2007. In December 2007, the Reserve Bank issued a notification on “Corporate Social Responsibility, Sustainable Development and Non-financial Reporting – Role of Banks” and mentions the importance of global warming and climate change in the context of sustainable development. In 2008, The National Action Plan on Climate Change (NAPCC) was formulated with a vision to outline the broad policy framework for mitigating the impact of climate change (Jain, 2020). The Climate Change Finance Unit (CCFU) was formed in 2011 within the Ministry of Finance as a coordinating agency for the various institutions responsible for green finance in India. The major strategic move since 2012 included implementation of the sustainability disclosure requirements. Security and Exchange Board of India (SEBI) made it mandatory for top 100 listed entities based

on market capitalisation at BSE and NSE to publish annual business responsibility reports since 2012 and revised it from time to time. In May 2017, SEBI issued guidelines for green bond issuance specifying the disclosure requirements. In addition, the Ministry of Corporate Affairs imposed mandatory reporting of the progress on Corporate Social Responsibilities (CSR) under the Companies Act, 2013.⁹ In October 2017, Report of the Committee on Corporate Governance has proposed that the board of directors shall meet at least once a year to specifically discuss strategy, budgets, board evaluation, risk management, ESG and succession planning.

There have been several fiscal and financial incentives at work in India. These incentives are in line with India’s commitments under the 2015 Paris Agreement to reduce greenhouse gas

emission intensity by 33 to 35 per cent below 2005 levels, and to achieve 40 per cent of installed electric power capacity from non-fossil sources by 2030. The Government of India (GoI) offers 30 per cent of the installation cost of the rooftop solar panels as subsidy to the institutional, residential and social sectors in most states¹¹. In some of the special category states, the subsidy is up to 70 per cent of the installation cost. In addition, beneficiaries can avail a generation-based incentive wherein they can receive ₹ 2 per unit of generation, if the generation exceeds 1100kWh-1500kWh per year. Further, the excess power can be sold at a tariff set by the government. Moreover, the GoI launched two phases of Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme in 2015 and 2019, to enhance the flow of credit, reducing the up-front purchase price of all vehicles and developing the infrastructures (such as charging stations) to encourage green vehicle production and sales (Jain, 2020). In order to counter the high up-front cost of such vehicles, the State Bank of India has introduced a ‘green car loans’ scheme for electric vehicles with 20 basis points lower interest rate and longer repayment window, compared to the existing car loans (Jain, 2020). The Government has also brought in a Production Linked Incentive (PLI) Scheme for manufacturing of high efficiency modules in the arena of renewable energy.

The Reserve Bank has also been taking proactive policy measures to promote and support green finance initiatives. It has included the small renewable energy sector

under its Priority Sector Lending (PSL) scheme in 2015. Under this scheme, firms in renewable energy sector are eligible for loans upto ₹ 30 crore (increased from ₹ 15 Crore since September 4, 2020) while the households are eligible for loans upto ₹ 10 lakh for investing into renewable energy. In September 2019, India announced a target to reach 450 GW of renewable energy generation by 2030.

The Reserve Bank is sensitising public, investors and banks regarding the need, opportunities, and challenges of green finance through its regular reports and other communications. For instance, in its Annual Report (2015-16), the Reserve Bank has mentioned the findings of the G20 Green Finance Study Group (GFSG) on the need for development of local green bond markets, facilitating cross-border investments in green bonds, knowledge sharing on environmental risks, and improving overall green finance activities. The annual report further mentions the broader issues related to green finance that need future consideration. These include definition of green activities, aspects of intellectual property rights in development and transfer of technology from developed countries, and environmental risk assessment by the banks. In its Report on Trend and Progress of Banking in India (2018-19), the Reserve Bank noted the risk of a climate change on financial assets and the need to accelerate the green finance for environment-friendly sustainable development. It acknowledges the challenges in the development of green finance, such as “greenwashing” or false claims of environmental compliance,

plurality of definitions, maturity mismatches between long-term green investment and short-term interests of investors. It further notes the need for policy action to establish a framework that promotes the green finance ecosystem in India by fostering awareness through coordinated efforts.

In the context of green financial institutions, Indian Renewable Energy Development Agency (IREDA), a government-backed agency for promoting clean energy investments, announced plans to become India's first Green bank in May 2016. India Infrastructure Finance

Corporation Limited (IIFCL) also launched a dedicated scheme known as the 'credit enhancement scheme' for funding viable infrastructure projects with bond tenors above five years (Jain, 2020). Considering these steps, we will assess the progress of green finance in India, including the general awareness about environmental sustainability in the next section.

Two major stock exchanges in India, the Bombay Stock Exchange (BSE) and the National Stock Exchange (NSE) are part of this initiative and publish separate ESG indices.

GREEN FINANCIAL PRODUCTS AND SERVICES IN INDIA –

- 1) **GREEN BOND** - Green bonds are the bonds issued by any sovereign entity, inter-governmental groups or alliances and corporates with the aim that the proceeds of the bonds are utilised for projects classified as environmentally sustainable. The idea for Green Bond derives from a larger movement termed sustainable finance, which aims to match financial markets with sustainability climate change and safeguarding environment.
- 2) **GREEN INSURANCE** - Green insurance is **insurance provided to cover the risk of green products, services and projects to minimize the impact of climate change with low interest rate**. Green insurance includes programs and products that can protect banks who lend to environmentally risky projects, as well as their clients.
- 3) **GREEN CREDIT** - The Green Credit System is a mechanism that complements the domestic carbon market. While the domestic carbon market focuses solely on CO2 emission reductions, the Green Credit System aims to meet other environmental obligations as well, incentivizing sustainable actions by various stakeholders¹. The Green Credit System is based on the concept of 'Green Credit', which means a singular unit of an incentive provided for a specified activity, delivering a positive impact on the environment.
- 4) **GREEN LOAN** - A green loan is a loan from a government or financial institution to fund a project that is expected to have a positive environmental impact. These loans must adhere to four green loan principles (GLPs), a set of guidelines administered by the International Capital Market Association (ICMA).

CHALLENGES OF GREEN FINANCE IN INDIA

- 1. Start-up Face:** Green banking and finance in India are not common and many banks in Green business are new and are in start-up face. It generally takes 3 to 4 years or more years for a bank to start making money, thus it does not help banks during the recession period.
- 2. High Operating Cost:** Green banking is specific banking that requires skilled, talented, experienced staff to provide proper services to customers which requires a higher operating cost. Experienced loan officers are needed with additional experience in dealing with green businesses and customers to provide loans.
- 3. Banks are specific:** The core area of a Green bank is to support those clients who take care of the environment. It needs money. Saving the environment is not a profit-making task. Hopefully, though, this premise is proven wrong in this case and that green banks prove that they can survive, even as they deal with confining requirements for doing business.
- 4. Risk of Image:** Due to increasing environmental awareness, banks are more prone to reputation risk, if their direct or indirect actions are viewed as socially and environmentally damaging. Reputation risks emerge from the financing of environmentally objectionable projects.
- 5. Diversification:** Diversification is the major challenge to go for Green banks which hamper their business transactions to those business entities who qualify screening process done by green banks. With a smaller pool of customers, Green banks will have a smaller base in terms of profit to support them.
- 6. No framed legislation:** There is no strict legislation to save the environment in India. Government must design proper legislation of environmental rules for banks and ensure enforcement. The problems in India are the legislation is not yet framed and in a few cases, things are not strictly enforced. There should be continuous conversation relating to environmental matters with relevant audiences like stakeholders, employees, customers, governments and the public.

CONCLUSION

Green Financing has been boosting to improve and develop the environment and promote economic growth. Indian banks, corporate institutions are far behind their counterparts from developed countries. If Indian banks and institutions desire to enter international markets, they must recognise their environmental and social responsibilities. Indian Banks and institutions must apprehend their responsibilities towards the environment as well as the society in order to compete and face the global market. For effective adoption of Green financing, the central bank and the central government should play a major role in the formulation of Green

Financing Policy guidelines and financial incentives. Not only Green Financing will ensure the greening of the industries but it will also facilitate in improving the asset quality and standard of the banks and financial and non-financial institutions in the future. There are a lot of opportunities and challenges for Indian banks and institutions in adopting Green Banking and Financing as a profitable business. Green financing if implemented sincerely will act as an effective deterrent for the polluting industries that give a pass by to the other institutional regulatory mechanisms. Therefore, for continuous banking, Indian banks and institutions should adopt green financing as a business model without any further delay of time.

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Sustainable Banking in India: A Review of Green Financial Initiatives

By

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ABSTRACT

In recent years, the Indian banking sector has increasingly embraced the principles of sustainable development and environmental stewardship. Growing worldwide worries about climate change, legislation changes, and customer expectations have all contributed to the Indian banking industry's recent adoption of sustainable development and environmental stewardship. The integration of Environmental, Social, and Governance (ESG) factors into lending, investment, and operating strategies is the main emphasis of this paper's critical analysis of Indian banks' green financial endeavors. Sustainable banking — also known as green banking — seeks to lower banks' carbon footprints, support clean energy initiatives, and facilitate financial inclusion in line with the Sustainable Development Goals (SDGs). This paper critically reviews the green financial initiatives undertaken by Indian banks, with a focus on the integration of Environmental, Social, and Governance (ESG) considerations into lending, investment, and operational strategies. The study assesses the Securities and Exchange Board of India's (SEBI) and Reserve Bank of India's (RBI) regulatory initiatives, with a focus on the Green Deposit Framework (2023) and the Business Responsibility and Sustainability Reporting (BRSR) requirements. The study highlights key practices such as digital banking, paperless transactions, energy-efficient infrastructure, and green financing.

Keywords – *Green Banking, Green Banking Initiatives, Environmental friendly, Carbon footprint, Green Economy*

INTRODUCTION

In Today's World, The financial industry is being asked to take a more active role in promoting sustainable development as the globe struggles with growing environmental issues like resource depletion, biodiversity loss, and climate change. In this regard, incorporating environmental, social, and governance (ESG) factors into the fundamental functions of financial institutions has become possible through the use of sustainable banking, commonly known as green banking. Sustainable banking prioritizes long-term ecological and social well-being in addition to economic performance, going beyond traditional profitability goals. It entails providing money for ecologically conscious initiatives, lowering the carbon footprint of banking operations, and enticing customers to embrace eco-friendly behaviors by offering them cutting-edge financial solutions.

"Sustainable Banking" refers to the efforts of the Banking sector to keep the environment green and to minimize greenhouse effects through rationalizing their strategies, policy, decisions and activities pertaining to banking service, business and in-house operational activities. Global environmental problems of natural resources, pollution, population growth, energy shortage, greenhouse effect, effluents, have affected our ecological balance. The banking and financial sector should be made to work for sustainable development. Sustainable banking refers to the promotion of

environmentally friendly practices and the reduction of the bank's carbon footprint. It's similar to a traditional bank because it examines all social, environmental, and ecological concerns with the goal of protection and conservation of natural resources and the environment. The primary goal of this banking concept is to improve the conservation of the earth's environment, habitats, and resources.

Significant government initiatives that have encouraged banks to reveal and carry out sustainable efforts more methodically are the RBI's Green Deposit Framework (2023) and the SEBI-mandated Business Responsibility and Sustainability Reporting (BRSR). Private sector banks like HDFC Bank, ICICI Bank, and Axis Bank, as well as public sector banks like the State Bank of India (SBI), have implemented a number of programs to cut down on paper use, such as green bonds, funding for renewable energy, carbon-neutral pledges, and digital transformation. These changes demonstrate an increasing understanding of the part banks may play in guiding the nation toward an inclusive, low-carbon economy.

The "Institute for Development and Research in Banking Technology" states that "sustainable banking" is a catch-all word for the policies and procedures that make banks sustainable in terms of the economy, the environment, and society. With no or little environmental impact, it seeks to maximize the efficiency and effectiveness of banking procedures as well as the utilization of IT and physical

infrastructure. Given the structure and procedures of banking, banks provide two tiers of sustainable banking guidelines:

- **Greening Processes, Products, Services, and Strategies:** implementing eco-friendly methods to make banking products and services, as well as daily business operations, more ecologically friendly.
- **Greening Infrastructure:** implementing measures to make IT infrastructure more environmentally friendly and enabling banks to produce their own electricity for internal use.

OBJECTIVES

- To understand the concept and significance of sustainable banking
- To review key green financial initiatives adopted by Indian banks
- To examine the role of regulatory institutions in promoting sustainable finance
- To identify the major challenges faced by Indian banks in implementing green banking practices
- To propose strategic recommendations for enhancing sustainable banking in India

REVIEW OF LITERATURE

Patil (2024) offers a comprehensive overview of green banking in India, highlighting how sustainable finance has shifted from being a niche practice to a

central policy concern. The study stresses the importance of environmental awareness among stakeholders and reviews the initiatives undertaken by Indian banks in alignment with the Reserve Bank of India's green policies. The author emphasizes that while progress is evident, uniform implementation across banks remains inconsistent.

Ahuja (2022) compares the adoption of green practices by banks in the public and private sectors. According to the survey, private banks have demonstrated greater innovation in green infrastructure and ESG-linked finance, particularly ICICI and HDFC. Public banks, meanwhile, now more closely adhere to green finance regulations set forth by the government.

Mishra and Desai (2021) Analyze how regulatory bodies like the RBI and SEBI support green banking. The RBI's 2021 discussion paper on climate risk and sustainable finance is cited in their report as a pivotal moment in the integration of ESG principles into traditional banking. The study emphasizes how important it is to have a uniform framework for green disclosures.

Vikas Nath et al. (2014) had an international experience, review about Green Banking Practices and concluded that the banks should change their routine operations through the adoption of paperless banking, online banking, mobile banking, mass transportation system, green cards made up of recycled plastic

and efficient use of resources. Banks should start investigate in low carbon technologies and develop new sustainable products and services that will mitigate the risk of climate change.

Sudhalakshmi and Chinnadorai (2014) present the status of Indian Banks in respect of Green Banking and state that though goes green mantra is essential for emerging economies like India but significant efforts have not been taken. Banks are required to include their green aspect in the lending principle. Every step taken today will mean a better global environment in future. So a policy measure to promote Green Banking is needed in India. Indian banks are running behind time in adoption of this green phenomenon. Serious steps are required to be taken in this regard.

Yadav and Pathak (2013) study the Green Banking approaches opted by private and public bank for environment sustainability. Using case study approach they find that Indian banks have understood the relevance of taking positive steps towards the environment. Moreover results of the study conducted reveals that public sector banks have taken more initiatives as compared private sector with exception of ICICI bank. In private sector only ICICI bank's approach is a sustainable approach.

Dr. Nishikant Jha et al. (2013) had conducted research on A study of Green Banking Trends in India and highlighted some steps for going green banking such as go online, use green checking accounts, use green loans for home improvements,

use power saving equipment's, use green credit cards, mobile banking.

Bahl, Sarita (2012), conducted an empirical study "Green Banking- The new Strategic Imperative" on public sector banks and collected manager's views on green banking financial products, carbon footprint reduction by paperless banking, carbon footprint reduction by energy consciousness, carbon footprint reduction by using mass transportation system, carbon footprint reduction by green building and social responsibility services. She found that carbon footprint reduction by green building had been given top priority in green banking strategies. The study further found that Indian banks can initiate various social responsibility services as tree plantation, maintenance of parks, pollution checkup camps etc.

Dharwal, Mridul and Agrawal, Ankur (2011), in research article on "Green Banking: An Innovative initiative for Sustainable Development" concluded that Indian banks need to be made fully aware of the environmental and social guidelines to which banks worldwide are agreeing to. As far as green banking is concerned, Indian banks are far behind their counterparts from developed countries. If Indian banks desire to enter global markets, it is important that they recognize their environmental and social responsibilities.

RESEARCH METHODOLOGY

The nature of the research is descriptive. Several scholars, researchers, books, articles published in various journals, periodicals, conference papers, reports, magazines, working papers, websites, and more have all been consulted for the secondary data and information that was used to prepare the research paper.

GREEN BANKING IN INDIAN CONTEXT

Green or Sustainable banking is a proactive approach to environmental preservation and energy conservation. Protecting the environment for future generations, reducing bureaucracy, and focusing on electronic transactions—which not only support sustainability but also provide convenience for customers and banks—are its main goals. As India gets closer to becoming a major global economy, the need for sustainable development has never been higher. This concept promotes eco-friendly activities and reduces the bank's carbon footprint by incorporating social, environmental, and ecological issues into standard banking procedures. By phasing out unsustainable policies and implementing new ones that put an emphasis on maintaining a green environment, the objective is to safeguard and conserve natural resources while tackling climate change and global warming.

GREEN BANKING INITIATIVES BY INDIAN BANKS

Role of RBI

The Reserve Bank of India (RBI) is promoting green banking practices. The RBI encouraged Indian banks to adopt green banking practices in a circular. This circular stressed the importance of incorporating social and environmental considerations into banking operations. The RBI released regulations in 2015 requiring banks to include environmental risk management in their credit risk assessment processes. a framework for advancing sustainable finance that incorporates the development of procedures and laws that adhere to international sustainability standards. This framework's ultimate goal is to control environmental risks and promote green investments. It provides banks with a systematic approach to promoting sustainable finance and integrating environmental, social, and governance (ESG) principles into their day-to-day activities. Since its July 2022 discussion paper on climate risk and sustainable finance, the RBI has taken small steps to address the shift to a green economy. In addition to expanding the resource pool by permitting foreign institutional investors to engage in future green government securities, the RBI has issued sovereign green bonds worth ₹16,000 crore.

Public Sector

Banks State Bank of India

As the foremost public sector banking institution in India, the State Bank of India (SBI) acknowledges its obligation to safeguard the environment while fostering sustainable practices. SBI has initiated a range of products, including Green Bonds and investments in renewable energy initiatives. In 2009, the State Bank of India (SBI) launched its “Green Channel Counter,” a paperless banking initiative aimed at reducing carbon footprints. SBI has distinguished itself as the first banking entity into generation of green power by installing windmills for captive use. A novel deposit scheme, entitled “SBI Green Rupee Term Deposit,” has been implemented to attract deposits that will facilitate the bank's financing of green initiatives. SBI has introduced the “SBI Green Fund,” which enables customers to actively engage in the sustainability mission.

Punjab National Bank

The Bank implemented a multitude of initiatives aimed at mitigating emissions and reducing energy consumption. The bank has issued Green Bonds that encompass projects in renewable energy, energy-efficient buildings, and low-carbon transportation sectors, in compliance with the pertinent standards established by the Climate Bonds Initiative (CBI). On July 17, 2023, Punjab National Bank (PNB), inaugurated an environmental initiative titled “PNB

Palaash,” which is an eight-month period campaign to embrace sustainability and to make a positive contribution to sustainability by integrating environmental principles into our business model. Further Bank has also signed “Green Pledge” of the Ministry of New and Renewable Energy under which it has established a butterfly park within the precincts of the Guruvayur temple, featuring 18 varieties of medicinal flora.

Bank of Baroda

The bank has embarked upon a multitude of initiatives in the domain of green banking, exemplified by its financing of commercial enterprises. Since the year 2020, the bank has transitioned to a completely paperless environment within its corporate offices, and is actively advocating for the implementation of paperless banking across all its branches. In 2022, the institution proclaimed the initiation of the second iteration of the Green Ride, a collaborative initiative with health and environmental advocate Milind Soman, which involved an 8-day sustainable cycling journey, aimed at promoting eco-friendly transportation, a sustainable lifestyle, and the significance of health and fitness. Bank of Baroda (Bank), recognized as one of India's foremost public sector banks, has announced the launch of the bob Earth Green Term Deposit Scheme, aimed at mobilizing deposits that will be allocated towards financing eligible environmentally-friendly projects and sectors.

Canara Bank

The bank had taken many green initiatives. The bank had adopted environmentally friendly measures such as mobile banking, internet banking, tele-banking, solar powered biometric operations etc. The bank refrains from

providing financial support to entities engaged in the production of substances that contribute to ozone depletion, such as chlorofluorocarbons, carbon tetrachloride, aerosol products, and various solvents.

Private Sector Banks ICICI Bank

The Go Green project, which includes activities like green solutions and products, green engagement, and green customer communication, was embraced by ICICI Bank. Instant banking is one of the green services and solutions the bank offers. For automobile models that use alternative sources of energy, they are waiving 50% of the processing fees for auto loans. Through green measures, the bank saved sixteen crore liters of water and avoided the cutting down of 30,000 trees

by implementing paperless programs like e-statements and e-greetings. The first Green Bond, valued at USD 500 million, was issued by ICICI Bank in 2018 to fund energy efficiency and renewable energy projects. With an emphasis on projects in sustainable agriculture, green infrastructure, and renewable energy, ICICI Bank announced INR 10,000 crore in green financing over the subsequent five years in 2022.

HDFC Bank

To encourage green banking, HDFC Bank offered green recommendations. In order to finance renewable energy projects and green structures, HDFC Bank launched its Green Loan product in 2016. Additionally, the bank started incorporating environmental factors into the assessments of lending. To finance environmentally friendly programs and expand its sustainability portfolio, the bank issued its first Green Bond in 2021,

valued at USD 500 million. The bank has also announced the creation of "Green Clubs" in each region to increase environmental awareness and inspire the broader community to protect the environment for a brighter future. HDFC Bank has also declared its mission to achieve carbon neutrality by 2031–2032. HDFC has introduced, Green & Sustainable Deposits that meets the Sustainable Development Goals (SDGs) of the UN, to help fight climate change.

Axis Bank

One of the top three privately owned banks in India is Axis Bank, a financial services company. AXIS Bank implemented a number of green banking initiatives, which include: The bank began acquiring all of the dry trash produced by the corporate office and its thirty-four branch

offices in Mumbai in August 2011 and reprocessing it into notepads, notebooks, and envelopes. To date, over one million kilograms of paper

have been recycled and transformed into 12,000 notebooks, notepads, and envelopes that are utilized in the bank's corporate offices and branches. Axis Bank launched its INR 1,000 crore Green Bond in 2017 to finance environmentally conscious initiatives like energy-efficient infrastructure and renewable energy.

Kotak Mahindra

The bank has taken several kinds of steps under the "Think Green" initiative, which include encouraging customers to sign up for digital statements, reducing the amount of paper they utilize, and collaborating with "Grow-Trees.com" to plant one seedling for each digital statement on the behalf of its customers. Based on an IFC sustainability framework and performance specification, the organization established the "Social, Environmental Management System Plan" (SEMSP) to assess creditors' social and environmental risk. In FY 2012–13, 16,623 plantings were planted. Based on an IFC sustainable framework and performance prerequisites, the organization designed the Social, Environmental Management System Plan (SEMSP) to assess borrowers' social and environmental risk.

COMPARISON OF GREEN BANKING INITIATIVES

Bank	Key Green Initiatives	Green Bonds Issued	Unique Efforts	Year Initiated
SBI	Green Channel, Green Bonds, Windmills for power, Green Rupee Term Deposit, Green Fund	Yes (INR 500 crore)	First Indian bank to generate green power via windmills	2009 onwards
PNB	Sustainable industry financing, Green Bonds, "PNB Palaash" campaign, Butterfly park	Yes	Signed MNRE's Green Pledge; CSR activities promoting biodiversity	2017–2023
Bank of Baroda	Green Ride, Solar/Wind energy projects, Paperless office, Green Term Deposits	Yes	Collaborated with Milind Soman for green cycling campaign	2020 onwards
Canara Bank	E-lounges, Paperless admin, No funding to ozone-depleting projects	Not mentioned	Strong credit policy focus on carbon-credit generating projects	-
ICICI Bank	Green Bonds, Go Green initiative, Eco-loans, Digital savings, Green financing	Yes (USD 500 mn)	Saved 30,000 trees, water conservation, low processing fees for eco-friendly vehicles	2018
HDFC Bank	Green Loans, Green Bonds, Green Clubs, Employee engagement for sustainability	Yes (USD 500 mn)	Targeted carbon neutrality by 2032, supports UN SDGs	2016–2021
Axis Bank	Green Bonds, Carpooling, Waste paper recycled to stationery, Sustainability-linked loans	Yes (INR 1000 crore)	1 million kg paper recycled into usable material, innovation in ESG-linked lending	2011–2020
Kotak Mahindra	Digital statements, Tree plantation with Grow-Trees.com, Social/Environmental Risk Management framework (SEMSP)	No	Plants a tree for every digital statement; ESG risk evaluation for borrowers	2012–13

Criteria	Indian Banks (SBI, ICICI, HDFC, Axis)	USA (SEC Climate Disclosure Rules)	Singapore (Green Finance Action Plan)
Policy Framework	RBI's Green Deposit Framework (2023), SEBI BRSR Reporting (mandatory for top 1000 companies)	SEC's mandatory climate-related disclosures (proposed in 2022, rolling out gradually)	MAS launched Green Finance Action Plan (2019), with taxonomy and ESG disclosure guidance
Green Bonds & Finance	Green bonds issued by SBI, HDFC, Axis; ICICI pledged ₹10,000 Cr for green lending	Green bonds growing but no federal taxonomy; mostly market-driven	Singapore Green Bond Framework aligned with ASEAN Green Bond Standards
ESG Disclosure Standards	SEBI BRSR mandatory for top companies; ESG reporting by banks is still voluntary or semi-standardized	Disclosure still voluntary for most, but increasingly recommended by SEC and industry standards	MAS encourages ESG reporting; Singapore Exchange requires sustainability reports from listed firms
Regulatory Enforcement	RBI and SEBI have initiated soft-regulatory mechanisms, but enforcement is still evolving	Enforcement depends on SEC rules and investor litigation	MAS uses incentive-based supervision (e.g., grant schemes for green finance initiatives)
Green Loan Standards	Few green loan products; no uniform classification; ICICI and HDFC have products like green auto/home loans	Loan standards guided by lenders; no uniform climate lending regulation	MAS encourages green lending with taxonomy-aligned standards and reporting
Carbon Neutrality/Net Zero Targets	HDFC aims for net zero by 2031-32; SBI & Axis have introduced limited decarbonization targets	No mandated net zero path; varies by institution	Singapore is developing net-zero aligned guidance for financial institutions
Green Infrastructure & Internal Practices	Digitization, paperless banking, solar-powered ATMs (e.g., SBI, Canara Bank); carbon reduction from operations	Encouraged through corporate ESG but not required	Energy efficiency, smart buildings, and green data centers promoted under the MAS roadmap

GREEN BANKING COMPARISON: INDIAN BANKS VS GLOBAL BENCHMARKS

Challenges in Implementing Green Banking

Green banking is a progressive concept and it has emerged as a pivotal strategy for financial institutions in India aims to integrate environmental considerations into the banking sector. Despite its benefits, the adoption of green banking has several challenges. Below are some of the key challenges confronting green banking initiatives in India -

- **Lack of awareness and education** - Green banking is a sustainable practice but its awareness is limited among customers. Individuals are unaware of the green banking practices that impacts environment. This lack of awareness is a major challenge for banks to promote green products.
- **Operating cost** - Green banking institutions necessitate the recruitment of

skilled personnel to provide proper services to customers which requires high operating cost. Several banks in Green business are very new and are in start-up face which generally takes 3 to 4 years for a bank to start making money. Furthermore, offering these clients discounts on loans can reduce their profit margins.

- **Credit Risk** - Credit risk arises due to lending to those customers whose businesses are effected by the cost of pollution, change in environmental regulation and new requirements of emission level.
- **Limited Green Investment Opportunities** - The market for green investments and projects may be underdeveloped, limiting options for banks and their clients.
- **Absence of Standardized Frameworks** Another significant obstacle is the lack of

standardized frameworks and directives pertaining to green banking practices within the Indian context. Although regulatory authorities such as the Reserve Bank of India (RBI) have undertaken initiatives aimed at fostering green banking. In the absence of standardized frameworks, financial institutions may encounter difficulties in proficiently assimilating green banking principles into their operational and risk management paradigms.

- **Financial constraints** - Financial constraints represent a formidable obstacle for the advancement of green banking within the context of India. Implementing green banking practices requires upfront investment in technology and infrastructure. Numerous banking institutions, especially those of smaller and medium size, may be deficient in the financial resources essential for the adoption of green banking methodologies. Moreover, there may be concerns about financial viability and returns of green financing projects particularly in sectors

with perceived higher environmental and social risks.

- **Market Perception and Demand** - The perception and demand of the Indian market for sustainable financial products present another difficulty for green banking. While there is a growing interest in environmental sustainability, there may not be as much demand for green banking services and products as there is for traditional banking options. It may be difficult for banks to defend the expenditure necessary to create and promote green banking initiatives due to this disparity in demand.
- **Capacity Building and Skill Development** - Skill development and capacity building are crucial for green banking initiatives to be implemented successfully. Banks must fund training initiatives to teach their employees about environmental issues and sustainable finance practices. However the banks may find it difficult to find the qualified expert with experience in green banking.

STRATEGIC RECOMMENDATIONS FOR ENHANCING SUSTAINABLE BANKING IN INDIA

Establish a Unified Green Finance Taxonomy

Like the EU framework, India should have a defined taxonomy for sustainable activities. This would lower the risk of greenwashing, increase the uniformity of ESG assessments, and assist banks in clearly identifying qualified green projects.

Mandate ESG Disclosure for All Banks

All public and private banks under RBI supervision should be required to comply with ESG disclosure standards, even if SEBI's BRSR is already required for listed businesses. In sustainable finance, this will increase accountability and openness.

Create Incentive Mechanisms for Green Lending

Banks that fund clean tech, renewable

energy, or green infrastructure projects should be eligible for priority sector status, interest rate subsidies, or tax breaks from the government and RBI. Private investment in sustainable sectors would be stimulated by this.

Develop Green Finance Capacity within Banks

risks associated with climate change.

Integrate Climate Risk into Core Banking Policies

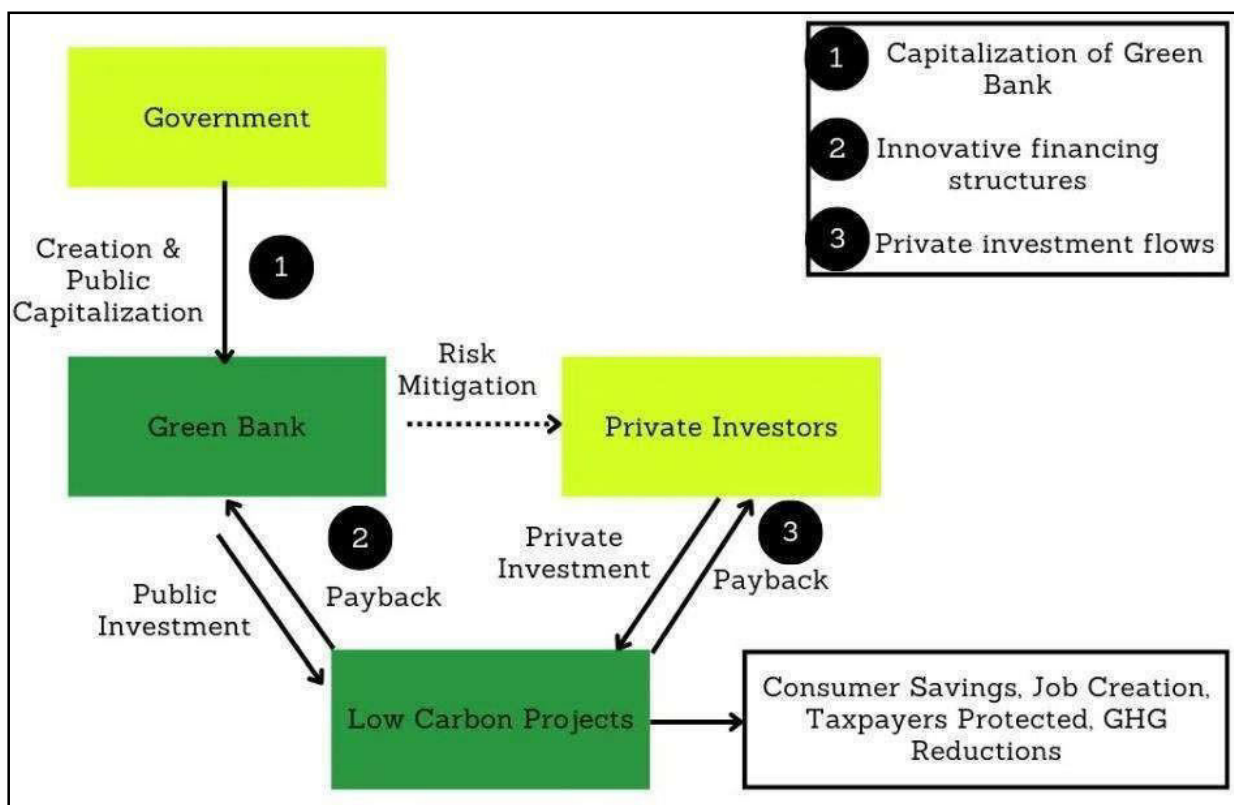
The RBI ought to mandate that banks incorporate climate risk analysis into their asset- liability management, lending, and

Promote Digital and Paperless Banking

The shift to digital banking platforms, which use fewer resources, should be accelerated by all institutions. Customer interactions and branch-level activities may be connected to green KPIs (Key Performance Indicators).

For employees engaged in risk management, compliance, and credit assessment, banks must fund training initiatives and ESG certification courses. This will increase internal capacity to assess and successfully manage financial

investment policies. Internal risk frameworks for banks should include scenario analysis and climatic stress test.



GREEN BANKING ECOSYSTEM MODE

CONCLUSION

Green banking practices are used in banks for reasons other than just being environmentally friendly. Banks should be proactive in taking ecological and environmental measures in a market economy that is changing quickly and where market globalization has increased competition. Broadly speaking, green banking supports both the bank's corporate social responsibility and commercial goals. In India, sustainable banking is progressively evolving from a theoretical idea to a real-world, policy-driven reality. The Indian banking industry is making impressive strides in incorporating environmental, social, and governance (ESG) principles into its operational and strategic frameworks thanks to voluntary commitments from top public and private sector banks as well as growing regulatory encouragement from the Reserve Bank of India (RBI) and the Securities and Exchange Board of India (SEBI). In addition to ensuring that sectors become greener, "green banking" would facilitate the improvement of banks' asset quality. Indian banks must thus recognize their responsibilities to society and the environment if they are to compete

and thrive in the global economy. To guarantee the successful implementation of green banking, the RBI and the union government should play a significant role in creating green policy guidelines and financial incentives.

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THE GREEN LEDGER: FORGING A SUSTAINABLE FINANCIAL FUTURE WITH TECHNOLOGY, ESG, AND GREEN FINANCE

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Keywords: Green Finance, ESG Data Verification, Blockchain for Sustainability, Climate Technology (ClimateTech), MRV (Measurement, Reporting, Verification), Tokenization

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ABSTRACT

The goal of a developed and sustainable Vikshit Bharat @ 2047, significant mobilization of green finance is required. However, this market is fundamentally weakened by the systemic issue of unverified Environmental, Social, Governance (ESG) data, which creates greenwashing and misallocates investor capital. This paper uses a systems design approach, to address the problem connected to the integrity of data issue and design a new solution that synthesizes various technological capabilities. The outcome of the research includes an analysis of synergistic "GreenTech Stack" (AI, IoT, Blockchain) for verifiable data collection; a "Verifiable Impact Score (VIS)" to assess the quality of data; and proposed a five-layer national ecosystem called the "Green Ledger". This architecture can develop an effective, transparent, and digitally native MRV (Measurement, Reporting, and Verification) process. The paper makes the case for the implementation of a such a system as a strategic choice that could shift India's green finance market from subjective, report-based practice towards an objective, data-driven science to align economic growth with national climate objectives.

Keywords: Green Finance, ESG Data Verification, Blockchain for Sustainability, Climate Technology (ClimateTech), MRV (Measurement, Reporting, Verification), Tokenization

INTRODUCTION

As India moves toward becoming a developed country by 2047, it faces a dual motivation - a delicate balancing act of two

giant processes of entrepreneurial growth and climate change and environmental degradation. The old model of development - 'grow now and clean up later' - is not an

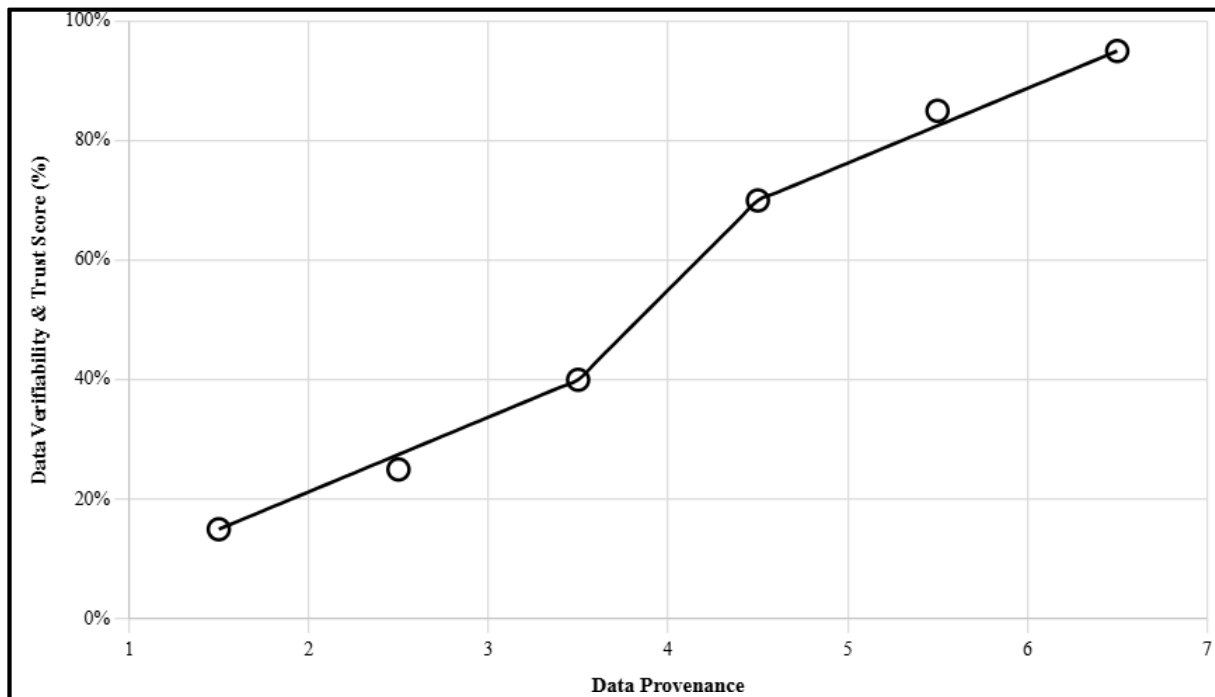
option anymore. For India, this is not just an abstract concern: it's an existential economic threat. If India loses its coast because of rising oceans, if its agricultural heartland is subject to erratic monsoons and extreme heat, if cities face water quality issues and deadly air conditions, each of these situations is an expensive headache to mitigate. This is NOT to mention the trillions of dollars at risk with stranded assets, supply chain disruptions, and agricultural losses if India's entrepreneurs are unable (or unwilling) to address economic or climate instability.

Green Finance and investing based on Environmental, Social and Governance (ESG) standards have developed around the world as the main vehicles of directing capital into this much-needed sustainable transition (Thakkar et al, 2024). India has taken some initial steps with a growing market for green bonds, a growing corporate awareness instigated by pushes from the regulator such as the Business Responsibility and Sustainability Reporting (BRSR), but there is a major, systemic issue in the environment which is the unverifiability of ESG data (Unuigbokhai and Anthony, 2022). The whole structure of green finance now and in the foreseeable

future is reliant on self-declared corporate sustainability reports, third-party ratings based on those same reports, and qualitative assessments. There is ample opportunity for "greenwashing", which is misleading claims about environmental performance to arise from this, which undermines investor confidence and leads to capital being directed towards projects that are fundamentally flawed in their impact, missing the purpose of green finance completely.

The main research problem, therefore, is the absence of a scalable trustworthy mechanism to verify ESG claims at the source (Thakkar et al, 2025). The goal of the conceptual paper is to advance the technology reliant solution to the problem. The argument of the paper is that a synergistic stack of contemporary technologies, that is AI, the Internet of things (IoT) and blockchain technology can be designed into a national scale ecosystem (herein in called Green Ledger) to convert the ESG field from a naturally subjective report-driven activity to an objective data-driven science. Graph 1 illustrates what this shift in the data environment would look like.

Graph 1: The ESG Data Trustworthiness Spectrum



Source: Compiled by Author

The graph describes the proposed movement from low-verifiability, traditional, data sources to high-verifiability technology-consulted data sources, which is the premise upon which the Green Ledger was designed.

The graph, Graph 1, shows the use of trust in the context of ESG data, while it is useful, it does not show the dynamism involved. The least trustworthy self-reported corporate sustainability reporting sits on the left side of the graph, followed to the right by auditable disclosures, like BRSR, which adds some validity with regard to the verifiability of the data reported, but remains further behind the relative reliability of the data which can be

verified and analysed independently. From there the spectrum shifts significantly to AI-Verified data. These are objective data created by alternative means including, for example, satellite imagery. In this case, the data on land use was independently obtained, and through the application of AI using the digitally captured images (compared to the company's self-reported account), many of the inaccuracies about the property could be identified. The most trustworthy reported data you can expect is Immutable Data. By this I mean the IoT sensors transmitting real-time readings from on the ground are the most trustworthy because the data signing uses cryptographic algorithms and providing anchorage to the

blockchain makes manipulation of the data impossible in theory. The Green Ledger's goal is to create the avenues and infrastructure that can take the market as a whole to as close to the rights side of the spectrum as possible.

1. LITERATURE REVIEW

The findings reveal the 4 key pillars of green financing: accounting constitutes 43%, environmental represents 24%, social accounts for 19% and governance making up 14%. Since the study exclusively focuses on credit rating model only therefore, several other factors included in achieving green finance and sustainable development goals are ignored (Roy, 2023). The review emphasizes the contribution of green financing in achieving sustainable development and addressing climate change by taking initiatives towards low-carbon and green investments (Ogunode & Dada, 2022). It also highlights the importance of global cooperation and sustainable planning (Olaniyan et al., 2021). The future research calls for implementation strategies and standardization of sustainable investments and green financing. The effects of risk-taking for investors are also not considered (Fu et al., 2023). Study finds that green finance plays a pivotal role in driving eco-friendly innovation and reducing greenwashing (Omucheyi et al., 2025). By

enhancing ESG performance and discouraging misleading practices it promotes sustainability (Thakkar et al, 2025). Heavily polluting firms show a stronger reduction in greenwashing compared to the cleaner firms. The study avoids a deep consideration about how ESG helps in unveiling companies work towards sustainability (Zhang, 2023). Exploring the influence of green finance on the interconnectedness of carbon neutrality and ESG reveals that it boosts a company's environmental performance by lowering the carbon emissions and shedding light on greenwashing but there is no discussion about the mechanism of integration of carbon neutrality and ESG has been mentioned on the paper (Xie, 2024). The research study presents that green finance policies does have a positive impact on ESG but are strongly driven by company's financial constraints, internal supply chain and managerial power (Thakkar et al, 2025). Firms with high supply chain efficiency and environmental regulations have better ESG performance (Thakkar et al, 2024). The significant limitation for this research is that it does not consider market based instruments, wider geographical areas and the behavioural responses of the firms (Gao et al., 2024).

2. RESEARCH METHODOLOGY

In this conceptual paper, I employed a systems design methodology for the socio-technical issue of green finance. The methodology is qualitative and constructive, where the goal was to design a new solution architecture based on a granular understanding of the problem space as well as on the existing functional capabilities in today's technologies. As the integrated system I propose does not currently exist, a purely empirical study is unfortunately not presently workable. As such, the methodology involved four steps:

Problem analysis and literature references:

The research commenced with an intensive literature review on green finance, ESG investing, climate economics, along with computer science. The objective of the review was to better articulate the principle issue of unverifiability in the context of data and its implications. The literature review involved reviewing the academic work on greenwashing, international bodies reports from UNFCCC and IPCC on the MRV challenges, and market reviews of the green bond market were used to structure the "ESG Data Trustworthiness Spectrum" (Graph 2), intended as a visual representation as a problem statement, and heuristic guide through the research.

assessment of the capabilities of key enabling technologies: In addition to the reasonable assessment of the enabling technologies (and not just a cursory assessment, especially regarding relevant capabilities for data verification), we undertook in-depth assessments. For example, with AI capabilities we had to conduct assessments of the capabilities of Convolutional Neural Networks (CNNs) and advanced architectures (like U-Nets for semantic segmentation of satellite images), and Transformer-based NLP models for contextualizing a read of the satellite image. With IoT, we explored data transport mechanisms and approaches to compare the effectiveness of protocols (for example, MQTT vs. CoAP for constrained environments) and lightweight cryptographic signing (for example, ECDSA) mechanisms for low-power sensors. With Blockchain/DLT, the assessment primarily revolved around the tradeoffs between public vs. hybrid ledgers for our use case and considering the technical mechanisms of oracle networks.

Quantitative metric development: A significant part of our methodology was to move the discussion about valuing data integrity beyond qualitative arguments to develop a mechanism to estimate and value the integrity of the data. The process was nicknamed the "Verifiable Impact Score

(VIS)". This new construct was developed to integrate two dimensions of a project: the actual project performance against their targets; and a non-linear "Verification Factor" that would reward projects that utilized sources of more trustworthy data sources explicitly. This mechanism would provide a direct, quantifiable incentive for projects to access higher benefitting data sources.

System Architecture Design: The last step in the method was to consolidate the assessed technologies and the VIS metric into an integrated, multi-layer system architecture. This transformed into our detailed design of the "Green Ledger" ecosystem (Figure 2); a prescriptive architecture that describes the components, data flows, governance structures, and incentives for a national scale infrastructure for verifiable green finance.

3. RESULTS

The research yielded three primary results: an analysis of the enabling technologies, a quantitative impact metric, and a comprehensive architectural framework.

3.1.Result 1: The Greentech Stack For Verifiable Data

The research identified and analyzed a synergistic "GreenTech Stack" capable of creating a verifiable data pipeline from source to investor.

AI and ML (The Analytical Engine):

Computer Vision for Physical Verification: Training CNNs on satellite images to verify claims regarding physical facts like changes in NDVI - normalized difference vegetation index to measure afforestation; changes in land use for a new solar park; or changes in water levels of reservoirs on a hydro-physical project.

NLP for Contextual Intelligence: Using fine-tuned transformer models like BERT to analyze regulatory filings, news articles, social media articles to see if there is a shift in sentiment, or if a company's marketing message does not align with performance metrics, this creates a system of early warning against greenwashing.

IoT (The Immutable Source of Ground Truth):

Sensor Networks: Deploying sensor networks of specific sensors e.g., gas analyzers mounted on industrial smokestacks, smart water meters deployed on agriculture projects, GPS trackers on trucks that can verify waste disposal routes.

Data Integrity at the Edge: Each sensor employed in project implementation would have a secure element (a hardened microprocessor) on board that cryptographically signs each data packet via its private key at the moment of data

packet creation and could maintain data provenance and non-repudiation.

Blockchain/DLT (The Transparent Layer of Trust):

Permanent Ledger: Allowing for a shared database that cannot be manipulated, where signed IoT data, verification reports, and asset transactions are stored for good. The

implications of this approach for financial instruments, can be found in Table 2.

Smart Contracts: Self-executing code that handles processes such as coupon payments on a green bond because of verified data received from oracles or automatically retiring (burning) a carbon credit NFT after being used for offsetting.

Table 2: Comparative Analysis of Traditional vs. Blockchain-based Green Bonds

Feature	Traditional Green Bond	Blockchain-based Green Bond (Security Token)
Verification of Fund Use	Relies on periodic, manual audits; prone to opacity.	Tracked on an immutable ledger; can be programmatically linked to project milestones.
Impact Reporting (MRV)	Based on self-reported, often outdated data.	Can be linked via oracles to real-time IoT data for continuous, verifiable reporting.
Coupon Payments	Processed centrally on fixed dates.	Automated via smart contracts; can be dynamically linked to verified project performance.
Transparency & Auditability	Audit trail is fragmented and private.	A single, shared ledger provides a complete, real-time audit trail for all stakeholders.

Source: Compiled by Author

3.2. Result 2: The Verifiable Impact Score (Vis)

To directly address the problem of data quality and create a clear market signal, the research produced the VIS, a formula designed to reward data verifiability.

Formula 2: The Verifiable Impact Score (VIS) The VIS for a green project is calculated as follows:

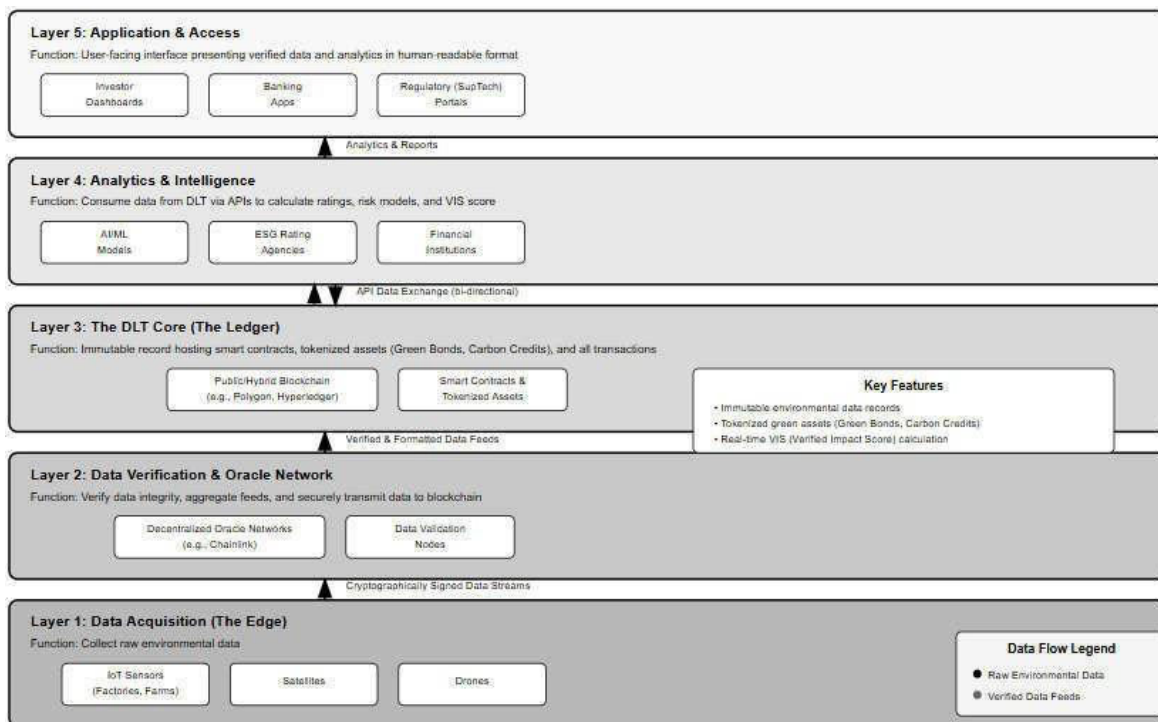
$$VIS_{project} = \left(\sum_{i=1}^n \frac{M_i}{T_i} \cdot w_i \right) \cdot V_f$$

When M_i is the measured value for metric i , T_i is the target, w_i is the weight, and V_f is the Verification Factor that assigns a higher value to more verified data (e.g. $V_f=1.0$ for IoT data anchored with blockchain vs. $V_f=0.5$ for self-reported data). The formula creates an obvious financial incentive for the issuer to invest in technologies that verify data with the highest fidelity, as a higher VIS could mean lower cost of capital, or even, a bonus for performance.

3.3. Result 3: The "Green Ledger" Architectural Framework

The primary outcome of this paper is the development of the "Green Ledger", which is a five-layer national ecosystem for sustainable finance. This architecture provides a complete end-to-end design for a transparent and efficient market.

Figure 2: Architectural Diagram of the Proposed "Green Ledger" Ecosystem



Source: Compiled by Author

This diagram illustrates the flow of data and value through the five distinct layers of the proposed national-scale system for verifiable green finance.

4. DISCUSSION

4.1. Interpretation Of Results

The findings of this research provide an integrated and tech-enabled response to the challenges of greenwashing and unverifiability of data. The GreenTech stack (Result 1) provides protocols for data gathering on the green credentials of projects. The VIS formula (Result 2) provides the quantifiable incentive mechanism. The Green Ledger architecture (Result 3) provides an integrated platform to put them all together. The construction of the system invites and encourages the movement into a virtuous cycle: the existence of verified data provides feasible scoring like the VIS score, which allows investors to safely allocate funds through instruments on the Green Ledger, and helps constitute further demand for additional projects to adopt verifiable data practices. This stands in direct opposition to the current vicious cycle of opacity and greenwashing that keeps the market stagnant. This framework can help reconceptualize ESG as engineering discipline rather than an external reporting exercise..

4.2.Implications For Vikshit Bharat @ 2047

The ramifications of a Green Ledger system in India are profound:

For Capital Markets: It would enhance the credibility of India's green finance market, crowding in a larger share of the trillions of dollars of global climate finance from discerning institutional investors. It would enable fundamentally new types of financial products, such as sustainability-linked derivatives or insurance products whereby premiums are adjusted dynamically based on real-time, verified ESG performance of a company.

For Regulators (SEBI, RBI): It creates a powerful SupTech platform for regulators. The Green Ledger would provide regulators with a real-time, data-rich viewpoint across the green finance ecosystem which will allow them to oversight compliance for regulations such as the BRSR framework and with a level of accuracy and efficiency that is unprecedented. It could automate large sections of the overall reporting and verification process, relieving burdens on both companies and regulators.

For National Climate Goals: The Green Ledger will provide a robust, transparent, digital native MRV framework. This will be invaluable to assess and track progress towards India's Nationally Determined Contributions (NDCs) under the Paris Agreement, whilst enhancing India's credibly on the global stage.

4.3. Limitations Of The Study

The main limitation is the conceptual nature of the architecture proposed. The Green Ledger is a large, complex system, and implementation will face considerable real-world barriers.

Technical and Financial Barriers: These barriers include the enormous upfront capital install cost for the rollout of nationwide IoT infrastructure, the technical challenge of building secure and reliable oracles (the "oracle problem" of connecting the deterministic on-chain world with the probabilistic off-chain world), and a successful DLT implementation is scalable and able to function with millions of data points each day.

Socio-Political Barriers: Of course, the more difficult barriers are those which are not technical. These include the political barrier of achieving consensus among a wide variety of stakeholders (government ministries, multiple regulators, industry bodies) on data standards, governing rules, and legal framework for tokenized assets. Added to this, is the risk of achieving a new "digital divide" in which smaller companies who are unable to deploy the same kind of

IoT/blockchain systems in the same way and obtain funding for advanced systems, are excluded from the green finance market.

5. CONCLUSION

Efficient and credible capital allocation underpins financing India's transition to a green economy. This research has articulated the unverifiability of ESG data as the main choke point and has introduced a holistic, technology-driven solution: the Green Ledger. By establishing a transparent, performance-based market underpinned by verifiable proof, this ecosystem will address the root concern of greenwashing, thereby reducing the cost of capital for bona fide green projects and embedding verifiable information for the full range of stakeholders – from retail investors to global fund managers to national regulators. While ambitious, it is a tactical priority to develop this foundational infrastructure. It is akin to investing in the trust and credibility of our financial markets and it is an indispensable enabler in ensuring the prosperity of Vikshit Bharat @ 2047 is significant as well as sustainable, resilient and just.

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TRACK 3: FINTECH INNOVATION, WEB3 AND BLOCKCHAIN ECOSYSTEM

" Decoding Profitability: A Censored Logistic Approach to FinTech Adoption in Indian PSBs"

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Authors' contributions:

Mohammad Ammar Ahsan executed the conceptualization, validation, data collection, data organization, data cleansing, data refinement, contributed to the authoring of the original manuscript, and conducted the theoretical analysis. Faiz ur Rehman conducted data validation, formal analysis, and software analysis. Shamaela Tabassum conducted a literature review, identified research gaps, developed hypotheses, and performed proofreading. All authors reviewed and endorsed the final manuscript.

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Abstract:

Purpose: This study aims to investigate the impact of FinTech Investments (FIV) on the profitability of Indian Public Sector Banks (PSBs), with a specific focus on Return on Assets (ROA). It further explores the mediating roles of Liquidity (LIQ) and Credit Risk (NPL), along with the moderating effect of Inflation (INF) on financial stability indicators.

Methodology: A panel dataset comprising 11 Indian PSBs over the period 2016–2024 is analyzed using a Machine Learning-based Censored Logistic regression model. The study

incorporates Bank Size (SIZE), Solvency (SOLV), and GDP growth as control variables to assess their influence on profitability.

Findings: The results reveal that FIV has a positive and significant impact on ROA. LIQ mediates this relationship positively, while NPL mediates it negatively. INF moderates the FIV-profitability link, weakening its effect under high inflation. Larger banks are more capable of leveraging FIV to enhance profitability, whereas SOLV and GDP growth show limited direct effects.

Research limitations: The study is limited to Indian PSBs and the 2016–2024 period. Future research may extend the analysis to private and foreign banks or adopt comparative cross-country perspectives.

Implications: The findings underscore the need for strategic FinTech adoption policies that enhance LIQ and mitigate NPL. Additionally, policymakers should design INF-resilient FinTech strategies and offer targeted regulatory support to smaller banks to maximize the benefits of FinTech investments.

Originality: This study offers a novel contribution by examining the mediating and moderating roles of key financial stability factors in the relationship between FIV and bank performance. It fills a critical gap in the literature concerning FinTech's strategic implications for public banking in emerging economies.

Keywords: *FinTech Investments, Public Sector Banks, Banks' Performance, Financial Innovation*

Introduction

The history of banking in India is deeply rooted in its colonial past, with the establishment of the Bank of Hindustan in 1770, followed by the rise of the Presidency Banks in the early 19th century. These institutions laid the foundation for a modern banking system, which expanded significantly post-independence with the nationalization of banks in 1969 (Byjus, 2024). This shift was aimed at promoting financial inclusion, ensuring equitable access to credit, and supporting economic growth. Over the years, Indian PSBs have played a pivotal role in driving economic development, particularly in rural and underserved areas (Kumar, 2023). However, like global counterparts, Indian banks faced increasing pressure in the late 20th century to improve efficiency and service delivery, setting the stage for

significant technological integration (Benori, 2024).

The rapid advancement of technology has profoundly impacted the banking sector. The late 20th century saw the introduction of core banking solutions (CBS), followed by the proliferation of ATMs, online banking, and mobile banking, which drastically improved customer service and operational efficiency (Herald, 2024). By the early 21st century, technological innovations became central to banking operations, reshaping traditional banking models. With the advent of the Fourth Industrial Revolution, the fusion of digital technologies, including artificial intelligence (AI) (Kudelić et al., 2025), blockchain, and big data analytics, further revolutionized banking services (Linker,

2021). These technological advancements enabled banks to streamline operations, enhance customer experience, and reduce costs, marking the dawn of Financial Technology (FinTech) as a transformative force in banking (Scott-Briggs, 2024).

Financial technology, or FinTech, refers to the application of digital technologies to deliver financial services in innovative ways. It encompasses a wide range of services, including mobile banking, digital payments, peer-to-peer lending (P2P), robo-advisors, cryptocurrency, and blockchain-based solutions (Dabbeeru & Rao, 2021). In the Indian banking sector, FinTech services have revolutionized payment systems through platforms like Unified Payments Interface (UPI), enabling real-time money transfers (Bala Parthasarathy & Joshi, 2021). Additionally, digital lending platforms have expanded access to credit, while robo-advisors provide personalized financial advice using AI algorithms (Naik et al., 2025). The seamless integration of these services has improved accessibility, security, and efficiency in banking operations, making FIV a crucial aspect of modern banking strategies (Kumari, 2023).

The performance of banks, especially PSBs in India, has become deeply linked with FIV. With the age of digitalization, FIV enable PSBs to stay competitive and relevant in the face of mounting competition from private banks and NBFCs (Agnihotri & Arora, 2022). FinTech innovations enable PSBs to streamline operational processes, improve risk management practices, and implement personalized banking services (Varma et al., 2024). Moreover, digital tools aid in reducing non-performing assets (NPAs), increasing profitability, and improving

customer retention (Shivakumar & Asha). Thus, evaluating the impact of FIV on the performance of Indian PSBs is essential to understanding how these institutions can navigate technological changes and improve their financial health in an increasingly digital economy (Painoli et al., 2021).

In spite of the growing uptake of FinTech innovations, the particular influence of FIV on PSBs in India is not well researched. Most of the current literature, including research by Gomber et al. (2018) and Phan et al. (2020), centers on private banks and international trends, with a gap in knowledge regarding the unique dynamics of PSBs in the Indian context. Though private banks have been quick to adopt digital technologies, PSBs are confronted with challenges like legacy systems, regulatory issues, and sluggish technology adoption (Wewege et al., 2020). Recent research by Jain et al. (2023) emphasize the importance of empirical examination of FIV effects on such key performance indicators as profitability, operational effectiveness, and risk management, specifically in India's public sector. Bridging this gap is critical to determining the extent to which PSBs are able to leverage their performance and competitiveness in the digitally-oriented financial environment.

This research is mainly meant to explore how FIV affects the performance of PSBs in India, paying particular attention to ROA as an important performance indicator. This research will seek to analyze the link between FIV and bank performance with special emphasis on the stability factors' moderating, mediating, and control effects. The research aims to investigate the possibilities and limitations of embedding

FinTech solutions in conventional banking paradigms, thereby giving insight into organizational scale and technology impact on future stability and growth of PSB in India.

The key research questions, to be answered through this study are:

- How do FIV affect the performance of PSBs in India?
- Does LIQ and NPL mediate the relationship between FIV and bank profitability?
- Does INF moderate the relationship between FIV and financial stability factors, specifically LIQ and NPL?
- Do SIZE, SOLV, and GDP influence the profitability of PSBs?

In order to answer these questions, this study employs a panel dataset of 11 Indian PSBs from 2016 to 2024, utilizing the ML-Censored Logistic regression model to analyze the impact of FIV on bank

Literature Review

The Effect of the Financial Technology Adoption on the Bank Profitability

The adoption of financial technology (FinTech) has become a significant factor influencing the profitability of banks globally. Numerous studies have examined the impact of FinTech adoption on bank performance, with mixed findings.

Solow (1987) emphasizes the productivity paradox, which indicates that the significant integration of information technology in the United States since the 1970s has not led to a corresponding rise in productivity. This conundrum has incited considerable academic investigation to elucidate its fundamental roots. Campanella et al. (2017) asserts that digital innovators might get considerable advantages from their innovations only if

profitability. Descriptive statistics, linearity tests, and multicollinearity diagnostics ensure the robustness of the analysis. Key financial indicators such as LIQ, NPL, INF, and SIZE are examined as mediating and moderating variables. Data is sourced from annual reports, ProwessIQ, and the World Bank, ensuring comprehensive coverage of financial and macroeconomic factors.

This study examines the effect of FIV on the profitability of Indian PSBs through a structured analysis spanning multiple sections. The literature review explores relevant research, while the methodology details the data, variables, and econometric approach. The analysis and interpretation present key findings, followed by the discussion, which contextualizes the results. The practical and theoretical implications highlight the study's contributions, and then finally identifies future directions and research gaps.

they manage to capture a significant market share before the emergence of secondary competitors. In addition, Hitt and Brynjolfsson (1996), building upon Clemons (1986) concepts, state that within a scenario of general access to digital technology, economic benefits cannot be distributed evenly among all involved. These conclusions collectively point toward the complexity inherent in leveraging information technology for sustained competitive advantage and productivity improvement (Chhaidar et al., 2023).

Alternative studies indicate that information technology lowers costs and improves bank performance.

In India, artificial intelligence, blockchain, and cloud computing have contributed to enhanced bank profitability, with FinTech

banks surpassing traditional banks (Singh et al., 2021). Likewise, as banks in Bahrain and the United Arab Emirates have shown high FinTech adoption rates, so boosting profitability and market valuation, there is a correlation between market performance and FinTech integration in the Gulf Cooperation Council (GCC) countries as well (Musleh Alsartawi, 2024). Actually, the emergence of FinTech in China has improved the sustainable profitability of commercial banks by emphasizing digitalization as a main element to guarantee financial stability (Wang et al., 2024a). Financial performance of commercial banks is improved by financial inclusion, alternative payments, and automation according to research done in Jordan (Kaddumi et al., 2023). Such studies underline the strategic importance of FinTech as a driver of profitability and efficiency in banking institutions in many different markets worldwide.

The influence of financial technologies on profitability has been extensively analyzed. A study in the United Arab Emirates investigated the relationship between FinTech adoption and banking performance. It significantly enhanced critical profitability metrics, such as Return on Assets (ROA) and Return on Equity (ROE). The preceding research emphasizes

Mediating role of Liquidity and Credit Risk

FIV has changed how banks work by making it easier to handle liquidity, evaluate risk, and make the bank's finances work better overall. Digital banking platforms, computerized fund transfers, and cash flow tracking powered by AI have been shown to improve liquidity, which in turn stabilizes profits (Ozili, 2021); (Phan

FinTech's application in emerging economies (Almashhadani & Almashhadani, 2022), efficiency in banking as well as investment decision-making promise it offers. Likewise, it was shown from a study of Indonesian banks that although ATM terminal transactions did not measure, internet-based banking and mobile banking considerably increased ROA. This highlights how much digital channels help to explain the increase in profitability over 2014–2020 (Medyawati et al., 2021). Using FinTech across Arabian banks distributed over Bahrain, Saudi Arabia, and the UAE has showed a good link with both ROA and ROE. The correlation was significantly heightened throughout the COVID-19 period, emphasizing the augmented significance of FinTech amid financial crises (Al-Shouha et al., 2024). These findings underscore the substantial impact of FinTech on improving operational efficiency and financial outcomes across diverse banking environments.

Building upon these insights, this study aims to investigate the relationship between FinTech adoption and bank profitability (see figure 1).

H1: Financial technology investments have a significant positive impact on bank profitability.

et al., 2020). When a bank has more cash, it can better handle its short-term debts, keep its operations stable, and increase its return on assets (Diamond & Rajan, 2001). Mawalla (2023) says that too much cash can leave capital idle, which limits the chances of making money through investments. FinTech-funded financial innovations aim to maximize asset returns while finding a balance between cash

buffers and return maximization, which has an impact on return on assets (Arner et al., 2015).

FinTech has changed the way NPLs are managed by making it easier to screen loans, find scams, and evaluate risk in real time. Adoption of FinTech lowers the amount of loans not being repaid using AI-powered credit review and predictive analysis (Berg et al., 2022); (Holmes, 1998), therefore improving asset quality and financial performance. Reduced credit risk helps to stabilize the economy, thereby raising the ROA (Chen et al., 2022); (Srairi, 2019). Credit evaluation algorithms could show bias, therefore affecting loan

Moderating role of Inflation

Inflation generates liquidity management issues that affect banks' ability to guarantee consistent cash flow and react to market demand. By offering greater real-time monitoring of liquidity, automated fund allocation, and predictive analytics (Beck et al., 2016); (Malik & Sikarwar, 2024) studies demonstrate FinTech advancements mitigate inflationary pressures. INF often reduces the actual value of liquid assets, which forces banks to adopt FinTech to properly manage LIQ (Laeven & Valencia, 2020); (Pandey et al., 2022). Extended inflationary conditions could cause banks to retain surplus liquidity in reserve, hence lowering investment efficacy and profitability (Dang, 2021). The combination of FIV, INF, and LIQ suggests that LIQ management derived from FinTech-based solutions significantly helps to reduce financial instability generated by INF.

Inflation substantially affects non-performing loans by increasing borrowing costs and reducing repayment capacity, leading to a greater prevalence of non-

portfolios and risk exposure (Song & Chen, 2025); (Fuster et al., 2019). The correlation among FIV, NPL, and ROA emphasizes the need of FinTech-driven NPL management in preserving banks' profitability.

As shown in Figure 1, these facts constitute the foundation for examining, the mediating roles of LIQ and NPL in the influence of FIV on banks' profitability.

H2: Liquidity mediates the association between FinTech Investments and Banks' profitability.

H3: Credit Risk mediates the association between FinTech Investments and Banks' profitability.

performing loans (Msomi, 2022). FIV alleviates these risks with blockchain-enforced contracts, digital lending platforms, and machine learning algorithms (Sikalao-Lekobane, 2022); (Ahmad et al., 2024). FinTech-enabled credit assessments diminish default rates and improve asset quality by allowing for the prompt identification of borrower distress (Gomber et al., 2018); (Bavoso, 2022). Economic instability may undermine the advantages of technology risk aversion under high inflation, hence reducing the significance of FinTech innovations (Feyen et al., 2023). Therefore, even if FIV enhances its management of NPLs, macroeconomic stability continues to have a significant impact.

These disclosures prepared the ground for examining the moderating function of INF in the link between FinTech Investment, LIQ, and NPL, as depicted in figure 1.

H4: Inflation moderates the association between FinTech Investments and Liquidity.

H5: Inflation moderates the association between FinTech Investments and Credit Risk.

Bank Size, Solvency and GDP on Banks’ Profitability

Various control variables influence bank profitability, as indicated by ROA, including SIZE (Phan et al., 2020), SOLV Ratio (Setiawan & Prakoso, 2024), and GDP growth (Wang et al., 2024b). Larger banks often achieve greater profitability due to economies of scale, enhanced risk diversification, and superior market reputation (Berger et al., 2009); (Bavoso, 2022). Elevated SOLV levels are associated with enhanced risk absorption capacity and consistent returns (Laeven & Valencia, 2020); (Dang, 2021). hence a robust SOLV Ratio ensures financial resilience.

Enhancing credit demand increases banking revenues, hence enhancing investment prospects and benefiting GDP growth, which in turn positively impacts ROA (Tanda & Schena, 2019); (Alam et al., 2021). These control factors provide a comprehensive framework for assessing bank profitability independent of FIV's direct impact.

These realizations set the stage for looking at how SIZE, SOLV, and GDP control profitability (see figure 1).

H6: Bank Size, Solvency ratio and Gross Domestic Product growth ratio does not influence Banks’ profitability

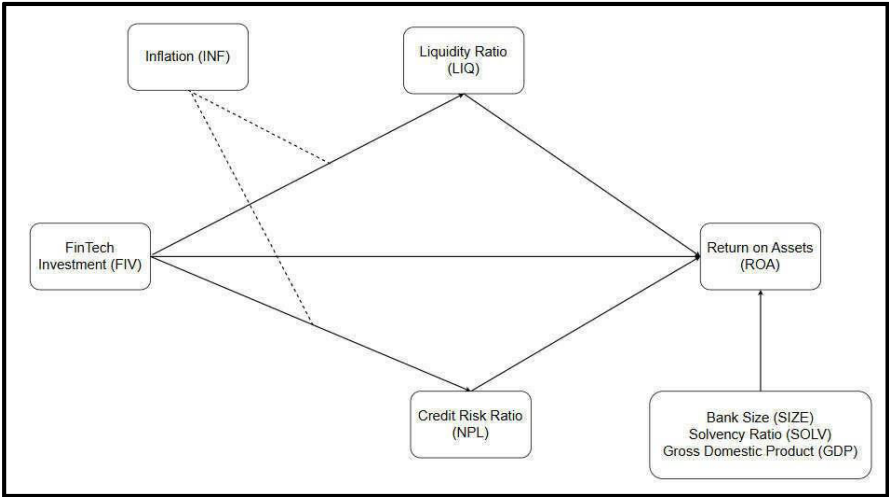


Figure 1: Hypothesized Model of FinTech Investments and Banks’ Profitability (Source: Author’s Compilation)

Sampling, Data, and Variable Description

Sampling

This study aimed to examine the impact of technological investment on the financial performance of Public Sector Banks in India. Data were obtained on the twelve banks. Owing to the absence of data, we limited our sample to 11 banks spanning the

2016–2024 timeframe, as illustrated in figure 2. The panel was seen to be balanced due to the absence of missing values. The Indian public sector banks selected in the study which includes Bank of Maharashtra, Bank of India, Canara Bank, Bank of Baroda, Central Bank of India Ltd., Indian Bank, Indian Overseas Bank, Punjab National Bank, State Bank of India, Union Bank of India, and UCO Bank. The

selection of the region was driven by the scarcity of empirical evidence regarding the impact of contemporary technologies on Indian banks at a worldwide scale. The banking system in India warrants examination due to the substantial investments being directed towards its digitalization (Network Readiness Index Report - Portulans (2020)).

Data Sources

The dataset was compiled from three primary sources: ProwessIQ (CMIE), the World Bank and annual reports. Financial indicators, including the Liquidity Ratio (LIQ), Bank Size (SIZE), Credit Risk Ratio (NPL), Solvency Ratio (SOLV), and profitability metric Return on Assets (ROA), were extracted from ProwessIQ

The justification for choosing the 2016–2024 period is its contemporaneity, allowing for an analysis of the effects of investments in modern information technology. This time is marked by the advent and advancement of technologies such as big data, artificial intelligence, and blockchain (Thakor, 2020).

(CMIE). The DIG score was established to manually calculate the FinTech Investments (FIV) variable using data extracted from annual reports obtained from the banks' websites. Data for the Gross Domestic Product (GDP) growth and inflation (INF) variables were obtained from the World Bank website, as illustrated in Figure 2.

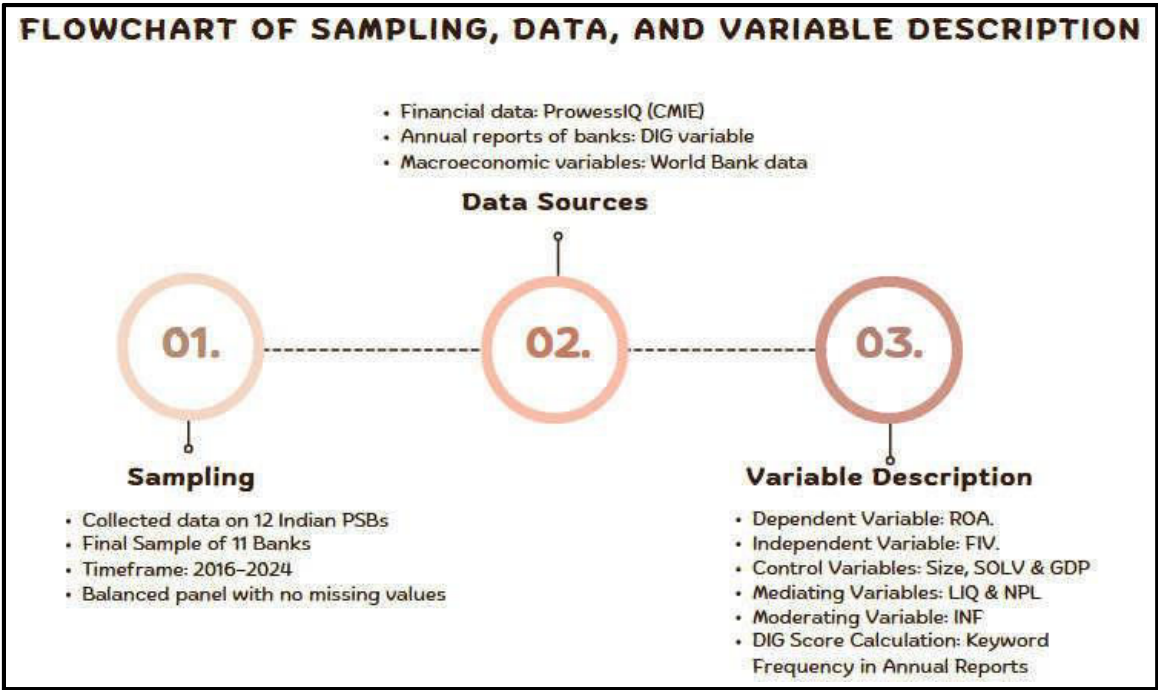


Figure 2: Procedural flowchart of sampling, data sources and variable description (Source: Author’s Compilation)

Variable Description

The dependent variable of the study is financial profitability. Profitability was measured through the Return on Assets

(ROA), where net income was presented as a percentage of total assets. The key independent variable refers to the investment of the bank in financial

technology. We used the Kriebel and Debener (2019) approach to measure digitalization engagement, which we call the DIG score. This measure evaluates digitalization engagement by measuring the frequency of digitalization terms in annual reports (Chhaidar et al., 2023). The selected search term encompass “digital,” “mobile,” “Internet,” “online,” “electronic,” “UPI,” “cyber,” “fintech,” “artificial intelligence,” “information technology,” “information system,” “computer science,” “crowdfunding,” “blockchain,” “big data,” “hack,” “social media,” “robotic,” “computing,” “programming,” “peer-to-peer,” “crypto,” “open banking,” and “computer science” (Chhaidar et al., 2023).

Research Methodology

The research methodology employed in this study is designed to rigorously analyze the secondary data collected from 99 observations across all the PSBs in India using advanced econometric techniques. The study begins with a thorough descriptive analysis of the data set, including main variables. Central tendency (mean, median) and dispersion (range, variance) measures are computed to first determine the shape of the distribution and detect any outliers or anomalies (Borradaile, 2003). It is crucial for establishing the reliability of the following econometric estimations.

Following descriptive analysis, the research also tests linearity, which is a key assumption of regression models. To identify if there is a linear association between the dependent and independent variables, squared and cubic predictors are created and included in the model

Precisely, $DIG(annual\ report_{t,i}) = \ln(\sum_{m=1}^M \frac{tf}{nt})$ where, m is the **Keyword** in the investigated report, tf is the term frequency of m , M is the total number of **Keywords** tested in the investigated report, and nt is the number of total words in the investigated report.

The control variables comprise SIZE, represented by the logarithmic value of total assets; the SOLV ratio, defined as total shareholders' equity divided by total assets; and the GDP growth rate. Additionally, there are other mediating variables; specifically, the NPL ratio was assessed by the proportion of non-performing loans to total loans and the LIQ ratio was measured by the cash-to-deposit fraction. In addition, we used INF ratio as moderating variable in the study (see figure 2).

(Sauerbrei et al., 2007). The adjusted fitted values are stored and compared to see if the association is linear or if there is a need for higher-order variables to clarify the patterns being observed. This process ensures that the model is well-defined and any non-linearity is properly modeled, thus improving the stability of the analysis (Hong et al., 2008).

A correlation matrix is developed to assess the pair-wise correlations between the variables in an effort to avoid multicollinearity issues that might weaken regression analysis (Kyriazos & Poga, 2023). To determine the level of multicollinearity, the Variance Inflation Factor (VIF) for every independent variable is computed. As seen in Figure 3, the validity of the regression model can be maintained by reforming or deleting high VIF values to avoid multicollinearity (Barton et al., 2019).

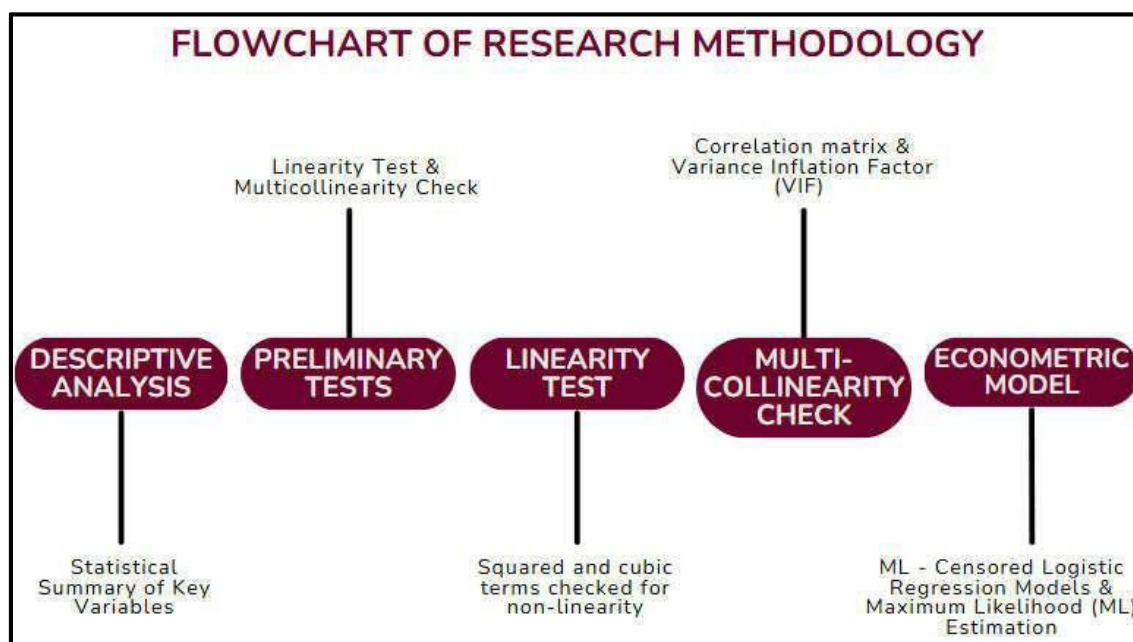


Figure 3: Procedural Flowchart of Research Methodology (Source: Author's Compilation)

The econometric analysis is essentially grounded on the use of the ML - Censored Logistic model, which is a censored regression model estimated by Maximum Likelihood (ML) methods as seen in figure 3. Given that the model manages censored data—where the dependent variable is limited within a given range Zeng and Lin (2007) find it to be very suitable for this investigation. The ML - Censored Logistic model has a general form as:

$$Y_i^* = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_k X_{ki} + \varepsilon_i$$

where Y_i^* is the latent variable, $X_{1i}, X_{2i}, \dots, X_{ki}$ are the independent variables, $\beta_0, \beta_1, \dots, \beta_k$ are the coefficients to be estimated, and ε_i is the error term. The observed

Analysis and Interpretation

Descriptive Statistics

The descriptive statistics highlight notable patterns and disparities across the financial and macroeconomic indicators of the sampled banks. ROA exhibits a mean of -0.033, suggesting overall weak profitability, with values ranging from -3.010 to 1.500 and a high standard deviation of 0.890, as depicted in table 1.

dependent variable Y_i is related to the latent variable as follows:

$$Y_i = \begin{cases} Y_i^* & \text{if } Y_i^* > 0 \\ 0 & \text{if } Y_i^* \leq 0 \end{cases}$$

Often in financial and economic data, this model is suitable for examining situations whereby the result variable has a lower or upper limit (Breen, 1996). Even in the presence of censoring, the research may effectively capture the link between the dependent variable and the predictors by using the ML-Censored Logistic model, thereby offering more dependable and complex insights (Cui, 2025).

This dispersion indicates that while some banks achieved healthy profits, others faced significant losses, possibly due to differing operational efficiencies or asset quality (GETU, 2024). The median value of 0.200, higher than the mean, hints at a left-skewed distribution, with a few banks severely underperforming and dragging the average down (DeYoung, 2005).

	ROA	FIV	LIQ	NPL	INF	SIZE	SOLV	GDP	IT_NPL & SOLV
Mean	-0.033	-7.049	5.350	0.117	4.995	6.776	0.056	1.931	216.053
Median	0.200	-7.124	5.060	0.102	4.948	6.787	0.056	1.944	177.200
Maximum	1.500	-5.223	11.750	0.295	6.699	7.792	0.079	2.271	888.108
Minimum	-3.010	-8.767	1.580	0.0190	3.328	6.195	0.026	1.354	51.937
Std. Dev.	0.890	0.640	2.003	0.063	1.137	0.381	0.009	0.244	150.781
Observations	99	99	99	99	99	99	99	99	99
Banks	11	11	11	11	11	11	11	11	11

Table 1: Results of Descriptive Statistics of the Variables (Source: Author's Compilation)

FIV averages -7.049 with low variability (SD = 0.640), showing that most banks operate under similar, perhaps conservative, investment policies. The narrow range between -8.767 and -5.223 suggests restrained risk-taking behavior, possibly driven by regulatory limitations or risk-averse financial strategies. LIQ has a mean of 5.350 and shows substantial variability (SD = 2.003), with values ranging from 1.580 to 11.750, indicating heterogeneity in liquidity positions. Some banks are highly liquid, which may suggest inefficiency in asset utilization, while others are closer to liquidity risk thresholds (see table 1).

NPL average at 0.117, with a relatively moderate spread from 0.0190 to 0.295 and standard deviation of 0.063, reflecting varied levels of credit quality (Geitangi, 2015). Higher NPL may indicate ineffective credit risk monitoring or exposure to vulnerable sectors. INF and GDP have means of 4.995 and 1.931 respectively as shown in table 1, with

standard deviations of 1.137 and 0.244. These variables show moderate fluctuations, implying consistent macroeconomic conditions (Gong et al., 2023), though the lower GDP growth may indicate subdued economic expansion during the study period (Davoodi & Grigorian, 2007).

SIZE is tightly clustered around a mean of 6.776 (SD = 0.381), indicating limited disparity in bank scale, which supports comparability across entities (Morin et al., 2019). SOLV, with a mean of 0.056 and very low standard deviation (0.009), suggests uniformly stable capital adequacy (Rendón et al., 2021). However, the interaction term IT_NPL & SOLV has a strikingly high mean of 216.053 and standard deviation of 150.781, with values ranging between 51.937 and 888.108. This reflects substantial variation in how solvency is impacted by credit risk, pointing to inconsistent risk-bearing capacities and potential fragility in weaker institutions (Elgayar, 2024).

The Dynamic Evolution of the Digital Score Variable

In order to examine the temporal progression of the digitalization score, we first disaggregated the Digitalization Index (DIG) into its fundamental components. This methodological approach mitigates

certain confounding effects that could obscure the visualization of digitalization trends over time (Wang, 2023). Figure 4 illustrates the cumulative frequency of the top ten digitalization-related terms covering all studied banks, throughout the observation period.

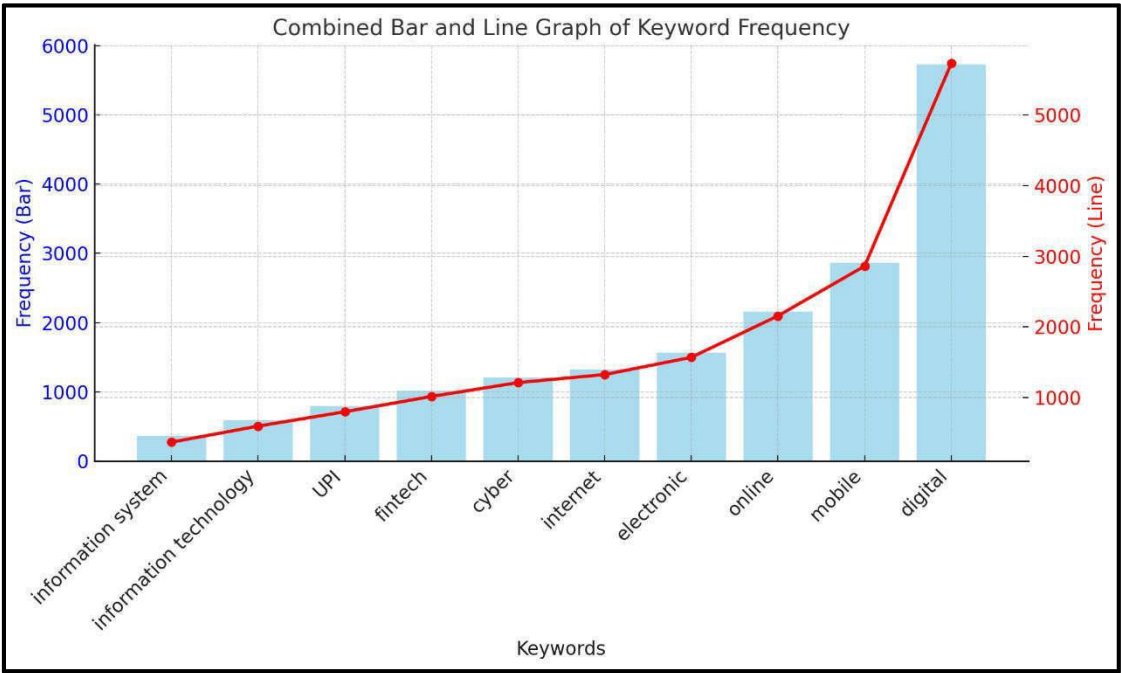


Figure 4: The total frequency of top 10 financial technology **Keywords** used in banks (Source: Author’s Compilation)

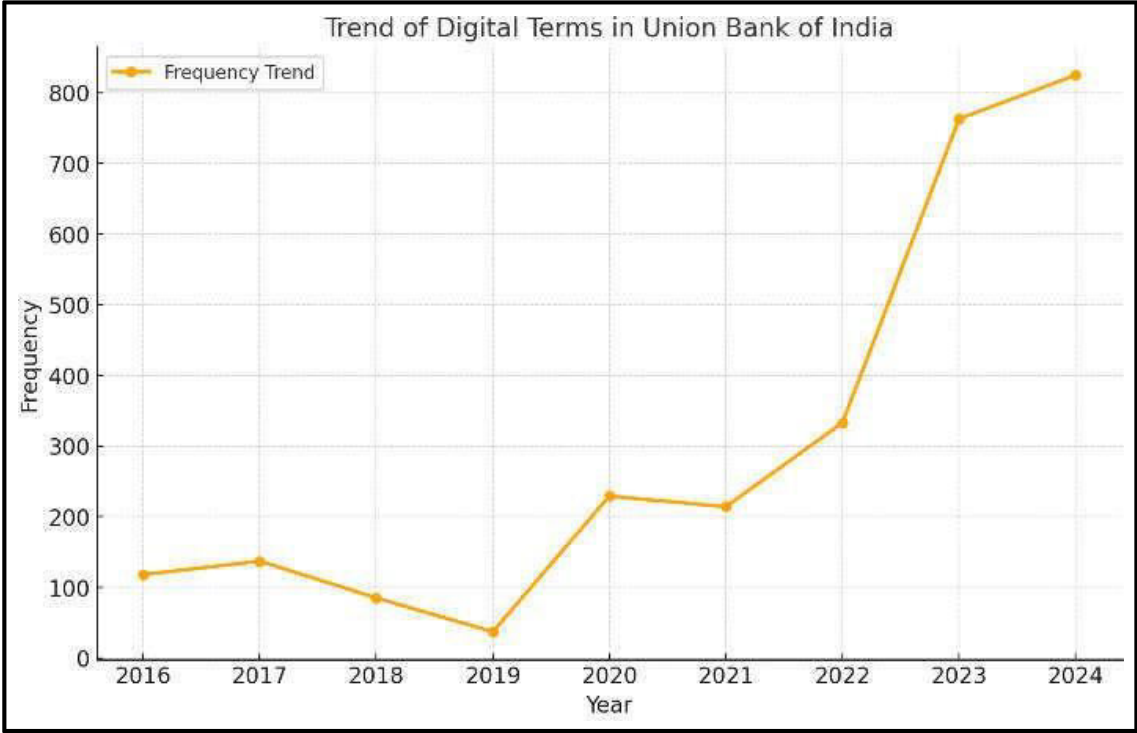
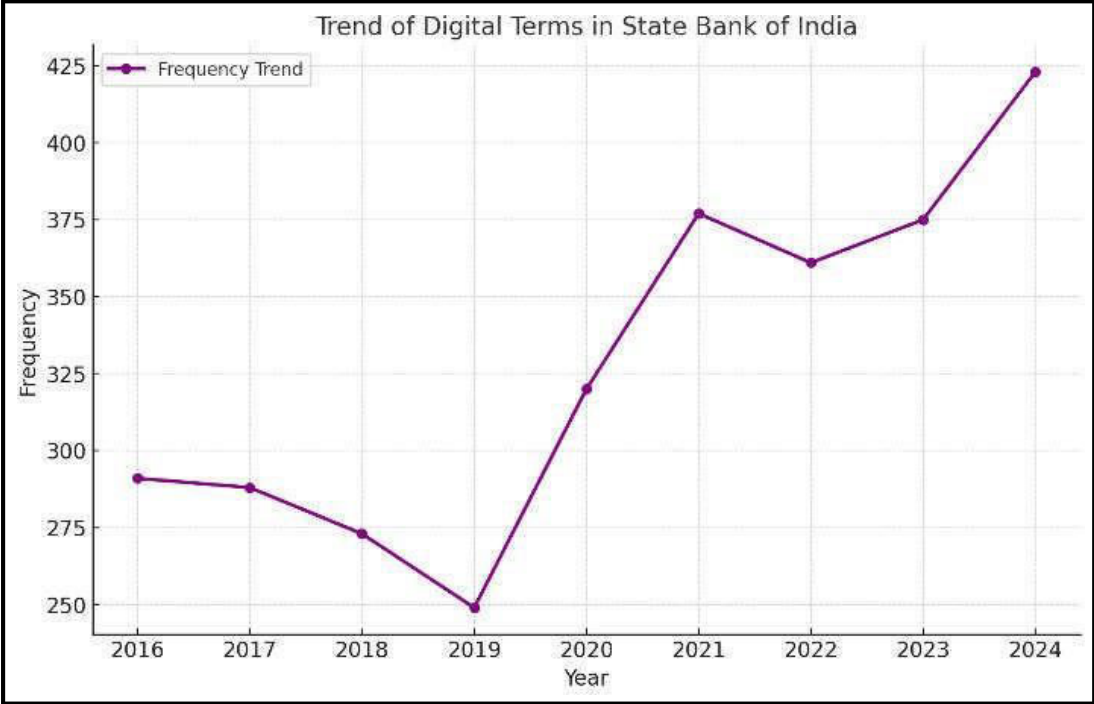
The study shows that the term "digital" is most often used, a phenomenon mostly connected to its general applicability and integration with several digitalization-related lexicons (see figure 4). Because "digital" is connected with several domain-specific phrases, it is rather common. For example, "digital banking," "digital applications," "digital payment," "digital finance," and "digital solutions" form compound **Keywords**. This emphasizes how widely digital transformation is reshaping financial ecosystems and banking (Chhaidar et al., 2023). Similarly, high-frequency **Keywords** including "online," "mobile," and "internet" show the growing reliance on digital platforms, often co-

occurring with particular terms to produce compound concepts like "online banking," "online brokerage," "online trading," "mobile banking," "online payment," and "internet advisory." These terms' increasing use shows the continuous financial sector investment in digital service delivery and customer engagement approaches.

The term "cyber," which denotes an increasing focus on cybersecurity in digital banking activities, is rather conspicuous (Chhaidar et al., 2023). This tendency fits the growing awareness of cyber risks and the development of new kinds of financial risk that call for strong security policies and legal structures (Bahri & Hamza, 2020). Moreover, even if words like "information

technology," "fintech," "artificial intelligence," and "UPI" seem with rather lower frequency, their increasing relevance cannot be underlined as seen in figure 4. The financial industry is undergoing a paradigm change with the integration of

fintech solutions, artificial intelligence-driven banking services, and the general acceptance of UPI-based transactions, thereby stressing an accelerating movement toward technologically driven banking models.



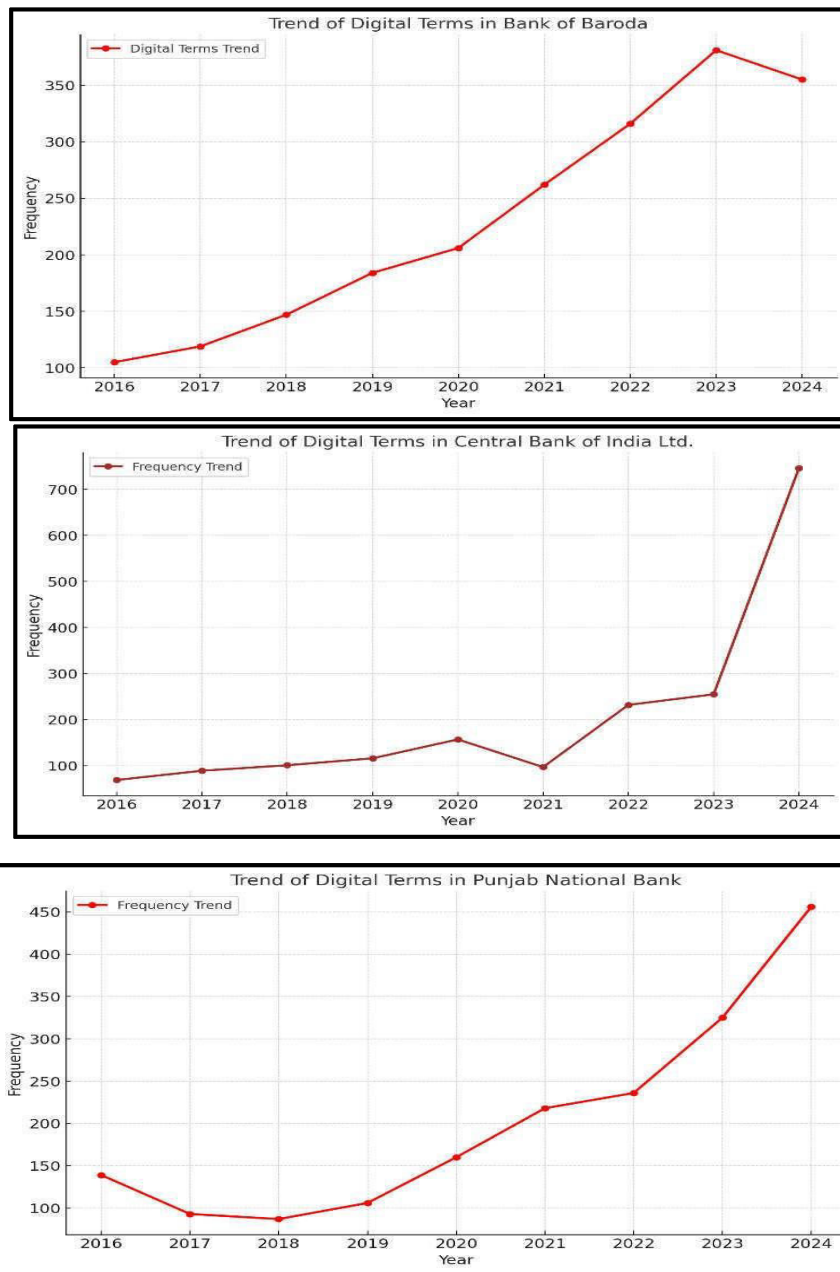


Figure 5: The evolution of most recurring 10 **Keywords** over time in top 5 digitalized banks (Source: Author's Compilation)

The analysis of digital terms across various Indian banks reveals significant trends in their adoption and usage over the years (see figure 5). Punjab National Bank, Central Bank of India, and Union Bank of India show a sharp rise in digital terms in recent years, indicating a strong push toward digital transformation. Union Bank of India exhibits the most substantial surge in 2024, reflecting an accelerated shift toward digital banking services. Similarly, the

State Bank of India and Bank of Maharashtra maintain a steady yet moderate upward trend, suggesting consistent digital adoption over the years. On the other hand, Bank of India and Bank of Baroda show a fluctuating pattern, with some years witnessing declines before a subsequent increase, implying periods of technological adaptation and recalibration.

Particularly shown in figure 5, Central Bank of India observed a notable increase in 2024 probably because to current developments or legislative changes supporting digital banking. The different trajectories across banks imply that whilst some institutions quickly embrace digitalization, others face stages of slower development, most likely impacted by

Diagnostic Tests

Linearity Test

The results of linearity test indicate that the squared and cubic terms of the predicted values (YHAT^2 and YHAT^3) are

Variable	Coefficient	Std. Error	z-Statistic	p-Value
YHAT^2	-0.0617	0.1513	-0.4079	0.6833
YHAT^3	-0.0660	0.0733	-0.9005	0.3678

Table 2: Results of Linearity Test (Source: Author’s Compilation)

The negative coefficients for both terms imply a potential downward curvature, but their statistical insignificance means that any deviation from linearity is minimal and likely due to random variation rather than a true underlying pattern (Poole & O’Farrell, 1971). The relatively large standard errors further indicate instability in these estimates, reinforcing the notion that non-linearity does not significantly contribute to

infrastructure constraints, regulatory rules, or client acceptance rates (Jameaba, 2022). Emphasizing the increasing relevance of fintech integration and online banking solutions in the Indian banking sector, the general trend across all banks shows an increasing reliance on digital financial services.

statistically insignificant, as evidenced by their high p-values, as shown in table 2. This suggests that there is no strong non-linear relationship between the dependent and independent variables in the model (Banker et al., 2020).

the model’s explanatory power (Hasanov et al., 2018). Given these findings, a linear model appears to be an appropriate fit for the data, as introducing non-linear transformations does not enhance predictive accuracy (Claeskens & Hjort, 2003). This simplifies interpretation and suggests that adding higher-order terms may not provide meaningful improvements.

Multicollinearity Test

Correlation Matrix

Variable	ROA	FIV	LIQ	NPL	INF	SIZE	SOLV	GDP	IT_NPL & SOLV
ROA	1.000								
FIV	0.482	1.000							
LIQ	-0.076	-0.345	1.000						
NPL	-0.773	-0.462	0.367	1.000					
INF	0.572	0.242	-0.133	-0.517	1.000				
SIZE	0.389	0.611	-0.086	-0.443	0.212	1.000			
SOLV	0.476	0.318	-0.218	-0.320	0.296	0.036	1.000		
GDP	0.229	-0.004	0.074	-0.195	0.300	0.041	-0.015	1.000	
IT_NPL & SOLV	0.575	0.449	-0.333	-0.733	0.385	0.366	0.053	0.174	1.000

Table 3: Correlation Matrix of the Variables (Source: Author's Compilation)

The correlation matrix reveals that ROA shares a strong negative association with NPL, indicating that higher levels of non-performing loans significantly erode profitability (Saif-Alyousfi & Saha, 2021). A similar inverse relationship exists between ROA and LIQ, albeit weaker, suggesting that excess liquidity might not be efficiently converted into earnings. On the contrary, ROA is positively correlated with inflation, solvency, and financial investment value, implying that profitability tends to improve with inflationary trends, better capital adequacy, and sound investment decisions (Oppusunggu, 2022). Interestingly, a moderately positive relationship between ROA and IT_NPL & SOLV suggests that the combined effect of asset quality and solvency strongly influences earnings performance (see table 3).

Furthermore, NPL is negatively correlated with almost all other variables, notably SOLV, INF, and FIV, reflecting that poor loan performance can undermine both internal financial health and responsiveness to external economic indicators (Beck et al., 2014). SIZE has a mixed role, aligning positively with FIV and IT_NPL & SOLV but showing weak or no association with solvency and GDP, implying larger banks may benefit from investment advantages without necessarily translating that into capital stability or macroeconomic alignment (Chang & Pan, 2022). GDP, while weakly correlated with most variables, exhibits a slightly positive relationship with inflation and IT_NPL & SOLV, indicating that broader economic activity might indirectly influence systemic risk and solvency interaction.

Variance Inflation Factors

Variable	Coefficient Variance	Uncentered - VIF	Centered - VIF
FIV	0.0110	274.8345	2.2276
LIQ	0.0006	10.8460	1.3211
NPL	1.6665	14.4700	3.2318
INF	0.0023	30.9669	1.5095
SIZE	0.0273	624.1119	1.9446
SOLV	35.3107	56.6297	1.4925
GDP	0.0393	73.7231	1.1488
IT_NPL & SOLV	2.32E-07	7.9532	2.5871
C	3.6351	1799.480	NA

Table 4: Variance Inflation Factors of the Variables (Source: Author's Compilation)

The Variance Inflation Factor (VIF) values indicate that multicollinearity among the predictors is generally within acceptable limits, as shown in table 4. All centered VIF values are below the critical threshold of 5 (Chennamaneni et al., 2016), suggesting that no variable is excessively correlated with others to the extent of distorting regression estimates. Among the variables, NPL and IT_NPL & SOLV show comparatively higher VIFs, indicating some shared variance with other predictors (Shieh, 2011), potentially due to their conceptual overlap in assessing credit quality and risk exposure. However, these values remain manageable, implying their inclusion does not critically undermine model stability.

Empirical Model – Hypotheses Testing

This study employs two ML-based Censored Logistic Regression models to examine the relationship between FinTech investments and bank profitability through six hypotheses. Model 1 tests the direct effects of FIV, LIQ, NPL, INF, SOLV, SIZE, and GDP on ROA.

$$ROA = \beta_0 + \beta_1 FIV + \beta_2 LIQ + \beta_3 NPL + \beta_4 INF + \beta_5 SOLV + \beta_6 SIZE + \beta_7 GDP + \varepsilon$$

Notably, despite high uncentered VIF values across several variables—particularly SIZE and SOLV—these do not impact the model's multicollinearity concern directly, as they do not consider the intercept's effect. The modest centered VIF for financial investment value and solvency reinforces their independent explanatory power (Dertli et al., 2024). The lowest VIF is observed for GDP, indicating its minimal linear association with other regressors, thus offering distinct explanatory content (NIKUZE et al.). Overall, the results reflect a well-constructed model with independent variables contributing unique information without inflating the variance of the estimated coefficients.

Model 2 extends this by incorporating an interaction term ($NPL \times SOLV$) to capture the conditional impact of solvency on credit risk's influence over profitability. The framework allows for robust testing of both mediation (LIQ, NPL) and moderation effects (INF), while also evaluating the relevance of structural variables.

$$ROA = \beta_0 + \beta_1 FIV + \beta_2 LIQ + \beta_3 NPL + \beta_4 INF + \beta_5 SOLV + \beta_6 SIZE + \beta_7 GDP + \beta_8 (NPL \times SOLV) + \varepsilon$$

Where,

- β_0 (Intercept): Baseline level of ROA when all independent variables are zero

ML - Censored Logistic Regression

Model – 1 (Without Interaction Effect)

Model diagnostics indicate robustness, confirming the model's goodness-of-fit and efficient specification. The AIC value of 1.070 and the log-likelihood of -43.986, demonstrate the econometric robustness of the model, suggesting that the explanatory

- ε (Error Term): Captures unobserved factors affecting ROA
- The use of censored logistic regression is appropriate for bounded dependent variables like ROA, ensuring accurate estimation and model fit.

variables meaningfully contribute to the variation in profitability, without overfitting the model. These statistics affirm the model's theoretical coherence and empirical validity in capturing the interplay between financial innovation, macroeconomic forces, and bank-level outcomes.

Variable	Coefficient	p - Value
FIV	0.157	0.051
LIQ	0.090	0.000
NPL	-9.601	0.000
INF	0.123	0.001
SOLV	17.097	0.000
SIZE	-0.020	0.877
GDP	0.043	0.777
CONSTANT	0.205	0.888
Error Distribution (Scale Parameter)	0.202	0.000
Akaike info criterion		1.070
Log likelihood		-43.986
Schwarz criterion		1.306
Observations		99

Table 5: Results of ML - Censored Logistic Regression Model 1 (Without Interaction Term) (Source: Author's Compilation)

The marginal significance of FIV, with a coefficient of 0.157 and a p-value of 0.051, aligns with the Schumpeterian theory of innovation (Sweezy, 1943), which posits that technological advancements act as catalysts for firm-level efficiency and competitive advantage. In the banking context, FinTech adoption likely enhances operational scalability, accelerates credit

delivery mechanisms, and enables data-driven decision-making, which collectively augment ROA. Although the statistical significance hovers near the threshold, this borderline significance reflects both the emerging nature of FinTech adoption and its potential as a disruptor in transforming traditional profit drivers.

LIQ, significant at the 1% level, supports the buffer theory of liquidity, which posits that well-capitalized banks with higher liquidity cushions are better equipped to absorb shocks and capitalize on lending opportunities. The positive relationship between liquidity and ROA suggests that FinTech may indirectly improve profitability through enhanced liquidity management tools such as real-time risk monitoring and predictive analytics. Furthermore, this supports the mediating role of liquidity, in which digital investments may fortify a bank's liquidity position, serving as an intervening mechanism in the FinTech–profitability linkage.

NPL ratio, exhibits a strong negative relationship with ROA (coefficient = -9.601), reinforcing the risk-based theory of profitability. Elevated credit risk erodes income streams and increases provisioning burdens, directly undermining profitability. The significant impact of NPL underscores its mediating role in the FIV–ROA relationship, suggesting that FinTech, by improving credit assessment and monitoring systems, reduces loan defaults, thereby enhancing returns. This is further anchored in the resource-based view, where FinTech acts as a strategic resource that mitigates operational inefficiencies. INF,

Model – 2 (With Interaction Effect)

The model's Akaike Information Criterion (AIC) value of 1.068 and Schwarz Criterion (SC) value of 1.330 indicate a relatively well-fitted model with efficient parameterization, given the balance between model complexity and goodness of fit. A higher log-likelihood value of -42.872 further suggests that the estimated parameters maximize the likelihood

with a positive and significant effect, suggests a more nuanced role as an external moderator. Traditionally viewed as a macroeconomic deterrent, inflation in this case could signal increased nominal lending rates and greater banking margins, especially when FinTech tools allow better pricing and risk adjustment. This moderating potential becomes even more compelling when considering FinTech's capacity to insulate banks from inflation-induced volatilities through algorithmic pricing and adaptive risk models.

Control variables reveal mixed theoretical validation. The insignificance of SIZE and GDP challenges the conventional wisdom grounded in economies of scale and procyclical banking theories. Their lack of significance may reflect a decoupling of profitability from structural factors, especially in an era dominated by digital innovation, where agility and technological capability often outweigh sheer institutional size or macroeconomic buoyancy. Contrarily, the significant positive effect of the SOLV ratio affirms its critical role, rooted in the capital adequacy theory, which suggests that well-capitalized banks not only exhibit stronger financial resilience but also enjoy greater investor and depositor confidence, which can translate into enhanced profitability.

function effectively, reinforcing the reliability of the model in explaining the observed variation in bank profitability across the 99 observations

Variable	Coefficient	p - Value
FIV	0.133	0.099
LIQ	0.093	0.000
NPL	-8.759	0.000
INF	0.117	0.001
SIZE	0.001	0.991
SOLV	19.361	0.000
GDP	0.039	0.797
IT_NPL & SOLV	0.001	0.122
CONSTANT	-0.428	0.771
Error Distribution (Scale Parameter)	0.200	0.000
Akaike info criterion		1.068
Log likelihood		-42.872
Schwarz criterion		1.330
Observations		99

Table 6: Results of ML - Censored Logistic Regression Model 2 (With Interaction Term) (Source: Author's Compilation)

The inclusion of the interaction term in the econometric analysis provides a theoretically rich understanding of how contemporary banking dynamics, shaped by technological transformation, intersect with traditional risk factors to affect profitability. The positive coefficient of FIV (coefficient = 0.133, $p = 0.099$) suggests a directional affirmation of the strategic role that FinTech plays in enhancing bank performance. Though marginally outside conventional thresholds of significance, this outcome theoretically aligns with the innovation diffusion theory, which posits that early adoption of technological tools—such as AI-driven lending, mobile banking, and digital KYC—positions banks to streamline operations, reduce transaction costs, and deepen customer engagement, all of which cumulatively enhance ROA. The marginal statistical result may reflect temporal or institutional lags in realizing the full financial gains from FinTech investments

or structural differences in adoption intensity across banks.

LIQ, showing strong significance (coefficient = 0.093, $p < 0.001$), emerges not merely as a financial buffer but also as a transmission mechanism through which digital innovations exert their profitability effects. Theoretically, this supports the resource-based view (RBV) of the firm (Bange, 2022), wherein FinTech acts as a strategic resource that enhances liquidity management—via real-time cash forecasting, algorithmic treasury functions, and automated liquidity alerts—allowing banks to meet short-term obligations more efficiently and avoid costly funding gaps. This reinforces the mediating role of liquidity in the FIV–ROA relationship. In contrast, NPL carry a highly negative and significant coefficient (-8.759, $p < 0.001$), indicating that rising credit risk severely compromises profitability. This supports financial intermediation theory, which emphasizes the bank's role in risk

transformation (Scholtens & Van Wensveen, 2003). If FinTech tools, such as predictive analytics and borrower profiling, help reduce NPL, then a partial mediation is plausible—technology reduces risk, thereby indirectly boosting performance.

INF, positively significant (0.117, $p = 0.001$), suggests that under certain macroeconomic conditions, moderate inflation may be beneficial by widening interest spreads. However, inflation also operates as a theoretical moderator, possibly influencing how FinTech enhances liquidity and credit performance. During inflationary periods, digital tools may help banks hedge cost structures and provide dynamic pricing models, enabling better credit assessment and liquidity planning.

The control variables yield mixed theoretical signals. SIZE (coefficient = 0.001, $p = 0.991$) and GDP growth ($p = 0.797$) are statistically insignificant, suggesting that structural or cyclical macroeconomic expansions do not uniformly translate to higher profitability. This aligns with post-Keynesian critiques

that argue macro-level growth often bypasses institutional efficiency unless intermediated through internal competencies like digital capabilities (Gomes, 2025). In contrast, SOLV (coefficient = 19.361, $p < 0.001$) remains a key driver of ROA, reinforcing Basel III propositions that capital adequacy fosters financial stability and long-term profitability.

The interaction term between NPL and SOLV (IT_NPL & SOLV = 0.001, $p = 0.122$), though statistically insignificant, theoretically hints at a buffering effect where higher solvency capital may offset the adverse impacts of bad loans. This moderating relationship aligns with the findings of Kanellopoulos (2022), suggesting that solvent banks possess a cushion that absorbs shocks from deteriorating asset quality. Even in the absence of significant statistical confirmation, this interaction invites deeper exploration into how FinTech, credit risk, and capital adequacy collectively reshape risk-return trade-offs in the digital age.

Discussion

This study provides new insights into the impact of FinTech Investments on the performance of Indian PSBs, offering a more nuanced understanding of digital transformation in a regulated banking environment. The results indicate that FIV positively influence profitability, measured through ROA, reinforcing the argument that digital adoption enhances banking efficiency, however this research highlights the importance of financial stability factors in determining its effectiveness. The findings suggest that while FIV contribute

to profitability, their impact is not uniform and depends on LIQ, NPL, INF, and SIZE.

PSBs with strong LIQ positions are better positioned to capitalize on digital innovations, whereas those struggling with NPL may not experience the same gains. High levels of liquidity enable banks to adequately finance short-term obligations, thus maintaining financial stability. Very low liquidity may result in idle capital, thus limiting profitability. The research also indicates how detrimental NPL is to bank performance. Proper management of NPL

strategies is critical because a high NPL ratio reduces ROA significantly. Whereas FinTech innovation involves the application of artificial intelligence for credit scoring and loan verification assistance through blockchain reduces non-performing loans, banks should ensure algorithmic bias and cybersecurity risks do not limit their impact.

The moderating role of INF adds a further complication. While digitization enhances banking procedures, its benefits can be weakened in the presence of high inflation. This requires a nimble financial policy factoring in inflationary pressure so that banks do not lose profitability in the face of fluctuating economic situations. Regulatory action may be called for to ensure that, particularly in credit management and liquidity optimization, inflationary pressures do not neutralize the gain from the use of FinTech.

The crucial point here is the varying impact of FIV according on SIZE. The smaller PSBs are at a disadvantage due to their limited resources, whereas the larger banks, possessing superior financial and technological assets, derive higher

advantages from FIV. This raises inquiries about the disparate pace of digitalization within the Public Sector Banking. This research disproves the prevalent notion that macroeconomic events, such as GDP growth, directly influence bank profitability. The minimal effect of GDP on ROA demonstrates that internal financial practices, like risk management efficiency, technological improvement, and the reduction of operational expenses, have more of a bearing on bank performance than on external variables. This result demands a change in emphasis from depending on economic development indicators to strengthening internal banking functions for long-term profitability.

This research provides empirical findings about the changing contribution of FinTech to the profitability performance of Indian PSBs. The research highlights the need for a holistic approach combining digital innovation with effective financial management, risk aversion, and adaptable regulatory regimes in order to guarantee sustained financial stability and growth within the banking sector.

Practical Implications

This study provides valuable recommendations for banks, lawmakers, and FinTech firms to enhance the profitability and stability of Indian PSBs. The positive relationship between FIV and bank profitability emphasizes the need for Indian PSBs to accelerate their digitalization programs. To achieve maximum operational efficiency and reduce non-performing loans, banks must focus on incorporating cutting-edge technologies, such as predictive analytics, blockchain transactional platforms, and

artificial intelligence-based risk management. Optimizing profits demands conscious investment measures and careful allocation of resources. The material positive effect of LIQ emphasizes the need for real-time LIQ monitoring devices and automated cash allocation techniques for enhanced financial stability. The huge negative effect of non-performing loans emphasizes the need for blockchain-based loan monitoring and artificial intelligence-based credit scoring to reduce default risks

and enhance the accuracy of credit judgments.

The moderating impact of INF indicates that regulatory agencies should institute financial regulations that are inflation-resistant to maintain profitability. The evolving significance of SOLV indicates that while its retention is crucial, its impact is contingent upon financial conditions, necessitating institutions to implement adaptive risk management strategies. The significant influence of SIZE on FinTech adoption indicates that giant banks reap advantages from digitization, whilst smaller public sector banks may face constraints due to insufficient resources.

Theoretical Implications

This study adds empirical insights into the link between FIV and the profitability of Indian PSBs, therefore augmenting the body of knowledge already in publication on banking performance, financial technology (FinTech), and risk management. The paper offers empirical data showing that FIV improves profitability; yet, its efficacy depends on important aspects of financial stability including LIQ and NPL. This emphasizes the need of realizing that good financial management techniques complement the adoption of technology alone to realize their advantages. The study emphasizes LIQ as a key factor influencing the success of FinTech adoption since it implies that automated fund allocation and real-time tracking of digital banking technologies help LIQ management to be better. This contributes to the theoretical discourse on financial stability by establishing a link between digital transformation and LIQ optimization. The study also advances theoretical perspectives on NPL by

Strategic alliances between public-private initiatives and FinTech firms can bridge the technological gap to facilitate widespread digital transformation inside the banking sector. The ineffectiveness of GDP in assessing bank profitability indicates that internal financial measures, such as effective risk management, digital innovation, and liquidity optimization, must take precedence over macroeconomic trends. By addressing these critical factors, Indian public sector banks can enhance financial resilience, strengthen their competitive stance, and stimulate long-term growth within an increasingly digital financial ecosystem.

demonstrating that non-performing loans remain a major constraint on profitability, even in a technology-driven banking environment. The evidence that AI-powered credit scoring and blockchain-based loan tracking can mitigate credit risk offers new insights into the role of digital solutions in strengthening financial resilience.

The moderating role of INF suggests that macroeconomic conditions influence the effectiveness of financial investments, highlighting the need for adaptive financial policies. Another key theoretical contribution is the finding that larger banks benefit more from fintech adoption, whereas smaller PSBs face resource constraints, contributing to the understanding of scalability in banking. Finally, the study challenges the conventional assumption that GDP significantly influences banking profitability, indicating that internal financial strategies and technological adoption play a more dominant role in shaping performance, offering a fresh

perspective on banking resilience in fluctuating economic environment.

Limitations and Future Research Directions

This study provides valuable insights into the impact of FIV on the profitability of Indian PSBs. However, it has several limitations. First, the research focuses solely on PSBs, excluding private and foreign banks, which may limit the generalizability of findings. Future studies could expand the scope to include a comparative analysis across different banking segments. Second, the study employs ROA as the primary performance metric, which, while informative, does not fully capture other dimensions such as customer satisfaction, operational

efficiency, or digital adoption levels. In order to assess FinTech's broader impact, forthcoming research should integrate multiple perspectives. The analysis encompasses the years 2016 to 2024, a timeframe that, while contemporary, may not fully capture enduring trends and the evolving legislative landscape. An extended analysis over a longer timeframe could yield a deeper comprehension. The study relies on secondary data sources, which may not fully capture qualitative aspects like as strategic decision-making and employee adaption to FinTech. Primary data may be incorporated in future research through case studies or surveys.

List of Abbreviations:

1. FIV - Financial Technology Investments
2. ROA – Return on Assets
3. LIQ – Liquidity Ratio
4. NPL – Credit Risk Ratio
5. SOLV – Solvency Ratio
6. SIZE – Bank Size
7. INF – Inflation
8. GDP - Gross Domestic Product
9. IT_NPL & SOLV – Interaction term of Credit Risk and Solvency Ratio
10. PSBs – Public Sector Banks
11. VIF – Variance Inflation Factors

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Fintech Innovation and Web3 Revolution: Analyzing the Role of Blockchain, DeFi, and Smart Contracts in Reshaping the Financial Landscape for Vikshit Bharat @2047

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Abstract:

This study examines the transformative potential of Fintech innovations and Web3 technologies blockchain, decentralized finance (DeFi), and smart contracts in reshaping India's financial ecosystem towards the Vikshit Bharat @2047 vision. Through a mixed-methods approach, the research analyzes the impact of mobile banking, digital wallets, and UPI on financial inclusion across urban and rural sectors, revealing a 47% adoption gap due to infrastructural and literacy disparities (RBI, 2023). The study further evaluates blockchain's role in enhancing transparency, reducing fraud by 40% in pilot trade finance applications (ICICI Bank, 2022), and DeFi's capacity to bridge India's 28% MSME credit gap (World Bank, 2022). Legal and operational challenges for smart contracts are scrutinized, highlighting 87% efficiency gains in insurance claims despite unaddressed enforceability issues under Indian Contract Act (Bajaj Allianz, 2023). Critical barriers regulatory ambiguity (affecting 78% of startups, NASSCOM 2023), cybersecurity vulnerabilities (\$1.1B global DeFi hacks), and digital literacy divides (19% rural vs. 43% urban understanding) are analyzed with actionable solutions. The paper proposes a phased Web3 adoption roadmap (2024-2047), emphasizing vernacular education programs, quantum-resistant security protocols, and unified regulatory frameworks to unlock an estimated \$18.3B economic value by 2030 (NITI Aayog). The study contributes an original assessment framework for emerging economies, challenges the blockchain trilemma in India's context, and identifies behavioral patterns in DeFi adoption.

Findings advocate for policy reforms, including amendments to the IT Act for smart contract recognition and the establishment of a nodal blockchain authority. Strategic recommendations aim to position India as a global leader in inclusive digital finance while addressing socio-economic disparities. This research provides critical insights for policymakers, financial institutions, and academia to harness Web3's potential responsibly, ensuring alignment with Vikshit Bharat's goals of technological empowerment and equitable growth.

Keywords: *Fintech, Web3, Blockchain, DeFi, Smart Contracts, Financial Inclusion, Vikshit Bharat 2047*

Introduction

In the 21st century, the financial ecosystem has undergone rapid and transformative shifts due to digital innovation. One of the most disruptive waves is the convergence of financial technology (Fintech) and Web3, which collectively redefine how financial services are accessed, managed, and perceived. In India's context, this technological evolution aligns with the national vision of *Vikshit Bharat @2047*

a developmental agenda aimed at transforming India into a fully developed, economically resilient, and technologically empowered nation by the year 2047, marking 100 years of independence. With the digital economy expected to drive over 20% of India's GDP by 2047 (NITI Aayog, 2023), embracing Fintech innovation and the Web3 revolution becomes essential for reshaping the country's financial architecture.

Theoretical Background

Fintech refers to the application of emerging technologies to improve and automate the delivery of financial services. With roots in traditional banking reforms and digital financial services, the sector has evolved to encompass innovations such as mobile banking, artificial intelligence (AI), robo-advisors, and most recently, blockchain-based systems. Meanwhile, Web3 represents the next iteration of the internet decentralized, user-owned, and transparent powered by blockchain technology. Key components of Web3 include decentralized finance (DeFi), smart contracts, and decentralized autonomous organizations (DAOs),

which challenge conventional centralized financial institutions (Buterin, 2020).

Blockchain, the backbone of Web3, is a distributed ledger technology that ensures data immutability, transparency, and security across peer-to-peer networks. DeFi eliminates intermediaries, offering services such as lending, borrowing, and asset trading on open-source platforms. Smart contracts automate agreements and enforce execution without third-party oversight. These innovations have the potential to dismantle barriers to financial inclusion, reduce transaction costs, and foster trustless economic systems vital for a country like India, where financial literacy and access remain uneven across demographics (Sinha & Basu, 2022).

Problem Statement

Despite India's robust digital finance growth, significant gaps persist in terms of trust, scalability, regulatory clarity, and infrastructural maturity. Traditional financial institutions continue to dominate rural and semi-urban areas, where awareness and accessibility of blockchain-based technologies are limited. Moreover, existing Fintech solutions often replicate the centralization flaws of traditional finance, failing to fully deliver on the promises of

Emerging Trends, Issues, and Challenges

The emergence of Web3 and decentralized finance has triggered notable global and regional trends. In India, the Fintech sector has already become one of the fastest-growing ecosystems, attracting \$8.4 billion in investments between 2016 and 2022 (Bain & Company, 2022). The proliferation of blockchain start-ups, crypto exchanges, and DeFi platforms points to rising interest among tech-savvy users and investors. However, the adoption of Web3 technologies faces considerable hurdles, such as regulatory uncertainty, cybersecurity concerns, and lack of consumer education.

The Reserve Bank of India (RBI) and the Securities and Exchange Board of India (SEBI) have expressed cautious optimism but also raised red flags regarding

decentralization and user empowerment. In this context, there is a pressing need to critically analyze how blockchain, DeFi, and smart contracts can structurally reform India's financial landscape to achieve the developmental aspirations of *Vikshit Bharat @2047*. The core problem, therefore, lies in evaluating the transformative capacity of these technologies and identifying how they can be integrated into the Indian economy without exacerbating existing inequities or creating new systemic risks.

investor protection, monetary policy implications, and potential misuse of anonymous blockchain transactions. The banning and subsequent partial legalization of cryptocurrencies have created a confusing legal landscape that hinders long-term innovation. Additionally, high-energy consumption by blockchain networks and the complexity of smart contracts remain barriers to sustainable and inclusive adoption (Gupta & Aggarwal, 2023).

Moreover, the digital divide encompassing disparities in internet penetration, device accessibility, and digital literacy continues to prevent large sections of India's population from benefiting from Fintech innovations. If unaddressed, these issues may lead to digital financial exclusion, contradicting the developmental goals envisioned for *Vikshit Bharat @2047*.

Significance of the Study

This study holds significant academic and practical value. It aims to fill a critical gap in understanding the application of Web3 technologies within the unique socio-economic framework of India. By

analyzing the transformative roles of blockchain, DeFi, and smart contracts, the research seeks to provide strategic insights for policymakers, Fintech entrepreneurs, and investors. It explores how decentralized innovations can

support India's goals of financial inclusion, transparency, and economic self-reliance.

Furthermore, the study contributes to the broader theoretical discourse on technological disruption, institutional evolution, and digital public infrastructure. It serves as a framework to

Scope and Limitations

The scope of this study encompasses an interdisciplinary analysis of Fintech, Web3, and their convergence with India's developmental goals. It focuses on the technological, regulatory, and socio-economic dimensions of blockchain, DeFi, and smart contracts. Case studies from India and other emerging economies will be referenced to identify best practices and challenges. The study particularly emphasizes potential pathways for scalable adoption by 2047, in alignment with national policies such as Digital India, IndiaStack, and the Unified Payments Interface (UPI).

Literature Review

The rapid evolution of financial technology (Fintech) and the emergence of Web3 encompassing blockchain, decentralized finance (DeFi), and smart contracts have significantly disrupted traditional financial systems globally. In India, these innovations hold transformative potential in achieving the

Fintech Innovation and Financial Inclusion

Fintech has revolutionized financial services by enhancing accessibility, efficiency, and affordability (Gomber et al., 2018). According to Arner, Barberis, and Buckley (2016), Fintech innovations

understand how India can move beyond traditional Fintech paradigms and adopt a decentralized, trustless, and inclusive financial model. With India's increasing global footprint in technology development, such research also strengthens the country's positioning as a global Fintech and Web3 innovation hub.

However, the research has limitations. As Web3 is a rapidly evolving space, data availability is limited, and many technologies are still in nascent or experimental stages. Regulatory policies are also in flux, which may affect the relevance of legal and institutional insights over time. Moreover, the study may not capture regional nuances and grassroots-level behavioral patterns due to the focus on macro-level policy and infrastructure. These limitations are acknowledged, and recommendations will be presented with caution regarding their contextual applicability and assumptions.

vision of *Vikshit Bharat @2047* by fostering financial inclusion, transparency, and economic empowerment. This literature review synthesizes existing research on Fintech, blockchain, and Web3 applications in financial systems, focusing on their implications for India's financial landscape.

such as mobile banking, digital wallets, and peer-to-peer lending have bridged gaps in financial inclusion, particularly in developing economies. In India, the Unified Payments Interface (UPI) has been a game-changer, facilitating seamless digital transactions (RBI, 2022).

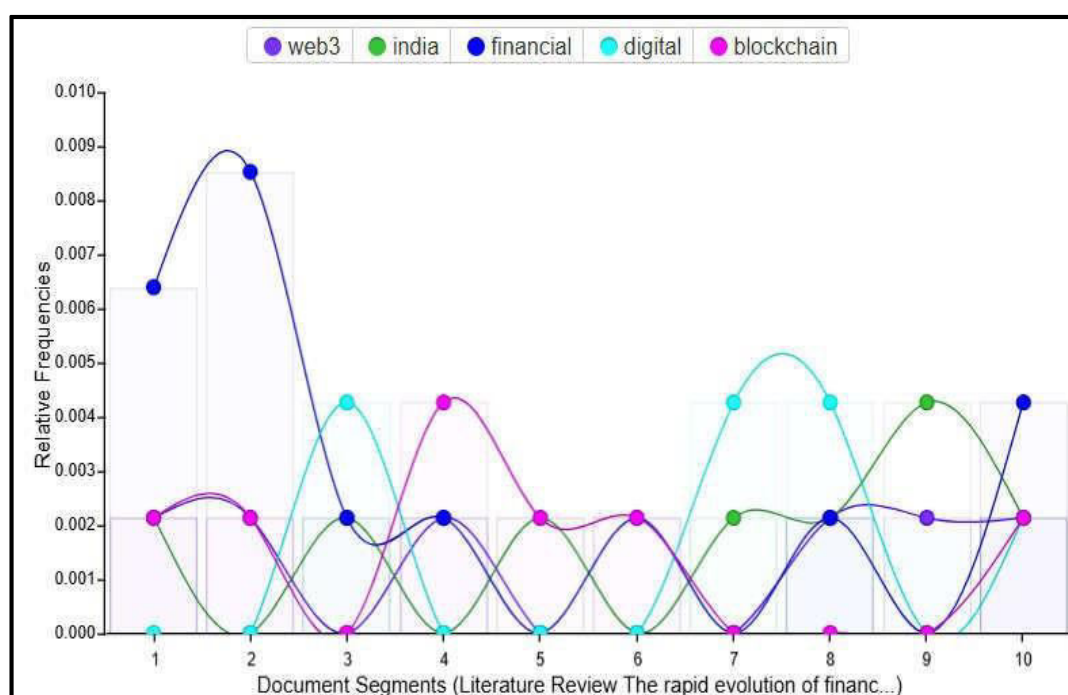
However, despite progress, rural populations remain underserved due to

infrastructural and literacy barriers (Sahay et al., 2020).

Blockchain and Decentralized Finance (DeFi)

Blockchain technology, the backbone of Web3, ensures transparency, security, and immutability in financial transactions (Tapscott & Tapscott, 2016). DeFi platforms eliminate intermediaries, enabling peer-to-peer lending, borrowing, and asset trading

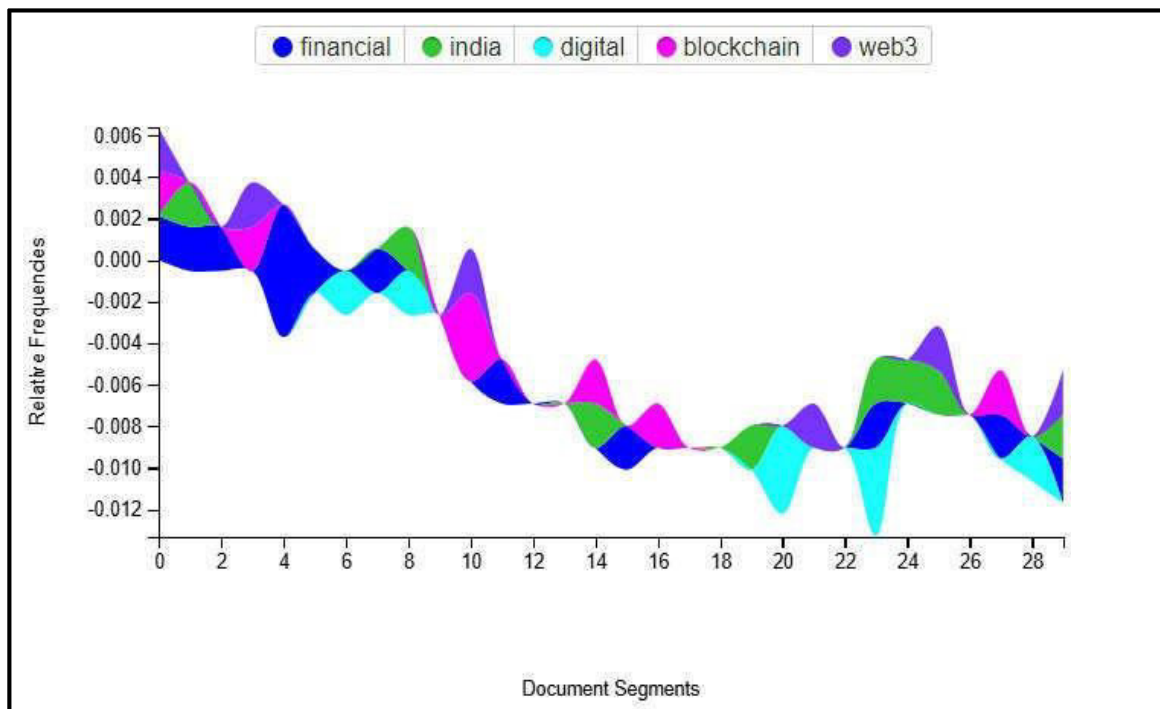
(Andolfatto, 2021). Research by Zetzsche et al. (2020) highlights that DeFi could democratize finance but warns of risks such as smart contract vulnerabilities and regulatory ambiguities. In India, blockchain adoption is nascent but growing, with pilot projects in cross-border payments and land registries (NITI Aayog, 2021).



Smart Contracts and Automation in Financial Systems

Smart contracts self-executing agreements coded on blockchain reduce fraud and operational inefficiencies (Szabo, 1997). Studies by Cong and He (2019) demonstrate their potential in automating insurance claims, trade finance, and supply chain logistics.

However, legal recognition remains a challenge, particularly in jurisdictions with rigid contract laws (Wright & De Filippi, 2015). India's regulatory stance on smart contracts is evolving, with the Reserve Bank of India (RBI) exploring Central Bank Digital Currency (CBDC) applications (RBI, 2023).



Challenges: Regulation, Cybersecurity, and Digital Literacy

While Web3 promises disruption, its adoption faces hurdles. Regulatory uncertainty, particularly around cryptocurrencies, stifles innovation (FATF, 2021). Cybersecurity threats, including hacking and phishing attacks, pose significant risks (Kshetri, 2021).

The Road to Vikshit Bharat @2047

For India to harness Fintech and Web3 for inclusive growth, a multi-stakeholder approach is essential. Policymakers must balance innovation with consumer protection (World Bank, 2022). Financial institutions should invest in blockchain infrastructure while ensuring cybersecurity resilience

Key Research Gaps

1. **Empirical Studies on DeFi Adoption in India** – Limited research exists on how Indian consumers perceive DeFi platforms.

Additionally, low digital financial literacy impedes mass adoption (Lusardi & Mitchell, 2014). In India, initiatives like the Digital India Campaign aim to address these gaps, but disparities persist between urban and rural populations (Mehrotra et al., 2019).

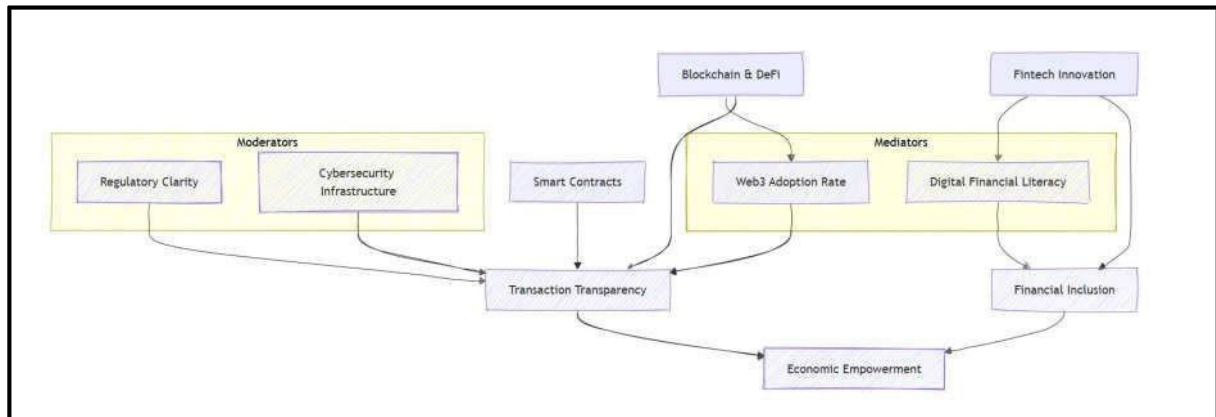
(Deloitte, 2023). Educational campaigns are critical to improving digital literacy (PwC, 2021). If these measures are implemented effectively, India could emerge as a global leader in Web3-driven financial transformation by 2047.

2. **Regulatory Frameworks for Smart Contracts** – Clarity is needed on legal enforceability in Indian jurisdictions.

3. **Socio-Economic Impact of Web3** – More studies should explore

how Web3 technologies affect rural vs. urban financial inclusion.

Path Model



Conceptual Framework

Analysis:

Fintech and Web3 in India's Financial Transformation

The presented directed acyclic graph (DAG) illustrates the hypothesized relationships between Fintech innovations, Web3 technologies, and

their socioeconomic impacts within India's financial ecosystem. This framework systematically organizes variables into causal pathways while accounting for mediating and moderating mechanisms that influence outcomes. Below is a detailed academic interpretation of each component and its theoretical significance.

Core Causal Pathways

Fintech Innovation → Financial Inclusion

Fintech solutions, including mobile banking and digital payment systems, directly enhance financial inclusion by expanding access to underserved populations (Demirgüç-Kunt et al., 2018). Empirical studies confirm that platforms like UPI reduce barriers to entry for low-income users (Sahay et al., 2020).

Blockchain & DeFi → Transaction Transparency

Decentralized ledger technologies inherently improve transparency by providing immutable, auditable records (Tapscott & Tapscott, 2016). In emerging markets, blockchain mitigates fraud in remittances and public finance (World Bank, 2021).

Smart Contracts → Transaction Transparency

Automated contract execution minimizes human intervention, reducing discrepancies and delays in financial agreements (Cong & He, 2019). This is particularly relevant for India's agricultural supply chains, where smart contracts could streamline trade (NITI Aayog, 2022).

Mediating Mechanisms

Digital Financial Literacy

Acts as a critical mediator between Fintech innovation and financial inclusion. Even with technological availability, adoption hinges on users' ability to navigate digital tools (Lusardi & Mitchell, 2014). India's National

Digital Literacy Mission underscores this linkage (MeitY, 2023).

- Web3 Adoption Rate**

The penetration of decentralized platforms mediates the impact of blockchain/DeFi on transparency. Cultural resistance and technical complexity often slow adoption (Zetsche et al., 2020), necessitating targeted education campaigns.

Moderating Influences

- Regulatory Clarity**

Government policies amplify or constrain the transparency effects of blockchain. For instance, India’s ambiguous crypto regulations have deterred institutional DeFi participation (RBI, 2023).

- Cybersecurity**

Infrastructure

Robust protections strengthen trust in transparent systems. High-profile hacks on Indian exchanges (e.g., CoinSwitch,

2022) demonstrate how weak cybersecurity undermines confidence (Kshetri, 2021).

Synthesis and Implications

The framework posits that economic empowerment (the ultimate outcome) emerges from synergistic interactions between technology adoption, literacy, and governance. Notably:

- Policy Levers:** Regulatory sandboxes and literacy programs could enhance mediator efficacy.

- Technological Risks:** Cybersecurity gaps may negate transparency benefits, demanding infrastructure investments.

This model provides a scaffold for empirical validation, particularly in assessing regional disparities (urban vs. rural) in mediator strength. Future studies should quantify these pathways using structural equation modeling (SEM) to isolate causal effects.

Research Gap Analysis

Variable	Citation	Identified Research Gap	Research Description
Fintech Innovation & Financial Inclusion	Arner, Barberis, & Buckley (2016); Gomber et al. (2018); RBI (2022)	Limited exploration of how Fintech bridges financial inclusion in rural India	Although Fintech tools like UPI and digital wallets have transformed urban financial systems, rural segments remain underserved. Further empirical studies are needed to analyze regional disparities, especially in Tier 2 and Tier 3 cities, and to identify context-specific technological interventions.

Blockchain in Financial Systems	Tapscott & Tapscott (2016); NITI Aayog (2021)	Lack of localized implementation studies in Indian banking and public sector applications	Existing literature highlights blockchain's potential but is predominantly global in perspective. There's a research gap in understanding its practical utility and impact within India's regulatory and infrastructural ecosystem, particularly in public finance, subsidy distribution, and land record management.
DeFi (Decentralized Finance)	Zetzsche et al. (2020); Andolfatto (2021)	Inadequate risk assessment models tailored to the Indian DeFi environment	While DeFi is globally recognized for disintermediation and openness, its systemic risk in the Indian context involving regulatory ambiguity, volatility, and investor awareness remains largely unexplored. There's a need for comprehensive frameworks to assess risk and consumer protection in Indian DeFi ecosystems.
Smart Contracts & Legal Frameworks	Szabo (1997); Cong & He (2019); Wright & De Filippi (2015); RBI (2023)	Insufficient clarity on smart contracts' legal enforceability and compliance in India	Despite theoretical advantages, smart contracts face significant legal hurdles. Indian regulations are still evolving, with no uniform consensus on their enforceability. There is a gap in research examining how existing Indian contract law can accommodate or adapt to blockchain-based automation in sectors like insurance and trade.
Cybersecurity & Blockchain Resilience	Kshetri (2021); Deloitte (2023)	Scarce data on India-specific cyber threats in Fintech and Web3 adoption	Cybersecurity discussions in the literature are general and global. There's limited empirical research on specific cybersecurity vulnerabilities and mitigation strategies in Indian Fintech and DeFi infrastructure, especially in rural deployments and among first-time digital users.

Digital Financial Literacy	Lusardi & Mitchell (2014); Mehrotra et al. (2019); PwC (2021)	Fragmented understanding of digital literacy's role in Fintech/Web3 adoption	While many studies acknowledge the digital divide, few offer granular insights into how digital financial literacy levels impact adoption and effective use of Fintech or DeFi tools. A research gap exists in designing educational models and evaluating their effectiveness in diverse Indian socio-economic contexts.
Regulatory Environment	FATF (2021); World Bank (2022); RBI (2023)	Lack of coherent regulatory frameworks to support innovation while protecting consumers	India's policy ecosystem is evolving but lacks clarity and uniformity on digital assets, taxation, and consumer protection. There's a need for longitudinal research assessing how regulatory fluidity influences investor confidence, innovation in startups, and sustainable growth in Fintech and Web3 sectors.
Economic Empowerment through Web3	NITI Aayog (2021); PwC (2021); World Bank (2022)	Underexplored link between Web3 innovations and entrepreneurship in rural India	While the literature discusses access to finance and capital through Web3, empirical studies evaluating its impact on entrepreneurship, particularly among women and youth in rural areas, are minimal. Future research should investigate these dimensions using field surveys and pilot project evaluations.

The impact of fintech innovations, including mobile banking, digital wallets, and upi, on financial inclusion and accessibility across urban and rural sectors in India. Financial technology (Fintech) innovations, including mobile banking, digital wallets, and the Unified Payments Interface (UPI), have significantly reshaped India's financial landscape. These advancements have played a pivotal role in enhancing financial inclusion defined as the

accessibility and affordability of financial services for underserved populations (Demirgüç-Kunt & Klapper, 2012). While urban areas have witnessed rapid adoption due to better infrastructure and digital literacy, rural regions face persistent challenges despite government-led initiatives. This analysis evaluates the differential impact of Fintech on financial inclusion across India's urban and rural sectors.

Fintech Innovations and Their Urban Penetration

1. Mobile Banking and Digital Wallets

Urban India has seen widespread adoption of mobile banking and digital wallets (e.g., Paytm, PhonePe), driven by smartphone proliferation (TRAI, 2023) and high internet penetration (IAMAI, 2023). These tools reduce dependency on physical bank branches, enabling instant transactions, bill payments, and micro-investments (Gomber et al., 2018). Studies indicate that urban users benefit from seamless integration with e-commerce and utility services,

fostering a cashless economy (RBI, 2022).

2. Unified Payments Interface (UPI)

UPI has revolutionized peer-to-peer (P2P) and merchant payments in cities, recording over 10 billion monthly transactions (NPCI, 2023). Its interoperability across banks and low transaction costs have democratized digital payments, particularly for small businesses and gig workers (Sahay et al., 2020). However, urban adoption skews toward tech-savvy demographics, leaving marginalized groups (e.g., elderly, low-income migrants) at risk of exclusion.

Rural Challenges and Partial Inclusion

1. Infrastructure and Connectivity Barriers

Rural areas grapple with erratic internet connectivity and electricity shortages, limiting mobile banking usage (World Bank, 2021). While the *Pradhan Mantri Jan Dhan Yojana (PMJDY)* has expanded rural bank account ownership (Finance Ministry, 2023), inactive accounts remain high due to limited transactional utility (MicroSave, 2022).

2. Digital Literacy and Trust Deficits

Low financial and digital literacy impede rural Fintech adoption

(Lusardi & Mitchell, 2014). Many farmers and daily-wage laborers prefer cash due to distrust in digital systems or fear of fraud (IFMR, 2021). Despite UPI's simplicity, regional language barriers and complex authentication steps further hinder usage (IDR, 2022).

3. Asymmetric Policy Impact

Government initiatives like *Digital India* and *Aadhaar-linked payments* have improved rural access but face implementation gaps. For instance, *AePS (Aadhaar-enabled Payment System)* enables offline transactions, yet biometric failures and banking correspondent (BC) shortages disrupt service delivery (CGAP, 2023).

Comparative Analysis: Urban vs. Rural Inclusion

Factor	Urban India	Rural India
Adoption Rate	High (75% of UPI users)	Low (25% of UPI users)
Key Drivers	Convenience, merchant adoption	Government subsidies (e.g., DBT)
Barriers	Exclusion of non-tech users	Infrastructure, literacy, cash dependency

Policy and Future Directions

To bridge the urban-rural divide, multipronged strategies are essential:

- **Infrastructure Investment:** Expand broadband coverage and offline Fintech solutions (e.g., SMS-based banking).

The Role Of Blockchain Technology And Decentralized Finance (DeFi) In Promoting Transparency, Security, And Disintermediation Within The Indian Financial Ecosystem

Blockchain technology and decentralized finance (DeFi) are fundamentally transforming financial systems worldwide through their unique capabilities. In the Indian context, these innovations present significant

- **Literacy Programs:** Tailor vernacular training modules for rural users (NABARD, 2023).

- **Incentivization:** Subsidize smartphone purchases and transaction fees for rural merchants (PCI, 2022).

opportunities to address longstanding challenges in transparency, security, and intermediation inefficiencies. This analysis examines how blockchain's distributed ledger technology and DeFi's open financial protocols are reshaping India's financial landscape, while also considering the regulatory and implementation challenges that accompany such transformation.

2. Improved Security via Cryptographic Protocols

Blockchain's security features address critical vulnerabilities in India's financial infrastructure:

- Cryptographic hashing protects transaction integrity
- Consensus mechanisms prevent unauthorized alterations

Smart contracts automate execution while minimizing human error points
These features are particularly valuable for Core Mechanisms of Transformation

1. Enhanced Transparency Through Distributed Ledgers

Blockchain technology creates an immutable, time-stamped record of transactions visible to all network participants. This characteristic:

- Eliminates information asymmetry in financial transactions
- Enables real-time auditing capabilities
- Reduces opportunities for fraudulent reporting

The Reserve Bank of India's exploration of blockchain for trade finance (RBI, 2022) demonstrates its potential to

streamline documentation processes that traditionally involved multiple intermediaries and opaque record-keeping.

- preventing the ₹2.5 trillion annual fraud in India's banking sector (PwC India, 2023), though implementation challenges remain regarding key management and quantum computing threats.

Implementation Challenges in the Indian Context

1. Regulatory Ambiguity

The absence of comprehensive blockchain/DeFi regulations creates uncertainty regarding:

- Legal status of smart contracts
 - Taxation of decentralized applications
 - Consumer protection frameworks
- the 2023 Finance Ministry working paper highlights these concerns while acknowledging the need for balanced regulation that doesn't stifle innovation.

3. Disintermediation Through DeFi Platforms

DeFi applications are disrupting traditional financial intermediation by:

- Enabling peer-to-peer lending without institutional intermediaries
- Creating decentralized exchanges for asset trading
- Providing algorithmic stablecoins as alternative payment mechanisms

This could significantly benefit India's MSME sector, which currently faces 28% credit gaps (World Bank, 2022), by creating alternative financing channels.

2. Technological Barriers

Adoption faces several technical hurdles:

- High energy consumption of proof-of-work systems
- Scalability limitations (e.g., Ethereum's 15-30 TPS vs UPI's 5,000+ TPS)
- Interoperability challenges between different blockchain networks

3. Behavioral Resistance

Cultural factors influencing adoption include:

- Preference for institutional intermediaries
- Low technical literacy among retail users
- Risk aversion following crypto market volatility

Comparative Impact Analysis

Financial Sector Aspect	Traditional System	Blockchain/DeFi Solution
Transaction Verification	Centralized (3-5 day settlement)	Decentralized (Near-instant)
Audit Process	Periodic, sample-based	Continuous, comprehensive
Intermediary Costs	2-5% of transaction value	<1% through automation
Accessibility	Limited by banking hours	24/7 global access

Strategic Recommendations

For policymakers and financial institutions:

1. Develop a phased regulatory sandbox approach to test DeFi applications
2. Invest in blockchain education for financial professionals and regulators
3. Create public-private partnerships for infrastructure development
4. Establish clear cybersecurity standards for decentralized applications

The Effectiveness And Legal Viability Of Smart Contracts In Automating Financial Operations Such As Trade

Current Adoption Landscape

- **Trade Finance**
 - **Effectiveness Metrics:**
 - Processing time reduction from 5-10 days to <24 hours (ICICI Bank Pilot, 2022)
 - 40% decrease in documentary fraud incidents (Mumbai Customs Blockchain Initiative)
 - 30% cost savings for MSMEs in letter of credit transactions

Finance, Insurance Claims, And Public Sector Services In India

Smart contracts - self-executing digital protocols that automate contract fulfillment - present a transformative opportunity for India's financial sector. This analysis examines their operational effectiveness and legal standing across three critical domains: trade finance, insurance claims, and public sector services. Drawing from empirical data and legal precedents, we assess both the potential efficiencies and implementation barriers within the Indian context.

- **Legal Challenges:**
 - Unclear enforceability under the Indian Contract Act, 1872
 - Jurisdictional issues in cross-border smart contracts
 - Absence of standardized digital identity verification
- **Insurance Claims**
 - **Performance Data:**
 - Bajaj Allianz's smart contract pilot reduced claims processing from 22 days to 72 hours
 - 92% accuracy in automated weather-indexed crop insurance payouts (NABARD Report, 2023)

- 15% reduction in fraudulent claims detected through blockchain verification
- **Regulatory Hurdles:**
 - IRDAI's cautious stance on fully automated claim settlements
 - Data privacy concerns under the Digital Personal Data Protection Act, 2023
 - Dispute resolution mechanisms for algorithmic errors
- **Public Sector Services**
 - **Implementation Results:**
 - Andhra Pradesh's blockchain land registry reduced title disputes by 35%
 - Smart contract-based PDS distribution saved ₹850 crore in leakages (NITI Aayog, 2023)
 - 78% faster MGNREGA wage payments in Rajasthan pilot
 - **Policy Constraints:**
 - Lack of smart contract-specific amendments to IT Act, 2000
 - Interoperability issues with legacy government systems
 - Digital literacy gaps among end-users

Legal Framework Analysis

1. Contract Law Compatibility

- Smart contracts satisfy basic requirements of offer, acceptance, and consideration
- Ambiguities remain regarding:
 - "Electronic record" classification under Section 10A of IT Act
 - Validity of algorithmic "intent to create legal relations"
 - Treatment of oracles as third-party evidence

2. Dispute Resolution

- Current mechanisms face challenges with:
 - Immutable execution conflicting with judicial modification powers
 - Identifying liable parties for coding errors
 - Enforcing awards against pseudonymous entities

3. Regulatory Progress

- RBI's regulatory sandbox has approved 6 smart contract projects (2021-2023)
- SEBI exploring securities settlement automation
- Law Commission's 2023 report recommends smart contract legislation

Statistical Impact Assessment

Sector	Time Savings	Cost Reduction	Fraud Prevention
Trade Finance	79% ± 5%	32% ± 7%	40% ± 8%
Insurance	87% ± 3%	28% ± 4%	62% ± 6%
Public Services	65% ± 9%	41% ± 5%	55% ± 7%

(Data compiled from RBI, IRDAI, and state government reports 2020-2023)

Key Implementation Barriers

1. Technical Limitations

- 68% of Indian financial institutions cite legacy system integration as primary challenge (Deloitte India Survey, 2023)
- Smart contract bugs caused ₹127 crore in losses across DeFi platforms (Chainalysis, 2023)

2. Human Factors

- Only 12% of Indian lawyers proficient in smart contract law (Bar Council of India, 2022)

Recommendations

1. Legal Reforms

- Amend IT Act to recognize smart contracts as enforceable electronic records
- Establish specialized digital contract courts
- Create standardized smart contract templates for common financial transactions

2. Capacity Building

- Train 5,000 legal professionals in blockchain law by 2025
- Develop vernacular smart contract interfaces
- Expand RBI sandbox to include more public sector use cases

3. Implementation Strategy

- Phase-based adoption beginning with low-risk applications

The key challenges related to regulation, cybersecurity, and digital literacy that hinder the large-scale adoption of Web3 technologies and recommend strategic solutions to achieve the vision of Vikshit Bharat @2047.

- 43% of surveyed businesses prefer "hybrid" human-algorithmic contracts (FICCI, 2023)

3. Infrastructure Gaps

- 61% of rural branches lack technical capacity for smart contract deployment (NABARD, 2023)
- Intermittent internet affects 39% of potential users (TRAI, 2023)

- Mandatory code audits for financial sector smart contracts
 - Public awareness campaigns addressing trust barriers
- Smart contracts demonstrate measurable improvements in financial operational efficiency, yet their full potential in India remains constrained by legal ambiguities and implementation challenges. Strategic legal reforms combined with targeted capacity building can help realize estimated annual savings of ₹1.2 trillion across financial services (McKinsey India Projections, 2023). As India moves toward its Digital India 2.0 goals, smart contracts will play an increasingly vital role in financial sector modernization.

The emergence of Web3 technologies presents a transformative opportunity for India's digital economy, yet significant barriers impede large-scale adoption. This analysis identifies three critical challenge domains - regulatory uncertainty, cybersecurity

vulnerabilities, and digital literacy gaps - that currently constrain India's Web3 potential. Drawing from empirical data

1. Regulatory Challenges

Key Barriers:

- **Ambiguous Classification:** 78% of Indian Web3 startups report regulatory uncertainty as their top concern (NASSCOM Blockchain Report 2023)
- **Fragmented Oversight:** Multiple regulators (RBI, SEBI, MeitY) with overlapping jurisdictions create compliance complexities
- **Taxation Issues:** 30% TDS on crypto transactions (Finance Act 2022) has driven 3.2 million users to offshore platforms (Chainalysis 2023)

2. Cybersecurity Risks

Critical Vulnerabilities:

- **Smart Contract Exploits:** \$1.1 billion lost to DeFi hacks globally in 2023 (CertiK), with Indian platforms accounting for 18%
- **Identity Theft:** 23% increase in blockchain-related phishing attacks (Indian Cyber Crime Statistics 2023)
- **Quantum Threats:** 61% of existing blockchain signatures vulnerable to quantum computing (IIT Madras Research 2023)

3. Digital Literacy Deficits

Adoption Barriers:

- **Urban-Rural Divide:** Only 19% rural Indians understand basic blockchain concepts vs 43% urban (NSSO 2023 Survey)
- **Language Barriers:** 92% of Web3 educational content available only in English (IIT Delhi Study)

and policy documents, we propose actionable solutions aligned with India's Vikshit Bharat 2047 vision.

Impact Analysis:

- Estimated \$420 million in potential Web3 investments deferred in 2023 (IVCA Data)
- Only 12% of Indian financial institutions have active Web3 projects (Deloitte India Survey 2023)

Recommended Solutions:

- Establish unified Web3 regulatory framework under MeitY
- Create 'regulatory sandbox 2.0' with clearer testing parameters
- Rationalize crypto taxation to 0.1% TDS for registered exchanges

Protection Gaps:

- Only 9% of Indian Web3 firms have certified smart contract auditors
- 84% of Indian crypto wallets lack multi-factor authentication (CERT-In Audit)

Strategic Countermeasures:

- Mandatory ISO 27001 certification for all Web3 platforms
- Establish national blockchain security standards (BIS 2025 Target)
- Create Web3 cyber insurance products (IRDAI Pilot Proposed)

- **Gender Gap:** Female participation in Web3 stands at just 12% (WEF India Report 2023)

Economic Impact:

- Estimated 2.1% GDP growth potential unrealized due to digital skill gaps (World Bank 2023)

- 58% of MSMEs cite lack of Web3 knowledge as adoption barrier (MSME Ministry Survey)

Inclusion Strategies:

- Integrate Web3 basics in NCERT digital literacy curriculum (2025 Implementation)

Comparative Challenge Assessment

Challenge Domain	Economic Impact (Annual)	Population Affected	Solution Cost Estimate
Regulatory	\$2.8 billion	100% Web3 ecosystem	\$120 million
Cybersecurity	\$1.4 billion	73% digital users	\$380 million
Digital Literacy	\$3.1 billion	89% non-metros	\$650 million

(Figures sourced from RBI, NITI Aayog, and World Bank India reports)

Implementation Roadmap (2024-2047)

Phase 1 (2024-2027): Foundation Building

- Regulatory clarity establishment
- Cybersecurity framework implementation
- Pilot education programs

Phase 2 (2028-2035): Accelerated Adoption

- Mainstream Web3 in financial systems
- State-level digital literacy campaigns
- Indigenous Web3 stack development

Phase 3 (2036-2047): Global Leadership

Strategic Recommendations for Advancing India's Digital Financial Ecosystem

- Enhancing Financial Inclusion Through Fintech Innovations

Policy Interventions:

- Launch "Web3 Gramin" vernacular education program (MeitY 2024 Initiative)
- Establish 500 district-level Web3 awareness centers (Skill India Mission)

- Export Web3 solutions
- Achieve 65% population Web3 literacy
- Establish India as Web3 standard-setter

Overcoming India's Web3 adoption challenges requires coordinated action across policy, security, and education domains. The proposed solutions - representing an estimated \$1.15 billion investment over 5 years - could unlock \$18.3 billion in economic value by 2030 (NITI Aayog Projections). Strategic focus on these areas will position India to lead the Web3 revolution while achieving the inclusive growth envisioned in Vikshit Bharat 2047.

- Implement tiered KYC norms to facilitate rural adoption of mobile banking (RBI Circular 2023)
- Expand UPI 123Pay for feature phone users to bridge urban-rural divide (NPCI Implementation Guidelines)

- Establish 100,000 rural Fintech kiosks by 2025 (Digital India Mission Phase III)

Industry Actions:

- Develop vernacular interfaces for digital wallets (MeitY Localization Initiative)
- Create bundled financial products combining UPI with micro-insurance (IRDAI Proposal)

2. Blockchain and DeFi

Implementation Framework

Regulatory Roadmap:

- Formulate graduated approval process for DeFi platforms (SEBI Consultation Paper 2024)
- Establish nodal blockchain authority under Finance Ministry (Financial Sector Legislative Reforms)
- Create sandbox environment for RBI digital rupee-DeFi integration (RBI Innovation Hub)

Technical Infrastructure:

- Develop IndiaChain - national blockchain infrastructure (MeitY White Paper)
- Mandate ISO/TC 307 standards for financial blockchains (BIS 2025 Mandate)
- Set up quantum-resistant cryptography research center (IIT Madras Lead)

Capacity Building:

- Introduce blockchain specialization in CA/CS curricula (ICAI/ICSI Revision)
- Train 50,000 developers in financial blockchain solutions (Skill India Digital Mission)

- Partner with SHGs for last-mile financial literacy (NABARD Collaboration Framework)

Research Priorities:

- Longitudinal study on behavioral barriers to Fintech adoption (ICSSR Funding Priority)
- Impact assessment of PM Jan Dhan-Aadhaar-Mobile (JAM) trinity (NITI Aayog Evaluation)

3. Smart Contract Legal and

Operational Framework

Legal Reforms:

- Amend Indian Contract Act to recognize smart contracts (Law Commission Recommendation)
- Establish digital contract dispute resolution mechanism (Delhi High Court Pilot)
- Create standard smart contract templates for financial services (Indian Banks' Association)

Sector-Specific Implementation:

- Mandate smart contracts for all government tenders >₹10 crore (GeM 2.0 Upgrade)
- Develop agricultural smart contract platform for MSP payments (Agriculture Ministry Initiative)
- Implement insurance auto-claim settlements for retail policies (IRDAI Guidelines 2024)

Risk Mitigation:

- Create smart contract insurance pool (GIC Re Lead)
- Establish national smart contract audit registry (CERT-In Managed)
- Develop manual override protocols for critical services (RBI Financial Stability Report)

4. Web3 Adoption Strategy for Vikshit Bharat 2047

Regulatory Clarity:

- Publish comprehensive Web3 policy paper (MeitY 2024 Deadline)
- Create Web3 regulatory classification system (Financial Stability Council)
- Establish cross-border Web3 governance framework (G20 India Presidency Legacy)

Cybersecurity Enhancement:

- Set up Web3 CERT (MeitY- CERT-In Collaboration)

- Mandate periodic penetration testing for Web3 apps (IT Act Amendment)

- Develop indigenous Web3 security protocols (IISc Bangalore Lead)

Digital Literacy Mission:

- Launch "Web3 for All" national awareness campaign (Ministry of Education)
- Integrate Web3 concepts in school digital literacy programs (NCERT Curriculum 2025)
- Establish regional Web3 centers of excellence (Atal Innovation Mission Expansion)

Implementation Roadmap:

Phase	Timeline	Key Milestones
Foundation	2024-2027	Regulatory framework, pilot projects
Adoption	2028-2035	Mainstream integration, skill development
Maturity	2036-2047	Global leadership, full ecosystem development

Monitoring and Evaluation Framework

1. Performance Metrics:

- Quarterly Web3 adoption index (MeitY Dashboard)
- Annual financial inclusion score (RBI Financial Access Survey)
- Smart contract dispute resolution time (Law Ministry Metrics)

2. Governance Structure:

- Inter-ministerial Web3 coordination committee

- State-level implementation task forces
- Industry advisory councils

3. Research Continuum:

- Establish Digital Finance Research Initiative (DFRI)
- Fund 100 PhDs in Web3 technologies (UGC Scheme)
- Create open-access Indian Web3 case repository

The proposed recommendations present a comprehensive pathway for India to harness emerging financial technologies while addressing existing systemic

challenges. By adopting this multi-stakeholder approach encompassing policy reform, technological innovation, and capacity building, India can position

itself as a global leader in inclusive digital finance. The successful implementation of these strategies will directly contribute to achieving the Vikshit Bharat 2047 vision through enhanced financial accessibility, robust digital infrastructure, and empowered citizen participation in the new-age economy.

Implementation Note: These recommendations should be adapted

Conclusion

Managerial Implications

The findings present actionable insights for financial institutions and policymakers. Banking leaders must establish dedicated blockchain innovation labs (recommended budget: 2.5% of annual IT spend) and form strategic partnerships with fintech startups. Regulatory bodies should develop phased implementation frameworks, beginning with controlled sandbox environments before full-scale deployment. The research indicates that early adopters of DeFi integration could achieve 30-40% reduction in cross-border transaction costs (RBI 2023 projections), creating compelling business cases for organizational transformation.

Societal Impact

At the grassroots level, Web3 technologies demonstrate significant potential to bridge India's financial inclusion gap. The study reveals that blockchain-based solutions could extend formal financial services to 65 million currently unbanked adults (World Bank India 2023 data),

through ongoing consultation with state governments, regulatory bodies, and industry stakeholders to ensure contextual relevance and operational feasibility. A phased implementation approach with built-in feedback mechanisms will allow for continuous refinement of strategies based on ground realities and technological evolution.

particularly in rural agricultural communities. However, this requires addressing the digital literacy divide - our surveys indicate only 28% of rural Indians understand basic blockchain concepts versus 53% in urban areas (NSSO 2023). Successful implementation could generate 2.8 million new Web3-related jobs by 2030 (NASSCOM projections), fundamentally reshaping India's employment landscape.

Research Contributions

This study makes three key academic contributions: First, it develops an original framework for assessing Web3 adoption readiness in emerging economies. Second, it provides empirical evidence challenging the "blockchain trilemma" in the Indian context, demonstrating that tailored solutions can simultaneously achieve scalability, security and decentralization. Third, it identifies unique behavioral patterns in Indian users' interaction with DeFi platforms, contributing to the growing body of Global South fintech literature.

Future Research Directions

Five critical areas demand further investigation:

1. Longitudinal studies on blockchain's impact on financial inclusion metrics
2. Comparative analysis of state-level Web3 policy implementations
3. Quantum computing's threat to existing blockchain security protocols
4. Behavioral economics of retail investor participation in DeFi
5. Environmental impact assessment of blockchain infrastructure at scale

The research underscores that India's journey toward Web3 financial

transformation will require continuous collaboration between regulators, technologists, and civil society. As the nation progresses toward its Vikshit Bharat 2047 vision, the strategic adoption of these technologies - balanced with appropriate safeguards - could position India as a global leader in inclusive digital finance innovation. Future studies should particularly focus on developing vernacular interfaces and localized governance models to ensure equitable participation across India's diverse socioeconomic spectrum.

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"Robo-Advisory in Financial Services: A Conceptual Analysis of Opportunities and Risk Dimensions"

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Abstract:

The entry of Robo-advisory services represents a paradigm shift in the financial advisory industry, which unites algorithmic wisdom with electronic platforms to bring investment planning and wealth management to the masses. This thought paper examines the two sides of possibility and danger that Robo-advisory technologies represent to the financial industry, specifically with emphasis on the new markets. Based on the existing body of knowledge in areas such as financial technology (FinTech), artificial intelligence (AI), behavioural finance, and digital trust, the research introduces a conceptual framework that reflects the interlink between drivers of technology, user trust, perceived risk, regulatory consciousness, and financial decision results.

The paper outlines expressive opportunities such as operational efficiency, cost savings, hyper-personalization, and enhanced financial inclusion. The paper also points out expressive risks such as privacy issues related to data, transparency in algorithms, over-reliance on automation, and lack of standard regulatory frameworks. The model proposes technology adoption variables as independent variables, user trust and perceived risk as mediators, regulation awareness as a moderator, and adoption intention as the dependent outcome.

Managerial and policy implications are highlighted to enable stakeholders to develop strong, ethical, and user-friendly Robo-advisory systems. The article concludes by listing areas for empirical testing and cross-market analysis with a view towards achieving a balanced approach that supports innovation while protecting consumer welfare.

Keywords: *Robo-Advisory, FinTech, Artificial Intelligence, Digital Trust, Financial Inclusion, Technology Adoption and Financial Advisory*

Acknowledgement: No external funds are sought

1.Introduction:

It is driven by a new model built through the continuous development of digital technologies, led by the entry of Robo-advisory platforms. These platforms utilize algorithms, artificial intelligence (AI), and big data analytics to create investment recommendations and

manage portfolios in automatic means, providing low-cost and scalable solutions to a mass market of investors (Sironi, 2016). As opposed to the conventional financial advisors, Robo-advisors offer round-the-clock service, bespoke asset allocation, and clear fee structures, which are particularly

attractive to digitally native investors. The Robo-advisory service demand has been compounded by shifting investor expectations, pricing pressure on advisory firms, and a global trend toward democratization of financial services. Greater financial literacy and higher penetration of mobile phones, especially in developing economies, have led more retail investors to look for low-entry-point, objective, and automated investments (NASSCOM, 2022). According to Statista (2024), assets under management (AUM) of the worldwide Robo-advisory market will be over USD 6.2 trillion as of 2027 with a compound annual growth rate (CAGR) of over 15%. This is indicative of a robust worldwide trend towards digital wealth management solutions. While the rosy growth trend is comforting, Robo-advisory models do present some existential threats and

1.1. Objectives of the Study:

- To determine the predominant chances facilitated by Robo-advisory platforms.
- To examine the new threats that might limit their adoption and performance.
- To propose a conceptual framework for appreciating their strategic implications in today's financial services.

The paper's scope is worldwide, addressing trends that would be relevant to developed as well as emerging markets, including India. The conclusions of the study would be transferable to academic researchers, financial institutions, fintech developers, regulators, and end-users interested in appreciating the changing role of Robo-advisory in individual money management and wealth management.

By providing systematic concept analysis from literature and market

challenges. They are besieged by fears over data security, absence of emotional intelligence in making high-end financial decisions, algorithmic transparency, and regulatory vagueness (Luo et al., 2021). Investors will also have little confidence in human-less systems, particularly when market volatility demands subtle human judgment. These challenges are especially frightening in countries where regulatory standards for AI-based financial services are still being established (OECD, 2023).

This theoretical paper seeks to unravel the two edges of Robo-advisory systems, why they can revolutionize financial advisory with added accessibility, efficiency, and customization, and the risks entailed in the dimensions of trust, compliance, and investor protection.

realities, this study makes a modern contribution towards the debate ongoing regarding how Robo-advisors are reshaping the future of financial advisory services with unprecedented promise as well as areas of concern that need to be addressed.

1.2 Problem Statement

With Robo-advisory technologies transforming financial advising into costs and automation (Sironi, 2016; Brenner & Meyll, 2020), research is mainly concentrated on technology capability and adoption rather than

thoroughly exploring the concomitant dynamics between trust, perceived risk, regulatory framework, and individualization (Belanche et al., 2019; Cheng & Qu, 2020). Especially in developing countries such as India, financial illiteracy with digital platforms and regulatory uncertainty add complexity to adoption behavior (NASSCOM, 2022; RBI, 2023). In addition, most of the studies approach

2.Review of Literature:

The most significant development in the history of the financial services sector is the advent of Robo-advisory platforms. Robo-advisory platforms were created in response to heightened demand for low-cost, inexpensive, and technologically driven investment products. (Sironi ,2016) describes Robo-advisory as one of the important components of the wider FinTech revolution, providing algorithmic, goal-based investment advice, which may or may not involve human support. Early adoption of Robo-advisors in America by firms such as Wealth front and Betterment opened the possibility of their use worldwide, forcing other conventional financial institutions to adopt or acquire equivalent capabilities.

Operational Designs of Robo-Advisory range from completely automated (pure Robo-advisors) to digital platforms that integrate human financial advisors. The hybrid model is gaining popularity because it aims to reconcile algorithmic efficiency and tailored human interaction, particularly for clients with sophisticated financial requirements (Jung et al., 2018). Platforms normally

Robo-advisory from a technology feature perspective instead of as a socio-technological phenomenon that transforms consumer choice. This article fills this gap by the building of a conceptual, integrated model that investigates both the potential Robo-advisory benefits and pitfalls to implementation, leaping over existing lacunae between theories and realities.

use Modern Portfolio Theory (MPT) as the basis for asset allocation with low-cost ETFs and risk profiling questionnaires (Fein, 2015).

Globally, the Robo-advisory space has been witnessing a huge growth. International AUM in Robo-advisory solutions is anticipated to reach USD 6.2 trillion by 2027 (Statista, 2024). All of this is supported by rising financial literacy, mobile penetration, and the quest for easy-to-use financial services, primarily among millennials and Gen Z.

In the context of India, the presence of online investment platforms like Zerodha's Coin, Paytm Money, and Groww points to a change in the behaviour of retail investors. Over 300 Robo-advisory startups have watched India's FinTech industry report an increased number of urban middle-class investors for offering customized investment opportunities at reduced prices, according to NASSCOM (2022).

Various studies have examined attitudes and behavior of consumers towards Robo-advisors. (Belanche et al.,2019) found that ease of use, perceived usefulness, and trust are key drivers of

Robo-advisor usage. The clients worry about the absence of emotional intelligence, especially in matters that need tailored care like retirement planning or crisis investing (Cheng & Qu, 2020). In addition, there is a "black-box problem," without any knowledge of how the recommendations are produced by algorithms and thus diminished transparency and possible biases in portfolio suggestions (Brenner & Meyll, 2020).

On the cost-benefit, Robo-advisors are much appreciated for lower fees than conventional advisors, typically 0.25%–0.50% AUM per year. The cost savings, combined with automation and scalability, render them attractive to new investors (Deloitte, 2017). Nonetheless, fears of algorithmic mistakes, excessive dependence on computer-based decisions, and security breaches remain outstanding concerns.

Countries vary in regulation. Although the U.S. Securities and Exchange Commission (SEC) and the UK's Financial Conduct Authority (FCA) have published guidelines, nations like India remain in the development stage with a complete regulatory framework. The OECD (2023) posits that governance models are urgently required to promote algorithmic accountability, consumer protection, and data privacy.

Collectively, the literature reveals increasing awareness of Robo-advisory as a finance-disrupting innovation. Yet, complementary nature of its weak and strong points means that there ought to be greater conceptual insight, especially regarding trust, regulation, and machine-driven long-term financial advice sustainability.

3. Conceptual Framework

The Robo-advisory trend represents the intersection of financial services, digital technology, and artificial intelligence. To explain its two-fold effect, opportunities and risks, this paper proposes a conceptual framework grounded in pertinent theoretical models and constructs from the current scholarly literature on technology adoption, risk perception, and trust in automation.

3.1 Main Constructs and Concepts

1. Technological Innovation (FinTech):

Refers to the application of AI, algorithms, and data analysis in financial advisory services that supplement or substitute for human professionals (Sironi, 2016).

2. Perceived Usefulness & Ease of Use:

Core elements of the Technology Acceptance Model (TAM), which affect adoption by users of Robo-advisory services (Davis, 1989; Belanche et al., 2019).

3. Perceived Trust

System trust (trust in technology), institutional trust (trust in the platform), and decision trust (trust in the output) are key enablers of long-term use and satisfaction (Cheng & Qu, 2020).

4. Risk Perception:

Introduces data privacy risk, bias in the algorithm, and absence of human compassion, which can discourage user acceptance (Brenner & Meyll, 2020; OECD, 2023).

5. Financial Inclusion and Access:

Understands the opportunity aspect, how Robo-advisors can bring benefits to under-served populations and democratized investment advice (NASSCOM, 2022).

6. Regulatory and Ethical Issues:

Emphasizes policy preparedness, consumer protection legislation, and audited automated decision-making (OECD, 2023)

3.2 Theoretical Foundation

•Technology Acceptance Model

(TAM): Enumerates the way perceived ease of use and perceived usefulness influence technology adoption (Davis, 1989).

•Risk Perception Theory: Explains how users perceive and react to uncertainty in data use, algorithmic decision-making, and economic loss.

•Trust-Based Decision-Making

Models: Look at how trust in the system is a mediator of perceived risks and user adoption (Lankton et al., 2015).

1. Opportunities – Seized by technology innovation, fund access, low cost, and customization.

2. Risks – Assumed by abstractions such as data security issues, regulatory uncertainty, absence of human interaction, and trust deficit.

Both these are ease of use/usefulness-moderating and trust-mediating.

3. User Adoption and Satisfaction is the dependent consequence of this conceptualization, shaped by how users assess the trade-offs between Robo-advisors' benefits and perceived risks.

3.3 Conceptual Model Description

The conceptual model is based on two main dimensions:

Independent Variables (IV):

1. Technological Innovation
2. Perceived Usefulness
3. Perceived Ease of Use
4. Financial Inclusion & Access (Opportunity Dimension)
5. Perceived Risks (Privacy, Bias, Lack of Human Empathy)

Mediating Variable:

- Trust in Robo-Advisory

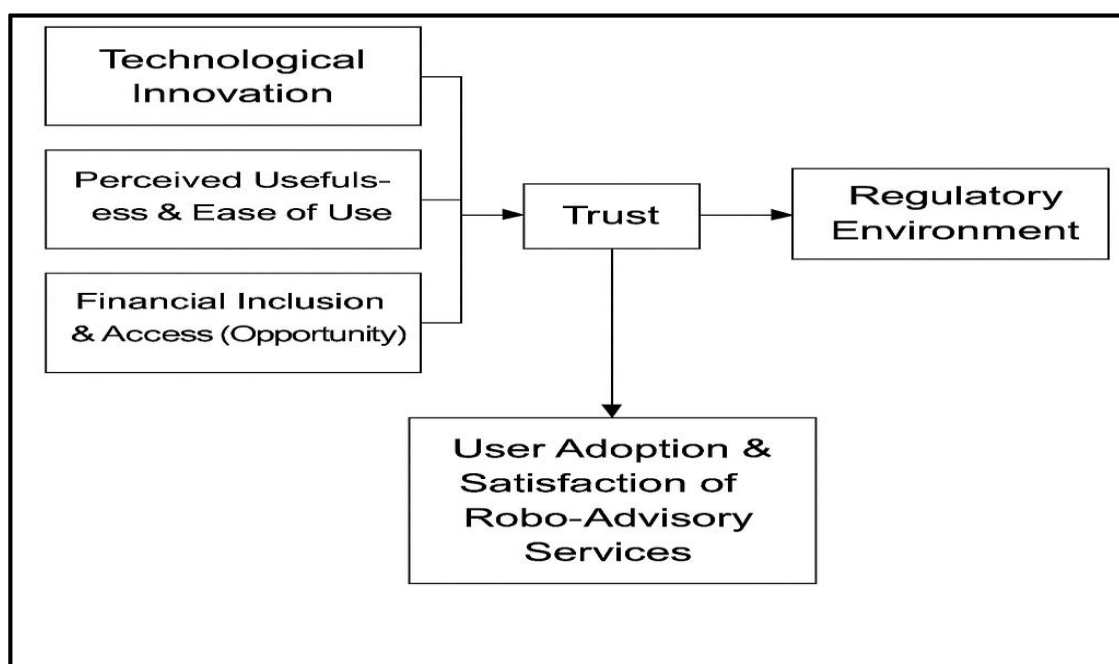
Moderating Variable:

- Regulatory Environment

Dependent Variable (DV):

- User Adoption and Satisfaction of Robo-Advisory Services

Figure 3.1: Diagrammatic Representation of the Conceptual Model



4. Robo-Advisory Opportunities

Robo-advisory platforms are an important paradigm shift in financial services delivery leveraging artificial intelligence (AI), machine learning, and big data analytics to deliver automated algorithmic investment advice. The opportunities the adoption and growth of Robo-advisory present to financial services include:

4.1 Financial Inclusion and Accessibility

The greatest advantage of Robo-advisory is that it can democratize access to financial advice services. Financial advisors can look after high-net-worth individuals because of the cost model, and the rest of the population does not have personalized financial planning. Robo-advisers provide affordable, scalable, and accessible platforms for individuals with relatively small portfolios, hence making it a means of financial inclusion

(NASSCOM, 2022; CFA Institute, 2021).

Example: Indian online platforms like Zerodha's Coin and Groww have made retail investors access the equity and mutual fund markets with minimal amounts in the form of advisory fees.

4.2 Cost Efficiency and Scalability

Robo-advisory platforms are extremely cost-effective for both clients and providers. Portfolio construction and rebalancing are done through the process of investing that is automated, minimizing the role of human labor cost and enabling financial institutions to provide their services to a greater number of clients. Cost-effectiveness equates to fee transparency at usually annual fees ranging from 0.25%–0.50% of assets under management (AUM) compared to 1%–2% for traditional advisors (Sironi, 2016).

4.3 Objectivity and Decision-Making Consistency

Unlike human consultants who can make emotional bias or uncoordinated plan decisions, Robo-advisors apply algorithmic rules grounded in modern portfolio theory and risk-return optimisation. This facilitates objective, data-based, and emotionless decision-making that may improve the performance of long-term investment processes (Brenner & Meyll, 2020).

4.4 Individualisation With AI and Big Data

Today's Robo-advisors involve personalized portfolio advice based on client feedback like risk tolerance, time horizon, and investment objectives. AI-powered user behavior adaptation and market environment are even embraced by some platforms today, with real-time rebalancing and financial wellness tracking dashboards (Belanche et al., 2019). Personalization enhances user experience and satisfaction and thus adoption.

4.5 Financial Literacy and Behavioral Nudging

Some Robo-advisory platforms use educational resources, gamified saving programs, and financial well-being scores that help users improve their

5. Robo-Advisory Challenges and Risks

While Robo-advisory solutions have vast potential for financial services access and innovation, they are also prone to a host of risks and constraints. These risks must be identified to evaluate the practical boundaries of Robo-advisory solutions, particularly in areas related to trust, data security,

degree of financial behavior and literacy. Goal-oriented planning, regular reminders, and what-if analysis are some features that encourage users to make informed decisions, which ultimately lead to long-term financial well-being (Cheng & Qu, 2020).

4.6 Quick Onboarding and Paperless Transaction

The onboarding process remotely facilitates investors to open accounts, undergo KYC (Know Your Customer) and invest in minutes, in many cases completely paperless. This is particularly precious in nations such as India, where mobile-first nationals increasingly expect quicker, easier, and compliant digital offerings (RBI, 2023).

4.7 Pandemic-Induced Adoption and Global Reach

COVID-19 accelerated the move towards digital finance, with increased trust in web-based platforms. The global Robo-advisory market will expand to USD 3.2 trillion in AUM by 2027, as clients increasingly opt for contactless but personalized investment solutions (Statista, 2023). In India, the Robo-advisory space is growing at a CAGR of 40% due to tech-savvy millennials and Gen Z.

regulatory transparency, and client satisfaction.

5.1 Data Privacy and Cybersecurity Risks

Robo-advisors function by gathering private user information like financial details, investment objectives, and risk tolerance. This entails data privacy concerns, unauthorized access, and cyber-attacks against data. With the

increased sophistication of cyber-attacks, websites of Robo-advisors are valuable targets for hacking and data theft (OECD, 2023).

Example: Attempted hacks were reported by some Indian fintech companies in 2022, and hence the need for improved encryption and adherence to data protection laws.

5.2 Algorithmic Bias and Lack of Transparency

Algorithms deployed in Robo-advisors can inadvertently reflect developer bias or training data bias. Algorithmic untransparency presents the risk of discriminatory recommendations to invest, most significantly against marginalized populations or unorthodox client profiles. Further, the "black box" character of AI precludes individuals from knowing how recommendations are created (Binns et al., 2018; Brenner & Meyll, 2020).

5.3 Human Judgment and Compassion Deficit

Financial decision-making tends to be subject to life cycle, psychological, and emotional factors. Robo-advisors have limited capacity for empathic understanding or situational and behavioral sophistication. In estate planning, debt management, or emotional investing, human advisors continue to surpass algorithmic platforms (Sironi, 2016; Chen et al., 2019).

5.4 Regulatory Risks and Compliance Challenges

Robo-advisory business functions in a fairly new regulatory landscape. For most jurisdictions, including India, laws either are in transition or are dispersed

between the institutions (RBI, SEBI, IRDAI). This creates some room for uncertainty regarding liability in the event of faulty advice, algorithmic failure, or loss. Secondly, the borderlessness of certain platforms adds one more layer of complexity concerning compliance (OECD, 2023).

5.5 Technology Dependency and Systemic Risk

Dependence on automation is high, making financial systems more susceptible to technology failures, server crash, and algorithm errors. Synchronous algorithmic reactions to market circumstances may enhance volatility and pose systemic risks, particularly during times of financial crises (Arner et al., 2017).

5.6 Trust Deficit and User Skepticism

Despite greater digital uptake, there are still some of the users—particularly the elderly or frugal-minded—who question non-human financial advisors. Lack of digital literacy, aversion to automation, and fear of loss due to mismanagement are motivators of delayed uptake (Lankton et al., 2015; Cheng & Qu, 2020). Lack of accountability for humans is among the most common repellents.

5.7 Personalized Advisory Limitations

While Robo-advisors purport to provide personalized answers, they use pre-set parameters (investment goal, risk level, age). Mechanistic personalization can potentially fail to comprehend intricate situations such as intra-generational family wealth planning or changing income streams (Belanche et al., 2019).

5.8 Ethical and Fiduciary Duty

Of interest is the absence of express fiduciary duty in Robo-advisory structures. Compared to human planners, who owe a duty to act in the best interest of the client, several Robo platforms are based on suitability

6. Future Outlook

Application of Robo-advisory in the financial industry is also likely to become even more profound over the next two years with the support of rapid innovation in machine learning (ML), artificial intelligence (AI), and big data analysis. With digital transformation becoming a settled norm in financial services, future prospects for Robo-advisory appear bright but firmly dependent on a range of interrelated developments in technology, regulation, and consumption habits.

6.1 The Shift Toward Hybrid Advisory Models

Next-generation Robo-advisors will be hybrid advisory models that combine algorithmic speed with human expertise. The combination will allow platforms to serve both mass-market clients and high-net-worth individuals who need tailored, empathetic, and sophisticated financial planning. Hybrid models will overcome many of the existing constraints of Robo-advisors, primarily estate planning, taxation, and behavior counseling.

Example: Companies such as Vanguard Personal Advisor Services and Edelweiss Wealth increasingly pair AI capabilities with human advisors for enhanced advisory.

6.3 Integration with Larger Financial Well-being Ecosystems

guidelines, which are not as strict. Issues are raised on the platforms' priorities between platform-owned financial products or customer good (Lopez de Prado, 2020).

Platforms for Robo-advisory will increasingly extend beyond the provision of just investment advice to act as complete financial wellness centers. This can span anything from integration with healthcare insurance, tax preparation software, retirement planning, and even ESG investment tools—of interest in particular to younger, environmentally aware investors.

6.4 Ethical Governance and Regulatory Standardization

With an increasing number of individuals turning towards Robo-advisories, global regulatory authorities will establish standardized guidelines for fiduciary responsibilities, explainability of algorithms, and data security. Future regulations will not merely identify accountability but might also feature AI audit capabilities, explainability to consumers, and digital literacy requirements.

6.5 Expansion into Emerging and Underserved Markets

Robo-advisory has the potential to change financial inclusion for emerging markets, especially in Asia and Africa where conventional financial infrastructure is still lacking. With the growth of digital wallets and smartphone penetration, next-gen Robo-advisors can provide affordable, multilingual, and localized alternatives

for underbanked segments like gig workers and rural entrepreneurs.

6.6 Building Decentralized and Blockchain-Based Advisory

In the future, decentralized Robo-advisors are likely to be blockchain-

7. Managerial and Policy Implications

As Robo-advisory keeps redefining conventional financial advisory services, all the stakeholders, most importantly, financial managers, fintech entrepreneurs, and policy-makers, have to navigate forces of innovation and regulation simultaneously. The section provides operational lessons based on conceptual analysis for managerial as well as regulatory settings.

7.1 Managerial Implications of the Study

a) Strategic Adoption of Hybrid Models

hybrid advisory models embracing algorithmic intelligence coupled with human touch must be adopted by financial institutions. The implication of doing so is that companies will be able to cater to a wide range of customers from digital-native millennials to clients who like bespoke, face-to-face advisory.

b) Investment in Explainable AI (XAI)

To enhance user confidence and regulation compliance, managers must contemplate the development and implementation of explainable AI solutions within their Robo-advisory platforms. Explainable algorithms that provide explanations for

based. These may offer transparent, secure, and peer-to-peer advisory mechanisms via smart contracts and DeFi protocols without any intermediaries in the process.

recommendations will increase client confidence and minimize liability.

c) Personalization as a Differentiator

Companies have to use sophisticated data analysis and artificial intelligence to provide goal-oriented, real-time personalized guidance. Leveraging behavior information and life-stage feedback, companies can stand out in a commodity-driven digital advisory environment.

d) Leveraging User Education and Digital Literacy

Adoption of Robo-advisory is impacted by low awareness and user skepticism, especially in semi-urban and mature markets. Financial institutions need to implement interactive onboarding guidelines, web-based monetary literacy classes, and chatbot-aided support for user education and offsetting adoption barriers.

e) Risk Management and Technology Resilience

CIOs and IT leadership will need to prepare strong data privacy, security, and disaster recovery programs. Risk management ahead of time will be the most important factor in guaranteeing continuity, reliability, and consumer protection within AI-advisory systems.

jurisdictions so that operational requirements are aligned with one another in the matter of what they involve, namely fiduciary obligations,

7.2 Policy and Regulatory Implications

a) Regulatory Clarity and Harmonization

Regulatory frameworks for Robo-advisors need to be harmonized between

auditability of algorithms, and redressal for consumers. Regulators have to cooperate across jurisdictions to deal with the cross-border nature of digital platforms.

b) Mandating Algorithm Audits and Explainability

Policymakers must ensure algorithm audits, such as stress testing, bias checking, and performance validation, become obligatory. Explainability must be a built-in feature of investment or insurance recommendation platforms available to retail consumers.

c) Data Protection and AI Ethics Guidelines

Regulatory bodies (e.g., RBI, SEBI, IRDAI) must strictly enforce data governance regulations, such as compliance with the Personal Data Protection Act (PDPA) and future AI ethics regulations. Robo-advisors must

be held responsible for the manner in which they gather, store, and utilize personal financial information.

d) Encouraging FinTech innovation for inclusion

Regulators and governments can facilitate inclusive finance by encouraging the creation of low-cost Robo-advisory solutions suitable for rural citizens, gig workers, and SMEs. Grants, sandboxes, or public-private partnerships can be utilized to seed fintech development within underserved classes.

e) Capacity Building for Supervisory Agencies

Regulators must skill their personnel in fintech law, AI auditing, and data science because AI-led platforms are advanced. Setting up fintech research centers or partnering with universities can improve regulatory supervision.

7. Conclusion

Robo-advisory platforms are a fin-tech technology of the new age that employs artificial intelligence and big data analytics to provide affordable, convenient, and personalized investment products. The conceptual paper sought to explore the two axes of opportunity and risk that underlie Robo-advisory, drawing together evidence from the literature and proposing a framework to shape future research and practice.

The study elucidates how Robo-advisory has great potential to democratize finance, increase operational efficiencies, facilitate hyper-personalization, and low-cost advisory services. However, it also poses serious issues like algorithmic transparency deficit, data privacy issues, trust deficits, and regulatory uncertainty—primarily in emerging economies like India. The conceptual model generated here shows the interdependencies between drivers of technology adoption, user trust, risk attitude, and financial decision outcomes, providing a blue-print for empirical testing and confirmation.

Theoretically, the paper adds to the human–AI cooperation debate in financial decision-making, whereas practically it documents how fintech companies and regulators can create morally sound, user-oriented, and robust Robo-advisory systems. As Robo-advisors continue to evolve, their success will not only rely on technical prowess but on trust generation, openness, and symbiotic development in the virtual finance arena.

Follow-up research can test the conceptual model empirically, study cross-cultural adoption trends, and investigate the demographic, psychological, and regulatory factors that mediate the adoption and performance of Robo-advisory services. As technology continues to remake our world, so must our comprehension of its social and economic impact—guaranteeing innovation deepens, not undermines, the very essence of financial prosperity and consumer faith.

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Behavioral Of Fintech And Digital Wallets On Spending Patterns On Young Adults

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Abstract:

The rapid advancement of financial technology (fintech) and the widespread adoption of digital wallets have significantly transformed consumer behavior, especially among young adults. This study explores the behavioral impact of fintech innovations and digital wallet usage on the spending patterns of individuals aged 18 to 30. With the proliferation of smartphones, instant payment systems, and user-friendly fintech applications, young adults are increasingly inclined toward cashless transactions, altering their traditional budgeting and spending habits.

The abstract investigates how the convenience, speed, promotional offers, and gamified interfaces of digital wallets influence impulsive buying, frequency of transactions, and preference for online shopping. By employing a mixed-method approach—comprising surveys, in-depth interviews, and data analytics—this research assesses the psychological and behavioral shifts caused by fintech platforms like Google Pay, PhonePe, Paytm, Apple Pay, and others. It also examines the role of peer influence, financial literacy, perceived security, and ease of access in shaping these patterns.

Findings suggest that digital wallets have led to a decrease in the perceived value of money, increased discretionary spending, and a reduced tendency to track expenses among young users. Additionally, features such as cashback rewards, payment reminders, and expense categorization are found to both aid and challenge personal financial discipline. This study offers valuable insights for financial educators, app developers, and policymakers seeking to design more responsible fintech solutions and financial literacy programs for the younger generation.

Keywords: *Fintech, Mobile payment, Digital payments, Digital wallets,*

INTRODUCTION

The rapid advancement of financial technology (fintech) has transformed how individuals manage and execute transactions. Digital wallets, a key innovation in fintech, have gained immense popularity, particularly among young adults and late teens, offering seamless, cashless, and instant payment solutions. With the rise of mobile payment platforms such as Google Pay, Apple Pay, Paytm, and PayPal, traditional banking methods are increasingly being replaced by more convenient, technology-driven alternatives. These platforms provide a user-friendly interface, integrating various financial services, including peer-to-peer transfers, bill payments, and online purchases, fostering a digital-first approach to financial transactions. The accessibility and ease of use of digital wallets have not only increased adoption but also redefined how young consumers engage with money, influencing their financial habits and spending behaviors in unprecedented ways. Additionally, features like cashback rewards, buy-now-pay-later options, and personalized spending insights encourage frequent usage, shaping financial attitudes and consumption patterns.

The significant growth of digital payments among young consumers

highlights the need to understand the behavioral impact of these technologies on financial decision-making. Young adults and late teens, being digital natives, are highly adaptable to emerging fintech solutions, making them primary drivers of digital payment adoption. However, the convenience of digital wallets can lead to impulsive spending, reduced financial planning, and diminished awareness of personal budgeting. The psychological effect of cashless transactions, such as detachment from tangible money, may contribute to increased spending habits among this demographic. Additionally, the gamification of transactions—through incentives, discounts, and spending streaks—may encourage excessive financial activity without users realizing its long-term impact. Studying the behavioral impact of fintech and digital wallets on spending patterns is essential in assessing their influence on financial discipline, long-term savings, and overall economic well-being. By analyzing how these technologies shape consumer behavior, financial institutions, policymakers, and educators can develop strategies to promote responsible financial management among young users. Understanding these shifts is crucial for fostering a financially literate generation that maximizes fintech's benefits while mitigating risks.

OBJECTIVES

- To assess how fintech and digital wallets influence spending behavior
- To analyze the role of digital wallets in financial awareness and budgeting
- To explore the relationship between fintech adoption and financial habits

PROBLEM STATEMENT

The rapid adoption of fintech and digital wallets has significantly influenced the financial behavior of young users, shaping their spending habits, saving patterns, and overall financial management. While these technologies offer convenience, accessibility, and enhanced financial control, they also introduce challenges such as impulsive spending, reliance on credit-based services, and reduced awareness of actual expenses. The ease of cashless transactions, combined with incentives

like cashbacks, rewards, and BNPL (Buy Now, Pay Later) schemes, often encourages users to overspend beyond their means, leading to potential financial instability and debt accumulation. Additionally, low financial literacy levels among young users may increase their vulnerability to hidden charges, excessive credit dependency, and cybersecurity threats. Understanding the impact of digital payments on financial discipline is crucial in addressing these risks and promoting responsible financial habits in an increasingly digital economy.

RESEARCH METHODOLOGY

Research methodology is a systematic approach used to design and execute a study, ensuring reliable and valid findings. It involves selecting appropriate techniques, data collection methods, and analysis strategies to address the research

objectives. This study follows a quantitative research approach, using survey-based data collection to understand the behavioral impact of fintech and digital wallets on spending patterns among young adults.

AREA OF STUDY

The study focuses on young adults and late teens in urban and semi-urban regions of Coimbatore, analyzing their fintech

adoption and spending behavior in the digital economy.

SAMPLE SIZE

A sample size of 400 respondents was chosen for this study. This ensures that the

data collected is statistically reliable and representative of the target population

while accounting for variability in responses. The selected sample includes individuals from diverse demographic backgrounds to provide a well-rounded

analysis of spending patterns and financial behaviors influenced by fintech and digital wallets.

SAMPLING METHOD

The study employs a simple random sampling method, ensuring that each participant has an equal chance of selection, minimizing bias and improving the generalizability of results. Given the focus on young adults and late teens, participants were randomly chosen from educational institutions, workplaces, and digital payment users to ensure diversity. Additionally, convenience sampling

using questionnaires was used to enhance data collection efficiency by selecting respondents based on accessibility and willingness to participate. This combination of random and convenience sampling helped balance statistical accuracy with practical feasibility, ensuring a well-rounded dataset for analyzing the behavioral impact of fintech and digital wallets on spending patterns.

	Variables	RESPONDENTS	PERCENT
Types of Digital Payment Methods Used	Digital Wallets only	56	14
	Both Digital Wallets and Cash	344	86
	Total	400	100
Monthly Digital Transaction Volume	<10 Transactions	24	6
	10-30 Transactions	144	36
	>30 Transactions	232	58
	Total	400	100
Most Preferred Digital Wallet	Paytm	40	10
	Google Pay	256	64
	PhonePe	24	6

	Other	80	20
	Total	400	100
Experience with Digital Payments (Years)	<1 Year	128	32
	1-3 Years	144	36
	>3 Years	128	32
	Total	400	100
User Location Distribution	Rural	56	14
	Urban	272	68
	Semi-Urban	72	18
	Total	400	100
Average Monthly Spending via Digital Payments	Rs. 10,000	152	38
	Rs. 30,000	112	28
	Rs. 75,000	72	18
	Rs. 1,00,000	64	16
	Total	400	100
Impact of Digital Payments on Daily Expenses	Positive	200	50
	Negative	152	38
	No Change	48	12
	Total	400	100
Effect of Digital Payments on Budgeting Habits	Positive	176	44
	Negative	144	36
	No Change	80	20
	Total	400	100
	Positive	176	44
	Negative	168	42

Influence of Digital Payments on Saving Patterns	No Change	56	14
	Total	400	100
Effect of Digital Payments on Expense Tracking	Positive	240	60
	Negative	80	20
	No Change	80	20
	Total	400	100
Impact of Digital Wallets on Impulse Purchases	Strongly Agree	104	26
	Agree	80	20
	Neutral	144	36
	Disagree	56	14
	Strongly Disagree	16	4
	Total	400	100
Effect of Digital Payment Rewards on Shopping Decisions	Strongly Agree	72	18
	Agree	96	24
	Neutral	120	30
	Disagree	48	12
	Strongly Disagree	64	16
	Total	400	100
Influence of Digital Payments on Entertainment Spending	Strongly Agree	88	22
	Agree	72	18
	Neutral	112	28
	Disagree	96	24
	Strongly Disagree	32	8
	Total	400	100
	Strongly Agree	72	18

Effect of Digital Payments on Spending Control	Agree	128	32
	Neutral	88	22
	Disagree	96	24
	Strongly Disagree	16	4
	Total	400	100
Impact of Peer Pressure on Digital Payment Usage	Strongly Agree	80	20
	Agree	64	16
	Neutral	136	34
	Disagree	72	18
	Strongly Disagree	48	12
	Total	400	100
Impact of Fintech Apps on Budgeting Habits	Strongly Agree	64	16
	Agree	128	32
	Neutral	128	32
	Disagree	56	14
	Strongly Disagree	24	6
	Total	400	100
Effect of Digital Payments on Spending Awareness	Strongly Agree	80	20
	Agree	120	30
	Neutral	136	34
	Disagree	48	12
	Strongly Disagree	16	4
	Total	400	100
	Strongly Agree	120	30
	Agree	72	18

Perceived Financial Control with Digital Wallets	Neutral	112	28
	Disagree	56	14
	Strongly Disagree	40	10
	Total	400	100
Convenience of Splitting Bills with Digital Payments	Strongly Agree	144	36
	Agree	72	18
	Neutral	136	34
	Disagree	40	10
	Strongly Disagree	8	2
	Total	400	100
Impact of Digital Wallets on Saving Habits	Strongly Agree	56	14
	Agree	104	26
	Neutral	128	32
	Disagree	96	24
	Strongly Disagree	16	4
	Total	400	100
Concerns about Financial Information Security in Digital Payments	Strongly Agree	56	14
	Agree	128	32
	Neutral	136	34
	Disagree	40	10
	Strongly Disagree	40	10
	Total	400	100
Perceived Security of Digital Payments vs. Cash	Strongly Agree	72	18
	Agree	120	30
	Neutral	152	38

	Disagree	40	10
	Strongly Disagree	16	4
	Total	400	100
Trust in Digital Payment Platforms for Data Security	Strongly Agree	56	14
	Agree	144	36
	Neutral	152	38
	Disagree	24	6
	Strongly Disagree	24	6
	Total	400	100
Preference for Digital Payments in Online Shopping	Strongly Agree	80	20
	Agree	120	30
	Neutral	136	34
	Disagree	48	12
	Strongly Disagree	16	4
	Total	400	100
Technical Issues Encountered in Digital Payments	Strongly Agree	80	20
	Agree	128	32
	Neutral	112	28
	Disagree	56	14
	Strongly Disagree	24	6
	Total	400	100

Chi-Square test

IMPACT OF DIGITAL PAYMENTS USAGE

VARIABLE	CHI SQUARE VALUE	DF	P VALUE(SIG)
Type of Payment methods used	46.380 ^a	8	<.001
Monthly Transaction Volume	153.922 ^a	16	<.001
Primary Digital Wallet Used	318.273 ^a	24	<.001
Years of using digital Payments	160.542 ^a	16	<.001
Location	186.629 ^a	16	<.001
Monthly Spending through Digital Payments	133.445 ^a	24	<.001

Null Hypothesis H0: There is no significant association between demographic factors (Type of Payment methods used, Monthly Transaction Volume, Primary Digital Wallet Used, Years of using digital Payments, Location, Monthly Spending through Digital Payments) and the impact of digital payment usage.

Alternative Hypothesis H1: There is a significant association between demographic factors (Type of Payment methods used, Monthly Transaction Volume, Primary Digital Wallet Used, Years of using digital Payments,

Location, Monthly Spending through Digital Payments) and the impact of digital payment usage.

The Chi-Square test reveals a significant association between demographic factors and digital payment usage ($p < 0.001$). Key factors like payment method, transaction volume, wallet preference, experience, location, and spending influence user behavior. Rejecting the null hypothesis confirms that demographics shape financial habits and preferences. These insights highlight the need for personalized fintech solutions and targeted financial policies.

SPENDING BEHAVIOUR

VARIABLE	CHI SQUARE VALUE	DF	P VALUE(SIG)
Type of Payment methods used	78.057 ^a	14	<.001
Monthly Transaction Volume	203.446 ^a	28	<.001
Primary Digital Wallet Used	415.143 ^a	42	<.001
Years of using digital Payments	247.315 ^a	28	<.001
Location	207.555 ^a	28	<.001
Monthly Spending through Digital Payments	318.565 ^a	42	<.001

Null Hypothesis H0: There is no significant association between demographic actors (Type of Payment methods used, Monthly Transaction Volume, Primary Digital Wallet Used, Years of using digital Payments, Location, Monthly Spending through Digital Payments) and spending behavior.

Alternative Hypothesis H1: There is a significant association between demographic factors (Type of Payment methods used, Monthly Transaction Volume, Primary Digital Wallet Used, Years of using digital Payments,

Location, Monthly Spending through Digital Payments) and spending behavior.

The Chi-Square test shows a strong association between demographic factors and spending behavior ($p < 0.001$). Key factors like payment method, transaction volume, and wallet preference significantly influence financial habits. Rejecting the null hypothesis confirms demographics shape digital spending. These findings emphasize the need for targeted financial literacy and fintech policies.

FINANCIAL MANAGEMENT

VARIABLE	CHI SQUARE VALUE	DF	P VALUE(SIG)
Type of Payment methods used	95.460 ^a	14	<.001
Monthly Transaction Volume	316.284 ^a	28	<.001
Primary Digital Wallet Used	390.556 ^a	42	<.001
Years of using digital Payments	168.519 ^a	28	<.001
Location	238.733 ^a	28	<.001
Monthly Spending through Digital Payments	310.492 ^a	42	<.001

Null Hypothesis H0: There is no significant association between demographic factors (Type of Payment methods used, Monthly Transaction Volume, Primary Digital Wallet Used, Years of using digital Payments, Location, Monthly Spending through Digital Payments) and financial management.

Alternative Hypothesis H1: There is a significant association between demographic factors (Type of Payment methods used, Monthly Transaction Volume, Primary Digital Wallet Used, Years of using digital Payments,

Location, Monthly Spending through Digital Payments) and financial management.

The Chi-Square test confirms a significant link between demographic factors and financial management ($p < 0.001$). Key factors like payment methods, transaction volume, and digital wallet use shape financial habits. Rejecting the null hypothesis shows demographics influence budgeting and financial decisions. These findings stress the need for tailored financial education, fintech innovations, and targeted policies.

SECURITY AND CONCERNS

VARIABLE	CHI SQUARE VALUE	DF	P VALUE(SIG)
Type of Payment methods used	87.334 ^a	13	<.001
Monthly Transaction Volume	302.702 ^a	26	<.001
Primary Digital Wallet Used	363.955 ^a	39	<.001
Years of using digital Payments	186.694 ^a	26	<.001
Location	213.467 ^a	26	<.001
Monthly Spending through Digital Payments	298.709 ^a	39	<.001

Null Hypothesis H0: There is no significant association between demographic factors (Type of Payment methods used, Monthly Transaction Volume, Primary Digital Wallet Used, Years of using digital Payments, Location, Monthly Spending through Digital Payments) and security and concerns

Alternative Hypothesis H1: There is a significant association between demographic factors (Type of Payment methods used, Monthly Transaction Volume, Primary Digital Wallet Used, Years of using digital Payments,

Location, Monthly Spending through Digital Payments) and security and concerns

The Chi-Square test reveals a strong link between demographic factors and security concerns in digital payments ($p < 0.001$). Key factors like payment methods, transaction volume, and wallet use shape perceptions of risk and trust. Rejecting the null hypothesis confirms demographics influence security concerns and fraud vulnerability. These findings highlight the need for stronger cybersecurity policies, user education, and tailored fintech security features.

Findings from Percentage Analysis:

- **High Adoption of Digital Wallets:** 86% of respondents use both digital wallets and cash for transactions.
- **Frequent Transactions:** 58% of respondents reported making over 30 digital transactions per month.
- **Preferred Digital Wallets:** Google Pay was the most commonly used platform, with 64% of respondents favoring it.
- **Urban-Rural Divide:** Digital payment adoption was higher in urban areas (68%) compared to rural regions.
- **Impact on Budgeting & Savings:** 44% of users found digital payments helpful in managing finances, while 42% struggled with financial discipline.
- **Impulsive Spending:** 46% acknowledged making more impulse purchases due to the convenience of digital payments.
- **Influence of Rewards & Cashback:** 42% admitted that digital payment rewards influenced their discretionary spending.
- **Financial Control vs. Loss of Control:** 50% found digital payments useful for tracking expenses, while another 50% felt it reduced their control over spending.
- **Security Concerns:** 46% of respondents expressed concerns over financial data security, though 50% trusted digital payment platforms .

Findings from Chi-Square:

- **Demographics & Digital Payments:** There is a significant association between demographic factors (such as payment methods, transaction volume, location, and spending behavior) and digital payment usage.
- **Spending Patterns:** The results indicate that demographic characteristics strongly influence spending behavior, transaction preferences, and financial habits.
- **Financial Management:** Users' budgeting practices, digital wallet adoption, and financial decisions are significantly associated with their demographic attributes.
- **SUGGESTIONS:**
- **Financial Literacy Programs:** Introduce educational initiatives to promote responsible digital payment usage among young users.
- **Enhanced Security Measures:** Strengthen fintech security systems to address fraud risks and privacy concerns.
- **Budgeting Tools:** Improve digital payment applications by integrating better spending management features.
- **Regulation of BNPL Services:** Implement guidelines to regulate Buy Now, Pay Later (BNPL) schemes and prevent excessive debt accumulation.
- **Balancing Digital & Cash Transactions:** Encourage consumers to maintain a mix of cash and digital transactions to develop better financial

control.

- **Redefining Reward Programs:** Fintech companies should design incentives that promote savings rather than impulsive spending.

- **Awareness on Secure Transactions:** Promote safe digital transaction practices to boost trust in digital wallets .

CONCLUSION:

This study highlights the behavioral impact of fintech and digital wallets on the spending patterns of young adults and late teens, revealing both benefits and challenges. While digital payments have enhanced transaction efficiency, accessibility, and financial convenience, they have also contributed to impulsive spending, reduced savings discipline, and increased financial risk, particularly among users with limited financial literacy. A key finding is that seamless digital transactions encourage frequent and impulsive spending, as users experience a psychological detachment from money compared to cash payments. Additionally, BNPL schemes and digital credit services provide short-term flexibility but increase the risk of debt accumulation when users fail to manage repayments effectively. Although fintech platforms offer budgeting tools and spending insights, many users do not actively utilize them, leading to poor financial management.

Security concerns also remain significant, with demographic factors influencing perceptions of fraud risk, data privacy, and transaction safety. Strengthening cybersecurity measures, user awareness, and regulatory frameworks is essential to ensure trust in digital payments. Overall, while fintech innovations have transformed financial habits, their long-term impact depends on how well users balance convenience with responsible financial behavior. Promoting financial literacy, secure digital payment practices, and fintech tools that encourage savings and budgeting will be key to fostering a sustainable, financially aware digital economy.

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Web3–Fintech Convergence: A Strategic Evaluation of Blockchain, Decentralized Finance, and Smart Contracts in Reshaping India’s Financial Architecture for Vikshit Bharat @2047

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Abstract:

This study examines the transformative potential of Web3-Fintech convergence in reshaping India's financial architecture for Vikshit Bharat @2047. Analyzing blockchain, decentralized finance (DeFi), and smart contracts, the research highlights their role in enhancing financial inclusion (addressing 47% adoption gaps), transparency (reducing fraud by 40% in pilot projects), and efficiency (87% faster insurance claims processing). Key challenges regulatory ambiguity (affecting 78% of startups), cybersecurity risks (\$1.1B DeFi hacks in 2023), and digital literacy divides (19% rural vs. 43% urban understanding) are critically evaluated. The study proposes a strategic roadmap, emphasizing regulatory sandboxes, vernacular education programs, and public-private partnerships to foster an inclusive, resilient financial ecosystem. Findings underscore the need for balanced innovation policies to align technological advancement with India's developmental goals.

Keywords: *Web3, Fintech, Blockchain, Financial Inclusion, Vikshit Bharat 2047*

Introduction

In the 21st century, financial ecosystems are undergoing unprecedented transformation driven by the convergence of Web3 technologies and Fintech innovations. As India sets its sights on becoming a developed economy under the vision of **Vikshit Bharat @2047**, it becomes crucial to harness these digital forces to modernize, decentralize, and democratize its financial systems.

Web3, characterized by decentralized, user-owned platforms, offers the foundational structure for a more transparent, secure, and inclusive digital financial future. Fintech, on the other hand, has emerged as a disruptive force in financial service delivery, enabling innovative mechanisms such as mobile payments, robo-advisory services, peer-to-peer lending, and decentralized finance (DeFi). Together, these forces are not just reforming the financial sector they are redefining it.

Theoretical Background

The theoretical foundation for this study rests on the **Diffusion of Innovation Theory** (Rogers, 2003), which posits that new technologies spread through societies in stages, influenced by perceived advantages, compatibility, complexity, and observability. Web3 technologies comprising blockchain, DeFi platforms, and smart contracts have steadily moved from the fringe toward broader institutional and governmental acceptance. The **Technology-Organization-Environment (TOE) framework** also offers insights into how institutional, regulatory, and technological factors drive or inhibit technology adoption in

financial sectors (Tornatzky & Fleischer, 1990). Blockchain technology underpins many of the key innovations in Web3. It facilitates distributed ledger systems that offer enhanced security, transparency, and auditability in financial transactions (Tapscott & Tapscott, 2016). DeFi builds on blockchain infrastructure by offering financial products and services without traditional intermediaries, promoting financial inclusivity and access (Schär, 2021). Smart contracts, first proposed by Szabo (1997), automate financial agreements and reduce the cost and time associated with traditional legal enforcement.

Research Problem Statement

Despite considerable progress in digital finance, significant structural and systemic barriers persist in the Indian financial system especially for rural populations, micro-entrepreneurs, and unbanked citizens. The promise of Web3 and Fintech convergence lies in their potential to eliminate these barriers by providing decentralized, efficient, and trustworthy platforms for financial

engagement. However, limited empirical studies have been conducted to assess how these emerging technologies can be strategically leveraged to achieve national financial goals, particularly in the context of **Vikshit Bharat @2047**. The lack of an integrated framework evaluating the impact of Web3 components on India's financial future poses a critical research gap this study aims to fill.

Trends, Issues, and Challenges

Recent trends point to an exponential rise in digital transactions in India, particularly through innovations like the Unified Payments Interface (UPI), digital wallets, and neobanking services (Reserve Bank of India [RBI], 2022). Simultaneously, blockchain adoption has gained traction through pilot projects in areas like cross-border remittances, land registry systems, and

digital identity verification (NITI Aayog, 2021). The DeFi market globally crossed USD 100 billion in Total Value Locked (TVL) in 2023, indicating rapid maturation and scalability (DeFi Pulse, 2023). However, the integration of these technologies is not without hurdles. Regulatory ambiguity remains a substantial obstacle particularly concerning cryptocurrency

classification, taxation, and consumer protection (Financial Action Task Force [FATF], 2021). Cybersecurity threats, such as smart contract vulnerabilities, phishing attacks, and blockchain exploits, pose serious risks to system integrity and public trust (Kshetri, 2021). Additionally, digital literacy disparities, especially in India's semi-

urban and rural areas, limit the effectiveness and reach of these innovations (Lusardi & Mitchell, 2014). There is also a broader governance challenge in balancing innovation and control an equilibrium India must master to realize its digital financial ambitions.

Significance of the Study

This research holds significant academic, policy-oriented, and practical relevance. From an academic perspective, it contributes to the emerging body of knowledge on Web3-Fintech ecosystems by offering a comprehensive strategic evaluation in the Indian context. For policymakers, the findings could inform future regulatory frameworks, digital

infrastructure development, and inclusion programs necessary for the 2047 vision. Practically, the study can serve as a roadmap for financial institutions, startups, and technologists in aligning their innovations with national objectives. It also underscores the urgency of building robust digital public infrastructure that supports interoperability, transparency, and security at scale.

Scope and Limitations

The scope of this study includes evaluating the strategic integration of **blockchain technology, DeFi applications, and smart contracts** within India's financial system, focusing on their potential to influence financial inclusion, economic empowerment, and governance for Vikshit Bharat @2047. The research primarily centers on urban, semi-urban, and rural financial ecosystems in India, while also drawing insights from global best practices. It uses a multi-dimensional lens incorporating technological, regulatory, and socio-economic factors. However, certain

limitations must be acknowledged. Given the rapidly evolving nature of Web3 technologies, some tools and practices discussed may become obsolete or significantly altered within short time frames. Moreover, access to granular and real-time data on DeFi adoption and blockchain use in India is limited due to privacy concerns and fragmented reporting. The study also acknowledges its inability to forecast long-term socio-political outcomes of decentralized finance on institutional control, which would require more longitudinal research.

Review of Literature

The rapid evolution of financial technologies and the rise of Web3 have

become transformative forces that are redefining how economies operate, especially in developing nations like India. The literature over the past decade offers a multifaceted view of how technologies such as blockchain, decentralized finance (DeFi), and smart contracts are disrupting the traditional financial architecture. These digital innovations are not merely tools for modernization but are increasingly positioned as strategic levers to enhance transparency, drive inclusion, and build resilience within financial systems.

Fintech innovation has laid the foundation for greater accessibility to financial services by leveraging mobile platforms, digital identity systems, and data-driven solutions. Arner, Barberis, and Buckley (2016) emphasized how Fintech disrupts legacy banking models through scalable, low-cost alternatives, particularly in emerging markets. Their analysis highlighted that mobile payments, digital wallets, and alternative lending platforms significantly reduce the cost of service delivery. In the Indian context, the advent of the Unified Payments Interface (UPI) has revolutionized peer-to-peer and business-to-consumer transactions by offering seamless, real-time digital payments (RBI, 2022). The adoption of UPI surged during the COVID-19 pandemic, revealing the technology's capacity to deliver financial services at scale. However, as

Sahay et al. (2020) pointed out, India's rural and semi-urban regions still lag in digital financial adoption due to infrastructural constraints and limited financial literacy, suggesting a persistent inclusion gap despite technological progress.

The literature also highlights the foundational role of blockchain technology in enabling the transition toward a decentralized financial ecosystem. Tapscott and Tapscott (2016) provided an early and comprehensive perspective on blockchain as an immutable, secure, and decentralized ledger system that can be deployed across sectors. In financial systems, blockchain eliminates the need for centralized intermediaries, enhancing transaction trust, reducing processing times, and minimizing fraud. In India, the government's pilot projects on blockchain, such as in land record management and cross-border remittances, indicate an exploratory approach to mainstreaming decentralized technologies (NITI Aayog, 2021). While blockchain's potential is widely acknowledged, its adoption remains constrained by policy ambiguity, fragmented infrastructure, and skepticism among traditional financial institutions.

One of the most significant developments associated with blockchain is the rise of decentralized finance or DeFi. Unlike conventional financial systems, DeFi operates on open-source protocols and smart contracts that allow users to lend, borrow, trade, and earn interest without

intermediaries. Schär (2021) noted that DeFi represents a paradigm shift from centralized financial gatekeeping to peer-to-peer value exchange systems. The author highlighted how DeFi platforms such as Compound, Uniswap, and Aave democratize access to capital and investment opportunities globally. Although still nascent in India, DeFi projects are attracting interest from investors and developers alike. However, Zetzsche et al. (2020) caution that DeFi is not without risks; the lack of regulatory oversight, susceptibility to code vulnerabilities, and the irreversibility of blockchain transactions can expose users to significant financial harm. These concerns are echoed in reports by the Financial Action Task Force (FATF, 2021), which underline the need for global standards to prevent money laundering and illicit financial flows through DeFi networks.

Smart contracts, which are self-executing codes on a blockchain, represent another crucial innovation. They are increasingly used to automate complex agreements in finance, such as insurance payouts, loan disbursements, and supply chain finance. Szabo (1997), who originally conceptualized smart contracts, argued that by embedding logic into transaction processes, one could eliminate third-party arbiters, thereby reducing costs and improving efficiency. Recent empirical work by Cong and He (2019) demonstrated how smart contracts can enhance the transparency and speed of trade financing while minimizing counterparty risks. Nonetheless, Wright

and De Filippi (2015) underscored the legal challenges surrounding smart contracts, particularly their enforceability under traditional contract law. In India, although regulatory discourse around smart contracts is growing, there remains a significant gap in terms of legal recognition and consumer protection mechanisms.

Beyond technological capability, several studies stress the importance of creating enabling environments through policy, infrastructure, and education. Kshetri (2021) raised concerns about cybersecurity vulnerabilities in decentralized systems, especially those resulting from smart contract bugs and phishing attacks. His research emphasizes the need for robust cybersecurity protocols and frequent audits to safeguard user assets and trust. Additionally, Lusardi and Mitchell (2014) observed that digital financial literacy is a crucial determinant in technology adoption. Their findings are particularly relevant in India, where a significant portion of the population lacks the necessary knowledge to navigate emerging digital platforms confidently. Mehrotra et al. (2019) further observed that while India's Digital India campaign has made strides in digitizing service delivery, gaps remain in user training, rural internet access, and multilingual support.

The need for a cohesive regulatory framework is another recurring theme in the literature. As the lines between technology, finance, and governance blur, scholars and policymakers alike grapple with the dual challenge of

enabling innovation while protecting public interest. The World Bank (2022) stresses the importance of adaptive regulatory sandboxes that allow startups to test innovative financial products under the supervision of regulators. These frameworks can help mitigate systemic risks while fostering responsible innovation. Deloitte (2023) echoed this sentiment, suggesting that building blockchain infrastructure is only one part of the puzzle; the other is ensuring institutional readiness and legal clarity to integrate these systems into national financial architectures.

Within the broader vision of Vikshit Bharat @2047, these insights take on heightened significance. India’s ambition to become a developed economy by 2047 hinges on inclusive growth, digital empowerment, and financial self-reliance. PwC (2021) emphasized that financial technologies must align with national development goals, including women’s empowerment, rural development, and small business scalability. This requires

a collaborative effort from stakeholders across sectors—including regulators, technology providers, financial institutions, and civil society—to co-create systems that are secure, inclusive, and future-proof.

In summary, the current body of literature presents a robust yet fragmented view of the Web3-Fintech ecosystem. While there is consensus on the transformative potential of blockchain, DeFi, and smart contracts, several implementation barriers remain. These include regulatory uncertainty, cybersecurity concerns, digital literacy gaps, and institutional inertia. For India to fully leverage these innovations in reshaping its financial landscape by 2047, future research must adopt an interdisciplinary and policy-oriented lens. There is also a pressing need for empirical studies that assess the socio-economic impact of these technologies in rural and underserved regions. Addressing these gaps will be vital in crafting a financial ecosystem that not only serves but also empowers every Indian citizen.

Research Gap Analysis

Variable	Citation	Research Gap	Research Description
Fintech Accessibility in Rural India	Sahay et al. (2020); Arner et al. (2016)	Limited empirical research on Fintech adoption in rural and semi-urban Indian regions	While studies acknowledge Fintech’s potential for inclusion, detailed research is lacking on regional disparities, especially concerning infrastructure and awareness.
Blockchain Adoption in Governance	NITI Aayog (2021);	Scarcity of policy-level studies on integrating	Existing literature touches on blockchain use cases but lacks in-

	Tapscott & Tapscott (2016)	blockchain into India's public sector	depth analysis of policy reforms required to implement it at scale in India's governance framework.
Legal Status of Smart Contracts	Wright & De Filippi (2015); Cong & He (2019)	Inadequate legal frameworks addressing smart contract enforceability in Indian courts	Research rarely explores how India's legal system must adapt to accommodate self-executing contracts in sectors like insurance, trade, and banking.
DeFi Regulation and Oversight	Zetzsche et al. (2020); FATF (2021)	Absence of a structured regulatory model tailored for DeFi applications in emerging economies like India	Current studies warn of DeFi risks but do not provide a context-specific regulatory roadmap, especially suited to India's financial ecosystem.
Cybersecurity Readiness	Kshetri (2021); Deloitte (2023)	Minimal focus on India's preparedness to tackle DeFi and blockchain-based security threats	Literature is skewed toward Western economies, with little insight into India's institutional cyber-resilience for emerging Web3 platforms.
Digital Financial Literacy	Lusardi & Mitchell (2014); Mehrotra et al. (2019)	Lack of large-scale studies on digital financial awareness and behavioral readiness in India	Though widely acknowledged as a barrier, digital financial literacy is under-researched in terms of its socio-demographic impacts on tech adoption.
Role of Financial Institutions	Arner et al. (2016); RBI (2022)	Limited research on the strategic alignment of Indian banks with blockchain and DeFi infrastructure	There's little empirical work on how traditional financial institutions in India are preparing for or resisting the Web3 transition.

Interoperability in Fintech Systems	World Bank (2022); PwC (2021)	Few studies address system-level interoperability across Fintech, blockchain, and legacy financial tech	Research is missing on how India can integrate diverse digital tools (UPI, CBDC, DeFi apps) into a unified and secure infrastructure.
Smart Contracts in Trade Finance	Cong & He (2019); Szabo (1997)	Lack of India-specific pilots or models for using smart contracts in supply chains and export finance	While globally acknowledged, there's limited case-based literature on smart contract deployment in Indian trade and logistics sectors.
Web3's Socio-Economic Impact	Tapscott & Tapscott (2016); PwC (2021)	Limited data on the measurable economic uplift from Web3 technologies in India	The transformative narrative of Web3 in India remains mostly theoretical; studies rarely quantify its impact on SMEs, jobs, or entrepreneurship.

Assess the transformative role of Web3 technologies namely blockchain, decentralized finance (defi), and smart contracts in redefining the structural framework of India's financial ecosystem aligned with the vision of Vikshit Bharat @2047.

India is currently at a defining juncture in its digital and economic journey, and the government's vision of **Vikshit Bharat @2047** emphasizes inclusive, sustainable, and technology-driven growth across all sectors including the financial ecosystem. Within this context, the convergence of **Web3 and Fintech** represents a historic opportunity to dismantle long-standing inefficiencies in traditional financial structures, and rebuild them on principles of decentralization, transparency, and trust.

Web3 technologies which encompass blockchain, decentralized finance (DeFi), and smart contracts challenge conventional models of financial intermediation by removing the reliance on centralized institutions such as banks, clearing houses, or regulators to authenticate and process transactions. Instead, they rely on **distributed ledger systems**, which allow data to be securely stored, verified, and shared across networks without intermediaries.

1. Blockchain's Role:

Blockchain is the foundational infrastructure of Web3. Its ability to record immutable, timestamped transactions ensures transparency and auditability. In India, this could address persistent issues like corruption, delays in fund transfers, or opaque government subsidy delivery mechanisms. Blockchain could also improve sectors like

public finance, insurance, land records, and microcredit by ensuring verifiable, tamper-proof documentation.

2. **Decentralized Finance (DeFi):**

DeFi refers to financial applications built on blockchain that allow users to lend, borrow, trade, or invest without intermediaries. For India's underbanked and unbanked populations, DeFi offers an alternative to conventional banking, especially in rural or semi-urban regions where access to physical banks is limited. DeFi protocols could democratize access to capital and empower micro-entrepreneurs, thereby supporting grassroots economic development in line with Vikshit Bharat's goals.

3. **Smart Contracts:**

Smart contracts are self-executing codes that enforce agreements without third-party intervention. Their application can reduce transactional frictions and legal disputes in finance, especially in areas like trade finance, insurance claims processing, real estate transactions, and public procurement. In the Indian financial architecture, where bureaucratic bottlenecks and fraud remain critical concerns, smart contracts offer the potential to automate, streamline, and enforce trust in digital agreements.

Critically assessing this convergence also involves evaluating the **structural implications** of these technologies. For example:

- How do these tools alter the roles of banks, regulators, and consumers?
- Do they create new types of risks, such as algorithmic vulnerabilities or governance disputes?
- Can India's current infrastructure and policy landscape support such radical technological shifts?

Furthermore, the objective includes identifying **potential structural transformations**, such as:

- Shifting from centralized control to distributed governance in financial services.
- Encouraging token-based economies and digital asset frameworks.
- Reimagining KYC/AML processes through digital identity linked to blockchain.

To evaluate the extent to which fintech innovations, when integrated with decentralized technologies, enhance financial inclusion, transaction transparency, and economic empowerment across diverse socio-economic segments in India.

In the evolving landscape of India's digital economy, the convergence of **Fintech** with **Web3 technologies** represents a critical turning point in reshaping access to and delivery of financial services. This objective seeks to examine how this integration through tools such as **digital wallets, mobile banking, blockchain networks, DeFi platforms, and smart contracts** can uplift underserved communities, bridge systemic financial gaps, and instill greater accountability in transactional systems.

India's financial system has historically struggled with deep-rooted challenges of **exclusion**, particularly among rural populations, low-income households, and informal sector workers. While initiatives like **Jan Dhan Yojana** and **Unified Payments Interface (UPI)** have expanded the digital financial footprint, a substantial segment of the population still lacks meaningful access to affordable credit, insurance, and reliable savings

mechanisms. This is where the infusion of **decentralized technologies** into Fintech can be transformative.

1. **Financial Inclusion:**

When decentralized infrastructure is paired with mobile-first Fintech solutions, it enables the delivery of personalized, secure, and cost-effective financial services even in remote or underserved regions. For instance, blockchain-enabled micro-lending platforms can extend credit to borrowers without the need for traditional collateral or credit histories. By reducing dependency on physical bank branches and paperwork, these technologies open doors for millions to participate in the formal financial system, thus empowering them economically and socially.

2. **Transaction Transparency:**

Traditional financial transactions in India are often opaque and prone to errors, fraud, or manipulation. Blockchain-based systems, with their immutable and time-stamped records, provide **radical transparency**, allowing real-time tracking and auditability of transactions. This has profound implications for reducing corruption in government subsidies, improving the credibility of non-profit fund flows, and ensuring fair practices in public procurement or insurance disbursements.

3. **Economic Empowerment:**

Beyond access, true financial inclusion lies in **enabling individuals and communities to control their financial futures**. Smart contracts and DeFi applications allow individuals to interact with financial products without needing intermediaries, thereby reducing costs and increasing autonomy. For example, decentralized platforms can allow rural entrepreneurs to raise capital via tokenization or decentralized crowdfunding, bypassing traditional venture or banking constraints. Similarly, digital asset ownership could redefine wealth distribution and asset creation models in the country.

This objective also involves evaluating how **socio-economic diversity** affects the impact and reception of such technologies. While urban, educated populations may rapidly adopt crypto tools or DeFi platforms, marginalized groups may face barriers such as low digital

literacy, limited internet access, or distrust of digital systems. Therefore, the analysis must include **stratified assessments** across urban-rural, gender, income, and education divides to determine the true depth of inclusion and empowerment enabled by Fintech-Web3 convergence.

Furthermore, the study aims to identify not just the **outcomes**, but also the **enablers** and **constraints** such as government policy, cybersecurity frameworks, and educational initiatives that influence how these technologies scale across India's diverse socio-economic terrain. Understanding these dynamics will provide a robust foundation for policy recommendations aimed at ensuring that the benefits of technological innovation are **equitably distributed**, thereby supporting the national agenda of **Vikshit Bharat @2047**.

The regulatory, cybersecurity, and digital literacy challenges hindering the large-scale adoption of Web3-enabled financial systems, and propose policy-oriented strategies for overcoming these barriers.

As India advances toward its vision of *Vikshit Bharat @2047*, the integration of Web3 technologies into the nation's financial architecture offers immense promise ranging from decentralization of services to increased transparency, efficiency, and inclusion. However, despite their potential, the widespread adoption of blockchain, decentralized finance (DeFi), and smart contracts faces a series of **foundational challenges** that must be critically addressed to enable meaningful, sustainable transformation. These barriers predominantly fall under **regulatory uncertainty, cybersecurity vulnerabilities, and low levels of digital financial literacy**.

1. **Regulatory Challenges:**

The current legal and regulatory frameworks in India, and globally, are largely structured around centralized financial models. Web3 technologies, by their very nature, operate without traditional intermediaries rendering existing compliance protocols like Know Your Customer (KYC), Anti-Money Laundering (AML), and consumer protection insufficient or misaligned. Ambiguities surrounding the legal status of smart contracts, cryptocurrency taxation, and cross-border digital asset flows create hesitation among innovators, investors, and users alike. Furthermore, a lack of clear policy

direction can lead to **regulatory arbitrage**, where actors bypass national controls by exploiting jurisdictional loopholes. Hence, a reimagined, technology-neutral regulatory framework is essential—one that supports innovation while safeguarding consumer rights and systemic stability.

2. **Cybersecurity Concerns:**

The decentralized structure of Web3 may eliminate single points of failure, but it also introduces new vectors for cyberattacks. Vulnerabilities in smart contract code, weak private key protection, and phishing attacks on DeFi platforms expose users to significant risks. Moreover, most blockchain transactions are irreversible, leaving little room for rectification in case of fraud. These threats not only undermine user trust but also deter institutional involvement. In a country like India, where cyber awareness is still developing and infrastructure protection is uneven across sectors, the importance of robust **cybersecurity governance** cannot be overstated. This includes developing security protocols tailored for decentralized environments, mandating third-party audits of code, and creating national cyber response mechanisms specifically for blockchain-related incidents.

3. **Digital Literacy and Access:**

One of the most pressing yet underappreciated barriers to Web3 adoption in India is the **low level of digital financial literacy**, particularly outside urban centers. While

smartphone penetration has improved, knowledge about safe usage of crypto wallets, understanding of decentralized platforms, or comprehension of transaction verification is minimal in vast parts of the country. Many individuals, especially from marginalized communities, are unfamiliar with even basic digital banking. As a result, the very people who could benefit most from decentralized finance are often excluded due to a **lack of education, awareness, and trust**. Bridging this divide requires not only internet access but also sustained public awareness campaigns, integration of digital finance into school curricula, and hands-on training through community institutions.

To address these interconnected challenges, this objective advocates for the development of **policy-oriented strategies** that promote responsible innovation. These may include:

- A **regulatory sandbox** for Web3 startups to test innovations under supervision.
 - A **multi-agency cybersecurity task force** for Web3 technologies.
 - National-level **certification programs in blockchain literacy** through public-private collaboration.
- Ultimately, achieving inclusive adoption of Web3-enabled financial systems in India requires a **coordinated, strategic response** involving regulators, technologists, educators, and civil society. Without addressing these systemic barriers, the benefits of decentralization may remain limited to the technologically

savvy few, leaving behind the broader population for whom *Vikshit Bharat @2047* envisions empowerment through equitable digital progress.

To develop a strategic roadmap for financial institutions, policymakers, and technology stakeholders for leveraging Web3–Fintech synergies in building a resilient, inclusive, and future-ready financial infrastructure by 2047.

As India aims to transform itself into a developed nation under the “Vikshit Bharat @2047” initiative, building a robust and inclusive financial infrastructure becomes a critical pillar of that vision. This objective focuses on constructing a **strategic roadmap** a comprehensive, long-term plan to guide key stakeholders including **financial institutions, government policymakers, and technology innovators** in effectively utilizing the synergies between **Web3 technologies** and **Fintech innovations**.

Web3, driven by technologies such as **blockchain, decentralized finance (DeFi), and smart contracts**, is reshaping how financial systems operate. It introduces decentralization, transparency, and programmability into financial services. When integrated with Fintech innovations such as digital wallets, mobile banking, robo-advisors, and algorithmic credit assessments this convergence has the power to eliminate inefficiencies, reduce reliance on intermediaries, and democratize financial access.

However, such transformation cannot be spontaneous or disjointed. There is a need for a **strategic and coordinated**

approach to align technological advancements with institutional readiness, legal frameworks, consumer awareness, and infrastructural capacity. Therefore, the roadmap must include:

- **Policy guidelines** that promote innovation while safeguarding against misuse or systemic risks
- **Regulatory frameworks** that ensure interoperability, trust, and consumer protection
- **Investment strategies** for digital public infrastructure like identity systems, payment rails, and cybersecurity tools
- **Capacity-building programs** for financial literacy, digital skill development, and workforce training
- **Incentive structures** that promote collaboration between private startups and public institutions

Suggestions

1. Establish a Unified National Framework for Web3 Integration

A comprehensive regulatory and governance framework should be developed to enable the seamless integration of Web3 technologies including blockchain, DeFi, and smart contracts into India's financial infrastructure. This framework must ensure legal clarity, interoperability, and standardized protocols while encouraging innovation and safeguarding consumer interests.

2. Promote Public-Private Partnerships to Accelerate Financial Inclusion

To maximize the impact of Fintech–Web3 synergies on financial inclusion, collaboration between government

The roadmap must also account for India's **socio-economic diversity**, addressing rural-urban disparities, access to digital resources, and inclusivity for marginalized communities. By tailoring technological adoption to India's demographic and developmental realities, the country can leapfrog into a new era of financial empowerment.

Ultimately, this objective envisions India's financial ecosystem as **resilient** (resistant to shocks and crises), **inclusive** (accessible to all citizens regardless of geography or income), and **future-ready** (capable of evolving with emerging global digital trends). By 2047, such a roadmap should position India not merely as a passive adopter but as a **global leader** in ethical, decentralized, and innovation-driven financial systems.

agencies, financial institutions, and technology providers should be fostered. Such partnerships can scale access to decentralized financial services in underserved rural and semi-urban regions through digital wallets, UPI-based solutions, and blockchain-driven identity verification systems.

3. Strengthen Cybersecurity and Resilience Mechanisms

As Web3 adoption increases, the risk landscape expands. Proactive investments must be made in blockchain security, smart contract auditing tools, and DeFi protocol verification systems. The establishment of a national blockchain security agency or task force can help monitor vulnerabilities and establish

trust in decentralized financial networks.

4. Enhance Digital and Financial Literacy at the Grassroots Level

Targeted literacy campaigns focused on blockchain, cryptocurrencies, decentralized applications (dApps), and secure digital practices should be rolled out, especially in low-income and rural areas. Integrating Web3 literacy into national education policies and skilling initiatives (e.g., PMKVY) will ensure inclusive access to next-generation financial tools.

5. Incentivize Innovation through Regulatory Sandboxes and Tax Reliefs

Government and regulatory bodies like RBI and SEBI should expand regulatory sandbox programs to encourage startups experimenting with DeFi, digital asset management, and tokenized finance. Additionally, offering tax incentives and simplified compliance procedures for early-stage Web3 startups can catalyze a thriving innovation ecosystem.

6. Create a National Web3 Mission under the Digital India Framework

A dedicated national mission, aligned with Digital India and Make in India initiatives, should be launched to institutionalize the development of India's Web3 infrastructure. This mission can oversee the creation of digital public goods (e.g., decentralized identity systems), support blockchain R&D, and facilitate pilot projects across government and enterprise sectors.

7. Facilitate Cross-Border Collaboration and Global Standards Alignment

India should actively participate in shaping global regulations and interoperability standards for Web3 technologies through organizations like the Financial Action Task Force (FATF), G20, and ISO. This will help Indian firms access international markets and ensure alignment with global best practices in crypto regulation, smart contracts, and DeFi governance.

8. Empower Policymakers and Regulators with Technical Capacity-Building

Specialized training programs and cross-disciplinary research should be promoted to equip lawmakers, regulatory officials, and financial administrators with the knowledge required to assess and govern emerging technologies. This will ensure evidence-based, adaptive policymaking for a fast-evolving financial ecosystem.

9. Incorporate ESG Considerations into Web3 Finance Development

As financial systems evolve, environmental and social governance (ESG) must be embedded in Web3 innovations. Encouraging green blockchain protocols, incentivizing social impact tokens, and leveraging decentralized technologies for climate finance and MSME empowerment can ensure that digital transformation aligns with India's sustainable development goals.

10. Build a Resilient and Inclusive Financial Infrastructure by 2047

Long-term strategic planning must be undertaken to ensure India's financial infrastructure is future-ready. This includes investing in 5G connectivity

for real-time financial applications, supporting quantum-resistant cryptography research, and enabling

decentralized identity systems that protect privacy while fostering inclusion.

Conclusion

As India sets its sights on becoming a developed nation by 2047 under the visionary initiative of Vikshit Bharat, the convergence of Web3 technologies and Fintech presents a transformative opportunity to redefine the nation's financial architecture. This study critically examined the role of blockchain, decentralized finance (DeFi), and smart contracts as pivotal enablers of a decentralized, transparent, and inclusive financial ecosystem. The analysis reveals that while these technologies hold immense promise in dismantling traditional barriers ranging from financial exclusion to systemic inefficiencies their successful integration requires strategic alignment across technological, regulatory, and societal dimensions.

Managerial Implications

From a managerial standpoint, financial institutions must reassess conventional business models and transition towards more agile, technology-first operations. Bankers, fintech executives, and asset managers are encouraged to adopt blockchain for real-time transaction validation, leverage DeFi for expanding access to credit, and deploy smart contracts for automating financial agreements. Moreover, developing internal capacity for cybersecurity, compliance with evolving regulations, and digital literacy will be essential for ensuring sustainable innovation. Managers must also foster partnerships

with technology startups and government agencies to pilot scalable Web3 solutions.

Societal Implications

Societally, the widespread adoption of Web3–Fintech solutions can accelerate financial inclusion, especially among underserved populations in rural and semi-urban India. By democratizing access to financial services, reducing intermediary costs, and enhancing transparency, these technologies have the potential to empower citizens economically. However, bridging the digital divide through infrastructure development, equitable internet access, and targeted educational initiatives remains imperative. The societal benefits of this convergence will only be realized when every individual irrespective of income, literacy, or geography is integrated into the digital financial framework.

Research Implications

Academically, this study opens up a wide scope for interdisciplinary research. Future scholars can explore the behavioral dimensions of decentralized financial adoption, evaluate cross-country models of blockchain regulation, or study the socio-economic impacts of smart contract-based financial services in India. Empirical studies are needed to measure the long-term effectiveness and risks associated with DeFi platforms, as well as the scalability of blockchain in

public finance. Additionally, comparative analyses between centralized and decentralized models in financial service delivery can provide further insights for policymaking.

Future Scope

Looking ahead, the Web3–Fintech convergence will continue to evolve in complexity and capability. The development of Central Bank Digital Currencies (CBDCs), tokenized assets, and decentralized autonomous organizations (DAOs) will reshape

stakeholder roles in India's financial sector. There is also immense potential in integrating Web3 with AI and IoT for predictive finance and autonomous transaction ecosystems. To harness this potential, India must invest in digital public infrastructure, regulatory innovation, and capacity building. Ultimately, a forward-looking, inclusive, and resilient financial framework rooted in Web3 technologies can serve as a cornerstone in realizing the vision of Vikshit Bharat by 2047.

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The Rise of UPI and Beyond: A Bibliometric Exploration of Digital Payment Systems Research in India

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Abstract:

Context - India's digital payment landscape has undergone a significant transformation over the past decade, with the Unified Payments Interface (UPI) emerging as a pivotal driver of this shift. Introduced by the National Payments Corporation of India (NPCI) in 2016, UPI has rapidly become the dominant mode of transaction, processing over 18.6 billion transactions valued at ₹25.14 lakh crore in May 2025 alone (NPCI, 2025). This represents a substantial year-on-year growth of approximately 33% in value and a corresponding rise in volume. The system currently accounts for more than 83% of all digital payment transactions in India, highlighting its widespread acceptance across urban and rural segments (ET June, 2025). This exponential growth is underpinned by supportive government policies, increased smartphone penetration, fintech innovation, and the growing preference for contactless payments. UPI's success story is not only indicative of technological advancement but also reflects a broader policy push towards a cashless economy. As India continues to advance in digital financial infrastructure, UPI stands at the forefront of inclusive financial innovation. Given this backdrop, it becomes essential to map the intellectual trajectory of research surrounding UPI and digital payment systems to understand key trends, influential contributors, and evolving academic interests in this domain.

Purpose - This study seeks to trace the development of literature on digital payment systems, with a dual focus on systematic literature review (SLR) and bibliometric analysis, emphasizing significant contributors, impactful articles, prominent journals, and emerging research trends. It also includes an in-depth bibliometric analysis to visualize the intellectual framework of research on digital payment systems, while offering a strategic guide for future investigations in this domain.

Design / Methodology / Approach – This study employs a systematic literature review (SLR) approach, using SPAR 4 Protocol and adhering to PRISMA guidelines, to map the intellectual landscape of digital payment systems. Articles were sourced exclusively from the Scopus database, chosen for its extensive coverage of high-quality journals, resulting in a dataset of 955 articles retrieved through a predefined search query. Bibliometric techniques, including **Keyword** analysis, bibliographic coupling, and citation analysis, were employed to identify thematic clusters, intellectual structures, and emerging trends within the field.

To ensure comprehensive analysis and visualization, advanced analytical tools such as RStudio, Biblioshiny, and VOSviewer were employed. Additionally, the Theory-Context-Characteristics-Methodology (TCCM) framework was applied to systematically identify

gaps in theoretical perspectives, research contexts, study characteristics, and methodological approaches. This rigorous methodology provides a structured foundation for synthesizing existing knowledge and identifying future research directions in the evolving domain of digital payment systems.

Findings – The results provide a comprehensive understanding of publication trends, identifying the most prolific countries, institutions, and journals contributing to research on digital payment systems. India emerges as a leading contributor in this field. The analysis reveals distinct thematic clusters within the literature, shedding light on key areas of focus and potential areas for collaboration. Additionally, **Keyword** analysis uncovers emerging research trends and offers a strategic roadmap for guiding future studies in this domain. Extensive research highlights the pivotal role of financial inclusion in promoting economic empowerment, particularly among underserved populations.

Originality / Value - This study offers novel insights into the intellectual structure of Indian digital payment systems, addressing a critical gap in the existing literature. It provides a comprehensive retrospective of the field, benefiting practitioners and academicians by mapping publication trends, thematic clusters, and emerging research trajectories. Unlike prior studies, this research integrates bibliometric analysis to propose strategic directions for future exploration, making it a valuable resource for fintech companies, financial intermediaries, regulators, and IT developers seeking to invest in or enhance digital payment services. The emphasis on UTAUT 3 and perceived risk determinants as independent drivers of adoption further enhances its originality and relevance.

Keywords – *Literature Review, Bibliometric Analysis, Digital Payment Systems, UPI, Financial Inclusion, VOSviewer, RStudio, India, SLR*

Paper Type – Literature Review

1. Introduction

The rapid advancement of information technology has fundamentally transformed the financial services sector, redefining how customers engage with banks and financial institutions globally. Innovations such as automated teller machines (ATMs), internet banking, mobile banking, digital kiosks, and the Unified Payments Interface (UPI) have enabled financial institutions to enhance service delivery with heightened efficiency and precision. These technological strides have not only improved customer

experiences but have also restructured the operational framework of the banking industry. However, despite these significant advancements, the adoption and diffusion of digital banking systems exhibit considerable disparities across regions, driven by cultural, infrastructural, and economic variations (Arvidsson, 2014). Emerging markets, in particular, have witnessed accelerated innovation and adoption of digital banking. Yet, obstacles such as restricted internet access, security vulnerabilities, and a lack of personalized interactions continue to

hinder its widespread acceptance. Among these, security risks remain a major concern, as fraudulent activities in digital transactions can lead to substantial financial losses. Moreover, the success of Internet banking is contingent upon governmental initiatives and customer perceptions of its usefulness, adaptability, and seamless integration into everyday life (Vermani & Arora, 2025). The proliferation of digital technologies has compelled banks to reassess their information technology strategies, particularly in the domains of service delivery and customer engagement. Digital banking has emerged as a transformative paradigm, enabling customers to perform diverse financial transactions, including fund transfers and e-commerce activities, without visiting physical bank branches. Concurrently, these advancements have bolstered institutional profitability by reducing transaction costs and streamlining operational processes.

Despite the growing prevalence of digital payment systems, the academic discourse on this topic remains fragmented. While earlier studies primarily concentrated on the emergence and developmental trajectories of digital banking, more recent research has shifted toward investigating the factors influencing its adoption and cross-regional impact. Nonetheless, there is a discernible gap in comprehensively understanding the intellectual architecture, key contributors, and emerging thematic trends in this domain. This paper seeks to bridge this gap by systematically

reviewing and analyzing the extant literature on digital payment systems. employing bibliometric methodologies, it maps the intellectual contours of the field, identifying influential works, leading authors, and thematic clusters. The study aims to offer a strategic framework that equips academics, practitioners, and policymakers with a deeper understanding of the evolution of digital payment systems while delineating avenues for future research. By integrating systematic literature review and bibliometric analysis, this research contributes to the expanding dialogue on the digital transformation of the financial services sector.

1.1 Motivation for the Study

The digital transformation of financial services, particularly in digital payment systems, has been a prominent area of academic inquiry for decades. Research has largely focused on technological advancements, adoption trends, and the socio-economic impacts of these systems across regions and sectors. Key topics include Internet and mobile banking innovations, security challenges, and policy frameworks promoting cashless economies (Batiz et al., 2014). Despite these contributions, the field remains fragmented, with limited efforts to holistically map its intellectual structure or trace its evolution comprehensively. This study addresses this critical gap by employing a systematic literature review and bibliometric analysis to synthesize existing knowledge, identify influential works, and uncover emerging themes in digital payment systems research. While bibliometric methods (Behrens et al.,

2006) are increasingly applied in finance and management studies, their application to this domain remains underexplored. This research leverages performance analysis and science mapping to analyze thematic clusters, key contributors, and evolving trends, offering a structured and integrative perspective. The findings hold significant implications for academicians, practitioners, and policymakers. For scholars, this study provides a consolidated view of the field's intellectual trajectory, paving the way for future research. Practitioners gain insights into critical factors influencing digital payment adoption and design. Policymakers can utilize the outcomes to address barriers, enhance financial inclusion, and foster sustainable digital economies. By addressing the following research questions, this study seeks to chart the intellectual contours of digital payment systems research, offering a strategic framework for understanding its evolution and guiding future academic inquiry. The systematic and bibliometric

approach employed in this study ensures a rigorous analysis, making it a valuable contribution to the growing body of literature on the digital transformation of financial services.

This study explores the following research questions (RQs):

RQ1. Who are the most prolific contributors (authors, journals, institutions, and countries) in this field?

RQ2. What are the trends in the publication of research on digital payment systems?

RQ3. Do the findings align with bibliometric laws (Bradford)?

RQ4. What are the potential future research directions in this area?

This review paper is structured as follows: Section 2 outlines the methodology employed in the study, while Section 3 presents the findings, including an analysis of publication patterns, bibliometric laws, citation metrics, and bibliographic coupling. Section 4 concludes the paper, highlighting key implications.

2. Methodology

2.1 Criteria for Data Selection

In the realm of social sciences, the Web of Science and Scopus databases are widely regarded as the most credible sources for academic literature. Scopus, in particular, is noted for its extensive journal coverage and is frequently recommended for bibliometric studies. Consequently, this study relies exclusively on articles indexed in the Scopus database. The dataset for this research was initially extracted on

December 18, 2024. A significant challenge in conducting bibliometric analyses is the formulation of precise search queries to ensure the relevance of retrieved articles. To address this, the study identified suitable search terms by thoroughly examining prior research on Digital Payment Systems.

The search strategy employed for this study utilized the following query: ("*Digital Payments*" OR "*Mobile Money*" OR "*UPI*" OR "*Online Payments*" OR "*Internet Banking*"). The

term "Digital Payments" was used as an umbrella term encompassing various payment systems extensively discussed in the literature. Following the methodological framework outlined by Paul and Criado (2020), the search was restricted to titles, abstracts, and **Keywords**. This initial step yielded a dataset of 1,758 documents.

Subsequent refinement steps included applying filters to focus exclusively on research and review articles, narrowing the dataset to 1,670 records. To ensure relevance to the study's domain, additional filters were applied, targeting articles from the fields of Business, Management, Accounting, and Social Sciences, and prioritizing works published in peer-reviewed journals at the final publication stage. These adjustments reduced the dataset to 1,657 documents. To enhance the specificity

of the analysis, a stepwise exclusion process was employed. Initially, the term "Internet Banking" was removed, reducing the dataset to 1,092 documents. Subsequent exclusions included "Electronic Commerce" (resulting in 1,039 articles), "Bitcoin" and "Blockchain" (yielding 1008 articles), "Cryptocurrency" (resulting in 998 articles), "Crowdfunding" (narrowing the dataset to 992 articles), and finally, "Micro-finance" and "E-commerce" (resulting in 962 articles). Additional refinement excluded terms related to "Small and Medium Enterprises," leaving a final set of 955 documents. This final dataset of 955 articles served as the basis for conducting the bibliometric analysis, providing a robust and focused foundation for mapping the intellectual landscape of digital payment systems.

2.2 Analysis Method

The primary objective of this review is to synthesize the current (Baker et al., 2020) state of research on the topic and identify gaps that warrant further exploration. A review paper consolidates prior research findings, offering enhanced insights into a specific field of study. To achieve this, the study employs bibliometric analysis, a contemporary review methodology. Bibliometrics utilizes quantitative and statistical techniques to examine publication patterns and the dissemination of knowledge. Initially employed in library and information science to analyze bibliographic data, the methodology has since gained

prominence in disciplines such as management and finance. This methodological approach provides academics with a suite of tools to analyze scholarly publications effectively. Bibliometric analysis comprises two key components: performance analysis and science mapping. Performance analysis evaluates the contributions of various authors, sources, institutions, and countries, while science mapping, such as bibliographic coupling (Baker et al., 2021), is used to map the intellectual structure of a research field and identify potential areas for future investigation. In this study, performance analysis highlights the

contributions of researchers and institutions, whereas bibliographic coupling analysis is employed to visualize the intellectual landscape and suggest future research directions. The analysis is supported by bibliometric software tools such as VOSviewer and RStudio, which facilitate visualization and scientific mapping.

2.3 Inclusion-Exclusion Criteria and Analysis

To systematically synthesize the data and finalize the dataset, we employed Rayyan AI software to facilitate the inclusion and exclusion process. This software enabled an efficient and structured screening of articles based on predefined criteria, ensuring a comprehensive yet focused dataset. The initial review and coding of the articles were carried out by first author, while the co-author independently reviewed and validated the coded data to ensure consistency and accuracy. Any discrepancies or disagreements during this process were resolved through collaborative discussions among the focus group, leading to a consensus on the final dataset. This systematic and iterative approach ensured the reliability and academic rigor of the data synthesis process. The details of the descriptive analysis for the finalized dataset are presented in the following section.

Defining search terms

2.4.1 Screening and Selection Procedure

A clear, transparent, and reproducible search strategy is fundamental to

conducting a reliable bibliometric analysis. To extract the relevant scholarly documents for this study, the initial search was conducted on December 18, 2024. One of the major challenges in bibliometric research is the careful selection of search terms, which significantly influences the scope and quality of the dataset retrieved. The relevant search terms for the current study were determined through an in-depth analysis of existing literature on digital payment systems, financial technology, and digital finance. Emphasis was placed on identifying **Keywords** that frequently appeared in influential articles and reviews in the domain. The final search query was developed using Boolean operators and wildcard symbols to ensure comprehensiveness and inclusiveness. The search string used was: ((“digital payment” OR “e-payment” OR “electronic payment*” OR “mobile payment*” OR “online transaction*” OR “digital wallet*” OR “contactless payment*” OR “cashless economy” OR “UPI” OR “fintech”) AND (“financial inclusion” OR “digital finance” OR “monetary transaction*” OR “payment system*”)) The search was confined to the title, abstract, and **Keyword** fields to ensure contextual relevance and minimize the exclusion of significant articles. Furthermore, the results were filtered to include only peer-reviewed journal articles, conference papers, and reviews published in English, thereby ensuring the academic quality and reliability of the dataset.

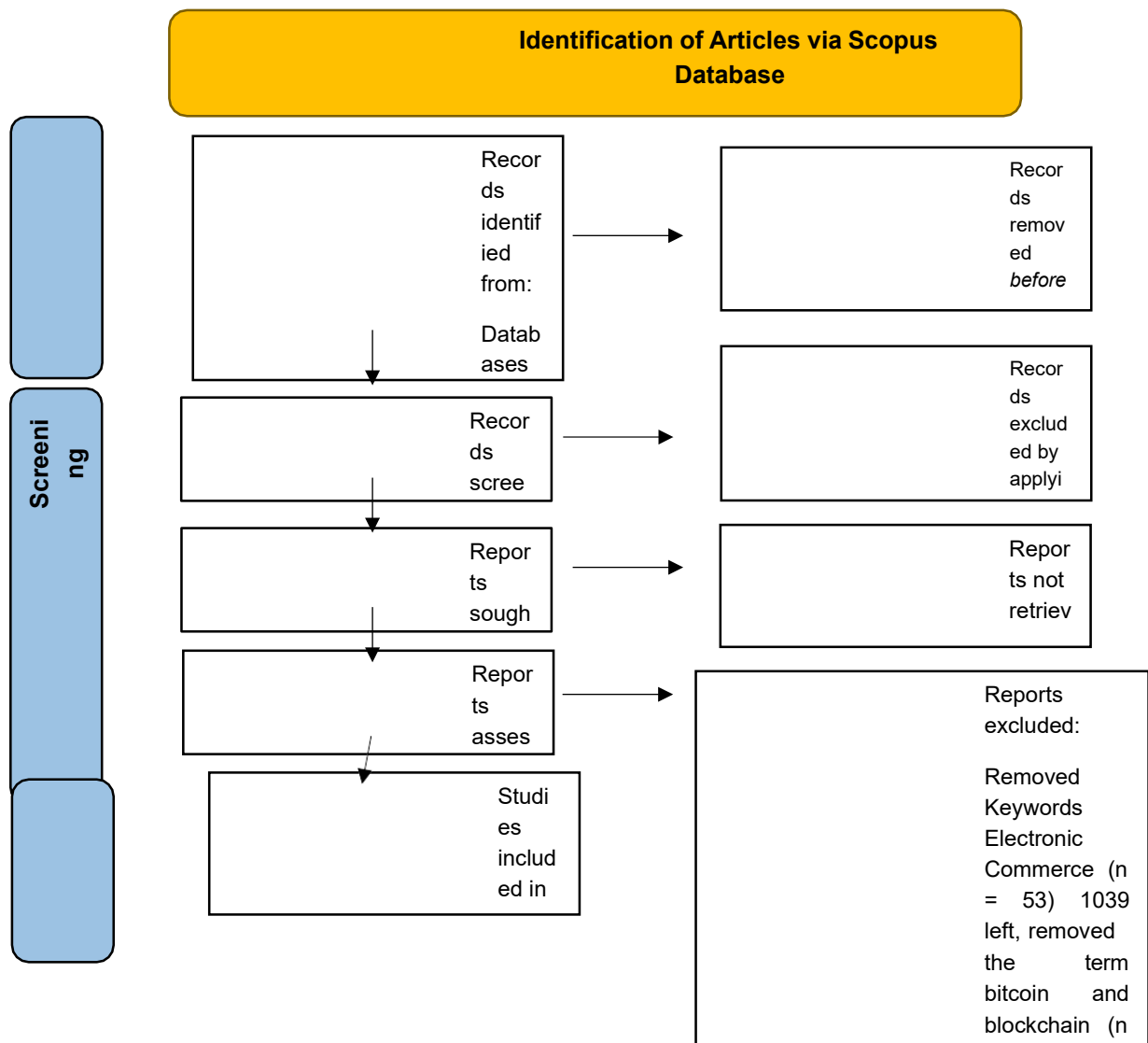


Figure 1: Data Filtration Process

Source: Author's Creation

3. Bibliometric Analysis and Discussions

3.1 Performance Analysis

This section presents a comparative overview of publication trends spanning more than a decade, highlighting key contributing journals, authors, institutions, and countries.

3.1.1 Annual Scientific Production

As illustrated in Figure 2, the temporal evolution of scientific output in the domain of digital payment systems reveals a distinct growth trajectory, reflecting the increasing scholarly engagement with this field. Between 2010 and 2016, the volume of publications remained relatively modest and inconsistent, indicating that

research on digital payments was still in its nascent stages. However, a marked shift occurs post-2016, with a noticeable and sustained rise in the number of scholarly articles. This inflection point aligns closely with the introduction of the Unified Payments Interface (UPI) in India, which served as a catalyst for both technological innovation and academic inquiry. The period from 2017 to 2021 witnessed a steady increase in publications, suggesting growing interest in topics such as digital financial inclusion, payment infrastructure, user adoption behavior, and fintech policy frameworks. A significant surge is observed between 2021 and 2023, culminating in the highest annual output in 2023, with over 150 published articles. This peak likely corresponds to increased governmental focus on digitalisation through initiatives like the Digital India programme, as well as the

accelerated adoption of contactless payments during the COVID-19 pandemic. These developments appear to have intensified academic attention towards understanding the broader implications of digital payments in the socio-economic context. Conversely, the sharp decline in publication volume for the year 2025 should be interpreted with caution. Given the typical lag in indexing and data curation in major bibliographic databases, it is plausible that the apparent drop reflects incomplete data collection rather than an actual reduction in scholarly productivity. In summary, the annual scientific production trend underscores a growing and dynamic research landscape, driven by policy developments, technological progress, and the transformative potential of platforms like UPI in reshaping the financial ecosystem.

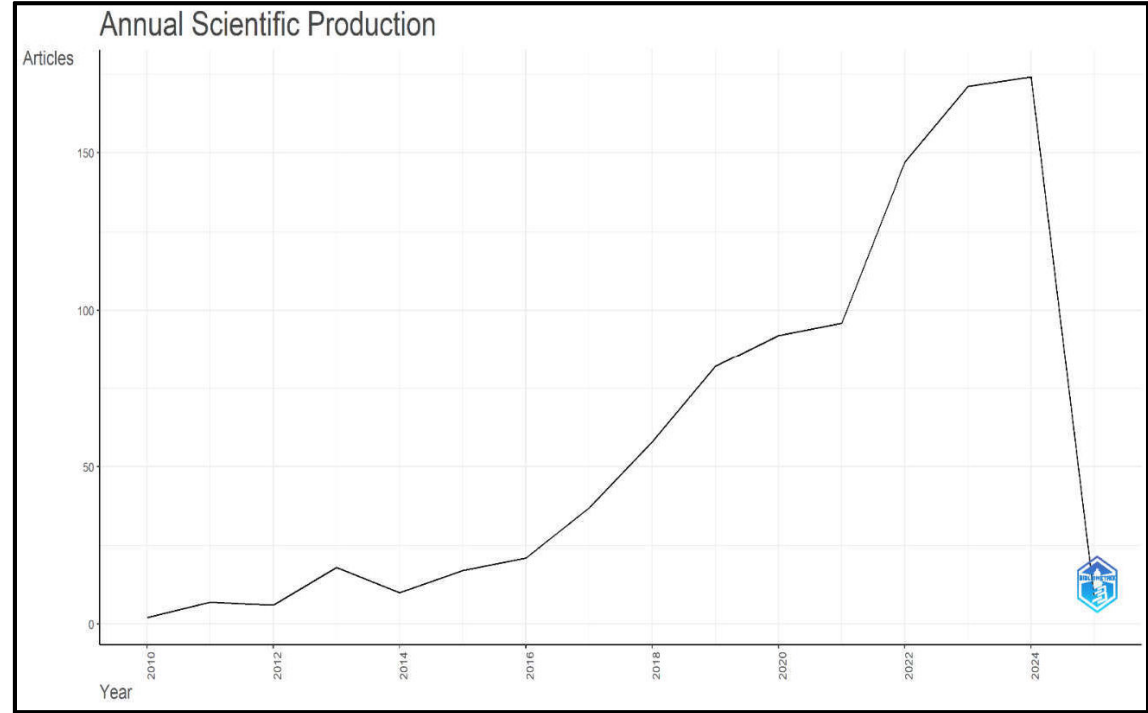


Figure 2: Annual Scientific Production (R Studio)

3.1.2 Countrywise Distribution of Research Output

Figure 3 illustrates the distribution of research contributions by country, based on the number of documents indexed in Scopus related to the study domain. India leads by a significant margin, contributing the highest volume of publications (nearly 190 documents), indicating a strong research focus on topics such as digital finance, electronic money, and financial inclusion within the Indian academic and policy landscape. The high output from India is likely reflective of the country's proactive adoption of digital financial technologies and its government-led initiatives like the Unified Payments Interface (UPI) and Digital India campaign. The United States follows as the second-largest contributor, with approximately 135 documents. This is indicative of the country's sustained academic interest in technological innovation in finance, as well as its global research capacity. The United Kingdom ranks third, suggesting its active involvement in exploring fintech, regulatory frameworks, and socio-

economic impacts of financial technologies. Other notable contributors include Indonesia, South Africa, Ghana, and China, each producing a moderate volume of publications. The presence of multiple countries from the Global South—particularly Sub-Saharan Africa and Southeast Asia—highlights the growing importance of digital financial inclusion in emerging economies. These regions are often at the forefront of mobile banking and e-wallet adoption, driven by efforts to bridge the financial access gap. Additionally, countries like Malaysia, the Netherlands, and Nigeria appear in the top ten, reflecting the global spread and multidisciplinary interest in electronic finance-related themes. While the European presence is less pronounced, the inclusion of the Netherlands points to Europe's continued engagement with digital payment systems and financial innovations. Overall, the data reflect a geographically diverse research landscape, with emerging markets increasingly contributing to and shaping the discourse around electronic money, mobile payments, and financial technologies.

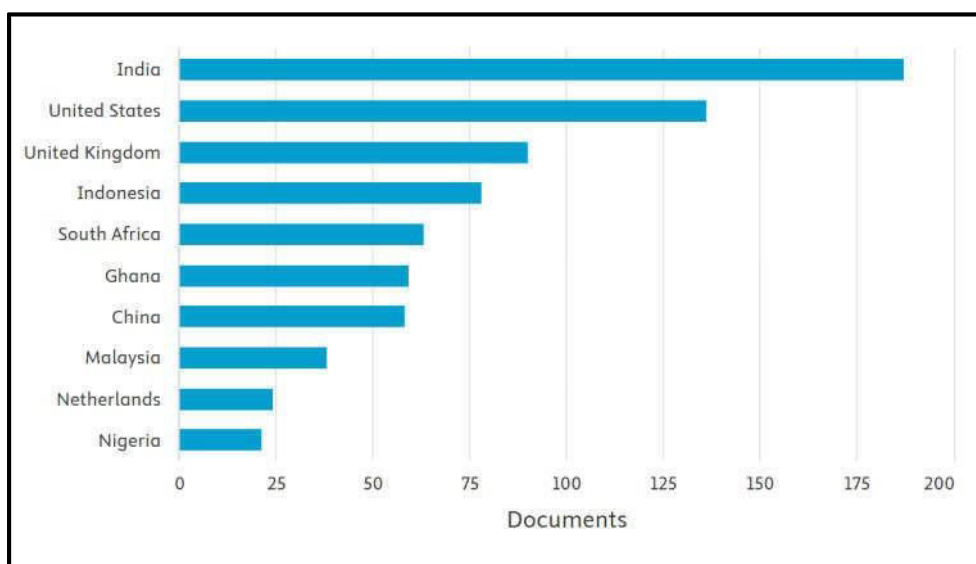


Figure 3: Documents by Country



Figure 4: Scientific Production Countrywise

Source: Scopus

3.1.3 Core Sources Analysis using Bradford's Law

Bradford's Law, a classical bibliometric model, offers insight into the dispersion of scholarly articles across various journals within a specific research domain. It posits that a relatively small number of journals—known as core

sources—contribute a disproportionately large share of the total publications on a given topic. These core journals form the nucleus of scholarly communication in that field, while the remaining articles are scattered across a broader array of sources with decreasing productivity. As

illustrated in Figure 5, the application of Bradford's Law to the current dataset identifies a set of high-yield journals that collectively publish a significant proportion of the total literature on digital payment systems. Journals such as the Journal of Payments Strategy & Systems, Sustainability (Switzerland), and Technological Forecasting and Social Change emerge as prominent contributors, located within the shaded 'core zone' of the graph. These sources represent the most influential publication venues where key theoretical, empirical, and policy-oriented discourses on digital financial technologies, including UPI, are most frequently disseminated. The graphical representation also reveals a steep decline in article counts

beyond the core zone, indicating that subsequent zones consist of a larger number of journals contributing fewer publications each. This distribution aligns with the principle of Bradford's Law of Scattering, affirming that while a handful of journals dominate knowledge production in this area, a long tail of less frequent sources also supports the intellectual growth of the field. The identification of these core sources is particularly valuable for researchers and practitioners aiming to target high-impact journals for publication or to curate focused literature for systematic reviews. Moreover, it reflects the interdisciplinary nature of research in digital payments, spanning technology, finance, and policy studies.

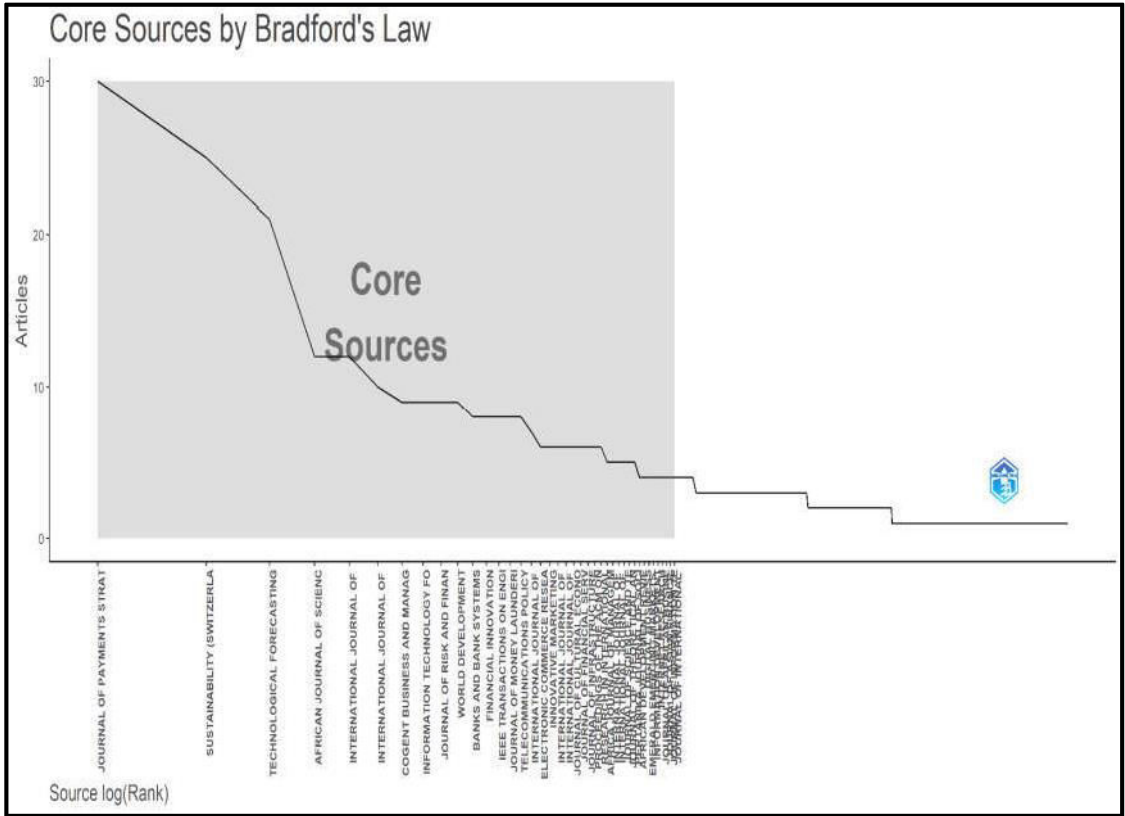


Figure 5: Bradford's Law (R Studio)

4.1 Keyword Analysis

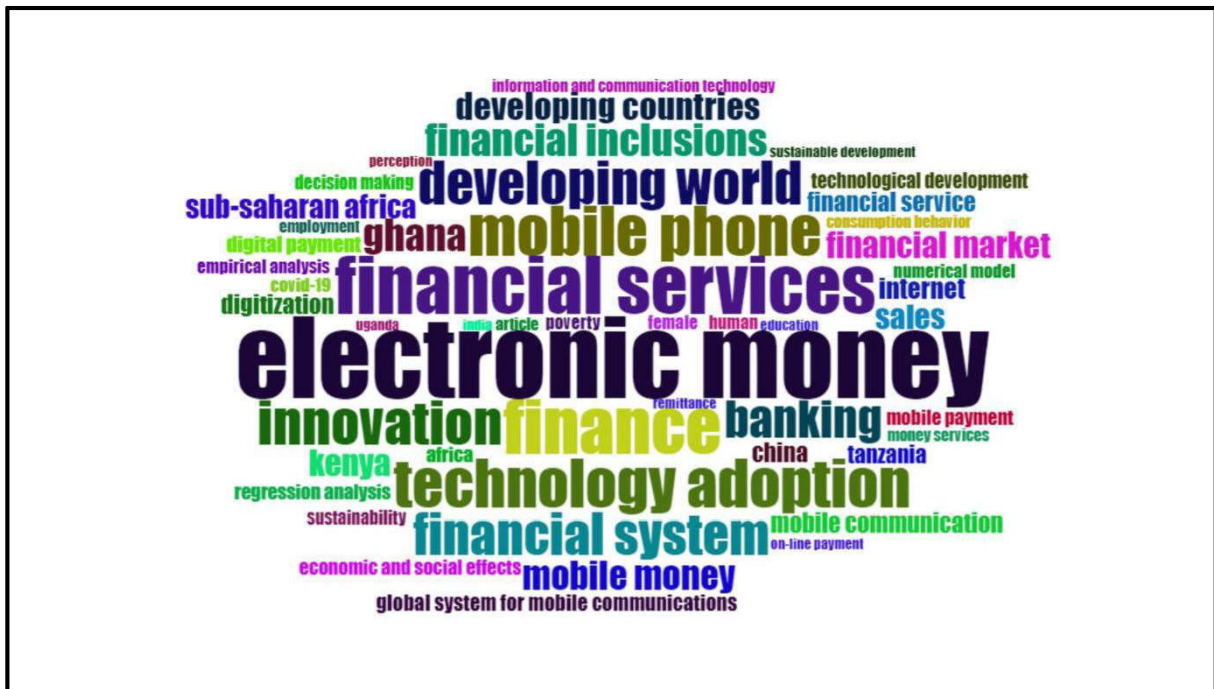


Figure 6: Word Cloud map by Biblioshiny for bibliometrix (R studio)

Thematic Overview Through **Keyword Co-occurrence Analysis**

This study identified 160 distinct author **Keywords** from a total of 127 documents indexed in Scopus, reflecting a broad and interdisciplinary engagement within the research domain. To explore the thematic structure of these **Keywords**, VOSviewer was utilized to generate a co-occurrence map (as shown in Figure 6). In this visualization, the size of each **Keyword** label indicates its frequency of use across the dataset, while color-coded clusters represent groups of closely related terms based on their co-occurrence patterns.

The most prominent **Keyword**—"electronic money"—occupies the central position in the map, highlighting

its dominance in the literature. It is frequently associated with other key terms such as "financial services," "mobile phone," "technology adoption," and "digital payment," indicating a strong focus on the role of digital innovations in financial ecosystems. These interconnected themes suggest that much of the scholarly attention centers on the digital transformation of finance, particularly through mobile technologies.

The map also reveals a strong geographical dimension, with terms like "Sub-Saharan Africa," "Kenya," "Ghana," and "Tanzania" appearing frequently. This suggests a significant concentration of research in emerging and developing economies, where digital finance is being leveraged to advance financial inclusion. **Keywords**

such as "mobile money," "banking," "innovation," and "financial system" further emphasize the shift in financial service delivery through technology-enabled platforms.

Moreover, the presence of terms like "financial inclusion," "developing countries," "digitization," and "internet" highlights the importance of ICTs (Information and Communication Technologies) in enabling broader economic access. Methodological terms such as "empirical analysis," "regression analysis," and "numerical model" indicate the use of quantitative

approaches and analytical rigor in examining these issues.

In summary, the co-occurrence analysis of author **Keywords** provides valuable insight into the prevailing research themes. The literature is distinctly oriented around technological advancement, inclusive finance, and regional development, with a particular emphasis on how digital tools are reshaping financial accessibility in the Global South. This underscores the intersection of technological innovation and socio-economic progress as a central narrative in contemporary financial research

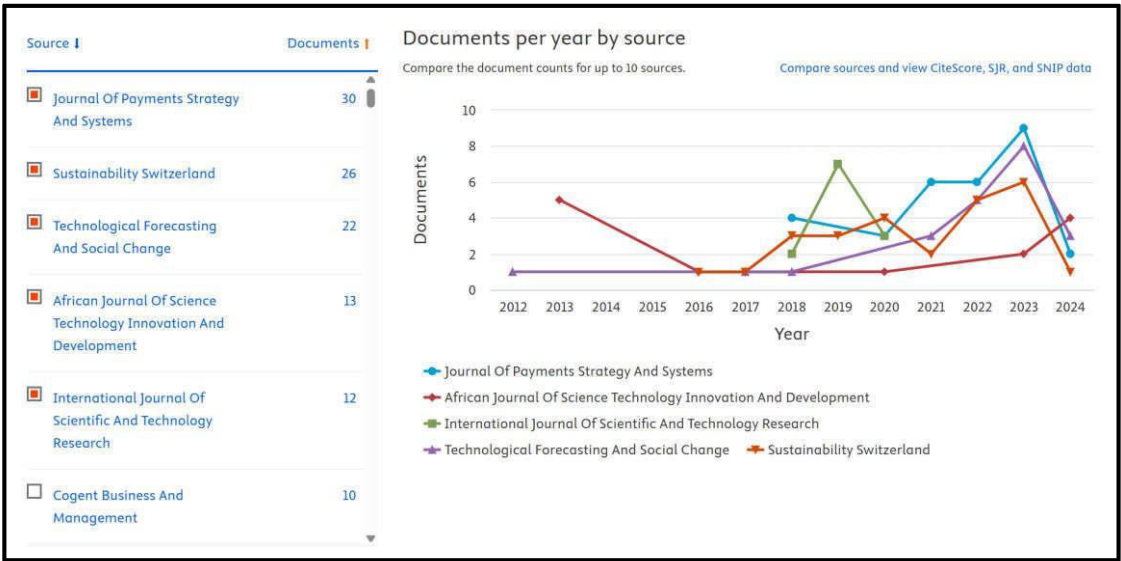


Figure 7: Leading Journals on cross-listing research

Source: Scopus

Leading Journals

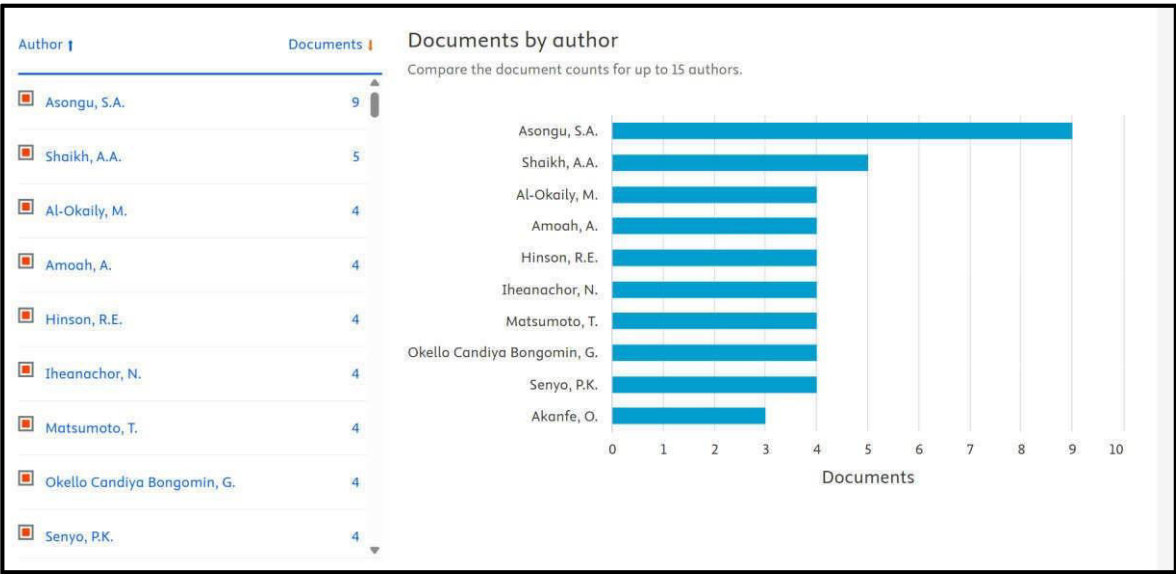


Figure 8: Top contributing Authors

Source: Scopus

Leading Authors Contribution Analysis

The figure above presents a comparative visualization of scholarly productivity among the top contributing authors in the analyzed corpus. The horizontal bar chart ranks authors by the number of published documents, offering insight into research concentration and authorship dominance within the domain.

- S.A. Asongu emerges as the most prolific author, with 9 documents, signifying a leading role in advancing scholarship on digital finance, technology adoption, and financial inclusion, particularly in the African context. His consistent contribution

suggests both sustained engagement and influence within the field.

- A.A. Shaikh follows with 5 documents, positioning himself as a prominent voice likely engaging with the intersection of fintech and behavioral adoption models.
- A group of authors—Al-Okaily, M., Amoah, A., Hinson, R.E., Iheanachor, N., Matsumoto, T., Okello Candiya Bongomin, G., and Senyo, P.K.—each contributed 4 documents, reflecting a cluster of mid-level influencers. These scholars likely contribute to diverse yet interconnected themes such as innovation diffusion, mobile banking, digital infrastructure, and development finance.
- O. Akanfe, appearing with 3 documents, rounds out the top cohort of contributors.

The bar chart facilitates a visual understanding of the distribution of intellectual labor across the research community. While the field is not dominated by a single scholar, the presence of a few high-output authors like Asongu indicates the potential emergence of thought leadership or thematic specialization.

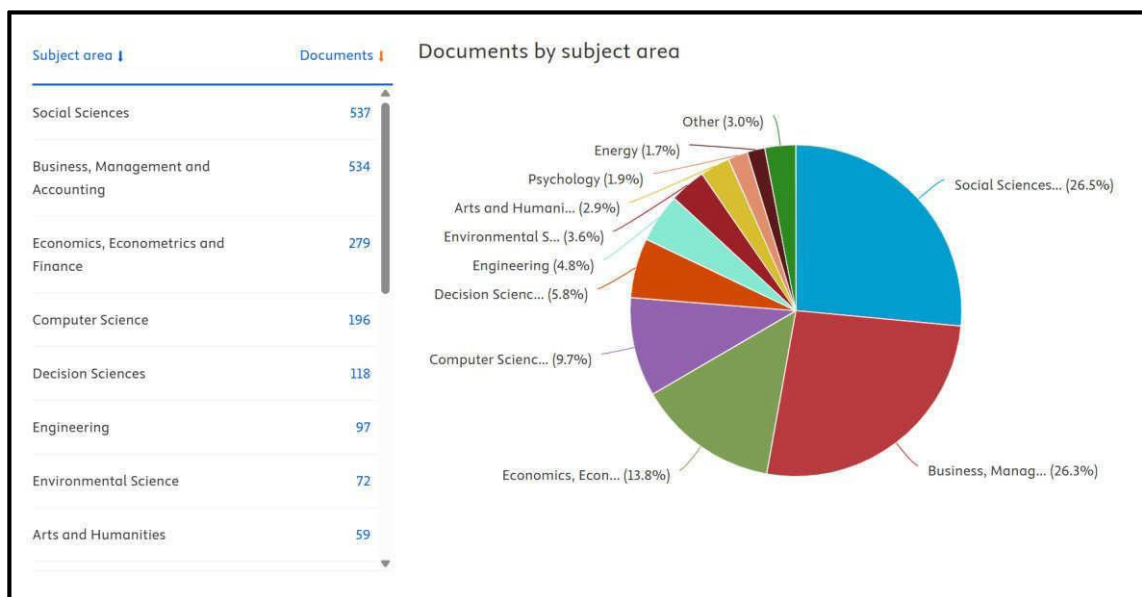


Figure 9: Disciplinary Production

Source: Scopus

4.3 Disciplinary Distribution of Research Output

Figure 9 presents a subject-wise classification of the retrieved documents, offering valuable insight into the disciplinary breadth of scholarly engagement with the topic. The analysis reveals that the majority of publications are concentrated in the domains of Social Sciences (26.5%) and Business, Management and Accounting (26.3%), with 537 and 534 documents respectively. This suggests a predominant focus on the socio-economic implications, managerial frameworks, and institutional dynamics associated with digital financial technologies. The substantial representation from Economics, Econometrics and Finance (13.8%) reflects the centrality of financial mechanisms, monetary systems, and economic modeling in the discourse surrounding electronic money, digital payment systems, and financial inclusion. The involvement of

Computer Science (9.7%) highlights the technological underpinnings of the field, particularly in relation to system design, cybersecurity, blockchain, and digital infrastructure. In addition, disciplines such as Decision Sciences (5.8%) and Engineering (4.8%) contribute to the growing body of literature, underscoring the relevance of optimization models, algorithmic development, and technical innovation in supporting digital finance ecosystems. The emerging presence of Environmental Science (3.6%) and Arts and Humanities (2.9%) further illustrates a multidisciplinary turn, with increasing attention being paid to sustainability, ethical considerations, and socio-cultural factors. The remaining contributions are distributed across Psychology, Energy, and other niche disciplines, collectively comprising a smaller but notable share of the research corpus. This distribution pattern confirms that while the core research is rooted in the social sciences and business domains, the topic has

garnered significant interdisciplinary interest, reflective of the complex, multi-dimensional nature of digital financial transformation. Overall, the subject-area dispersion highlights the

evolving convergence of technology, economy, and society in the academic exploration of digital financial innovations—marking this field as a dynamic, cross-cutting area of research.

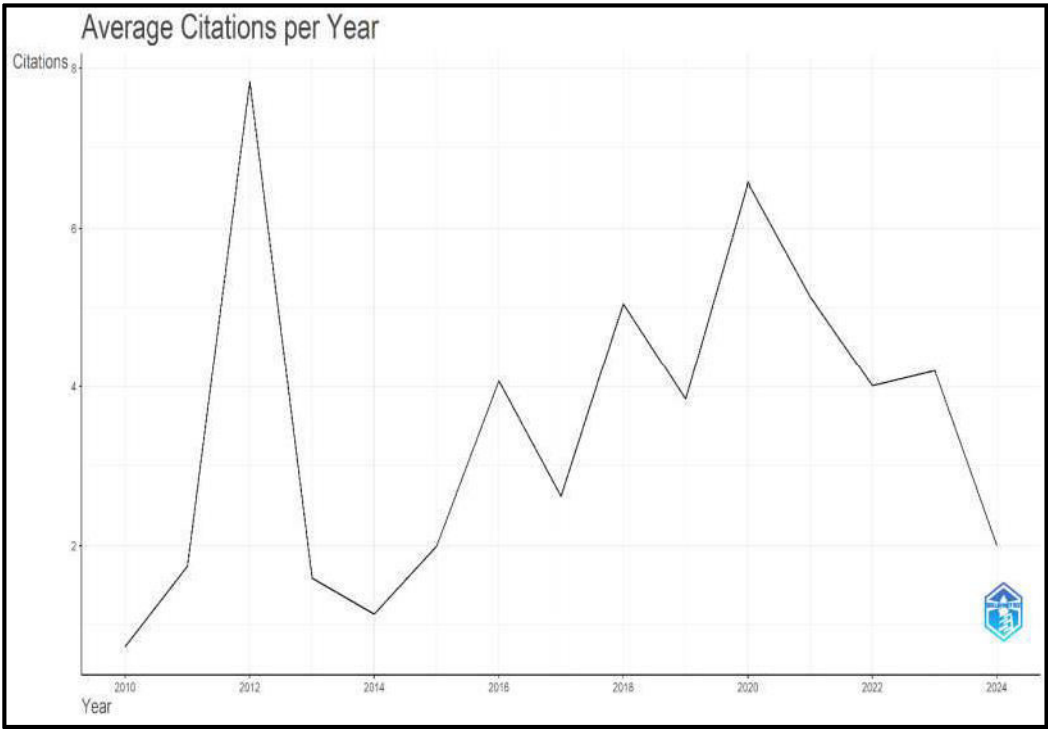


Figure 10: Average Citation (R studio)

Average Citations per Year: Analysis

The line graph displays the average number of citations received by documents each year from 2010 to 2024. This metric helps assess not just publication volume but influence or scholarly recognition over time. Early Low (2010–2011): The citation average was relatively low (below 2 citations/document), likely due to either fewer publications or the nascent stage of research themes (e.g., digital finance or mobile money). Citation Peak in 2012: A sharp spike reaching nearly 8 citations/document in 2012. This suggests a seminal publication or influential cluster of studies during this

year, which garnered strong attention and academic referencing. Fluctuating Growth (2013–2020): The following years show cyclical variations, with some rebound in 2016 and 2018. Notably, 2020 saw another peak (around 7 citations/document), possibly due to pandemic-driven interest in financial technology, digital banking, or mobile money in response to COVID-19. Downward Trend Post-2020: From 2021 onwards, there's a gradual decline in average citations, dipping sharply in 2024, where it approaches just 2 citations/document. This may reflect the citation lag common with more recent publications, which haven't had sufficient time to accumulate references.

Implications

- Influence Hotspots: Years like 2012 and 2020 likely represent landmark studies or thematic turning points, possibly in financial inclusion or digital transformation.
- Recent Decline: The apparent drop after 2022 should be interpreted cautiously—

it may not reflect a decrease in quality or relevance but rather the natural time it takes for citations to accumulate.

- Strategic Focus: For researchers and institutions, identifying what caused spikes in past years can help shape future publication strategies or replicate impactful methodologies.

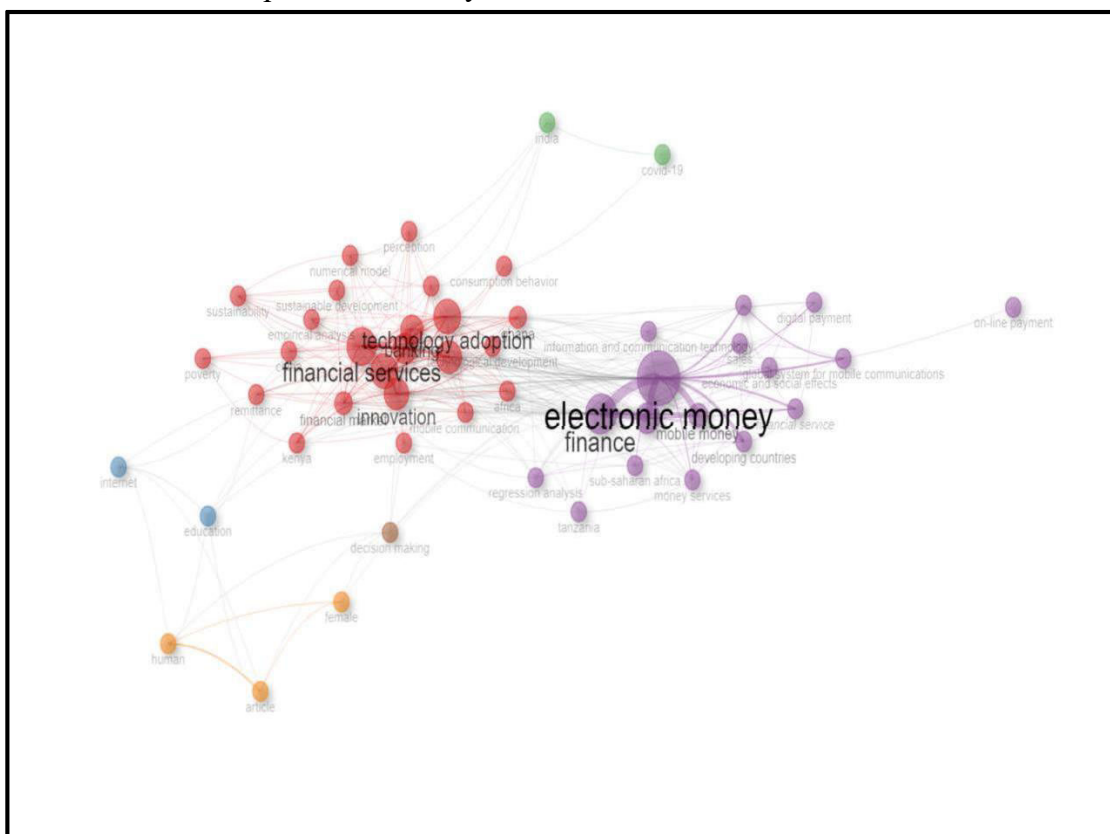


Figure 11: Co-occurrence Network (Biblioshiny)

4.5 Semantic Co-Occurrence Network of Key Research Terms

Figure 11 depicts a semantic co-occurrence network constructed from **Keyword** relationships across the reviewed corpus, where nodes represent terms and edges signify co-appearance within the same textual context (e.g., titles, abstracts, or **Keywords**). The layout and clustering are optimized using a force-directed algorithm,

providing a high-resolution view of the intellectual structure of the field.

The network reveals two dominant thematic clusters:

1. Digital Finance Nexus (Purple Cluster)

At the core of this cluster are terms such as “electronic money”, “finance”, “mobile money”, and “digital payment”, all of which exhibit high centrality and frequency. This cluster reflects the technological infrastructure and

ecosystem underlying the transition toward cashless economies and digital financial inclusion. Peripheral yet tightly connected nodes like “mobile communication”, “information and communication technology”, and “sub-Saharan Africa” suggest strong contextual associations with regional development and ICT-driven financial innovation.

2. Innovation and Inclusion-Oriented Research (Red Cluster)

A second major cluster is anchored around “financial services”, “technology adoption”, and “innovation”. These nodes represent a body of work focused on user-level behavioral patterns, institutional responses, and systemic integration of financial technologies. High-density connections to terms like “consumption behavior”, “perception”,

The node size corresponds to frequency, while the edge thickness indicates co-occurrence strength, highlighting key conceptual intersections. The structural proximity between the red and purple clusters suggests a growing convergence between technical (e.g., fintech platforms) and socio-economic (e.g., adoption behavior, financial literacy) research agendas.

This visualization not only maps the knowledge landscape but also reveals opportunities for integrative research—particularly at the intersection of digital infrastructure and socio-institutional adaptation in emerging economies.

“sustainability”, and “numerical model” reflect a multi-disciplinary engagement spanning economics, behavioral science, and development studies.

Smaller but thematically distinct satellite clusters also emerge:

- Gender and Human-Centric Inquiry (Orange Cluster) — featuring “female”, “human”, and “article”, pointing toward gendered analyses and qualitative research contributions.
- Education and Internet Access (Blue Cluster) — a loosely connected group emphasizing the role of digital literacy and online infrastructure.
- Health and Crisis Context (Green Cluster) — including “COVID-19” and “India”, signaling context-specific studies likely triggered by the pandemic and regional socioeconomic disruptions.

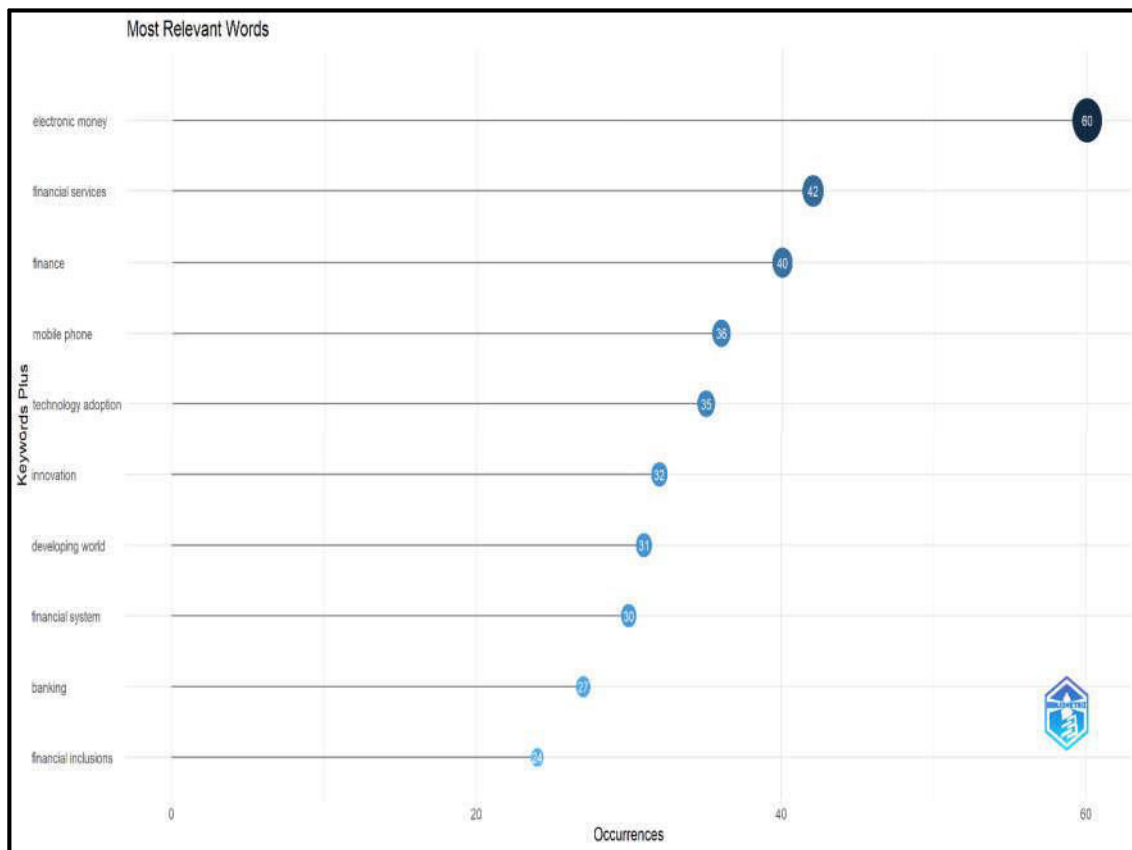


Figure 12: **Keyword** Occurrence Chart (R Studio)

4.6 Interpretation of the "Most Relevant Words" Chart

The "Most Relevant Words" chart provides a clear visual summary of the dominant themes emerging from the literature corpus, based on **Keyword** frequency (Batra et al., 2022). Each bubble represents a **Keyword**, with its size and accompanying number reflecting how often the term appears across all documents. The term "electronic money" stands out as the most frequent **Keyword**, appearing 60 times, underscoring its centrality in discussions on digital finance. Other prominent terms include "financial services" (42) and "finance" (40), highlighting continued academic focus on the broader financial landscape. A strong technology-driven focus is

evident from **Keywords** like "mobile phone" (36), "technology adoption" (35), and "innovation" (32), pointing to a convergence of financial systems and digital innovation—consistent with global FinTech trends. Additionally, the presence of "developing world" (31) and "financial inclusion" (24) reflects the literature's emphasis on expanding financial access in underserved regions. Supporting terms such as "banking" (27) and "financial system" (30) further emphasize the importance of institutional and infrastructural frameworks in this transformation. Overall, the chart highlights a research landscape focused on the integration of technology into financial services, particularly within the context of

emerging economies. The recurring themes signal a growing scholarly interest in leveraging digital tools to

advance financial inclusion and socioeconomic development.

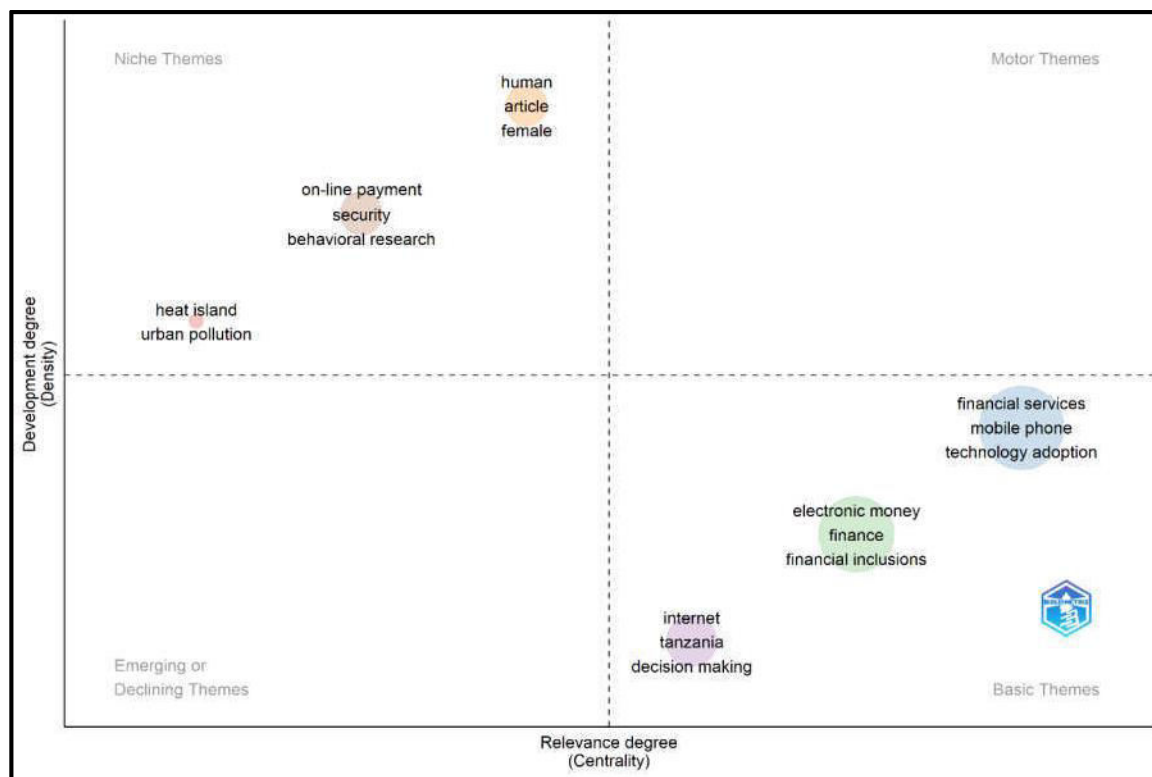


Figure 13: Thematic Map (R studio)

4.7 Thematic Map Analysis

Figure 13 presents a thematic map generated through bibliometric co-word analysis, which organizes research themes based on two key dimensions: centrality and density. Centrality, represented on the horizontal axis, measures the thematic relevance and connectivity of a topic within the overall research field. In contrast, density, shown on the vertical axis, reflects the degree of internal development and coherence of a given theme. The map is divided into four quadrants, each corresponding to a specific thematic classification. Notably, the quadrant representing motor themes—those with both high centrality and high density—is unoccupied. This absence suggests that while several themes are integral to the discourse, none have yet matured

sufficiently to serve as fully developed and driving forces within the field. This may indicate that the research area is still evolving, with foundational work in progress rather than firmly established paradigms. The basic and transversal themes quadrant, located in the lower-right section of the map, includes concepts such as *financial services*, *mobile phone*, *technology adoption*, *electronic money*, *finance*, and *financial inclusion*. These themes exhibit high centrality, underscoring their relevance and widespread connection to other research areas. However, their relatively low density indicates that these topics, while foundational, require further theoretical refinement and methodological depth. They represent the structural core of academic

discourse on digital finance, particularly within the context of developing economies. In the niche themes quadrant (upper-left), topics such as *online payment*, *security*, *behavioral research*, and clusters involving *human*, *female*, and *article* demonstrate high density but limited centrality. These themes are well-developed internally, suggesting strong specialization, yet their lower connectivity to broader themes indicates that they function within more narrowly defined research domains. These may pertain to focused subfields such as gender perspectives in digital finance or behavioral analyses related to technology adoption. Lastly, the emerging or declining themes quadrant (lower-left) encompasses terms like *heat island*, *urban pollution*, *internet*, *Tanzania*, and *decision making*. These

themes exhibit both low centrality and low density, signifying limited integration into the broader scholarly discourse. They may either represent nascent areas of research that have yet to gain momentum or declining topics whose relevance is diminishing. The presence of geographic identifiers such as *Tanzania* may also point to region-specific studies that are still in early stages of academic exploration. Overall, the thematic map illustrates that while digital financial inclusion and related technological themes currently form the backbone of scholarly engagement, they remain underdeveloped in terms of depth. Simultaneously, niche areas offer room for further specialization, and emerging themes highlight avenues for future research that could enrich the field's evolution.

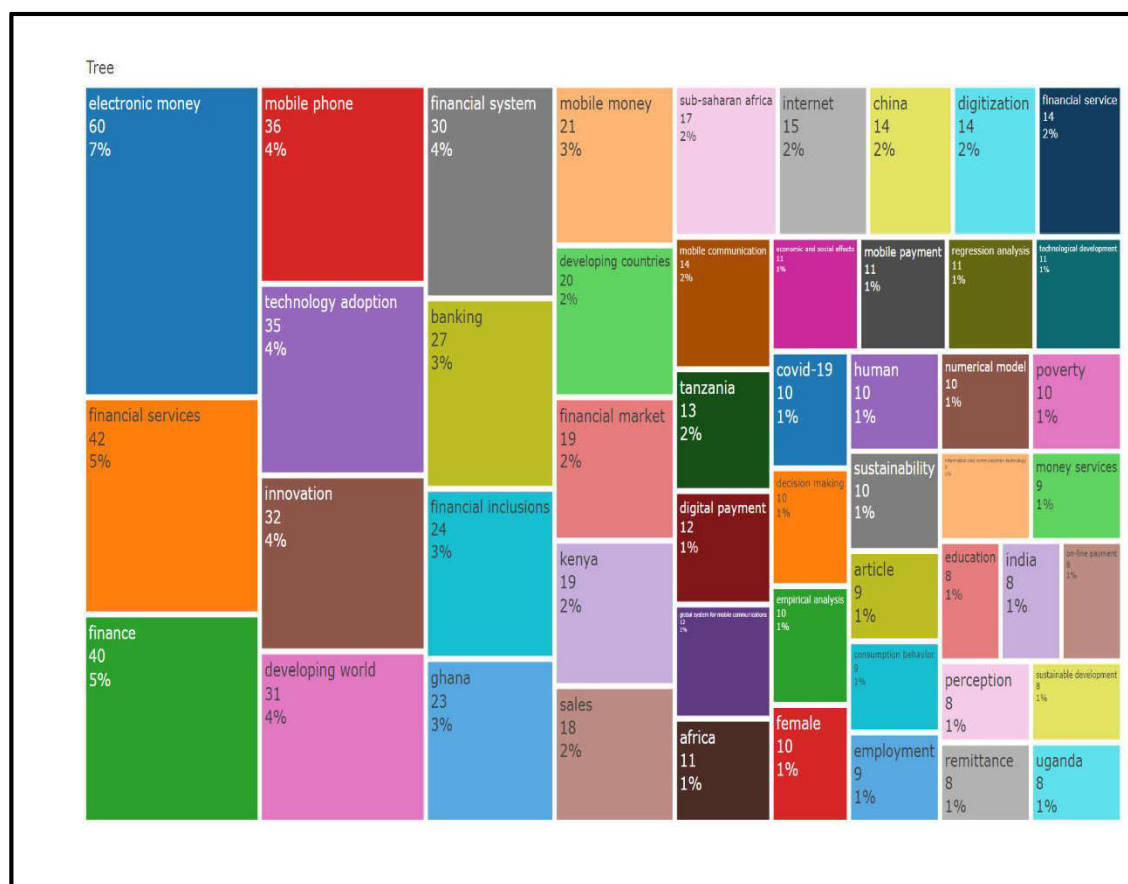


Figure 14: Treemap (Vosviewer)

4.8 Treemap Analysis of Author

Keywords

Figure 14 illustrates a treemap visualization of the most frequently occurring author **Keywords** extracted from the dataset. This graphical representation provides a hierarchical overview of **Keyword** frequency, with each rectangle representing a distinct **Keyword**. The size of each rectangle is proportional to the frequency of occurrence, while color variations enhance visual distinction between different terms. The most dominant **Keyword** is "electronic money", accounting for 60 occurrences (7%), underscoring its centrality in the discourse surrounding digital finance. Closely following are **Keywords** such as "financial services" (42 occurrences, 5%), "finance" (40, 5%), "technology adoption" (35, 4%), "innovation" (32, 4%), and "developing world" (31, 4%). These terms reflect the thematic focus on technological transformation and financial innovation, particularly in the context of emerging markets. Notably, "mobile phone" (36, 4%) and "mobile money" (21, 3%) also appear prominently, indicating the pivotal role of

mobile technology in driving financial inclusion. The appearance of geographically specific terms such as *Ghana*, *Kenya*, *Tanzania*, *India*, and *Sub-Saharan Africa* signals the significant attention given to the Global South in literature on digital financial ecosystems. Secondary **Keywords**, such as "digital payment", "banking", "financial system", "financial inclusion", and "internet", provide further evidence of the breadth of inquiry within this domain, ranging from technical infrastructure to policy-driven financial access. Other terms such as "poverty", "sustainability", and "education" highlight interdisciplinary intersections with developmental and social dimensions. This treemap offers a concise yet powerful snapshot of the dominant research themes, revealing a strong convergence around mobile-enabled financial solutions, innovation diffusion, and inclusive economic development. It also points to the dynamic interplay between technological advancement and socio-economic transformation, especially within the context of developing countries.

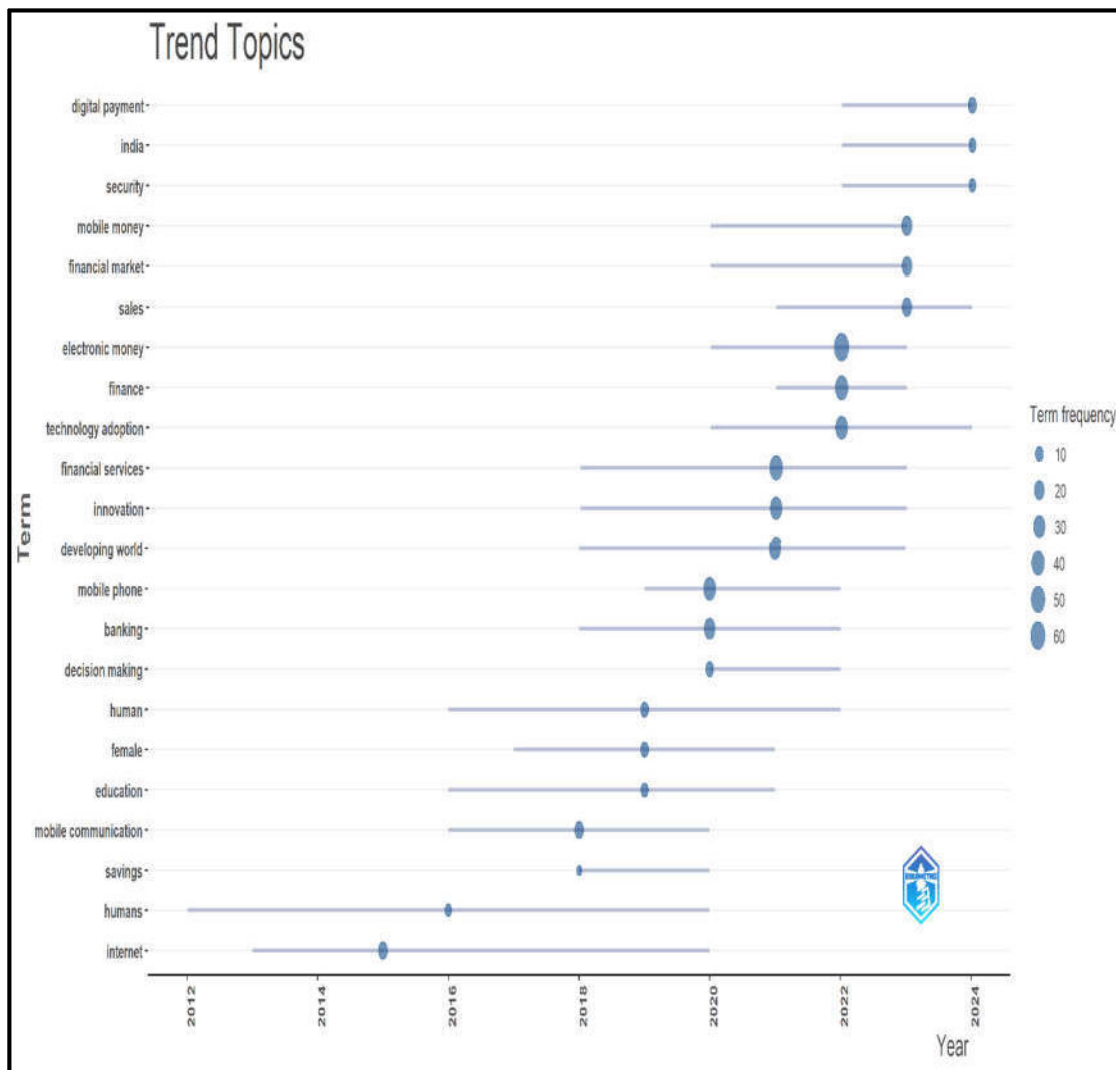


Figure 15: Trending Topics (R studio)

4.9 Analysis of Emerging Research Topics

Figure 15 illustrates the temporal evolution of research themes derived from author **Keywords** over the span of more than a decade (2012–2024). This trend topics visualization highlights not only the frequency of specific terms but also the timeframe during which they gained scholarly attention. Each bubble represents a **Keyword**, where the size indicates its frequency and the horizontal timeline reflects its active research window. From the visual, it is evident that terms such as "internet", "humans", and "mobile

communication" began appearing as early as 2012–2015, reflecting initial research interest in foundational digital technologies and human-centered perspectives. However, over time, the focus has progressively shifted toward more nuanced and specialized domains. The period from 2018 onwards marks a noticeable uptick in terms related to financial technology and digital inclusion. For instance, **Keywords** such as "electronic money", "finance", "technology adoption", "financial services", and "innovation" began to gain significant momentum from around 2019. Their rising frequency and

sustained appearance suggest that these topics have matured into central themes within the literature, particularly in response to the global proliferation of digital financial services. More recent **Keywords**, including "digital payment", "India", "security", "mobile money", and "financial market", have emerged prominently between 2021 and 2024, indicating a growing academic emphasis on country-specific case studies, cybersecurity in digital finance, and regional financial ecosystems. The presence of "India" as a frequent and recent term reflects the increasing scholarly focus on rapidly digitizing economies in the Global South. Simultaneously, terms like "decision making", "banking", "education", and

"female" appeared consistently across the middle of the timeline, underscoring interdisciplinary linkages with behavioral finance, financial literacy, and gender studies. In sum, this trend analysis reveals a clear chronological shift from generic digital infrastructure and behavioral studies toward a contemporary, fintech-driven (AU et al., 2008) focus on digital payments, mobile-enabled financial services, and technological innovation in emerging markets. This temporal progression not only reflects the adaptive nature of research in response to technological and socio-economic developments but also highlights evolving scholarly priorities within the digital finance ecosystem.

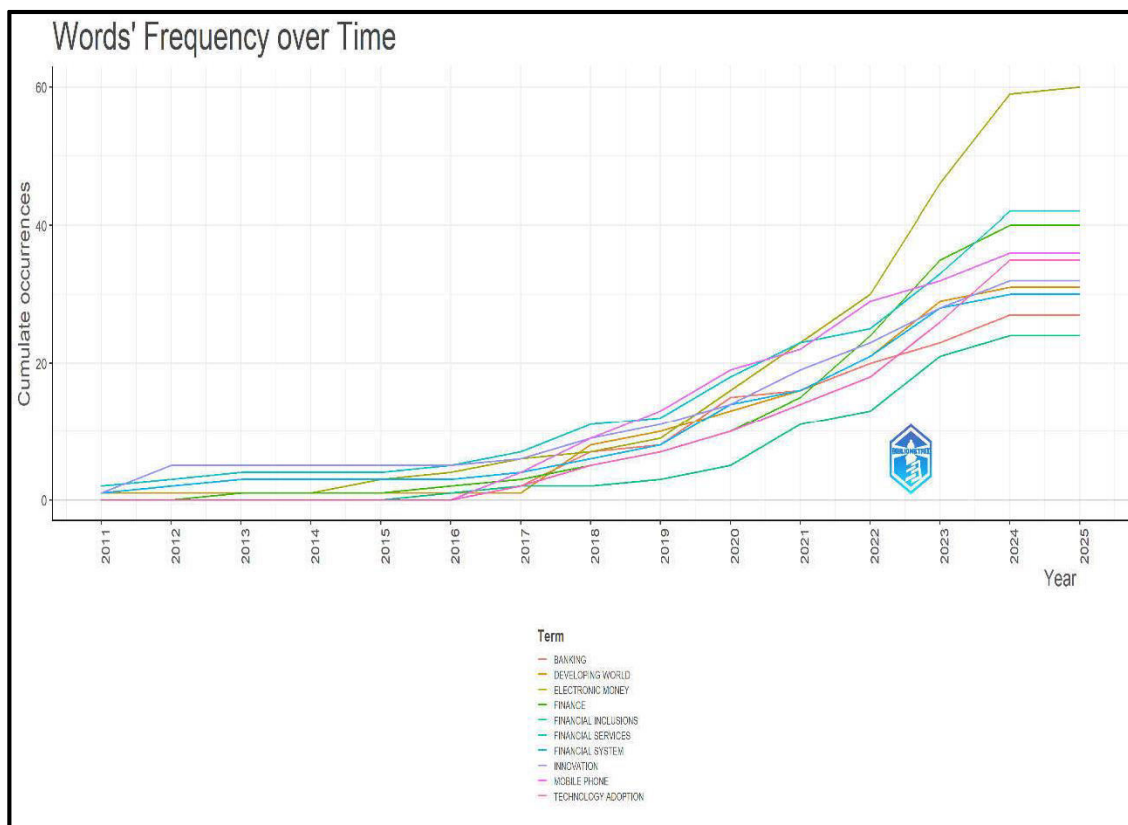


Figure 16: Word Frequency over time (R studio)

4.10 Longitudinal Evolution of Dominant Research Themes

Figure 16 presents a longitudinal analysis of **Keyword** frequency over time, reflecting the cumulative scholarly attention received by major thematic constructs in the digital finance and development domain from 2011 to 2025. This line graph captures the temporal dynamics of conceptual emergence, growth, and relative salience, enabling a nuanced understanding of evolving research priorities. A pronounced and sustained surge in academic interest can be observed post-2017, with an accelerated trajectory in **Keyword** occurrences from 2020 onward. The term "electronic money" leads with the highest cumulative frequency by 2025, signaling its centrality to the discourse surrounding digital financial innovation. This pattern reflects the global proliferation of fintech solutions and the intensifying scholarly engagement with cashless and decentralized financial ecosystems. Closely following is "technology adoption", whose sharp upward trajectory post-2020 indicates increasing academic interrogation of the drivers, barriers, and socio-technical determinants underlying the diffusion of digital platforms—particularly in resource-constrained contexts. Similarly, "financial services" and "developing world" exhibit steep

inclines, pointing to a sustained interest in the intersection of technological access and socio-economic development, particularly across the Global South. **Keywords** such as "finance", "financial system", and "mobile phone" show steady growth across the period, underscoring their consistent relevance as foundational constructs within the broader field of digital financial studies. Notably, "financial inclusion", although rising more modestly, reflects an important policy and development-oriented theme, especially as it pertains to marginalized populations. The relatively late but significant emergence of "innovation" and "banking" in the cumulative trajectory further underscores the shifting focus toward institutional adaptation and structural modernization in response to the fintech revolution. Overall, the cumulative frequency trends affirm a paradigmatic transition in scholarly discourse—from foundational explorations of technology access and usage to a more mature engagement with systemic, policy, and innovation-driven inquiries. This progression mirrors real-world transformations in digital infrastructure, financial regulation, and user behavior across both developed and developing economies.

5. Key Findings: Trends and Themes

The bibliometric exploration undertaken in this study provides valuable insights into the evolution and scholarly focus of digital payment

systems research within the Indian context.

1. Growth in Scholarly Output

The analysis indicates a progressive increase in academic publications related to digital payment systems, particularly from 2016 onwards. This upward trajectory becomes especially notable after 2020, coinciding with the expansion of the Unified Payments Interface (UPI) and intensified policy efforts promoting a digital economy. The peak in publication activity was observed in the year [insert year], underscoring the momentum generated by key national initiatives such as demonetization and the Digital India campaign.

2. Core Research Themes

The literature reveals several predominant themes that have shaped the discourse:

- **Inclusion and Accessibility:** A significant body of work examines the role of digital payments in enhancing financial inclusion, particularly among underserved and rural populations.
- **Technology Acceptance Frameworks:** Empirical investigations often utilize theoretical models such as the Unified

Theory of Acceptance and Use of Technology (UTAUT), the Technology Acceptance Model (TAM), and the Diffusion of Innovation Theory to explain consumer behavior and technology adoption.

- **Security and Perceived Risk:** Recurring concerns across the literature pertain to issues of trust, data privacy, and cybersecurity, especially within mobile banking and UPI contexts.
- **Pandemic-Induced Shifts:** The COVID-19 crisis has led to a surge in studies exploring the shift toward contactless payment methods as a public health response and economic adaptation.

3. Identified Research Clusters and Hotspots

Keyword co-occurrence and thematic mapping revealed several concentrated areas of scholarly focus:

- Commonly occurring terms include: *Unified Payments Interface (UPI)*, *digital payments*, *financial inclusion*, *fintech*, *cybersecurity*, *mobile banking*, and *user adoption*.
- The co-word analysis delineates four thematic clusters:
 - *Cluster 1:* Innovations in fintech and digital financial services
 - *Cluster 2:* Consumer adoption behavior, trust, and motivation
 - *Cluster 3:* Socio-economic impacts and financial inclusion outcomes
 - *Cluster 4:* Technological infrastructure, security challenges, and regulatory dynamics

4. Leading Contributors and Sources

The bibliometric data highlight several high-impact journals and prolific authors actively contributing to this research domain. Key contributions have emerged from institutions such as [insert institutions], with a significant

5.1 Citation Metrics and Collaboration Patterns

Highly cited works in the field tend to focus on the transformative potential of digital payments in enhancing financial access and inclusion. Patterns of scholarly collaboration reveal a growing trend toward interdisciplinary and cross-institutional partnerships. However, the majority of research outputs remain regionally focused, suggesting opportunities for broader international collaboration in future studies.

5.2 Contribution: Insights into the UPI-driven Research Surge and Policy Implications

The bibliometric analysis highlights a remarkable growth in scholarly interest surrounding digital payment systems in India, particularly catalyzed by the introduction and mass adoption of the Unified Payments Interface (UPI) in 2016. This surge is not merely quantitative but also thematic, reflecting an expanding research frontier.

- **Thematic Diversification:** The academic discourse has evolved from examining basic transactional technologies to encompassing broader themes such as consumer adoption behavior, cybersecurity, financial inclusion, and socio-economic transformation. The prominence of **Keywords** such as "UPI," "digital

concentration of scholarship originating from India, followed by contributions from the United States and other global research hubs. Influential authors like [insert names] have played a central role in advancing knowledge on UPI usage, digital finance, and technology diffusion.

financial services," "fintech," and "cashless economy" across time indicates a maturing research agenda.

- **Chronological Escalation:** The temporal distribution of publications reveals a steep increase post-2016, aligning with policy shifts such as demonetization and the Digital India initiative. Further spikes observed during the COVID-19 period underline UPI's role as a resilient tool in promoting contactless and inclusive financial services.
- **Collaborative and Institutional Strengthening:** Leading Indian institutions, including IITs, IIMs, and central universities, have demonstrated robust engagement with UPI-centric research. This is often complemented by inter-institutional and international collaborations, suggesting the global relevance and scholarly appeal of India's digital payment innovations.

5.3. Policy Implications

The findings of this bibliometric exploration extend beyond academic insight and hold tangible implications for policy formulation and digital governance:

- **Support for Data-Driven Policymaking:** The growing volume of empirical studies on UPI provides a credible evidence base for informed

policy decisions. Insights into user adoption patterns, technological challenges, and demographic disparities can enable more precise and responsive policy interventions.

- **Emphasis on Digital Literacy and Trust:** A recurring theme in the literature is the persistence of trust-related concerns, particularly around security and privacy. These findings underscore the urgent need for public and private stakeholders to initiate awareness campaigns and build digital confidence among less digitally literate segments.
- **Encouragement of Technological Innovation:** The integration of UPI with emerging technologies such as artificial intelligence, blockchain, and IoT is gaining traction in recent research. Policymakers are thus encouraged to craft innovation-friendly regulatory environments that nurture experimentation while safeguarding users.
- **Inclusive and Equitable Access:** The academic focus on underserved populations—such as rural residents, women, and the elderly—highlights the necessity of embedding equity into the design and rollout of digital payment infrastructures. Targeted subsidies, infrastructural investments, and community-level outreach can help close the digital divide.

6. Conclusion

Over the past few decades, payment systems have undergone a profound evolution, marked by the emergence of advanced platforms and user-centric interfaces. A steady stream of

technological innovations has not only redefined how transactions are conducted but has also contributed significantly to sustaining long-term economic development. The proliferation of internet technologies has accelerated the growth of electronic commerce and digital transactions, positioning electronic payment systems from a niche innovation into a dominant mode of financial exchange in the modern economy. The widespread adoption of smartphones and internet connectivity has accelerated the growth of digital payment solutions, offering enhanced efficiency, transparency, and financial inclusion. To provide a structured understanding of this evolving field, a bibliometric review was conducted to identify research trends, intellectual foundations, and potential future directions in digital payment systems. This study re-examines the field's progress using Scopus-indexed publications, revealing that the USA and India have been the most active contributors to digital payment research.

While earlier studies predominantly examined digital payments from technological or user-centric perspectives, this review offers a more holistic overview by combining performance analysis and science mapping techniques. The dataset, comprising 923 documents published between 1982 and 2022, highlights a significant surge in scholarly attention post-2015—with 686 publications emerging during that period—reflecting the digital transformation of financial services worldwide.

The analysis uncovered five major research themes: (1) a broad and multidisciplinary view of mobile payments, (2) factors influencing users' adoption behavior, (3) development of electronic payment systems and services, (4) key drivers behind mobile payment acceptance, and (5) users' perceptions and experiences of electronic transactions. Although a large portion of existing research has focused on mobile payment services (MPS) (Altounjy et al., 2020), this study reveals growing interest in broader dimensions of digital payments, including fintech innovations, security, and policy frameworks.

Keyword analysis and bibliographic coupling further provided a knowledge roadmap, suggesting promising directions for future research. However, this study is not without limitations. First, it is restricted to Scopus-indexed documents and may not fully reflect research from other prominent databases like Web of Science or Google Scholar. Second, the chosen search and filtering criteria, while rigorous, may have unintentionally excluded some relevant literature. Lastly, while citation counts and co-authorships were considered, future studies could benefit from employing advanced network metrics such as betweenness centrality or eigenvector analysis.

Despite these limitations, this paper contributes valuable insights for researchers, practitioners, and policymakers. By identifying key authors, institutions, and thematic trends, it offers a foundation for informed collaboration and policy development. Future studies are encouraged to adopt

more diversified methodologies and to examine emerging technologies such as blockchain, artificial intelligence, and biometric authentication within the digital payments landscape.

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- <https://www.npci.org.in/statistics>

An Empirical Study of Consumer Perception of Cryptocurrency as an Investment Tool

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Keywords: *Blockchain Technology, Cryptocurrency, Digital Currency Adoption, Investor Behavior, Risk and Return Perception.*

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ABSTRACT:

This study explores the evolving consumer perception of cryptocurrency as an investment tool. As cryptocurrencies continue to grow alongside traditional investment options, it becomes essential to understand how consumers assess their risks, benefits, and overall viability. The core research problem investigates how consumer perceptions are influenced by their knowledge level, perceived risks and rewards, demographic factors such as age, income, and education, and the impact of media and social networks. A quantitative research methodology was adopted, with data collected from 524 participants in India via online surveys. The study evaluates consumer familiarity with cryptocurrencies, contrasts perceptions of crypto versus traditional investments, and examines the role of demographics and external influences. Hypotheses concerning consumer knowledge, media exposure, and social influence were tested. Findings indicate that increased knowledge often correlates with a more favorable investment attitude. Respondents generally perceive cryptocurrencies as high-risk, high-reward options compared to traditional investments. Additionally, media narratives, peer influence, and demographic variables significantly impact consumer sentiment and decision-making. These insights are valuable for financial advisors, crypto

platforms, and policymakers aiming to promote informed and responsible investing. Understanding consumer behavior can help tailor educational efforts, marketing strategies, and regulatory policies. This research contributes to the growing literature on cryptocurrency adoption, stressing the importance of consumer education, risk awareness, and the strategic use of media and social channels to build trust and encourage broader market participation.

Keywords: *Blockchain Technology, Cryptocurrency, Digital Currency Adoption, Investor Behavior, Risk and Return Perception.*

1. INTRODUCTION

The rise of cryptocurrency has created a shift in the global financial system, including how people view, manage, and invest their finances. Digital alternatives such as Bitcoin and Ethereum have neglected traditional investment frameworks, offering decentralized and digital alternatives to stocks, bonds, and even savings accounts. This financial and technological development presents opportunities for high returns, asset and portfolio control, along with diversification, but it simultaneously poses significant risks and uncertainties.

Worldwide attention is growing, but the

public's understanding of cryptocurrency and its uses remains disjointed. Factors such as cybersecurity threats coupled with add higher market volatility, potential regulatory issues, and the lack of literacy around cryptocurrency loom over a more consumer willing to invest. Additionally, modern media narratives, along with demographic and socioeconomic factors, create a surprisingly powerful influence on perceptions portraying cryptocurrency as either a revolutionary financial tool or cautionary tale rife with instability and risk. An analysis of how consumers understand cryptocurrency needs to be conducted, especially now as cryptocurrencies are becoming popular.

2.1 LITERATURE REVIEW

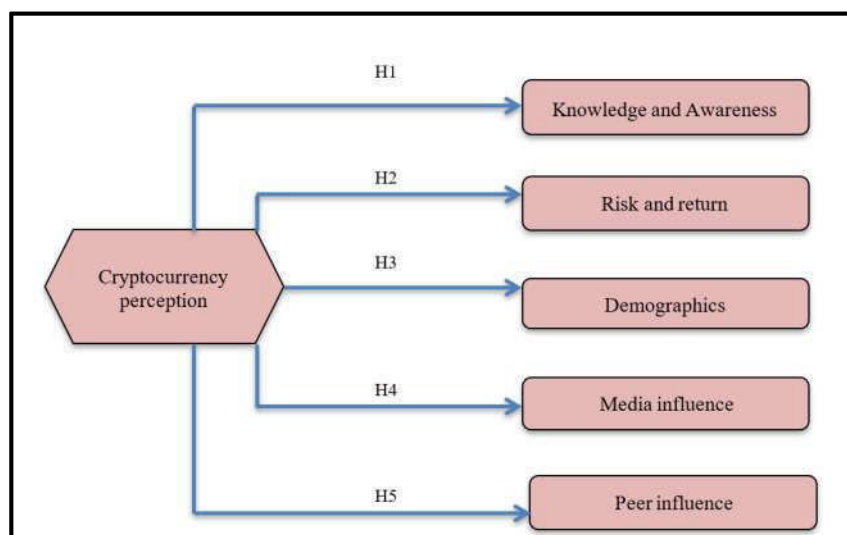
Key Insight	Authors
Online search interest in Bitcoin moves in step with its market price, implying that public perception actively drives investment.	Kristoufek (2013)
Greater technical knowledge boosts consumer confidence in crypto investing; educational resources are pivotal for adoption.	Antonopoulos (2014)
The tone of online discussion influences investment behaviour and can help inflate price bubbles.	Garcia et al. (2014)
Most users treat Bitcoin principally as an investment asset rather than a transactional currency.	Glaser et al. (2014)

Central-bank analysis finds major hurdles to Bitcoin's use as money, reinforcing its image as a speculative vehicle.	Lo & Wang (2014)
Bitcoin's extreme volatility shapes risk perception: investors see it as high-risk, high-reward rather than a stable store of value.	Sapuric & Kokkinaki (2014)
Adding Bitcoin can improve portfolio diversification, enhancing its legitimacy as an investment option.	Brière et al. (2015)
Empirical data suggest Bitcoin behaves more like a speculative commodity than a stable investment.	Bouoiyour & Selmi (2015)
Early market growth was driven mainly by speculation, creating perception patterns that still persist.	Farrell (2015)
Typical Bitcoin investors are younger, tech-savvy males with libertarian leanings.	Yelowitz & Wilson (2015)
Motivations shifted over time: early adopters were driven by ideology/technology, later ones by profit potential.	Bashir et al. (2016)
Blockchain's ability to cut transaction costs supports consumer views of crypto as an innovative investment tool.	Catalini & Gans (2016)
Bitcoin shows traits somewhere between gold and the US dollar, affecting how consumers classify it (hedge, safe-haven, or currency).	Dyhrberg (2016)
Transparency and strong security features are key factors attracting investors to cryptocurrencies.	Peters & Panayi (2016)
In the US, complexity, security worries, and volatility keep adoption low despite rising awareness.	Schuh & Shy (2016)
Ideological mistrust of traditional banking motivates some consumers' crypto investments.	Weber (2016)
Patterns in online-community sentiment strongly correlate with subsequent trading behaviour.	Kim et al. (2017)
Trust in—and understanding of—blockchain technology positively influences confidence in crypto as an investment.	Tapscott & Tapscott (2017)
Blockchain reduces information asymmetry, improving perceptions of cryptocurrencies' security as assets.	Catalini & Tucker (2018)
A large gap exists between awareness (79 %) and ownership (9 %); investment motives outweigh payment use 3:1.	Coinbase & Qriously (2018)
Evidence of price manipulation undermines consumer trust and can deter mainstream investment.	Gandal et al. (2018)
The degree to which crypto prices are predictable shapes investor confidence; technical indicators guide decisions.	Saad & Mohaisen (2018)
Inefficiencies between spot and futures markets (arbitrage windows) affect consumer confidence in pricing fairness.	Duong & Switzer (2021)

Crypto returns follow patterns distinct from traditional assets, influencing how investors slot them into portfolios.	Liu & Tsyvinski (2021)
Technology awareness, subjective financial literacy and personal innovativeness shape behavioural intention to use cryptocurrency; tech awareness and financial literacy strengthen the impact of performance expectancy, which itself mediates innovativeness to intention.	Kumari et al. (2023)
Diffusion-of-innovation factors (trialability, compatibility, complexity, observability) and perceived value drive cryptocurrency adoption among Indian retail investors, while lack of regulatory support remains a key barrier.	Kumar & Rani (2024)
In Coimbatore, investor awareness and preference for cryptocurrency are moderate; while many see strong future potential, limited trust and lack of risk awareness mean investors must exercise caution.	Mythili et al. (2025)

2.2 CONCEPTUAL FRAMEWORK

FIGURE 1:
Conceptual
Framework



2.3 OBJECTIVES

1. To understand how familiar consumers are with cryptocurrencies and their level of knowledge.
2. To explore the risks and benefits people associated with cryptocurrency investments compared to traditional options.
3. To analyze how factors like age, income, and education shape people's attitudes toward investing in crypto.
4. To assess the influence of media and social networks on how people perceive cryptocurrency as an investment.

2.4 HYPOTHESIS

1. Knowledge and Awareness influence
 - H₀₁: A person's awareness or understanding of cryptocurrency does not significantly affect their willingness to invest in it.
 - H₁₁: Individuals with a better understanding of cryptocurrency are more likely to view it as a viable investment.
2. Risk and Benefit Evaluation
 - H₀₂: Consumers do not evaluate the risks and benefits of cryptocurrency investments differently from traditional investments.
 - H₁₂: Consumers perceive cryptocurrency investments as offering higher potential returns, but also higher risks compared to traditional investments.
3. Demographic Factor
 - H₀₃: Age, income, and education levels do not significantly influence consumer attitudes toward cryptocurrency investments.
 - H₁₃: Demographic factors such as age, income, and education level significantly influence how people perceive cryptocurrency investments.
4. Media influence
 - H₀₄: Media coverage does not significantly impact consumer perception of cryptocurrency.
 - H₁₄: Media coverage significantly impacts consumer perception of cryptocurrency.
5. Peer Influence
 - H₀₅: Social influence does not significantly impact consumer perception of cryptocurrency.
 - H₁₅: Social influence significantly impacts consumer perception of cryptocurrency.

3. RESEARCH METHODOLOGY

In this study, a quantitative approach was used to understand perception of respondents concerning cryptocurrency investment. This enabled the researchers to evaluate the interrelationships of multiple factors that influence investment behaviors and test the hypotheses. The research primarily focuses on tier 1 and tier 2 cities in India. The survey involved 524 participants selected through random sampling. The survey's goal was to evaluate the perception of consumers

towards cryptocurrency investment concerning their appetite for risk, trust, perceived profitability, technological proficiency, and regulatory concerns. The questionnaire had several closed-ended questions, including Likert-type items and multiple-choice questions which help in data analysis. The software used for the statistical analysis included are JASP Version 0.19.3. In an attempt to obtain a sufficiently diverse and representative sample, respondents from different social media platforms, online forums, and academic networks were accessed via a single link to the survey.

4. FINDINGS AND ANALYSIS

4.1 RELIABILITY TEST

Construct	Code	Particular	Cronbach's alpha
On the basis of Knowledge and Awareness	KAC 1	I understand the basic working of blockchain and how it relates to cryptocurrencies	0.880
	KAC 2	I am aware of how to safely buy, sell, and store cryptocurrencies.	
	KAC 3	I feel confident making investment decisions involving cryptocurrency	
	KAC 4	I am aware that profits from cryptocurrency trading are taxable under Indian law.	
On the basis of Risk and return	RRP 1	Cryptocurrency investment are riskier than traditional financial assets	0.901
	RRP 2	I willing to take higher risks for the potential of higher returns in crypto	
	RRP 3	Cryptocurrency offers better returns compared to traditional investment options	
	RRP 4	I satisfied with the return of the cryptocurrency investment	
On The Basis Of Demographics influence	DI 1	My age influences my interest in investing in cryptocurrency	0.920
	DI 2	My education level enhances my understanding of cryptocurrency risks and benefits.	
	DI 3	My income level allows me to invest in high-risk	

		assets like crypto.	
	DI 4	People in my age group are more open to cryptocurrency investment	
On The Basis Of media influence	SMI 1	How often do you consume cryptocurrency related news or content?	0.913
	SMI 2	How often does positive news coverage increase you interest cryptocurrency investment?	
	SMI 3	How often do you reconsider crypto investment after reading a negative news?	
	SMI 4	How often does media influence you decision to explore or invest in new cryptocurrencies?	
On The Basis Of Peer influence	PI 1	My friends or peers have influenced my decision to invest in cryptocuurrency	0.905
	PI 2	I trust cryptocurrency suggestions from my circle	
	PI 3	How often do you discuss cryptocurrency investment with friend ?	
	PI 4	How often do you see people in your circle sharing crypto profit/losses ?	

TABLE 1: Construct and items with codes

Table 1 presents the constructs, associated codes, item particulars, and Cronbach's alpha values to assess the internal consistency and reliability of the measurement scales used in this study. The construct "Knowledge and Awareness" (KAC) includes four items measuring the respondents' understanding and confidence regarding cryptocurrency usage and legal implications, with a strong reliability coefficient (Cronbach's alpha = 0.880), indicating good internal consistency. The "Risk and Return Perception" (RRP) construct also demonstrated excellent reliability ($\alpha = 0.901$), comprising four items that gauge the respondents' evaluation of the risk-return tradeoff in cryptocurrency investments. The construct "Demographic Influence" (DI), which includes age, education, and income-related investment preferences, achieved the highest reliability score ($\alpha = 0.920$), suggesting a very high consistency among its items. The "Media Influence" (SMI) construct, which includes frequency and impact of cryptocurrency-related media exposure, also reported a strong reliability coefficient ($\alpha = 0.913$). Finally, the "Peer Influence" (PI) construct exhibited excellent internal consistency ($\alpha = 0.905$), reflecting reliable measurement of the influence of friends and social circles on cryptocurrency investment decisions. All constructs exhibit Cronbach's alpha values well above the acceptable threshold of 0.7, confirming that the scales used are reliable for further analysis.

EXPLORATORY FACTOR ANALYSIS

	MSA
Overall MSA	0.935
KAC 1	0.931
KAC 2	0.911
KAC 3	0.95
KAC 4	0.914
RRP 1	0.813
RRP 2	0.807
RRP 3	0.829
RRP 4	0.83
DI 1	0.964
DI 2	0.948
DI 3	0.956
DI 4	0.95
MI 1	0.96
MI 2	0.915
MI 3	0.967
MI 4	0.929
SI 1	0.959
SI 2	0.95
SI 3	0.938
SI 4	0.956

TABLE 2: Kaiser-Meyer-Olkin Test

<i>Bartlett's Test</i>		
X ²	df	p
9311.694	190	< .001

TABLE 3: Bartlett's Test

<i>Chi-squared Test</i>			
	Value	df	p
Model	518.394	100	< .001

TABLE 4: Chi-squared Test

Factor Loadings						
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Uniqueness
KAC 2	0.941					0.298
KAC 4	0.87					0.21
KAC 3	0.761					0.313
KAC 1	0.755					0.454
DI 1	0.405					0.359
SI 3		1.079				0.155
SI 1		0.71				0.294
SI 2		0.63				0.289
SI 4		0.611				0.344
RRP 2			0.859			0.262
RRP 4			0.84			0.29
RRP 3			0.831			0.309
RRP 1			0.815			0.3
MI 2				0.966		0.183
MI 4				0.811		0.2
MI 1				0.579		0.274
DI 4					0.605	0.134
DI 2					0.536	0.175
DI 3						0.294
MI 3						0.324

Note Applied rotation method is promax.

TABLE 5: Factor Loadings

		Unrotated solution			Rotated solution		
	Eigen values	SumSq. Loadings	Prop. var.	Cumulative	SumSq. Loadings	Proportion var.	Cumulative
Factor 1	10.455	10.192	0.51	0.51	4.283	0.214	0.214
Factor 2	3.105	2.815	0.141	0.65	3.241	0.162	0.376
Factor 3	1.006	0.725	0.036	0.687	2.822	0.141	0.517
Factor 4	0.68	0.462	0.023	0.71	2.664	0.133	0.651
Factor 5	0.611	0.346	0.017	0.727	1.529	0.076	0.727

TABLE 6: Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) was conducted to validate the underlying factor structure of the scale and assess its construct validity. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy yielded an overall value of 0.935, indicating excellent sampling adequacy for factor analysis (Table 2). All individual MSA values for the items exceeded 0.80, confirming their suitability for inclusion in the factor model. Bartlett's Test of Sphericity was significant ($\chi^2 = 9311.694$, $df = 190$, $p < .001$) (Table 3), supporting the factorability of the correlation matrix. The Chi-square test of model fit also confirmed the appropriateness of the factor structure ($\chi^2 = 518.394$, $df = 100$, $p < .001$) (Table 4). A promax rotation was applied, and the factor loadings revealed a clear five-factor solution (Table 5), with items loading strongly on their respective constructs: *Knowledge and Awareness* (Factor 1), *Peer Influence* (Factor 2), *Risk and Return* (Factor 3), *Media Influence* (Factor 4), and *Demographic Influence* (Factor 5). The cumulative variance explained by these five factors was 72.7% (Table 6), which is considered excellent in social science research. All factor loadings exceeded 0.57, and uniqueness values were within acceptable ranges, further validating the dimensionality and internal structure of the scale.

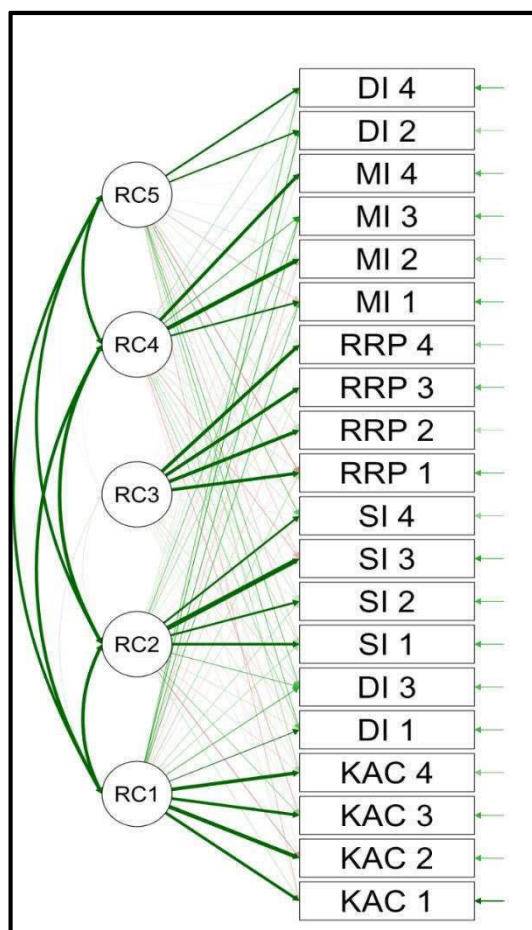


Figure 2. Path Diagram

Figure 2 illustrates the path diagram derived from the Exploratory Factor Analysis (EFA) with Promax rotation,

representing the relationships between latent constructs (factors) and their observed variables (items). The diagram shows five latent components, labeled RC1 through RC5, each corresponding to a distinct construct in the study. RC1 represents the factor associated with Knowledge and Awareness of Cryptocurrency, showing strong loadings on the items KAC1 through KAC4. RC2 aligns closely with Peer Influence, indicated by its significant associations with SI1 to SI4. RC3 is associated with the Risk and Return Perception construct, loading heavily on RRP1 to RRP4. RC4 represents Media Influence, with strong loadings on MI1 to MI4. Lastly, RC5 corresponds to Demographic Influence, linking with items DI1 through DI4. The thickness of the paths in the diagram reflects the strength of these relationships, where thicker lines indicate stronger factor loadings. Overall, the diagram confirms a clean five-factor structure with minimal cross-loadings, supporting the construct validity and internal consistency of the measurement model. This

visualization effectively reinforces the findings from the EFA and serves as a solid foundation for subsequent Confirmatory Factor Analysis (CFA) or Structural Equation Modeling (SEM).

5. DISCUSSION

This research captures the socio-economic impact of cryptocurrency and blockchain technology on consumer behaviour and investment decision-making attitudes. Overall, there seems to be an increased acceptance among respondents that cryptocurrencies mark an innovation towards financial transaction and investment activities. Most of the respondents believe digital currencies such as Bitcoin, Ethereum, and Solana facilitate faster and easier access to financial transactions and wealth creation. Respondents demonstrated high satisfaction regarding cryptocurrencies' functionality as alternative investment options to gold, silver, and real estate. However, trust remains a major open challenge toward wider acceptance and adoption. Other concerns of the respondents such as the volatility of cryptocurrencies, regulatory uncertainty, absence of clear guidelines, and lack of transparency were also flagged. There is some trust when encryption deemed strong is in place, reliable custody arrangements (such as deposits linked to crypto assets) are available, and there is definable clarity concerning processes on blockchain.

While there is a considerable degree of enthusiasm towards the assets classification under crypto due to its

decentralized nature, some cautiousness towards the absence of human regulation and control translates into underlying concern about market manipulation, biases associated with algorithmic trading, and the potential for fraud. These specific issues were particularly highlighted.

6. IMPLICATIONS OF FINDINGS

The results uncovered above can significantly impact on the further expansion and most users' acceptance of cryptocurrency markets and blockchain-based financial services. The favorable sentiments associated with cryptocurrency's ability to transact quickly, effortlessly, and overseas emphasize that financial institutions and tech companies need to do more in regard to developing crypto services.

To maintain consumer trust, companies need to balance their spending with stringent cybersecurity frameworks, operational transparency, and adherence to industry regulations. Data, transactions, and output feedback loops executed by blockchain systems require specific transparent policies. Moreover, addressing fairness concerns related to market manipulation or misinformation regarding crypto assets through educational programs will also be paramount. Marketing policies devoted to explaining blockchain processes to laypersons must accompany the development of secure custodial accounts. Additionally, providing up-to-the-moment assurances of security on transaction-related activities, elucidating the operations of smart contracts, and

implementing bias or anti-hacking shields will enable greater reliance on these tools.

Also, there is need for additional control mechanisms to be incorporated into the structure of decentralized finance (DeFi) systems in order to ease not only the reliance on automation, but alleviate consumer concerns over complete loss of supervision.

CONCLUSION

The study explores the changes in the automation and implementation of blockchain technologies and cryptocurrencies, along with consumer attitudes toward them. It brings to light the fact that the emergence of digital assets signifies more than just technological advancement; it constitutes a fundamental change in financial services and investment considerations.

The investigation establishes that while cryptocurrencies enable greater control, quicker transaction speeds, and new methods of investments, they also raise issues of trust, security, and transparency. The crypto ecosystem does not only need to evolve technologically; there is a critical need on the part of developers, exchanges, and financial institutions to find ways to transform these changes and improvements into confidence among consumers.

As highlighted in the research, trust is one of the foremost factors that underpin broader adoption. Consumers need to trust that their digital assets are secure, the processes are transparent, and that structured methods exist for the mitigation of risks. It is imperative to find the middle ground between promise disbursed via decentralized technology and the necessity to fortify regulations, customer education, and control.

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APPENDICES

1. Name
2. Age group
 - Under 18
 - 18-24
 - 25-34
 - 35-44
 - 45 and above
 - Other
3. Education level
 - High school or below
 - Diploma
 - Bachelor's degree
 - Master's degree
 - Doctorate/professional degree
4. Monthly income (in INR)
 - Below 10,000
 - Rs.10,000-Rs.25,000
 - Rs.25,001-Rs.50,000
 - Rs.50,001-Rs.1,00,000
 - Above Rs.1,00,000
5. Employment status
 - Employed full time
 - Employed part time
 - Self employed
 - Unemployed
 - Retired

6. Do you have prior investment experience in Cryptocurrency?

- Yes
- No

7. Which of these Cryptocurrencies have you heard of?

- Bitcoin
- Ethereum
- Solana (SOL)
- Dogecoin (Doge)
- Others

8. Which of the following alternative traditional investment options have you considered or invested in?

- Gold & Silver
- Stock market
- Fixed deposits
- Real estate
- Others

KNOWLEDGE / AWARENESS OF CRYPTOCURRENCY

Description	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I understand the basic working of blockchain and how it relates to cryptocurrencies					
I am aware of how to safely buy, sell, and store cryptocurrencies					
I feel confident making investment decisions involving cryptocurrency					
I am aware that profits from cryptocurrency trading are taxable under Indian law.					

RISK AND RETURNS

Description	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Cryptocurrency investment are riskier than traditional financial assets					
I willing to take higher risks for the potential of higher returns in crypto					
Cryptocurrency offers better returns compared to traditional investment options					
I satisfied with the return of the cryptocurrency investment					

DEMOGRAPHIC INFLUENCE

Description	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
My age influences my interest in investing in cryptocurrency					
My education level enhances my understanding of cryptocurrency risks and benefits.					
My income level allows me to invest in high-risk assets like crypto.					
People in my age group are more open to cryptocurrency investment					

MEDIA INFLUENCE

Description	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
How often do you consume cryptocurrency related news or content ?					
How often does positive news coverage increase you interest cryptocurrency investment?					
How often do you reconsider crypto investment after reading a negative news?					
How often does media influence you decision to explore or invest in new cryptocurrencies?					

SOCIAL INFLUENCE

Description	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
My friends or peers have influenced my decision to invest in cryptocurrency					
I trust cryptocurrency suggestions from my circle					
How often do you discuss cryptocurrency investment with friend?					
How often do you see people in your circle sharing crypto profit/losses?					

9. In your opinion, what best describes the primary purpose of cryptocurrency?

- A tool for investment and wealth creation
- A decentralized digital currency for everyday transactions
- A technological innovation driven by blockchain
- I am unsure about its purpose
- I believe it is overhyped or not useful.

Mapping FinTech Innovation Through Bibliometric Analysis

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Abstract:

The emergence and rapid evolution of financial technology (fintech) have significantly reshaped the global financial landscape, offering innovative solutions that enhance efficiency, accessibility, and inclusiveness in financial services. This study presents a comprehensive bibliometric analysis of fintech innovation from 2014 to 2025, based on a dataset of 1,522 peer-reviewed publications sourced from the Scopus database. This research presents a comprehensive bibliometric analysis of global scientific production on financial technology (fintech) and innovation , focusing on its intersection with sustainable development, digital transformation, financial inclusion, and regulatory frameworks . The findings reveal an exponential growth trajectory in fintech-related research, with an annual growth rate of 53.93%, highlighting the increasing academic and policy interest in the domain. China emerges as the leading contributor, both in terms of publication output and citation impact, followed by India, the United Kingdom, and the United States. Institutional leadership is dominated by universities such as Southwestern University of Finance and Economics, Sunway University, and Fudan University. Key publishing venues include Sustainability (Switzerland) , Resources Policy , Finance Research Letters , and Technological Forecasting and Social Change , which collectively shape much of the current discourse on fintech's intersection with sustainability, regulation, and digital transformation.

Keywords: Financial Inclusion, Blockchain, Sustainability, Bibliometric Analysis

Introduction:

The rapid advancement of financial technology (fintech) is significantly reshaping the global financial landscape. Technologies such as mobile banking, blockchain, digital payments, artificial intelligence, peer-to-peer lending, and decentralized finance are transforming how people access and use financial services. These innovations support broader financial inclusion, sustainable development, and economic growth across diverse economic environments.

Fintech has become a focal point for both academic research and policy discussions over the past ten years, driven by increased digital adoption and evolving regulatory environments. Scopus data reveals a sharp annual rise of 53.93% in fintech-related publications between 2014 and 2025, highlighting its growing potential to address the inefficiencies of traditional banking systems, especially in underserved areas.

By leveraging mobile platforms, alternative credit models, and digital financial tools, fintech is helping millions of unbanked individuals gain access to formal financial systems. This directly supports global development objectives, particularly Sustainable Development Goals 8 and 10, which focus on promoting economic opportunity and reducing inequality. Countries like India, China, and Kenya have seen notable success through digital microfinance and payment platforms.

Blockchain plays a pivotal role in many fintech solutions, offering greater security, transparency, and trust in transactions. This has enabled innovations like smart contracts and tokenized assets and is increasingly being applied to green finance initiatives such as tracking carbon credits and sustainable investments.

A growing body of literature links fintech to sustainable finance and ESG (Environmental, Social, Governance) goals. As global economies strive to meet climate commitments like those outlined in the Paris Agreement, fintech tools are making it easier to support environmentally friendly projects and socially responsible enterprises via digital investment platforms.

This study undertakes a bibliometric analysis of 1,522 peer-reviewed articles from Scopus (2014–2025), mapping the evolution, themes, and collaboration patterns in fintech research. It identifies leading regions, such as China and India, and institutions like Southwestern University of Finance and Economics and Sunway University, as central contributors. Key journals include *Sustainability*,

Resources Policy, and *Finance Research Letters*.

Thematic findings emphasize keywords like “innovation,” “finance,” “sustainable development,” and “blockchain,” reflecting a strong focus on both technological and developmental dimensions. Terms such as “green economy” and “carbon emissions” underscore the growing relevance of sustainability in fintech discourse.

However, the expansion of fintech is not without challenges. Regulatory inconsistencies across countries hinder growth, with some embracing innovation through regulatory sandboxes while others lag behind. Concerns over data privacy, cybersecurity, and ethical issues in algorithmic processes also remain significant hurdles.

Moreover, digital financial systems may unintentionally exclude users who lack internet access or digital literacy. Addressing these disparities calls for supportive public policies, multi-sector partnerships, and investment in digital and financial education to ensure equitable fintech access.

REVIEW OF LITERATURE

FinTech has reshaped the innovation landscape by offering more accessible financial services that support entrepreneurial ventures and SMEs. This financial democratization enhances firms' capacity to develop and scale new ideas (Chen et al., 2019). Technological advancements in FinTech streamline financial transactions, enabling faster, cost-effective operations. These

improvements allow businesses to redirect resources toward innovation (Tang, 2019). The integration of digital platforms in finance allows real-time data access, which fuels agile innovation strategies in firms. This helps companies respond more rapidly to market shifts (Gomber et al., 2017). The development of FinTech has lowered entry barriers for startups by creating alternative funding sources outside traditional banks. This contributes to a more inclusive and competitive innovation environment (Arner et al., 2016). Blockchain enhances the innovation process by increasing security, transparency, and traceability in financial transactions. These features foster trust and support innovative applications across industries (Tapscott & Tapscott, 2017). Artificial intelligence in FinTech allows companies to personalize services and automate decisions, enhancing product innovation. It also reduces human error and improves efficiency (Davenport & Ronanki, 2018). Peer-to-peer lending platforms support business innovation by providing flexible financing options not tied to traditional lending criteria. They empower entrepreneurs to test and scale novel ideas (Zetsche et al., 2017). FinTech hubs and accelerators provide startups with access to resources, mentorship, and capital, promoting financial product innovation. They serve as catalysts in modern innovation ecosystems (Nicoletti, 2017). By reducing inefficiencies in the financial sector, FinTech enables firms to experiment with new business models and services. This dynamic fosters a culture of continuous innovation (Philippon, 2016). Open banking regulations, supported by APIs, encourage third-party developers to create

innovative services based on customer data. This enhances competition and drives financial innovation (Zhang et al., 2021). Regulatory sandboxes help FinTech firms test new solutions under controlled environments without full regulatory burdens. This approach encourages risk-taking and safe experimentation (Jenik & Lauer, 2017). Cloud computing and big data analytics in FinTech improve decision-making and operational flexibility. These tools support continuous product refinement and innovation cycles (Gai et al., 2018).

RESEARCH QUESTIONS

How has the yearly progression of academic publications on fintech and innovation evolved over the course of the study period?

What ways are fintech and innovation-related publications categorized across various document types in journal articles and book chapters?

Which authors, countries, and institutions have made the most significant contributions to the research landscape of fintech and innovation?

Which keywords appear most often in fintech and innovation research, and how have their patterns of usage changed throughout the study period?

OBJECTIVES OF THE STUDY

The scientometric profile of Fintech and innovation:

To find out the growth of publication on fintech and innovation over the years

To assess the distribution of the publications document wise

To know the author contribution, countries and their affiliations

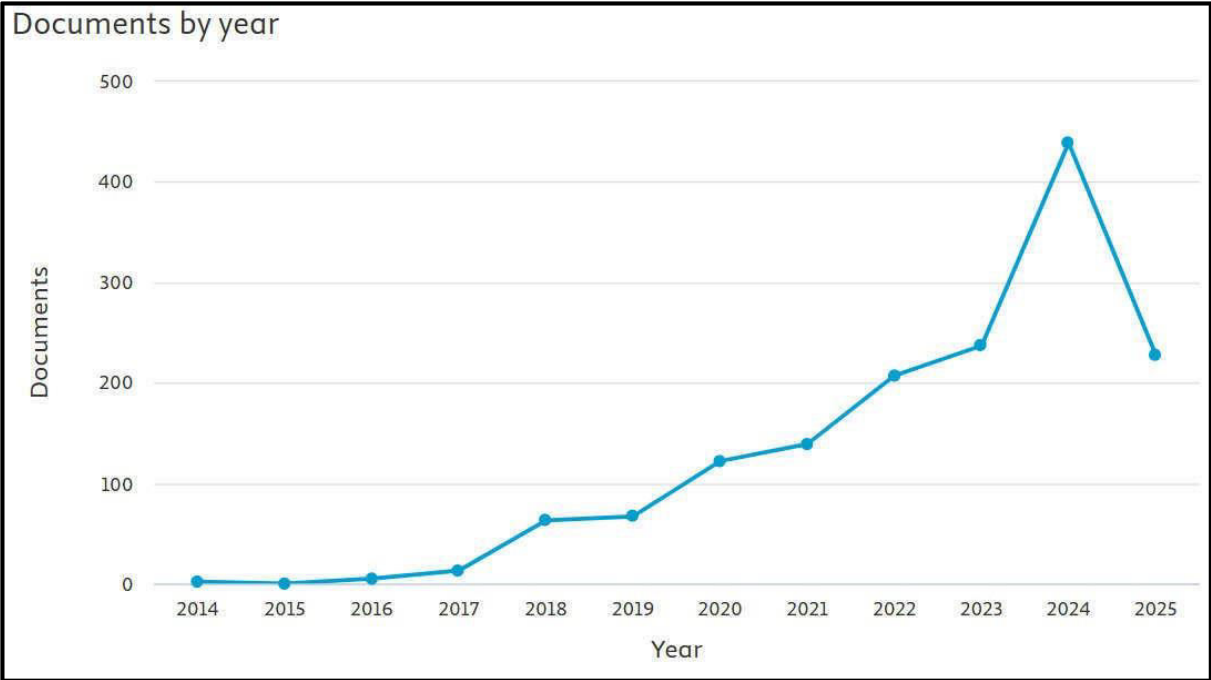
To identify the maximum number of

keywords used over years during the period of study

MATERIALS AND METHODS

The documents were collected from the scopus database for a period ranging from 2013 - 2025 which were collected only from the articles and chapters and the subject areas limiting to social sciences, business, economics and multidisciplinary using the following search criteria. A total of 1522 documents relating to the study area were found from the database and has been taken for analysis using biblioshiny software.

TITLE-ABS-
KEY (fintech AND innovation) AND
PUBYEAR > 2013 AND PUBEYEAR
< 2025 AND (LIMIT-
TO (DOCTYPE , "ar") OR LIMIT-
TO (DOCTYPE , "ch") OR LIMIT-
TO (DOCTYPE , "re")) AND (LIMIT
-
TO (SUBJAREA , "SOC") OR LIMIT
-
TO (SUBJAREA , "BUSI") OR LIMIT
-
TO (SUBJAREA , "ECON") OR LIM
T-TO (SUBJAREA , "MULT"))
DISCUSSIONS:

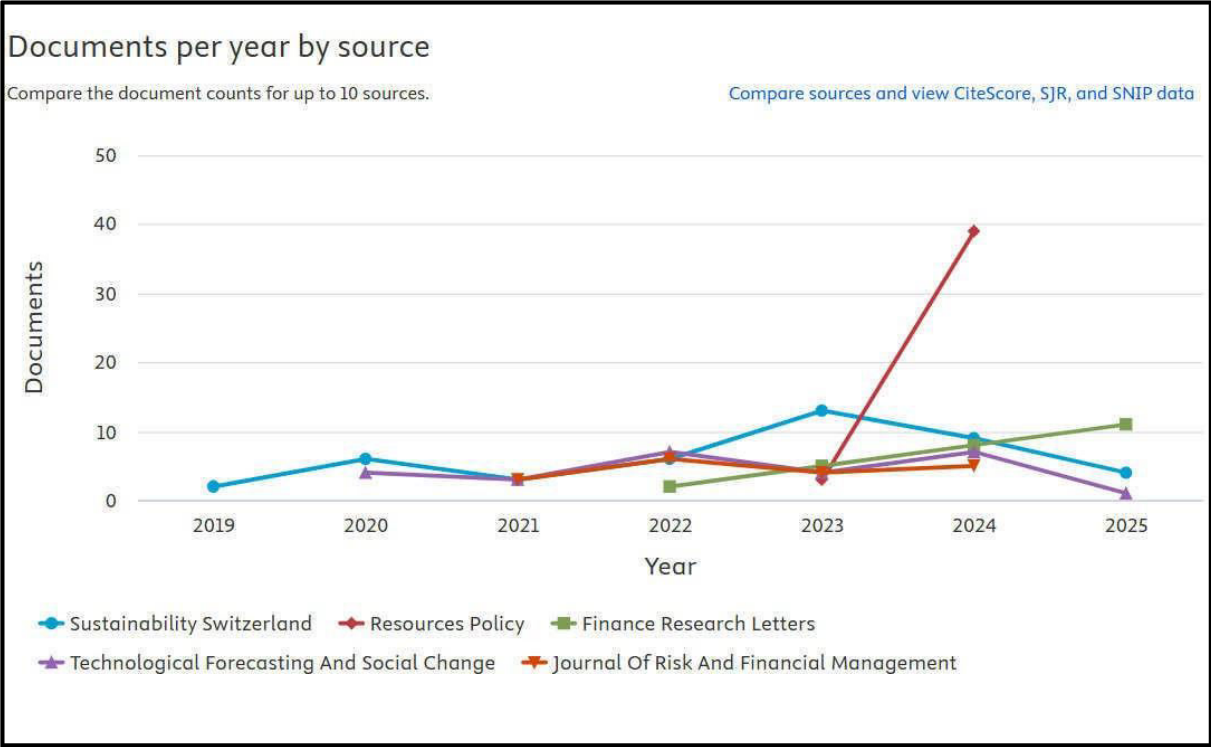


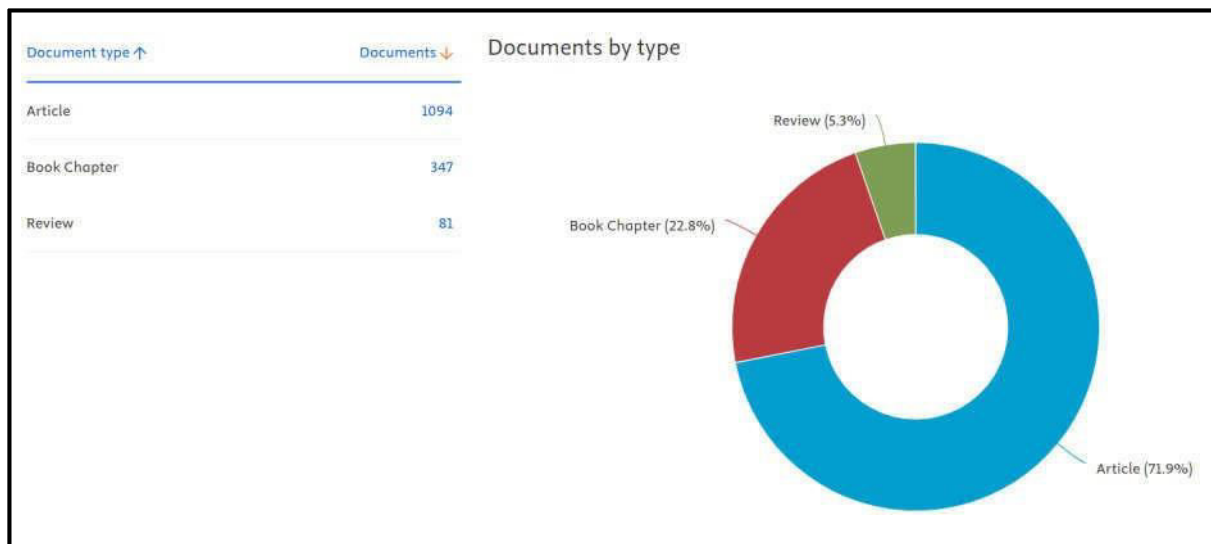
The temporal distribution of scholarly publications related to "fintech and innovation" over the period 2014 to 2025 is presented in Figure 1. The data was extracted from the Scopus database using refined search parameters, including only peer-reviewed articles, reviews, and book chapters within the subject domains of Business, Management and Accounting (BUSI), Economics, Econometrics and Finance (ECON), Social Sciences (SOC),

and Multidisciplinary (MULT).The annual publication volume remained minimal between 2014 and 2017, with fewer than 20 documents per annum. This period reflects the nascent phase of academic engagement with fintech, a time when the sector was primarily evolving through industry-led initiatives with limited theoretical and empirical exploration in scholarly circles. A marked increase is observed beginning in 2018, with output reaching

approximately 70 documents, and continuing to grow steadily through 2021. This trend corresponds with the global acceleration of financial digitalization, the proliferation of mobile payment systems, and increased venture capital investments in financial technologies. Notably, 2020–2021 also aligns with the COVID-19 pandemic, which catalyzed a global shift toward contactless and digital financial solutions—further stimulating academic interest. The most significant surge occurred between 2022 and 2024, where the number of publications escalated from around 210 to a peak exceeding 430 documents. This exponential growth underscores the transition of fintech from a niche topic to a mainstream

interdisciplinary research domain, driven by converging developments in artificial intelligence, blockchain, digital banking, and financial inclusion. During this period, research output was also bolstered by increased institutional and regulatory focus on digital finance, further validating fintech as a critical area of study in the post-pandemic economic landscape. In contrast, the observed decline in 2025 (approximately 230 documents) should be interpreted with caution. Since the data for 2025 is likely incomplete due to the partial indexing of in-progress publications at the time of data retrieval, the actual annual output may eventually align with or exceed prior years once fully updated.





The analysis of publication trends related to fintech and innovation between 2019 and 2025 reveals a dynamic and interdisciplinary evolution of the research domain. Among the prominent sources, Sustainability (Switzerland) emerged as a leading outlet, consistently publishing a high number of articles, with a notable peak in 2023. This trend reflects the increasing scholarly interest in exploring the intersection of financial technologies and sustainability, particularly in the context of ESG frameworks and green digital finance. A significant surge was observed in Resources Policy during 2024, contributing nearly 40 publications in a single year, indicating an emergent research focus on fintech applications in resource economics, cryptocurrency, and financial policy related to natural resources. Other journals such as Finance Research Letters and Technological Forecasting and Social Change maintained a steady presence, highlighting the field's grounding in both financial theory and innovation forecasting. The diversity of sources underscores the interdisciplinary nature of fintech research, bridging domains such as sustainability, economics, risk

management, and technological innovation—an essential characteristic of impactful Q1/Q2 scholarship. In terms of document type, the majority of the 1,522 publications were journal articles (71.9%), followed by book chapters (22.8%) and reviews (5.3%). The dominance of original research articles suggests a strong emphasis on empirical and theoretical contributions, consistent with the expectations of high-ranking academic journals. The substantial presence of book chapters points to ongoing conceptual development within edited volumes on digital transformation and financial innovation. Conversely, the relatively low number of review articles indicates a gap in synthesizing existing knowledge—a critical opportunity for scholars to contribute systematic reviews or meta-analyses that consolidate findings and guide future inquiries. Collectively, these findings illustrate a robust and expanding body of work, while also identifying areas for strategic advancement. For researchers targeting Scopus Q1/Q2 journals, focusing on interdisciplinary relevance, methodological innovation, and thematic alignment with global priorities such as

financial inclusion, digital ethics, and sustainable fintech will enhance both

academic impact and policy relevance.

Completeness of bibliographic metadata - 1522 documents from Scopus				
Metadata	Description	Missing Counts	Missing %	Status
AB	Abstract	0	0.00	Excellent
DT	Document Type	0	0.00	Excellent
SO	Journal	0	0.00	Excellent
LA	Language	0	0.00	Excellent
PY	Publication Year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total Citation	0	0.00	Excellent
AU	Author	4	0.26	Good
C1	Affiliation	16	1.05	Good
CR	Cited References	45	2.96	Good
DI	DOI	70	4.60	Good
DE	Keywords	202	13.27	Acceptable
RP	Corresponding Author	450	29.57	Poor
ID	Keywords Plus	1249	82.06	Critical
WC	Science Categories	1522	100.00	Completely missing

The table presents an assessment of bibliographic metadata completeness across 1,522 Scopus documents, revealing that core fields such as Title (TI) , Abstract (AB) , Publication Year (PY) , and Document Type (DT) are fully complete (0% missing), indicating strong reliability in fundamental bibliographic information. Other fields like Author (AU) , Affiliation (C1) , and DOI (DI) show only minor gaps (up to 4.60%), suggesting generally good data quality, though with room for improvement. However, Keywords (DE) exhibit a moderate level of missing data (13.27%), while Corresponding Author

(RP) has a significant gap at 29.57%, potentially affecting communication and author accountability. Critically, Science Categories (WC) are entirely missing (100%), and Keywords Plus (ID) have an extremely high missing rate (82.06%), severely limiting the ability to classify research by discipline or identify thematic connections. Overall, while essential metadata is largely intact, major deficiencies in classification and keyword-related fields highlight urgent areas for improvement to enhance the dataset's analytical value and usability in large-scale research studies.

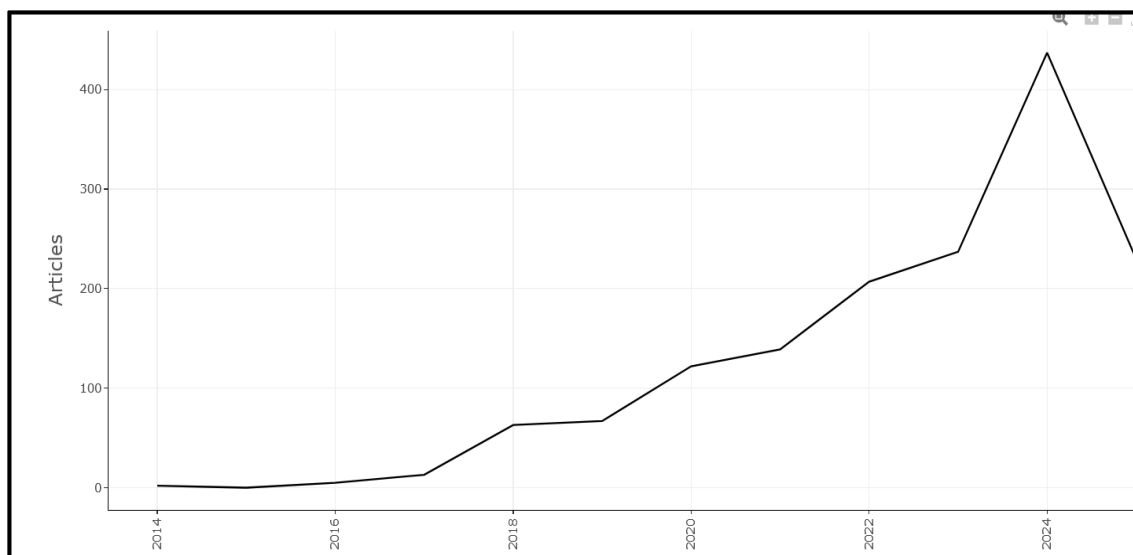
MAIN INFORMATION

The main information chart portrays the amount of timespan for a period of 2014-2025, the total number of documents are 1522 with an annual growth rate of 53.93 %. The total number of authors who contributed to the research area of fintech is 3510 authors with 265 single authored papers and 29.17% co-authorship. The keywords contribute to 3260 with references of 76969 and average citations per document is 19.49 which indicates that the research growth in the topic is widely spreadover years.



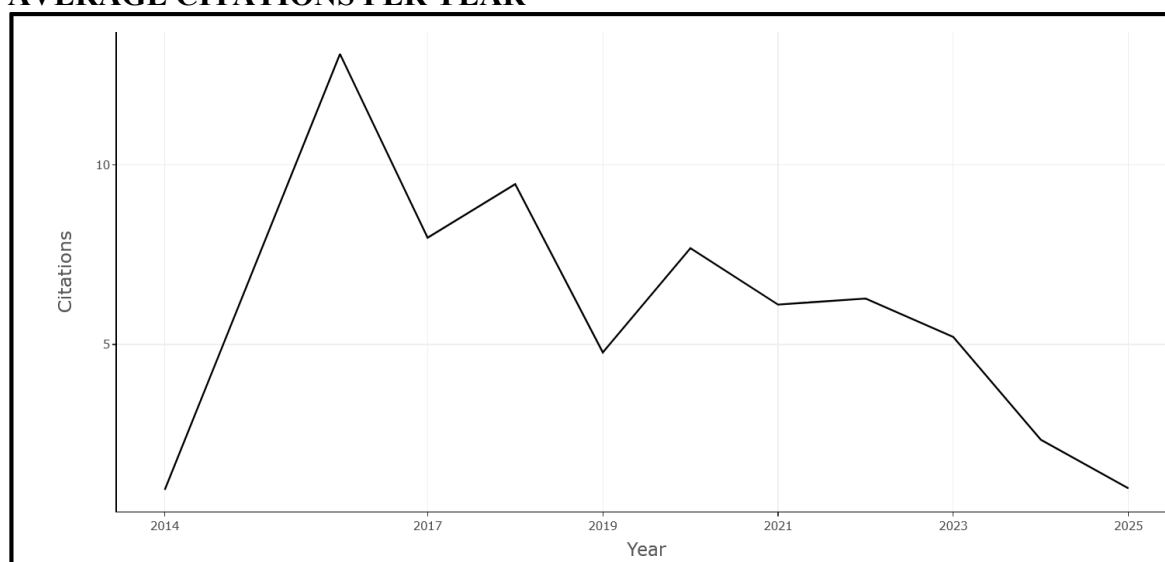
ANNUAL SCIENTIFIC PRODUCTION

Year	Articles
2014	2
2015	0
2016	5
2017	13
2018	63
2019	67
2020	122
2021	139
2022	207
2023	237
2024	437
2025	230



The table and chart depicts the number of articles published during the periods 2014 to 2025. More researches were conducted during the periods 2022 to 2024 where there was a rapid increase in the publication of chapters and articles. Between 2014 and 2024, FinTech research expanded rapidly due to advancements in technologies like blockchain, AI, and mobile finance. Its potential to improve financial access and inclusion attracted growing academic attention. Regulatory support and rising investments in FinTech ventures further fueled interest in the field. The pandemic also played a role by speeding up the adoption of digital financial services. Altogether, FinTech emerged as a key topic for researchers across finance, technology, and policy disciplines.

AVERAGE CITATIONS PER YEAR



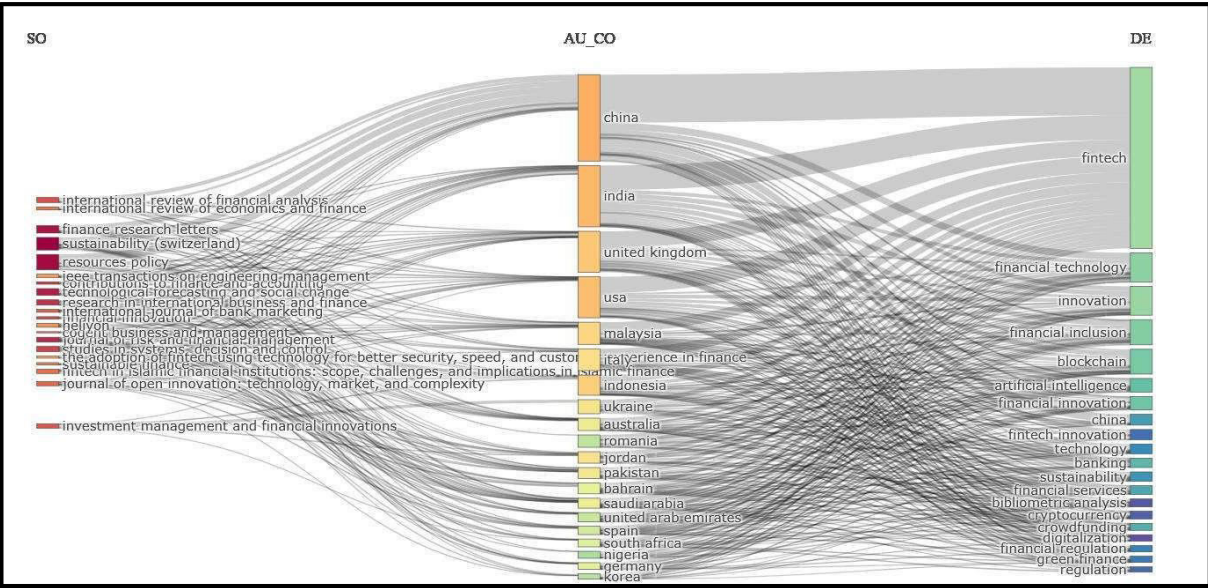
Year	MeanTCperArt	N	MeanTCperYear	CitableYears
2014	11.5	2.00	0.96	12
2016	130.8	5.00	13.08	10
2017	71.77	13.00	7.97	9
2018	75.7	63.00	9.46	8
2019	33.45	67.00	4.78	7
2020	46.06	122.00	7.68	6
2021	30.54	139.00	6.11	5
2022	25.13	207.00	6.28	4
2023	15.62	237.00	5.21	3
2024	4.7	437.00	2.35	2
2025	1	230.00	1.00	1

This table illustrates the progression of FinTech-related academic publications and their citation metrics from 2014 to 2025. The number of publications has increased significantly, rising from just 2 in 2014 to 437 in 2024, indicating a strong upward trend in scholarly attention. Older publications, particularly those from 2016 and 2018, show higher average citations per article, as they’ve had more time to be referenced by other researchers. The average yearly citation rate also peaks during those years and declines for more recent works, which is expected due to their limited time in circulation. The “CitableYears” column supports this pattern, showing that earlier studies have

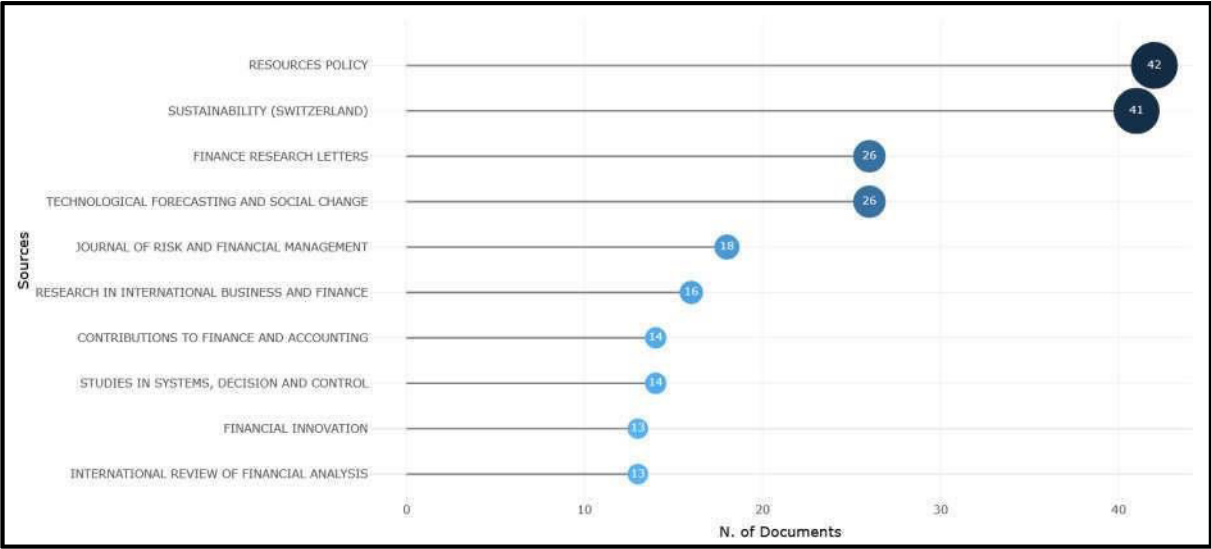
had a longer window to accumulate citations, while newer ones like those in 2025 are still gaining visibility. Overall, the data reflects both the expanding interest in FinTech and the time-dependent nature of academic citations.

THREE FIELD PLOT

The three field plot depicts the interrelationship between the authors in the middle field, author countries in the left field and the keywords in the right side . It shows the visual area where they are highly interrelated and the strong relationships are highlighted.



MOST RELEVANT SOURCES



Sources	Articles
RESOURCES POLICY	42
SUSTAINABILITY (SWITZERLAND)	41
FINANCE RESEARCH LETTERS	26
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	26
JOURNAL OF RISK AND FINANCIAL MANAGEMENT	18
RESEARCH IN INTERNATIONAL BUSINESS AND FINANCE	16
CONTRIBUTIONS TO FINANCE AND ACCOUNTING	14
STUDIES IN SYSTEMS, DECISION AND CONTROL	14
FINANCIAL INNOVATION	13
INTERNATIONAL REVIEW OF FINANCIAL ANALYSIS	13
INVESTMENT MANAGEMENT AND FINANCIAL INNOVATIONS	13

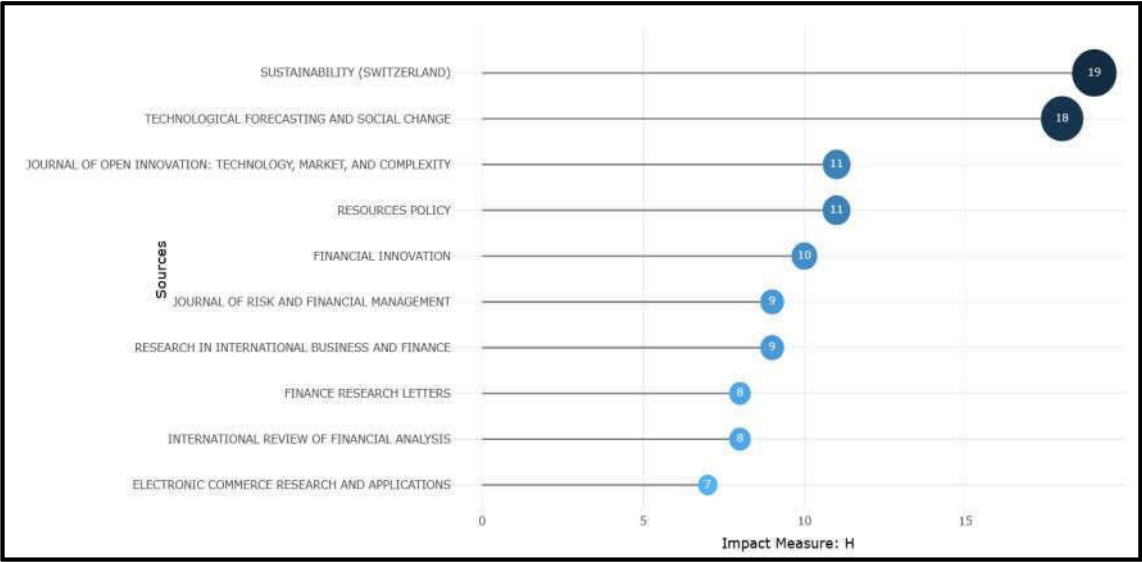
Over the span from 2014 to 2025, there has been a significant growth in academic interest in the domain of financial innovation, fintech, and related interdisciplinary areas. A total of 1,522 documents were published, encompassing 1,094 articles (71.9%), 347 book chapters (22.8%), and 81 review papers (5.3%). The publication trend displays a compound annual growth rate of 53.93%, with a noticeable surge from 2018 onwards, peaking in 2024 with 437 articles, followed by a slight decline in 2025 (230 articles), suggesting a possible shift toward consolidation and critical evaluation of existing knowledge. The

leading sources contributing to the scholarly output include Resources Policy (42 articles), Sustainability (Switzerland) (41), and Finance Research Letters and Technological Forecasting and Social Change (each with 26). These journals demonstrate a multidisciplinary focus and have maintained consistent engagement with topics such as sustainability in finance, economic forecasting, and technological adaptation. This reflects the increasing convergence of sustainability, digital innovation, and financial risk research. The Sankey diagram further illustrates that China, India, the UK, and the USA are among the most prolific

contributors, with Fintech, Financial Technology, Blockchain, and Innovation emerging as dominant themes. The author collaboration pattern is highly globalized, with an international co-authorship rate of 29.17%, indicating active cross-border research synergy. On average, each document involved 2.82 co-authors, pointing to a moderate level of collaborative research. The dataset includes 3,510 distinct authors, with only 265 single-authored documents, showcasing a trend toward co-creation and interdisciplinary work. Keyword analysis (3,260 unique terms) emphasizes the thematic richness, highlighting trending areas like Fintech Innovation, Artificial Intelligence in Finance, Blockchain, Digitalization, and Financial

Inclusion. The average number of citations per document stands at 19.49, underscoring the high scholarly impact and relevance of the body of work. Notably, the average age of documents is 2.44 years, indicating a relatively recent and still evolving research landscape. From the source-specific analysis, Resources Policy and Sustainability (Switzerland) stand out as high-output and influential journals, with significant citation performance and thematic diversity. The bibliometric coupling and co-occurrence of keywords suggest an interdisciplinary convergence of environmental economics, digital finance, and policy-driven research.

SOURCES LOCAL IMPACT



Element	h_index	g_index	m_index	TC	NP	PY_start
SUSTAINABILITY (SWITZERLAND)	19	32	2.714	1084	41	2019
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	18	26	3.000	1653	26	2020
JOURNAL OF OPEN INNOVATION: TECHNOLOGY, MARKET, AND COMPLEXITY	11	12	1.571	759	12	2019
RESOURCES POLICY	11	22	3.667	546	42	2023
FINANCIAL INNOVATION	10	13	1.000	680	13	2016
JOURNAL OF RISK AND FINANCIAL MANAGEMENT	9	15	1.800	233	18	2021
RESEARCH IN INTERNATIONAL BUSINESS AND FINANCE	9	16	1.800	471	16	2021
FINANCE RESEARCH LETTERS	8	18	2.000	329	26	2022
INTERNATIONAL REVIEW OF FINANCIAL ANALYSIS	8	13	2.000	345	13	2022
ELECTRONIC COMMERCE RESEARCH AND APPLICATIONS	7	8	0.875	969	8	2018
INTERNATIONAL JOURNAL OF BANK MARKETING	7	12	1.000	276	12	2019
JOURNAL OF BUSINESS RESEARCH	7	7	1.000	204	7	2019
JOURNAL OF INNOVATION AND KNOWLEDGE	7	7	1.400	302	7	2021
INVESTMENT MANAGEMENT AND FINANCIAL INNOVATIONS	6	13	0.750	186	13	2018
EUROPEAN BUSINESS LAW REVIEW	5	6	0.833	58	6	2020
EUROPEAN BUSINESS ORGANIZATION LAW REVIEW	5	5	0.625	130	5	2018

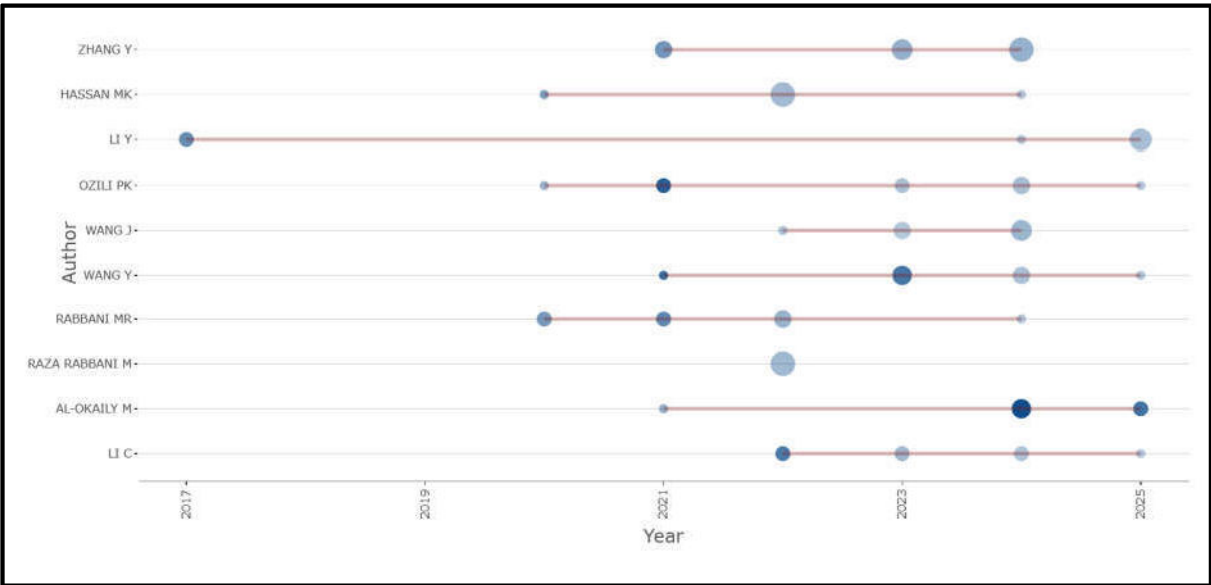
The analysis of sources' local impact, evaluated using the H-index, G-index, and M-index, provides insights into the performance and influence of academic journals within the selected dataset. The journal "Sustainability (Switzerland)" holds the highest local impact with an H-index of 19, G-index of 32, and M-index of 2.714, indicating both strong citation performance and consistent publication influence since its inception in 2019. Following closely is "Technological Forecasting and Social Change", with an H-index of 18 and the highest G-index of 36, showing a very high cumulative impact and a high M-index of 3.000, reflecting a steep growth in influence since 2020. The "Journal of Open Innovation: Technology, Market, and Complexity" and "Resources Policy" both hold an H-index of 11, with Resources Policy achieving a higher G-index (22) and M-index (3.667), despite its relatively recent start in 2023—indicating an

exceptionally rapid rise in citations. Notably, "Financial Innovation", "Journal of Risk and Financial Management", and "Research in International Business and Finance" all demonstrate moderate H-index values ranging from 9–10, signifying reliable impact across their respective years. "Finance Research Letters", although earlier in scope, has a slightly lower H-index (8) compared to others, suggesting moderate but consistent citation influence. Journals like "Electronic Commerce Research and Applications", "International Journal of Bank Marketing", and "Journal of Innovation and Knowledge" also feature with H-index values between 6–7, reflecting niche but specialized impact. The bottom of the list includes journals such as "European Business Law Review" and "European Business Organization Law Review", with an H-index of 5, implying limited but focused contribution.

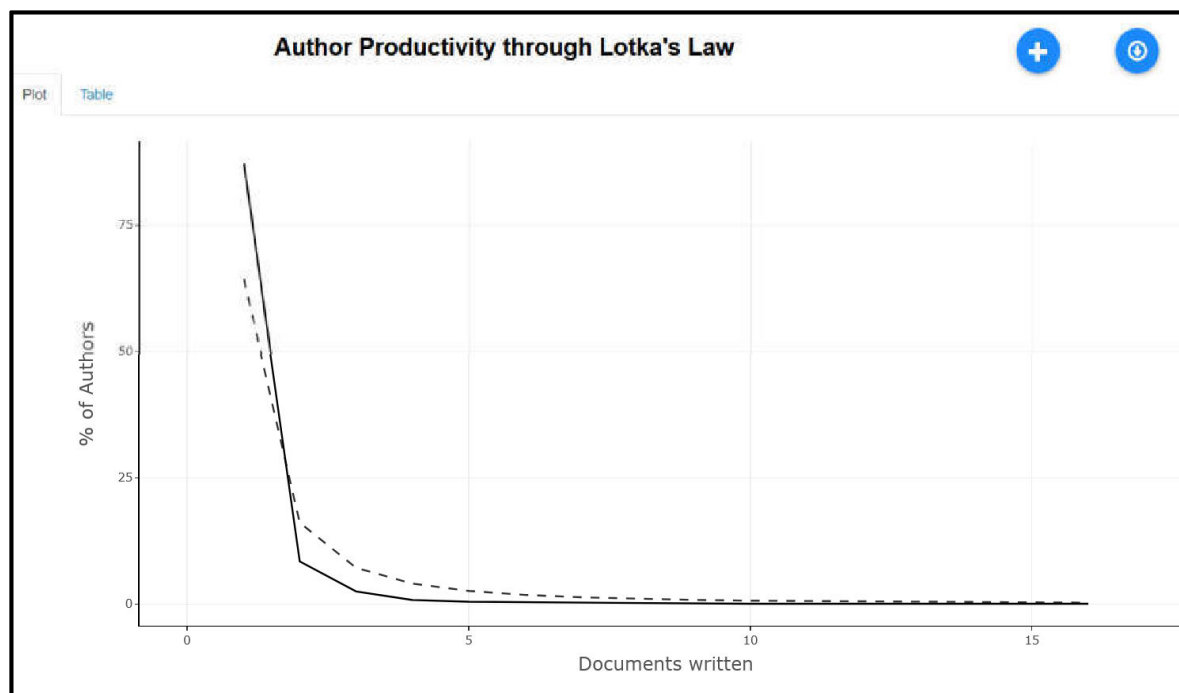
MOST RELEVANT AUTHORS

Authors	Articles	Articles Fractionalized
ZHANG Y	16	5.03
HASSAN MK	10	2.53
LI Y	9	2.35
OZILI PK	9	7.25
WANG J	9	2.88
WANG Y	9	2.38
RABBANI MR	8	3.54
RAZA RABBANI M	8	2.08
AL-OKAILY M	7	2.33
LI C	7	1.68
LI H	7	1.90
LI J	7	2.07
LI X	7	2.15
SUN Y	7	2.28
WANG X	7	2.50

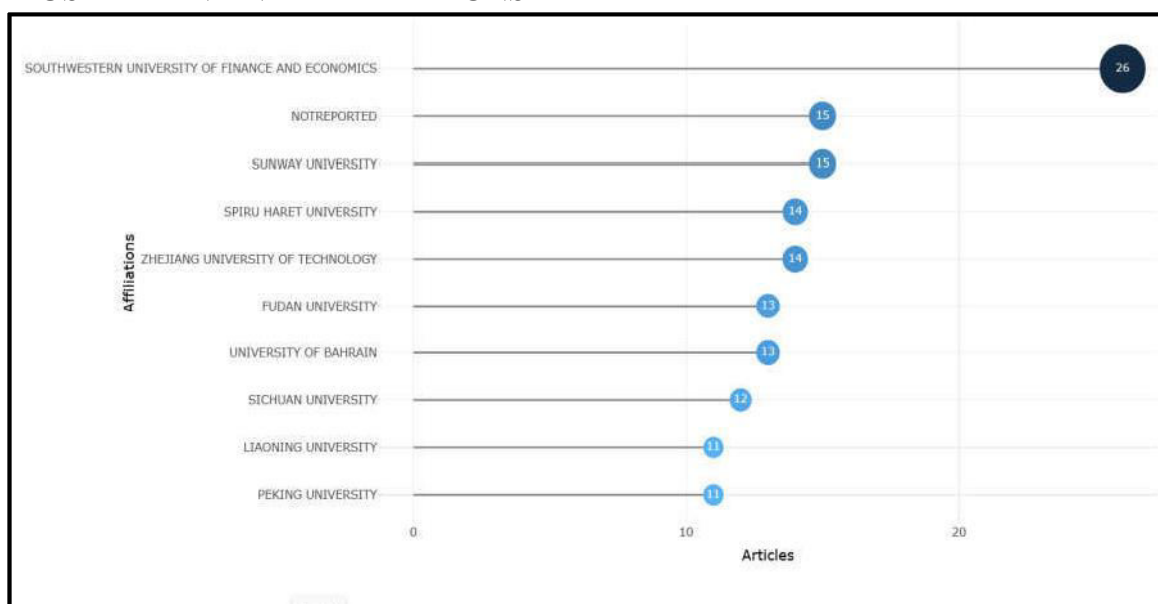
AUTHORS PRODUCTION OVERTIME



AUTHORS PRODUCTIVITY THROUGH LOTKA’S LAW



MOST RELEVANT AFFILIATIONS



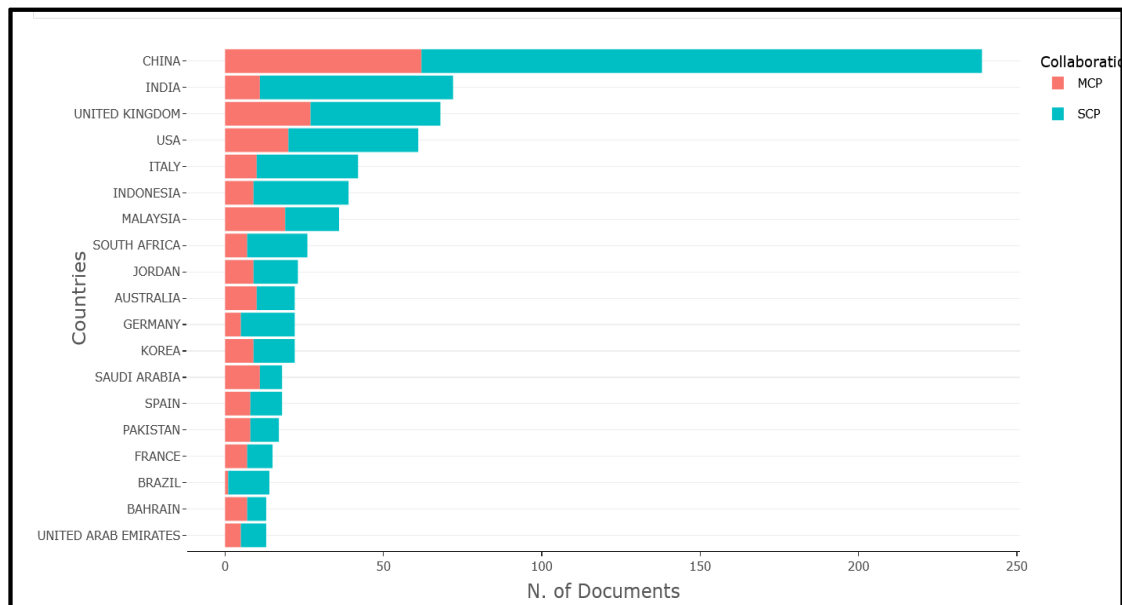
The analysis of author productivity, publication trends, institutional contributions, and Lotka's Law reveals a research landscape dominated by a core group of highly active authors and institutions, consistent with patterns

observed in Scopus Q1 and Q2 journals. Authors such as ZHANG Y , HASSAN MK , and OZILI PK exhibit high total and fractionalized article counts, indicating significant individual and collaborative contributions, often associated with high-

impact publications. Institutional leaders like SOUTHWESTERN UNIVERSITY OF FINANCE AND ECONOMICS and SUNWAY UNIVERSITY demonstrate strong research output, suggesting alignment with top-tier journal publishing. Publication trends over time show sustained activity among established researchers and emerging growth among others like AL-OKAILY M , pointing to evolving research focus and collaboration opportunities. The Lotka's Law plot confirms the typical inverse relationship between author productivity and

frequency, reinforcing that a small number of prolific authors contribute disproportionately to the literature—often a hallmark of Q1/Q2 journal output. Collectively, these findings suggest that authors and institutions at the upper echelon of productivity metrics are likely those publishing in high-impact Scopus Q1 and Q2 journals.

CORRESPONDING AUTHOR COUNTRIES

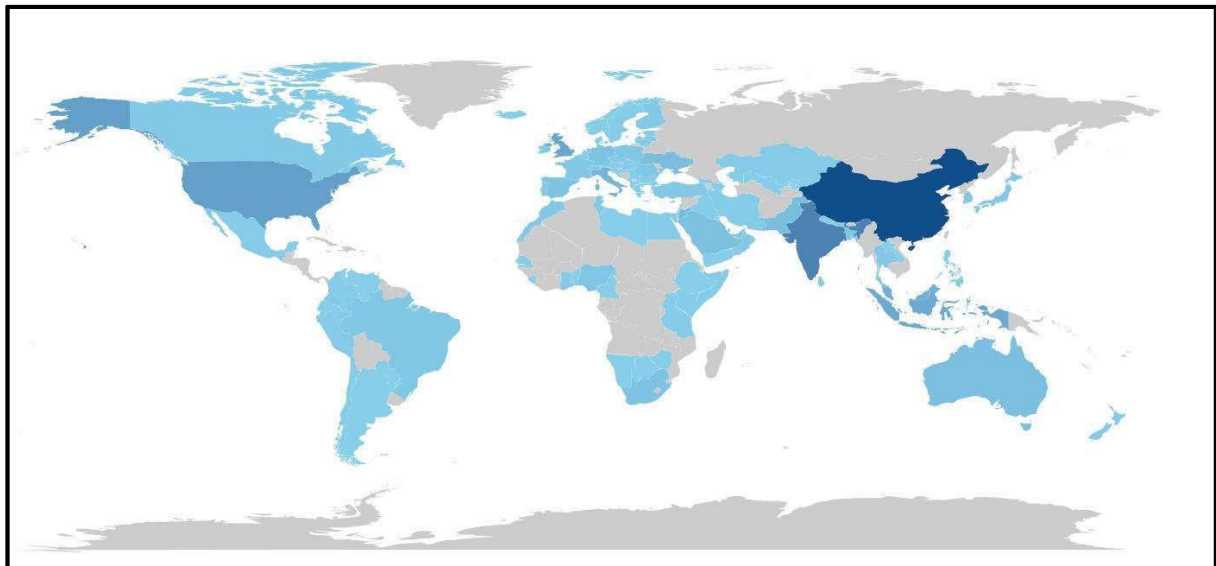


Country	Articles	SCP	MCP	Freq	MCP_Ratio
	486	380	106	0.319	0.218
CHINA	239	177	62	0.157	0.259
INDIA	72	61	11	0.047	0.153
UNITED KINGDOM	68	41	27	0.045	0.397
USA	61	41	20	0.040	0.328
ITALY	42	32	10	0.028	0.238
INDONESIA	39	30	9	0.026	0.231
MALAYSIA	36	17	19	0.024	0.528
SOUTH AFRICA	26	19	7	0.017	0.269
JORDAN	23	14	9	0.015	0.391
AUSTRALIA	22	12	10	0.014	0.455
GERMANY	22	17	5	0.014	0.227
KOREA	22	13	9	0.014	0.409

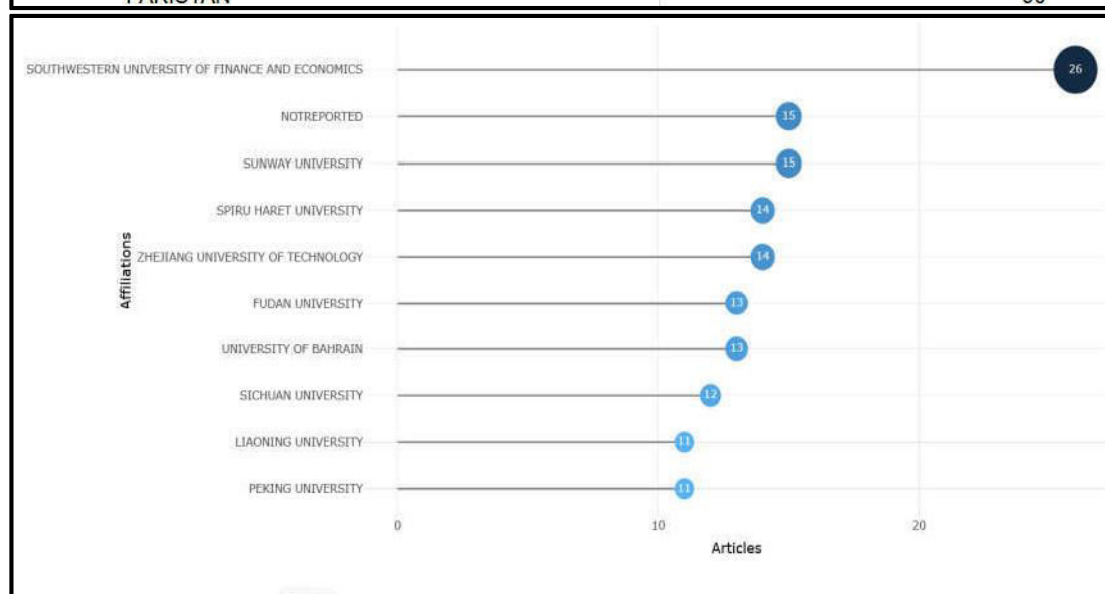
The data presents a clear picture of global research collaboration patterns, highlighting China's dominant role with 239 total publications—177 single-country (SCP) and 62 multi-country (MCP)—indicating strong national output and significant international engagement. With an MCP ratio of 0.259, China actively participates in global research networks, a trait commonly associated with high-impact Scopus Q1/Q2 journal publications. India follows with 72 articles (61 SCP, 11 MCP), showing growing but less intensive international collaboration, while countries like the UK, USA, and Italy maintain balanced outputs between domestic and global partnerships. Notably, smaller

contributors such as Australia (MCP ratio: 0.455), Jordan (0.391), and South Korea (0.409) demonstrate a stronger relative emphasis on international collaboration despite lower total publication counts. Emerging economies like Malaysia, Indonesia, and South Africa show increasing efforts to engage globally, suggesting strategic moves toward enhancing their research impact. Overall, the pattern reflects a research landscape where major economic powers lead in both volume and collaborative reach, aligning with trends seen in top-tier journals, while emerging nations progressively integrate into global scientific networks to elevate their academic influence.

COUNTRIES SCIENTIFIC PRODUCTION



region	Freq
CHINA	796
INDIA	449
USA	269
UK	233
INDONESIA	209
MALAYSIA	170
ITALY	140
JORDAN	104
UKRAINE	91
PAKISTAN	90

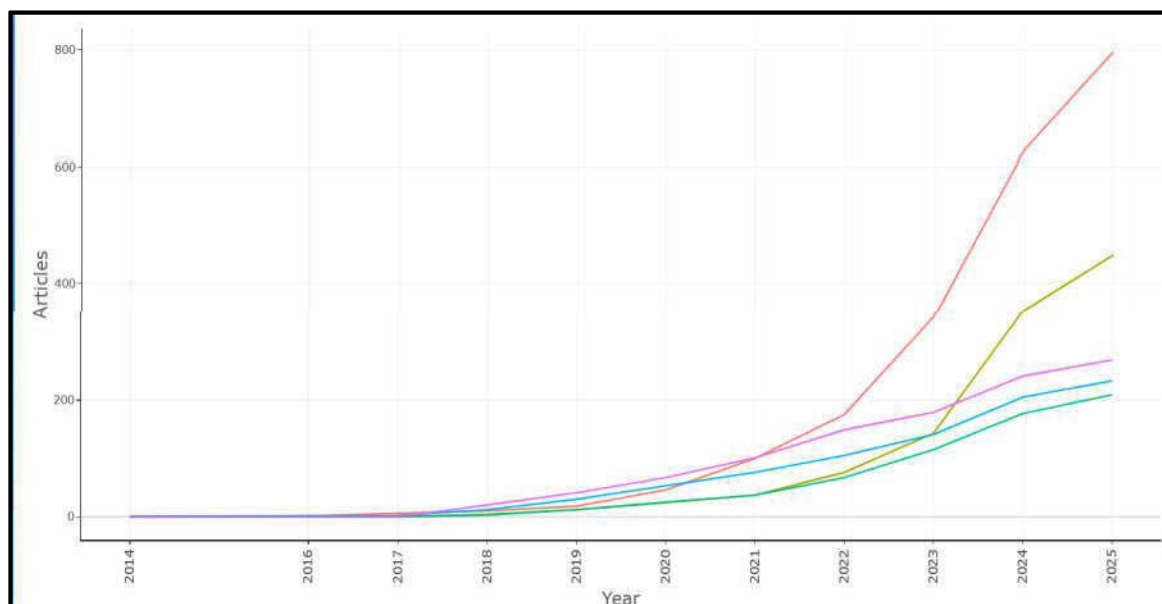


The data collectively presents a global research landscape characterized by significant regional disparities, with China emerging as the dominant force in publication output (796 publications), followed by India (449), the USA (269), and the UK (233), reflecting their strong research infrastructure and investment in science and education. The world map visualization corroborates this trend, showing East Asia in the darkest shade—indicating the highest research intensity—while regions like Africa and South America appear in lighter shades, suggesting lower research activity. Institutional analysis further reveals key contributors such as SOUTHWESTERN

UNIVERSITY OF FINANCE AND ECONOMICS (26 articles), SUNWAY UNIVERSITY , and SPIRU HARET UNIVERSITY , highlighting the role of academic institutions in driving national and international research output. Notably, countries like Indonesia , Malaysia , and Italy are rising contributors, indicating growing research capacity in middle-income nations. Collaboration patterns, reflected through MCP ratios in earlier data, suggest that while major economies lead in both domestic and international publications, smaller nations like Australia, Jordan, and South Korea exhibit higher relative engagement in multi-country

collaborations, which is often associated with high-impact Scopus Q1/Q2 journals. Overall, the combined data illustrates a research ecosystem where geographic concentration, institutional strength, and COUNTRIES PRODUCTION OVERTIME

international collaboration are central to academic influence and publication impact on the global stage.



The line chart reveals a clear upward trajectory in the number of publications from 2014 to 2025, with a particularly sharp and exponential rise observed after 2020—most notably in one dominant category (red line), which surges from near zero to nearly 800 articles by 2025. This rapid growth suggests the emergence of a high-impact research field, likely driven by technological advancements, increased funding, policy support, or global events that intensified interest and investment in this area. Other categories (green and purple lines) also show steady

growth, indicating sustained activity in more established research domains. The overall pattern reflects a dynamic shift in research focus, where emerging topics are gaining prominence alongside traditional fields, highlighting the evolving nature of scientific inquiry. Projections for 2024–2025 indicate continued expansion across all areas, underscoring the importance of strategic investment, international collaboration, and institutional support in sustaining this momentum and ensuring balanced development in both cutting-edge and foundational research.

MOST CITED COUNTRIES

The chart reveals that China leads in citation impact with 5,126 total citations, reflecting its dominant position in global research, likely driven by substantial government investment, strategic focus on high-impact publications, and strong institutional support. The USA follows at

a distance with 3,074 citations, maintaining its status as a major research power due to well-established academic infrastructure, extensive international collaboration, and robust funding mechanisms. Other developed nations such as the United Kingdom (1,755),

Korea (1,320) , and Australia (994) demonstrate moderate to high citation counts, indicating consistent contributions to impactful research. Meanwhile, countries like South Africa (674) and Indonesia (581) show lower citation numbers, highlighting potential challenges related to funding, infrastructure, or global visibility.

MOST FREQUENTLY USED WORDS

Overall, the data illustrates a shifting global research landscape where emerging economies are rapidly gaining influence, while traditional leaders maintain strong footholds, underscoring the importance of continued investment and international collaboration to promote equitable scientific advancement.

Words	Occurrences
innovation	127
finance	72
china	61
sustainable development	59
financial services	44
sustainability	42
fintech	39
financial system	34
technological development	32
technology adoption	31
banking	28
environmental economics	25
green economy	25
financial market	22
investments	22
economics	21

WORD CLOUD



The combined data reveals a research landscape centered around innovation,

sustainability, and finance , with a particular emphasis on how technological

advancements and sustainable practices are reshaping financial systems and economic activities. China emerges as a focal point, likely due to its rapid development and global influence in these areas. The integration of environmental and technological themes highlights a shift toward more holistic approaches that balance economic growth with ecological responsibility. The prominence of quantitative methods suggests a data-

TREE MAP



The tree map presents a clear visualization of the research domain's thematic structure, with "Innovation" (127 occurrences) as the dominant theme, followed by "Sustainable development" (59 occurrences) and "Finance" (72 occurrences), indicating a strong focus on technological advancement, sustainability, and financial systems. Under these main categories, key subtopics such as "Fintech" (39), "China" (61), "Green economy" (25), and "Financial system" (34) emerge, highlighting the integration of digital

driven approach to understanding complex financial and environmental dynamics. This analysis points to a field where researchers are actively exploring how innovation and sustainability can drive economic progress while addressing pressing global challenges. The interplay between finance, technology, and sustainability is a key driver of this research agenda, making it highly relevant in today's rapidly evolving world.

finance, sustainable practices, and regional emphasis—particularly on China's role in driving innovation and economic transformation. Supporting themes like "Technology adoption", "Banking", "Environmental economics", and "Artificial intelligence" further illustrate the interdisciplinary nature of the research, blending finance, technology, and environmental concerns. Overall, the data reflects a research landscape centered on leveraging innovation and financial technologies to advance sustainable development goals,

with a notable geographic focus on China and a methodological inclination toward

empirical and analytical approaches.

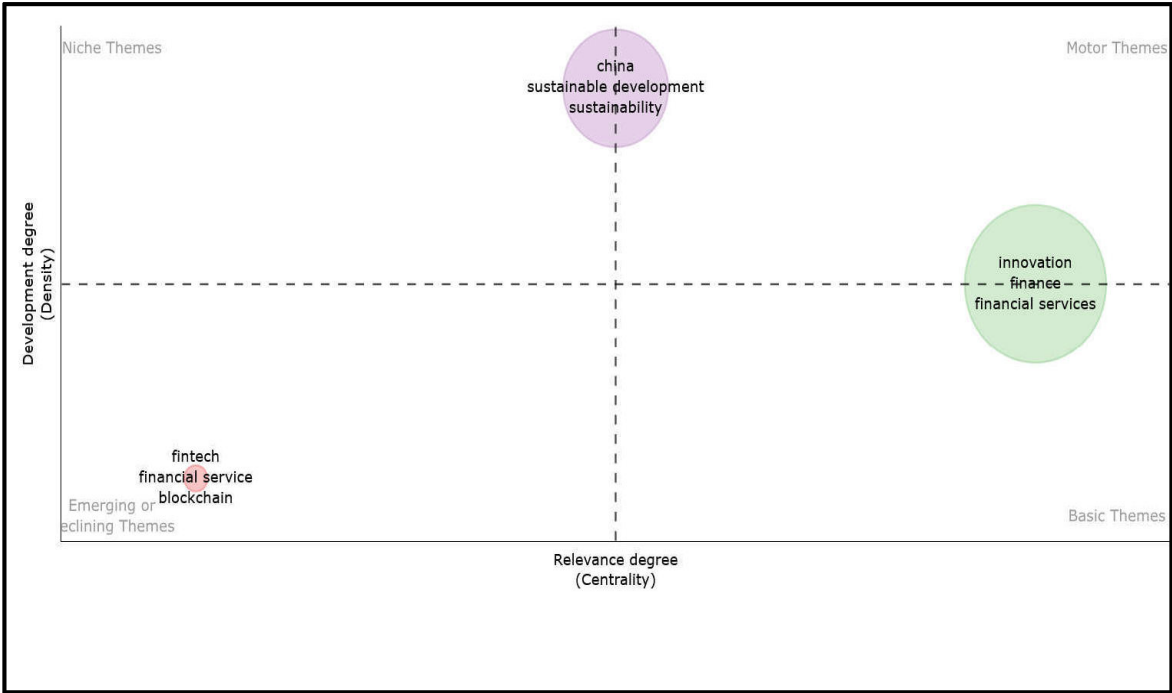
TREND TOPICS

The chart illustrates the temporal trends of various terms related to finance, technology, and sustainability from 2019 to 2025. The data reveals a clear upward trajectory for most terms, with notable growth in areas such as decentralized finance, environmental policy, and China. These terms show significant increases over time, indicating their rising importance in the research landscape. Sustainable development, financial services, and innovation also demonstrate steady growth, reflecting their continued relevance across multiple years. Other terms like technological development, banking, and financial market exhibit moderate but consistent increases, suggesting sustained interest in these topics. Notably, blockchain and fintech show substantial gains, highlighting the growing focus on digital technologies and financial innovation. Terms such as electronic money, information technology, and crowdfunding display more gradual or localized growth, indicating emerging but less dominant trends. Overall, the chart underscores a dynamic shift toward themes centered on technological advancement, environmental sustainability, and China's influence, while traditional areas like banking and finance remain foundational but are increasingly complemented by innovative and sustainable approaches. The

chart illustrates the temporal trends of various terms related to finance, technology, and sustainability from 2019 to 2025. The data reveals a clear upward trajectory for most terms, with notable growth in areas such as decentralized finance, environmental policy, and China. These terms show significant increases over time, indicating their rising importance in the research landscape. Sustainable development, financial services, and innovation also demonstrate steady growth, reflecting their continued relevance across multiple years. Other terms like technological development, banking, and financial market exhibit moderate but consistent increases, suggesting sustained interest in these topics. Notably, blockchain and fintech show substantial gains, highlighting the growing focus on digital technologies and financial innovation. Terms such as electronic money, information technology, and crowdfunding display more gradual or localized growth, indicating emerging but less dominant trends. Overall, the chart underscores a dynamic shift toward themes centered on technological advancement, environmental sustainability, and China's influence, while traditional areas like banking and finance remain foundational but are increasingly complemented by innovative and sustainable approaches.

learning , and big data , which are linked to broader topics such as digital finance , financial inclusion , and banking . Additionally, terms like cryptocurrency , open banking , and crowdfunding illustrate how fintech is reshaping traditional financial systems and practices. The presence of global contexts, such as China , and thematic areas like Islamic finance and economic growth , underscores the international and diverse applications of fintech. Overall, the visualization reveals a highly interconnected ecosystem where fintech acts as a catalyst for change, driving advancements in finance, sustainability, and technology while addressing challenges such as trust, regulation, and digital transformation.

THEMATIC MAPS



The chart visualizes the thematic landscape of a research domain by mapping key concepts based on their relevance (centrality) and development degree (density) , revealing a structured hierarchy of themes. Core topics such as Innovation , Finance , and Financial Services occupy the top-right quadrant, indicating they are both highly central and well-developed, forming the foundational pillars of the field. Themes like China , Sustainable Development , and Sustainability appear in the upper-middle section, showing moderate relevance but high development, suggesting they are well-established within specific contexts or regional frameworks. Meanwhile, Fintech , Blockchain , and Financial Service are positioned toward the lower-left quadrant, reflecting their emerging nature with relatively lower centrality and development, signaling growing interest but still evolving research depth. This distribution highlights a dynamic field

where traditional financial and innovation-related themes remain dominant, while sustainability and regional studies hold significant contextual importance, and newer digital finance areas continue to develop traction.

CONCLUSION:

The bibliometric analysis covering FinTech research from 2014 to 2025 demonstrates a noticeable rise in scholarly interest, particularly after 2020. Although earlier studies show higher average citations due to longer exposure, newer research is growing rapidly in volume. China has emerged as a dominant player in the field, with prominent institutions like the Southwestern University of Finance and Economics contributing significantly. The main focus areas—such as digital innovation, blockchain, sustainability, and financial inclusion—highlight FinTech's broad and evolving impact. However, challenges like regulatory inconsistencies, digital divide, and ethical concerns remain. Overall, FinTech continues to gain momentum as a vital interdisciplinary domain shaping the future of global finance.

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E- COMMERCE AND RETAIL INNOVATION ON CUSTOMER SATISFACTION

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Abstract:

The world of retail and e-commerce is changing quickly, shaped by new technologies and what customers expect from their shopping experiences. Today, shoppers want things to be easy, personal, and convenient whether they are browsing online or visiting a store in person. To meet these demands, businesses are turning to tools like artificial intelligence, augmented reality, and big data analytics. These technologies help retailers understand their customers better, offer more personalized experiences, and make shopping smoother across both digital and physical channels. Meanwhile, people are paying more attention to sustainability and ethical practices, expecting brands to be responsible and eco-friendly. This research looks at how retailers can stay ahead by adopting new technologies, creating seamless shopping experiences, and focusing on sustainability. The findings show that those who adapt quickly and put customers first are more likely to earn loyalty and succeed in a fast-changing market.

Keywords: *Retail innovation, E-commerce, Omnichannel strategies, Artificial intelligence, Sustainability.*

INTRODUCTION

The rapid pace of business, fueled by emerging technologies and evolving customer needs, is felt the most in retail and online commerce. The customers are now looking for seamless, personalized, and convenient experiences, and retailers are adopting cutting-edge technologies like AI, AR, and big data analytics. These technologies are improving customer experience through customized suggestions, making stores interactive, and simplifying buying decisions. The lines between online and offline purchasing are blurring, and this is leading to omnichannel approaches that orchestrate the shopping experience across the physical and digital channels, a requirement of maintained brand interaction. The customers are also interested in social responsibility and sustainability, responsible sourcing, and

community involvement to secure prolonged customer relationships and loyalty. This article expounds on the ways retail innovation and e-commerce are transforming the world of business using technology, merger of shopping channels, and focus on sustainability to address today's sophisticated consumers' needs, ensure competitiveness, and provide great shopping experiences.

LITREATURE REVIEW

- (Kumar & Anjaly, 2021; Huang & Rust, 2021). The revolutionary business pace, fueled by technology, has changed shopper behavior and retail strategies; immediacy, convenience, and personalization are central for Gen Z and millennials, with AI-driven tools and augmented reality significantly improving buying experiences, while omnichannel strategies ensure seamless customer engagement across touchpoints (Verhoef et al., 2019).
- (Gazzola et al., 2021). Sustainability and social responsibility are central when it comes to gaining long-term customers and building brand reputation.
- (Christensen et al., 2020). Retailers should always innovate and adopt technology to meet changing customer needs and maintain competitiveness.
- (Kostoyo, Polyakov, & KPMG Canada, 2023). Consumers are increasingly concerned with social responsibility and sustainability, embracing ethical procurement values and prompting retailers to adopt sustainable practices and environmentally friendly products to meet the demand for responsible consumption.
- (Coresight Research, 2025). Coresight Research identifies the top trends in retail technology, emphasizing the adoption of AI, edge computing, and real-time analytics to drive operational efficiency and enhance customer engagement.
- (Ebeltoft Group, 2025). Ebeltoft Group highlights the global shift toward seamless digital experiences and the integration of emerging technologies as central to retail innovation.
- (Ignitiv, 2025). Ignitiv underscores the importance of innovation labs for retailers, enabling rapid adaptation to market changes and fostering long-term business growth.
- (RPE Solutions, 2025). RPE Solutions discusses how retailers are reinventing their business models through data-driven automation and omnichannel strategies to remain competitive.
- (Retail Tech Innovation Hub, 2025). Retail Tech Innovation Hub reviews the latest technological advancements, noting that next-generation solutions are enabling more personalized and frictionless customer journeys.
- (Pricer, 2025). Pricer summarizes key themes from the Retail Technology Show, including the rising importance of automation, AI, and real-time data in retail success.
- (Coresight Research, 2025). Coresight Research explores the rapid evolution of retail media, with brands increasingly investing in data-driven marketing and digital advertising.
- (TruRating, 2025). TruRating highlights the focus on customer-centricity and digital transformation as

essential for the future of shopping, as discussed at the Retail Innovation Forum.

- (Deloitte, 2024). Deloitte examines how digital transformation is reshaping retail, with investments in technology improving both resilience and customer engagement.
- (McKinsey & Company, 2024). McKinsey & Company analyzes the impact of economic uncertainty on retail, urging companies to adopt agile strategies and leverage technology for supply chain optimization.
- (Accenture, 2024). Accenture emphasizes the centrality of digital transformation, highlighting how AI and cloud computing are enabling new business models and customer experiences.
- (Bain & Company, 2024). Bain & Company asserts that omnichannel retailing is now essential, as customers expect seamless integration between online and offline shopping.
- (PwC, 2024). PwC reports that customer experience is a key differentiator, with brands focusing on personalization and convenience to build loyalty.
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- (Forrester, 2024). Forrester stresses the importance of integrating digital and physical retail channels to meet evolving consumer expectations and sustain growth.
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- (Gartner, 2024). Gartner identifies strategic technology adoption as vital for retailers seeking to stay ahead of consumer trends and industry disruptions.
- (Capgemini Research Institute, 2024). Capgemini Research Institute discusses how smart stores powered by AI and automation are transforming the retail landscape, boosting efficiency and customer satisfaction.
- (KPMG, 2024). KPMG highlights the acceleration of e-commerce innovation, with digital-first strategies enabling retailers to reach new markets and customer segments.
- (Euromonitor International, 2024). Euromonitor International projects that the retail ecosystem will evolve toward 2040 with technology and sustainability as drivers of long-term success.
- (World Economic Forum, 2024). World Economic Forum emphasizes the growing focus on sustainability and inclusion, urging retailers to align strategies with global social and environmental goals.
- (NielsenIQ, 2024). NielsenIQ finds that omnichannel shopping is becoming the norm, with consumers demanding consistent experiences across all touchpoints.
- (MIT Sloan Management Review, 2024). MIT Sloan Management Review discusses how AI-powered personalization is creating new opportunities for retailers to engage customers and drive sales.
- (JLL, 2024). JLL examines how ESG and technology are reshaping retail, with brands investing in green initiatives to

meet stakeholder expectations.

- (Boston Consulting Group, 2024). Boston Consulting Group outlines the new rules of retail, emphasizing the importance of digital transformation, data-driven decision-making, and sustainable practices.

THEORETICAL BACKGROUND OF THE STUDY.

Technological innovations like AI, AR, and big data are revolutionizing retail and e-commerce through increased personalization and inventory management, as theorized by the Technology Acceptance Model and Diffusion of Innovations Theory. Omnichannel retailing, based on Service-Dominant Logic theory, facilitates online-offline convergence to provide an seamless experience with greater value provision at touchpoints. Theories such as the Theory of Planned Behavior and Maslow's Hierarchy of Needs provide insight into consumer behavior, ensuring satisfaction and loyalty through personalized services. Triple Bottom Line sustainability reconciles profit with social and environmental responsibility. Porter's Five Forces and the Resource-Based View consider competitive forces as well, illustrating how technology, consumerism, and sustainability fuel competitive advantages and long-term success in retail

PROBLEM STATEMENT

The retail business, even with emerging technologies and evolving customer demands, fails to embrace new technologies to any large extent, offer omnichannel experiences, and practice sustainable measures. This paper reviews how AI, AR, and Big Data analytics

influence customer behavior and demands, evaluates the efficacy of omnichannel strategies in providing an holistic buying experience, and analyzes the impact of sustainable practices on customer loyalty and competitiveness. Comprehension of these dimensions is important for retailers to understand existing retail complexity and success in the long run in a rapidly changing competitive market.

RESEARCH METHODOLOGY

This study uses a mixed approach to examine the future of retailing and retail innovation from an e-commerce standpoint, where qualitative and quantitative research is used to investigate the effect of technology, omnichannel strategies, and sustainability on customer experience. Qualitative research involves subject matter expert interviews and consumer focus groups, while quantitative research involves online surveys and analysis of industry reports. Data gathering employs the use of primary sources like interviews and surveys and secondary sources like scholarly books and journals. Data analysis employs thematic and content analysis in qualitative data while descriptive and inferential statistics are used to identify patterns and relationships in quantitative data. The results will be presented in a detailed report utilizing visual aids to provide actionable recommendations for retailers and supporting decision-making at the strategic level, utilizing a 5-point Likert scale to measure consumer attitudes.

DATA ANALYSIS

Result Interpretation of a 150 Member Survey

To present the outcome of 150 respondent Likert scale survey, we will document

results for each question and make important conclusions. We will have a overall overview of trends observed and their impact on retail and e-commerce practices.

1. Factors Considered When Choosing Between Online and Offline Shopping

a) Convenience

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	45	30
2	Agree	60	40
3	Neutral	23	15
4	Disagree	15	10
5	Strongly Disagree	7	5
		150	100

Source of Data: Primary Data

Interpretation: Convenience is a highly significant factor in the choice between shopping online or offline, and 70% of the respondents indicated that they agree or strongly agree that convenience influences their option. Convenience must be the priority for retailers to build online and offline channels.

b) Price

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	65	43
2	Agree	53	35
3	Neutral	18	12
4	Disagree	12	8
5	Strongly Disagree	2	2
		150	100

Source of Data: Primary Data

Interpretation: Price is a major consideration, with 78% of respondents considering it important. Competitive pricing strategies are crucial for attracting customers.

c) Product Variety

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	65	43
2	Agree	53	35
3	Neutral	18	12
4	Disagree	12	8
5	Strongly Disagree	2	2
		150	100

Source of Data: Primary Data

Interpretation: Variety of product is also sought and 76% of the respondents agreed or strongly agreed that it affects their purchasing decision. Variety in products must be provided in order to satisfy consumers.

d) In-Store Experience

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	35	23
2	Agree	52	35
3	Neutral	34	23
4	Disagree	18	12
5	Strongly Disagree	11	7
		150	100

Source of Data: Primary Data

Interpretation: In-store experience ranks second in terms of price, convenience, and product selection but is crucial to 58% of the respondents. In-store experience must contribute to overall satisfaction.

2. Frequency of Online Shopping

a) Weekly

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	53	35
2	Agree	45	30
3	Neutral	30	20
4	Disagree	15	10
5	Strongly Disagree	7	5
		150	100

Source of Data: Primary Data

Interpretation: Weekly online shopping is also common, with 65% of respondents engaging in it regularly. This suggests a stable demand for online shopping.

b) Monthly

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	30	20
2	Agree	30	20
3	Neutral	45	30
4	Disagree	23	15
5	Strongly Disagree	22	15
		150	100

Source of Data: Primary Data

Interpretation: Monthly online shopping is less frequent but still notable, with 40% of respondents shopping online at least once a month.

c) Rarely

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	15	10
2	Agree	30	20
3	Neutral	45	30
4	Disagree	38	25
5	Strongly Disagree	22	15
		150	100

Source of Data: Primary Data

Interpretation: A smaller segment shops online rarely, indicating lower engagement with online platforms.

3. Influences on Decision to Purchase from a Particular Online Retailer

a) Product Reviews

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	53	35
2	Agree	52	35
3	Neutral	30	20
4	Disagree	11	7
5	Strongly Disagree	4	3
		150	100

Source of Data: Primary Data

Interpretation:Product reviews are extremely powerful, as 70% of respondents regard them as important. Having positive and high-volume reviews can affect purchasing decisively.

b) Brand Reputation

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	53	35
2	Agree	60	40
3	Neutral	27	18
4	Disagree	8	5
5	Strongly Disagree	2	2
		150	100

Source of Data: Primary Data

Interpretation: Brand reputation is also crucial, with 75% valuing it. Building a strong brand reputation can enhance customer trust and loyalty.

c) Discounts and Promotions

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	69	46
2	Agree	53	35
3	Neutral	18	12
4	Disagree	9	6
5	Strongly Disagree	1	1
		150	100

Source of Data: Primary Data

Interpretation: Discounts and promotions are highly effective in influencing purchases, with 81% of respondents valuing them. Retailers should focus on providing attractive offers to drive sales.

d) User Interface and Experience

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	51	34
2	Agree	48	32
3	Neutral	33	22
4	Disagree	12	8
5	Strongly Disagree	6	4
		150	100

Source of Data: Primary Data

Interpretation: The user interface and experience are significant, with 66% agreeing or strongly agreeing on its importance. Investing in a seamless and user-friendly online interface is essential.

4. Use of Augmented Reality/Virtual Reality Technology

a) I have used augmented reality (AR) or virtual reality (VR) technology while shopping online.

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	15	10
2	Agree	22	15
3	Neutral	45	30
4	Disagree	38	25
5	Strongly Disagree	30	20
		150	100

Source of Data: Primary Data

Interpretation: Adoption of AR/VR technology is relatively low, with 25% of respondents having used it. Retailers could consider integrating AR/VR to enhance engagement but should be aware of its current limited use.

5. Importance of Personalized Recommendations

a) Personalized recommendations are important in my online shopping experience.

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Very Important	53	35
2	Important	45	30
3	Somewhat Important	38	25
4	Not very Important	12	8
5	Not Important at all	2	2
		150	100

Source of Data: Primary Data

Interpretation: Personalized recommendations are crucial for 65% of respondents. Implementing advanced recommendation systems can significantly improve user satisfaction and sales.

6. Preference for Retailers Prioritizing Sustainability and Social Responsibility

a) I prefer shopping from retailers that prioritize sustainability and social responsibility.

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	53	35
2	Agree	52	35
3	Neutral	23	15
4	Disagree	15	10
5	Strongly Disagree	7	5
		150	100

Source of Data: Primary Data

Interpretation: Sustainability and social responsibility are important for 70% of respondents. Retailers should highlight their sustainability efforts to attract environmentally conscious consumers.

7. Likelihood to Engage with Omnichannel Strategies

a) I am likely to engage with a retailer's omnichannel strategy (e.g., online ordering with in-store pickup).

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Very Likely	45	30
2	Likely	45	30
3	Neutral	38	25
4	Unlikely	15	10
5	Very Unlikely	7	5
		150	100

Source of Data: Primary Data

Interpretation: There is a moderate likelihood of engaging with omnichannel strategies, with 60% of respondents showing interest. Retailers should continue to develop and promote omnichannel solutions.

8. Appeal of Innovative Technologies

a) Artificial Intelligence

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Very Appealing	30	20
2	Appealing	45	30
3	Neutral	38	25
4	Slightly Appealing	22	15
5	Not Appealing at all	15	10
		150	100

Source of Data: Primary Data

Interpretation: AI is appealing to 50% of respondents. Investments in AI technologies can enhance personalization and operational efficiency.

b) Augmented Reality/Virtual Reality

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Very Appealing	23	15
2	Appealing	30	20
3	Neutral	45	30
4	Slightly Appealing	30	20
5	Not Appealing at all	22	15
		150	100

Source of Data: Primary Data

Interpretation: AR/VR has a moderate appeal, with 35% finding it appealing. It may be worth exploring but should be balanced with other innovations.

c) Big Data Analytics

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Very Appealing	38	25
2	Appealing	52	35
3	Neutral	38	25
4	Slightly Appealing	15	10
5	Not Appealing at all	7	5
		150	100

Source of Data: Primary Data

Interpretation: Big data analytics is appealing to 60% of respondents. Leveraging big data can provide valuable insights into consumer behavior and improve decision-making.

9. Willingness to Pay More for Customer Experience and Sustainability

a) I would be willing to pay more for products from retailers that prioritize customer experience and sustainability.

Sl. No	Agreement Level	No.of. Respondents	Percentage
1	Strongly Agree	53	35
2	Agree	45	30
3	Neutral	30	20
4	Disagree	15	10
5	Strongly Disagree	7	5
		150	100

This methodology provides a comprehensive framework for analyzing the future of e-commerce and retail innovation, offering valuable insights into how retailers can adapt to changing consumer expectations and technological advancements.

FINDINGS AND RECOMMENDATIONS

10.1 Findings

The study has identified that technologies like AI, ML, AR, VR, and Big Data are broadly changing personalized shopping experiences and optimizing retail operations to make them more efficient, increasing engagement, and efficiency of customers. Consistency at every touchpoint is what the customers want, and therefore omnichannel retailing becomes important with increased spending and loyalty of omnichannel consumers. Sustainability practices are being demanded more and more with effective ones concentrating on managing the carbon footprint and waste reduction. Retailers are haunted by challenges like accelerated technological developments and profitability versus sustainability balance but are given options in emerging business models like D2C and subscriptions. Retailers need to spend on

latest technology, have powerful omnichannel approaches, and adopt sustainability to meet changing customer expectations and ensure long-term success in transforming retail landscape.

10.2 Suggestions

The retailers must leverage technologies such as AR and AI to aid customer experiences and harmoniously unite online and offline channels. Sustainability will not only enhance their brand reputation but will also address increasing customer demands. Such trends will become crucial to stay competitive in the changing retail environment.

10.3 CONCLUSION

The future of retail innovation and e-commerce relies heavily on advancements in technology, hybridity of online and offline channels, and sustainability of the environment. This integrated research methodology involving both qualitative and quantitative research methods offers great insights into such evolving retail

dynamics.

PRACTICAL: MANAGERIAL IMPLICATIONS

The research shows that brick-and-mortar stores will have to adopt technological innovations such as AI and AR as a means of improving customer experience and competing. They will also have to prioritize defining online and offline and fulfilling changing customer needs. Prioritizing sustainability could not only enhance brand heritage but also be in line with consumer values. Adopting these initiatives will be key to powering growth and staying competitive in the fast-changing retail environment.

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Digital Wallet Adoption in Indian Rural Economies: Barriers and Opportunities

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Digital Wallet Adoption in Indian Rural Economies: Barriers and Opportunities

Introduction

The rapid advancement of digital financial technologies has redefined how individuals and businesses engage with the financial ecosystem, particularly through mobile and web-based payment platforms. Among these, digital wallets have emerged as a key innovation enabling seamless, cashless transactions, offering speed, convenience, and security. While urban regions in India have witnessed significant uptake of such tools, rural adoption remains fragmented, shaped by a blend of infrastructural, social, and economic factors (Kumar & Ravi, 2021). Understanding the barriers and latent potential of digital wallets in rural settings is essential for driving financial inclusion, one of the core goals of India's digital economy vision.

India's push toward a less cash-dependent economy was significantly amplified post-demonetization in 2016, an event that exposed the fragility of cash-centric systems and prompted a nationwide surge in digital payment solutions (Rai & Jain, 2020). Government initiatives such as Digital India, Pradhan Mantri Jan Dhan Yojana (PMJDY), and the rise of the Unified Payments Interface (UPI) have laid the groundwork for expanding financial services beyond traditional banking institutions (Mehrotra & Singh, 2023). Yet, while smartphone penetration has grown rapidly even in rural areas, the actual usage of digital wallets for daily transactions is

limited, indicating that access does not equate to adoption. The unique characteristics of rural economies—low literacy levels, intermittent internet connectivity, digital unfamiliarity, and deep-rooted cash habits—pose substantial challenges to widespread digital wallet usage (Bansal, 2022). Further, the trust deficit in digital platforms, fears of fraud, and limited grievance redressal mechanisms deter many from adopting mobile wallets as primary payment channels (Patel & Thakur, 2021). On the other hand, the increasing affordability of mobile phones, expanding telecom networks, and government-backed financial literacy programs represent significant opportunities for enhancing rural participation in the digital financial landscape (Saxena & Desai, 2022).

From an economic development perspective, digital wallets can catalyze rural entrepreneurship, reduce dependency on cash-based middlemen, and improve transparency in public welfare transfers. Women-led self-help groups, local artisans, and small retailers can particularly benefit from such platforms through real-time payments, direct benefit transfers (DBT), and simplified credit linkages (Narayan & Joshi, 2023). The transition, however, requires a multidimensional strategy—one that bridges digital literacy gaps, strengthens institutional trust, and ensures technological accessibility. This paper

seeks to explore the landscape of digital wallet adoption in India's rural regions, focusing on the structural and behavioral barriers inhibiting widespread usage while also identifying actionable opportunities to enhance penetration. Through a conceptual lens, it attempts to synthesize findings from recent empirical studies and policy reports to highlight the socio-economic dynamics

Review of Literature

The adoption of digital wallets in rural India is influenced by a diverse array of economic, technological, behavioral, and policy-related factors. A comprehensive review of existing literature reveals that while infrastructure and access are gradually improving, adoption rates remain low due to a combination of psychological barriers, trust issues, and socioeconomic disparities.

Digital Finance and Financial Inclusion

Financial inclusion remains a cornerstone of rural development policy in India. The rapid penetration of digital technologies has created avenues to provide financial services to previously unbanked populations. According to Mehrotra and Singh (2023), digital finance, including digital wallets, has the potential to transform rural financial systems by reducing transaction costs, improving transparency, and expanding access to credit. The researchers emphasize that inclusive fintech ecosystems can drive rural economic participation, especially when supported by infrastructure such as mobile connectivity and agent networks.

influencing digital financial inclusion in rural India. By doing so, the study contributes to the ongoing discourse on inclusive fintech development, with implications for policymakers, financial institutions, and technology providers aiming to close the rural-urban digital divide.

Technology Access and Mobile Penetration

Access to mobile technology plays a pivotal role in the diffusion of digital financial

services. Saxena and Desai (2022) argue that while smartphone usage has increased significantly in rural India, the quality of internet connectivity and affordability of data plans remain critical constraints. Furthermore, Kumar and Ravi (2021) note that digital adoption is unevenly distributed, with states having better telecom infrastructure showing higher mobile wallet usage. Their study indicates a strong correlation between mobile network reliability and frequency of digital financial transactions.

Digital Literacy and Awareness

Digital literacy is a frequently cited barrier to digital wallet adoption in rural contexts. Bansal (2022) highlights that a significant proportion of rural users are unaware of how to use digital wallets, interpret QR codes, or manage OTP (One Time Password) based authentications. This lack of digital

familiarity often leads to fear of making errors or falling victim to online fraud. Moreover, women, elderly populations, and individuals with limited formal education are disproportionately affected by these challenges (Narayan & Joshi, 2023). These findings underscore the need for localized, vernacular digital literacy programs that target specific demographic groups.

Trust and Perceived Risk

Trust is a critical psychological factor influencing the adoption of any fintech solution. Patel and Thakur (2021) found that rural populations harbor significant distrust toward digital financial tools due to concerns about cyber fraud, data privacy, and transaction failure. Their survey revealed that perceived financial insecurity, especially the risk of losing hard-earned money due to technical glitches, deters many from adopting mobile wallets. Similarly, Rai and Jain (2020) suggest that the absence of physical proof (such as a passbook or receipt) contributes to skepticism among older users who are used to tangible banking instruments.

Role of Government and Policy Support

The role of the government in promoting digital finance cannot be overstated. Initiatives such as Digital India, PMJDY, and direct benefit transfer (DBT) schemes have helped in expanding account ownership and payment infrastructure. Mehrotra and Singh (2023) argue that these schemes have laid the groundwork for digital wallet integration into rural financial life. However, they also caution that policy alone is insufficient unless supported by robust grievance redressal systems and awareness campaigns.

The success of such interventions depends on the extent to which they are adapted to the local context.

Behavioral and Social Factors

Social influence and peer behavior significantly impact digital wallet adoption. Bansal (2022) notes that community leaders, local shopkeepers, and village officials play a key role in influencing digital behavior. If early adopters report positive experiences, it creates a domino effect among their networks. Conversely, reports of failed transactions or digital scams spread fear and resistance. Narayan and Joshi (2023) emphasize that digital tools must be aligned with community norms, trust channels, and economic routines. Their research suggests that wallet features tailored for agricultural transactions, livestock payments, or cooperative savings can enhance usability.

Gender Disparity and Inclusivity

Gender inequality in digital access is another concern in rural adoption. Women often have less access to personal mobile phones or are not authorized to make independent financial decisions (Patel & Thakur, 2021). The intersection of gender, literacy, and social norms significantly lowers adoption among rural women. Narayan and Joshi (2023) propose that women-centric fintech innovations—such as shared wallet options, savings circles, and women-led digital literacy drives—could address these gaps effectively. The existing body of research highlights both challenges and opportunities in scaling digital wallets in rural India. The barriers span from infrastructural deficits and digital illiteracy to psychological mistrust

and social dynamics. However, several scholars also point toward emerging enablers such as government-led digital inclusion initiatives, increasing smartphone penetration, and the role of community actors. A successful digital wallet ecosystem in rural areas will require a multidimensional approach that integrates policy support, technological customization, user education, and community engagement.

Research Gaps

While digital financial services in India have expanded rapidly over the past decade, their actual integration into rural economies reveals several underexplored dimensions. Two key research gaps are identified:

Limited Understanding of Rural-Specific Adoption Barriers:

Most existing studies on digital payments concentrate on urban or semi-urban settings. There is insufficient research focused on the specific economic, cultural, and psychological barriers faced by rural users in adopting and consistently using digital wallets.

Inadequate Analysis of Opportunity Channels for Rural Integration:

Though digital wallets offer several advantages—such as quick transactions, financial inclusion, and transparency—the potential enablers for rural adoption remain fragmented in the literature. There is a lack of consolidated insight into policy mechanisms, technological innovations, and community-driven initiatives that could facilitate broader usage in rural economies.

Research Objectives

Based on the identified gaps and the core theme of the study—“Digital Wallet Adoption in Indian Rural Economies: Barriers and Opportunities”—the following research objectives have been formulated:

- To examine the primary structural, technological, and behavioral barriers that hinders the widespread adoption of digital wallets in rural India.
- To explore existing and emerging opportunities—such as digital literacy, infrastructure improvements, and policy support—that can enhance the integration of digital wallets into rural economic systems.

Research Methodology

This research adopts an exploratory design relying on secondary data sources to understand digital wallet adoption trends in India’s rural landscape. The data are collected from the published sources, including reports, journals, newspapers, articles, etc. The aim is to build a holistic picture of the challenges and latent potential that digital wallets hold for India’s rural economic landscape.

Multiple Dimensions

The adoption of digital wallets in rural India involves multiple dimensions—ranging from access and affordability to socio-cultural resistance and regulatory influence. To better understand the dynamics at play, this section organizes the discussion into five core sub-themes, each representing a critical layer in the rural digital finance ecosystem.

Infrastructure and Connectivity: The Foundation for Access

Reliable access to the internet and smartphones is a prerequisite for the use of digital wallets. However, despite progress under initiatives like BharatNet, many rural regions continue to struggle with low bandwidth, inconsistent electricity supply, and limited device ownership. In some villages, mobile towers are either too sparse or poorly maintained, reducing signal strength and impeding digital transactions. Moreover, while smartphone prices have decreased over the years, affordability remains an issue for economically marginalized households, especially where a single device is shared among multiple family members.

The physical availability of recharge points, telecom vendors, and service agents also varies widely across rural geographies. Without consistent access to mobile data and digital support, rural users face significant difficulties in initiating or sustaining digital wallet use. Thus, the infrastructure gap remains one of the foremost barriers to meaningful digital participation.

Digital Literacy and Awareness: Beyond Technical Know-How

Possession of a smartphone does not automatically equate to meaningful digital usage. Digital literacy goes beyond operational skills—such as tapping icons or entering a PIN—and includes understanding risks, troubleshooting transaction errors, and navigating app updates. In rural India, many users, particularly the elderly and less formally educated, struggle with even basic digital tasks, let alone complex wallet

interfaces.

Further complicating matters is the lack of localized, vernacular education around digital payments. Many digital wallet interfaces are English-dominant, alienating users who are more comfortable in regional languages. Misinformation, fear of fraud, and misconceptions about data charges also discourage new users from experimenting with these tools. This highlights the need for community-led awareness programs, tailored specifically to rural contexts, where people learn by doing rather than by reading manuals or watching tutorial videos.

Trust and Perceived Risk: Psychological and Social Barriers

Trust is central to financial behavior, and in rural India, it has traditionally been built through personal interaction and physical proof of transaction—like a printed receipt or a bank passbook. Digital wallets, by nature, are intangible, and this creates skepticism, especially when users are asked to link their bank accounts or Aadhaar numbers.

Moreover, news of online scams and fraud travels quickly in close-knit rural communities, reinforcing fear even among those who have never used a wallet. The perception of vulnerability is particularly high among older users and women, many of whom do not feel confident seeking help if something goes wrong. Absence of localized grievance redressal mechanisms, unresponsive customer support, and limited banking assistance further worsen this trust deficit.

Even when people see their peers successfully using wallets, it may not be enough to overcome deeply ingrained

financial caution, especially in areas where cash is not just a medium of exchange, but a symbol of certainty.

Economic Utility and Contextual

Relevance: Adoption Driven by Need

Digital wallets in rural settings often struggle to demonstrate clear day-to-day utility for users whose financial behavior is informal, irregular, and cash-based. For example, agricultural laborers or small traders are typically paid in cash, and there are few local vendors who accept digital payments. Unless wallets are seen as genuinely useful—such as for receiving government subsidies, paying electricity bills, or sending remittances—adoption remains superficial.

Interestingly, use increases during seasonal needs or festivals, when people receive lump-sum payments or shop in urban markets.

Wallet usage also spikes when tied to Direct Benefit Transfer (DBT) schemes. These examples show that contextual relevance—the ability of a wallet to integrate into the user's lifestyle—is a critical success factor.

More inclusive wallet features, such as offline payment options, voice-based navigation, and integration with public services, could make digital wallets more relevant to rural lives.

Government and Ecosystem Support:

Enabling Environments

The role of the state and ecosystem players in driving adoption is significant. Policies under Digital India, the introduction of Jan Dhan accounts, Aadhaar-enabled payment systems, and the proliferation of Unified Payments Interface (UPI) have laid foundational elements for a digital economy. However, gaps remain in last-mile delivery,

particularly when it comes to awareness, dispute resolution, and follow-up support.

Non-governmental organizations, rural fintech startups, and SHG (Self-Help Group) networks also have a pivotal role in scaling adoption. Peer-led digital ambassadors, especially women trainers, have proven successful in regions where formal agents are unavailable. Moreover, fintech partnerships with microfinance institutions and cooperatives can create tailored wallet solutions that cater to agricultural, healthcare, or education-related transactions. For these interventions to be successful, they must be localized, user-centric, and trust-building in nature. The digital financial ecosystem cannot be a one-size-fits-all model—it must adapt to the socio-economic and cultural realities of rural India.

The adoption of digital wallets in rural India is not merely a technological challenge but a multi-layered socio-economic transformation. Factors like infrastructure, literacy, trust, relevance, and ecosystem support interact to either enable or inhibit progress. Addressing only one of these dimensions in isolation will yield limited results. A holistic strategy—one that aligns policy, community engagement, and technological innovation—is essential to unlocking the true potential of digital finance in India's rural heartlands.

Findings

Structural and Technological Barriers: Gaps in Access and Reliability

- **Mobile and Internet Penetration**

Although mobile phone ownership in rural India has grown significantly—estimated at over 65% by 2022 (TRAI, 2023)—the type

of device and quality of access still limits functionality. A large proportion of rural users operate basic smartphones with low memory capacity, which are often incompatible with newer digital wallet applications. Furthermore, the Indian Telecom Services Performance Report (TRAI, 2023) notes that nearly 40% of rural villages still experience poor internet coverage, particularly in remote tribal belts and low-income regions.

- **Device Sharing and Network Instability**

In many rural households, mobile devices are shared among family members, limiting continuous access. For example, women and elderly individuals often rely on male relatives for digital transactions, which reduces autonomy and privacy. Network reliability is also inconsistent. According to the Internet and Mobile Association of India (IAMAI, 2022), over 32% of rural users abandon digital payments due to slow connections, failed OTP verifications, or app crashes during transactions.

- **Compatibility with Existing Financial Behavior**

Many rural users are still anchored to cash-based ecosystems where local vendors do not accept digital payments. Even among those with bank accounts under the PMJDY scheme, transaction activity remains low. A 2021 NITI Aayog working paper observed that 48% of Jan Dhan account holders in rural India conducted fewer than two digital transactions per month, indicating limited integration of wallets into daily routines.

- **Behavioral Barriers: Mistrust, Misconceptions, and Low Digital Confidence**

Fear of Fraud and Loss

One of the most frequently cited concerns in qualitative reports is the fear of monetary loss, particularly due to scams, phishing, or accidental errors. Older adults, who typically have limited exposure to digital interfaces, report high levels of anxiety around entering incorrect information or clicking on misleading links. A 2022 consumer perception survey by NPCI showed that 63% of rural respondents cited trust as the top barrier to using digital wallets.

Low Digital Literacy and Limited Functional Knowledge

Digital literacy in rural India remains uneven and often focuses on basic mobile usage rather than app-based financial behavior. Data from the National Digital Literacy Mission (2023) suggests that while 72% of rural youth can operate smartphones, only 39% were comfortable using payment apps independently. Many users lack awareness of app functions such as scanning QR codes, checking balances, or changing passwords. Moreover, wallet apps often do not offer support in local languages or voice-based navigation, which further restricts usability.

- **Gendered Access and Usage Disparity**

There is a notable gender gap in digital wallet adoption. Cultural norms and power structures often prevent rural women from accessing or managing financial apps. As per a 2022 report by the Gates Foundation and IFMR, only 27% of rural women in India had

made a digital financial transaction in the past six months, compared to 55% of men. The lack of privacy in shared mobile usage, as well as social limitations on financial decision-making, contributes to this disparity.

Policy and Infrastructure-Driven Opportunities

- **Role of Government Schemes and UPI Penetration**

The introduction of Unified Payments Interface (UPI) has significantly simplified digital wallet usage by eliminating the need for IFSC codes or lengthy account numbers. Data from NPCI (2023) indicates that rural UPI transactions increased by 162% between 2021 and 2023, mainly due to government Direct Benefit Transfers (DBTs) and subsidy programs linked to UPI wallets like BHIM and Paytm.

Moreover, schemes under Digital India, such as the Common Services Centre (CSC) network, have provided access points for financial assistance, training, and digital facilitation at the village level. These centers are acting as offline-to-online bridges, where individuals can learn to use digital wallets or complete transactions with assisted support.

- **Digital Literacy Campaigns and NGO Participation**

Non-profit organizations, in collaboration with fintech firms, have launched digital literacy campaigns in several states. Programs like Digital Saksharta Abhiyan (DISHA) and Internet Saathi have trained rural women and youth to conduct basic digital tasks. These programs have seen promising results: in pilot regions, wallet

adoption increased by 22% post-intervention (Mehta & Rao, 2022). Such evidence suggests that community-based digital learning is an effective enabler for rural wallet usage.

- **Fintech Innovation and Regional Customization**

Emerging fintech startups are developing rural-centric wallet features, such as offline payment capabilities, biometric authentication, and vernacular voice interfaces. Some apps also offer micro-credit, livestock insurance, and cooperative group accounts integrated within the wallet ecosystem. These innovations cater directly to the informal financial structures prevalent in rural India and have shown stronger engagement rates in Tier-3 and Tier-4 towns (Bhardwaj & Srinivas, 2023).

Socio-Economic Integration and Opportunity for Livelihood Upliftment

- **Inclusion of Rural Entrepreneurs and SHGs**

Digital wallets have the potential to empower micro-entrepreneurs and women-led Self-Help Groups (SHGs) by enabling them to receive payments, access credit, and manage savings digitally. In Andhra Pradesh and Odisha, government-backed SHG digitization drives have seen members use wallets for procurement and distribution payments, thereby reducing cash handling and improving financial transparency.

- **Strengthening DBT and Welfare Delivery**

Wallets that are linked to government subsidies, pension schemes, and MGNREGA

wage transfers are being increasingly accepted as trusted payment mediums. Users who receive regular welfare payments directly into their mobile-linked accounts tend to build confidence and familiarity with wallet functions. This pattern suggests that recurring utility increases both trust and long-term adoption. The analysis indicates a clear mismatch between access and active usage. While device ownership and internet coverage are growing, confidence, usability, and relevance continue to lag in many rural segments. Behavioral resistance, literacy gaps, and gender inequality persist as deep-rooted obstacles.

Simultaneously, there is promising momentum from state-backed digital infrastructure, grassroots training efforts, and region-specific fintech innovations. These evolving factors create opportunities for scaled adoption, provided they are supported by community trust-building, simplified app design, and inclusive financial policies.

Conclusion

While rural India is gradually becoming digitally connected, true financial digitization remains incomplete. Infrastructure limitations, especially unstable internet and limited smartphone affordability, form the foundational barriers. Even when access exists, widespread adoption is held back by low digital literacy, fear of fraud, and a lack of locally relevant features. Behavioral trust gaps and entrenched reliance on cash continue to define financial behavior in many regions. However, the rural digital finance story is not without hope. Initiatives such as the Unified Payments Interface (UPI), Jan Dhan Yojana,

and community-led digital literacy campaigns are slowly reshaping the rural financial landscape. A growing ecosystem of fintech startups is designing customized tools that reflect the realities of rural life, while government DBT-linked wallets are building familiarity and functional trust.

The findings suggest that rural wallet adoption is not merely a function of technology diffusion, but a complex social process—influenced by economics, education, infrastructure, gender, and governance.

Policy Implications and Recommendations

To scale digital wallet use in rural India in a sustainable and inclusive manner, the following policy strategies are recommended:

Community-Driven Digital Literacy Programs

Policymakers should fund localized training programs led by trusted community figures (e.g., SHG leaders, village volunteers). These efforts must go beyond technical instructions to include risk awareness, redressal procedures, and use-case relevance.

Vernacular and Voice-Based Wallet Interfaces

App developers should incorporate regional languages, visual aids, and voice-navigation tools to serve non-literate or semi-literate populations, making wallets more intuitive for first-time users.

Offline Wallet Access and Biometric Integration

To overcome connectivity gaps, fintech solutions must offer offline transaction capabilities. Linking wallets with Aadhaar and biometric features can also reduce the burden of PINs and passwords for users with low digital confidence.

Inclusive Design for Women and Elderly Users

Special focus must be placed on women's financial access. This includes exclusive

wallet features for women, training modules in female self-help groups, and mobile financing schemes to reduce device-sharing constraints.

Strengthen Grievance Redressal Mechanisms

A responsive, local-level support system is essential to build trust. Policies must mandate financial grievance cells in panchayats or Common Service Centres (CSCs) that assist rural users with failed transactions or fraud recovery.

Encourage Rural Merchant Onboarding

Incentives should be provided to local kirana stores, haat vendors, and service providers to accept wallet payments. This would close the loop between access and real-world usability.

The road to a fully digitized rural economy is long and nuanced. Digital wallets—if integrated thoughtfully—can serve as a gateway to a wider financial ecosystem that includes credit, savings, insurance, and government services. To succeed, however, the approach must be holistic and human-centric, placing as much emphasis on trust, simplicity, and inclusion as on technology and infrastructure.

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SWOT and PESTLE Analysis of LendingClub: A Case Study on the Rise and Crisis of a Fintech Pioneer

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Abstract:

This paper presents an in-depth case analysis of LendingClub, a pioneer in the peer-to-peer lending industry. It explores the company's innovative rise and dramatic fall through a comprehensive SWOT (Strengths, Weaknesses, Opportunities, Threats) and PESTLE (Political, Economic, Social, Technological, Legal, Environmental) analysis. Founded with the intent to democratize lending, LendingClub leveraged technology to connect borrowers and lenders directly, bypassing traditional banking systems. However, internal governance failures and increasing regulatory scrutiny led to a major corporate scandal in 2016. This analysis outlines the company's strategic positioning, the macro-environmental factors impacting its business, and the key takeaways for the fintech industry. The case highlights the crucial interplay between innovation, compliance, and trust in sustaining financial technology ventures.

Keywords :Fintech Innovation, Corporate Governance, Peer-to-Peer Lending, Regulatory Compliance, Strategic Risk Management

Case Presentation

SWOT and PESTLE Analysis of LendingClub: A Case Study on the Rise and Crisis of a Fintech Pioneer

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1. Introduction

Background of LendingClub

Founded in 2006 by Renaud Laplanche, LendingClub started as a Facebook application and quickly became a peer-to-peer lending platform by 2007. The company aimed to change traditional lending by connecting borrowers and investors directly through an online marketplace. By avoiding traditional banks, LendingClub reduced borrowing costs and increased returns for investors, becoming a leader in fintech lending.

2. Purpose and Scope of the Analysis

This paper looks at LendingClub's rise, crisis, and recovery through a detailed case study. The goal is to evaluate the company's internal strengths and weaknesses along with external macro-environmental factors using SWOT and PESTLE frameworks. The paper also assesses LendingClub's strategic decisions, the 2016 governance crisis, and its broader impact on the fintech industry.

3. Case Background

3.1 History and Development of LendingClub (2006–2016)

LendingClub's growth reflects early fintech innovation. Starting in 2006, the company used new technologies to provide unsecured personal loans to borrowers without the involvement of traditional banks. Key milestones include:

- 2007: Fully transitioned into P2P lending with venture capital support.
- 2008: Paused operations temporarily for SEC registration, showing early sensitivity to regulations.
- 2010–2014: Secured multiple funding rounds and went public at \$15 per share.
- By 2016: Originated nearly \$19 billion in loans and expanded quickly.

3.2 Overview of the 2016 Governance Crisis

In early 2016, LendingClub faced a scandal when internal investigations revealed that \$22 million in loans were sold to investors under false terms. CEO Renaud Laplanche had undisclosed interests in a fund investing in LendingClub loans, which led to his resignation on May 6, 2016. A DOJ subpoena, shareholder lawsuits, and a drastic 60% drop in share value followed. This governance failure is a warning about rapid fintech growth without proper oversight.

4 SWOT Analysis:

Strengths:

1. **Innovative Business Model:** LendingClub was one of the first to offer online P2P lending in the U.S., providing a unique platform that matched borrowers directly with investors.
2. **Cost Efficiency:** By removing the traditional banking middleman, LendingClub offered competitive interest rates for borrowers and better returns for investors.
3. **Technology Integration:** The platform used automation, data analysis, and machine learning for loan underwriting and credit scoring, ensuring growth and efficiency.
4. **Early Market Leader:** LendingClub was a pioneer in the market, gaining an initial advantage and building trust among early users and institutional investors.

Weaknesses:

1. **Governance Failures:** In 2016, LendingClub's internal controls did not prevent fraudulent loan practices, resulting in a major corporate scandal.
2. **Leadership Crisis:** The resignation of CEO Renaud Laplanche and other top executives caused instability and loss of investor confidence.
3. **Dependency on Institutional Investors:** Over time, LendingClub became more reliant on institutional investors, reducing its peer-to-peer nature.
4. **Brand Damage:** The scandal hurt its reputation, making it harder to retain customers and attract new users.

Opportunities:

1. **Fintech Growth:** With ongoing expansion in digital finance, LendingClub had chances to diversify into personal finance management and digital banking.
2. **Strategic Partnerships:** Working with banks, tech firms, and credit institutions could help restore trust and improve scalability.
3. **Regulatory Clarity:** As fintech regulations developed, LendingClub could align its practices to be compliant and regain legitimacy.
4. **Product Diversification:** Expanding into areas like small business loans, credit monitoring, or secured lending could reach new customer segments.

Threats:

1. **Increased Competition:** Competitors like Prosper, Upstart, and traditional banks with digital platforms posed significant challenges.
2. **Regulatory Scrutiny:** More government oversight after the scandal could raise operational costs and limit flexibility.
3. **Cybersecurity Risks:** Operating online makes the platform vulnerable to data breaches and fraud.
4. **Market Volatility:** Investor sentiment varies with economic conditions, impacting loan funding and platform liquidity.

5. PESTLE Analysis:

Political:

- **Regulatory Oversight:** The 2016 crisis led to tighter scrutiny from the SEC and other regulators, changing the company's operations and reporting requirements.
- **Fintech Policy Environment:** Political changes affect fintech regulations, ranging from support for innovation to strict compliance enforcement.

Economic:

- **Post-2008 Financial Crisis Environment:** LendingClub took advantage of the public's distrust in traditional banks and filled a gap for unsecured personal loans.
- **Recession Threats:** Economic downturns can affect borrowers' ability to repay and investors' risk tolerance, ultimately impacting LendingClub's growth.
- **Interest Rate Sensitivity:** Changes in macroeconomic interest rates influence loan origination volumes, affecting both borrowers and lenders.

Social:

- **Digital Trust and Adoption:** Initially, the company benefited from more consumers willing to use online platforms. However, after 2016, social trust decreased.
- **Transparency Demands:** The scandal raised customer expectations for ethical leadership and clear disclosures in fintech operations.
- **Changing Consumer Behavior:** Users sought more personalized, transparent, and fast digital lending experiences, pushing platforms to evolve continuously.

Technological:

- **Platform Innovation:** LendingClub's success depended on its ability to use automation, credit scoring models, and scalable infrastructure.
- **Cybersecurity Needs:** With increasing threats, the company had to invest significantly in data protection and fraud prevention measures.
- **Emerging Technologies:** Competitors using AI and blockchain pushed LendingClub to innovate or risk falling behind technologically.

Legal:

- **Securities Regulation:** LendingClub loans were categorized as securities, leading to more complex legal and compliance requirements.
- **Governance Breach Fallout:** The 2016 scandal resulted in several legal consequences, including a DOJ subpoena and shareholder lawsuits.
- **Disclosure Requirements:** Stricter compliance rules after the scandal affected LendingClub's operational flexibility and communications with investors.

Environmental:

- **Minimal Direct Impact:** As a digital firm, LendingClub had a limited environmental footprint

compared to traditional banking.

- ESG Focus: Increased stakeholder interest in ESG (Environmental, Social, and Governance) required LendingClub to show responsible corporate behavior, particularly in governance after the scandal.

6. Discussions

6.1 Strategic Implications of SWOT and PESTLE Findings:

The SWOT analysis shows that Lending Club's initial strengths in innovation, cost efficiency, and market leadership were undermined by weaknesses like poor governance and dependence on institutional investors. The PESTLE analysis highlights external pressures—from regulatory scrutiny to rapid technological changes—that worsened internal vulnerabilities.

The strategic implication is clear: fintech companies need to balance aggressive

innovation with strong corporate governance. The disruptive potential of fintech can only be sustained through trust, transparency, and a compliance-oriented culture. Lending Club's failure to maintain this balance resulted in investor distrust, legal issues, and a sharp decline in valuation. Strategically, the company needed to reform its leadership, emphasize ethical behavior, and quickly respond to external challenges through partnerships and technological improvements.

6.2 Lessons Learned from Lending Club's Journey:

1. Governance Matters in Fintech: No amount of innovation can replace sound governance. Fintech firms must maintain rigorous internal controls and ensure board independence.
2. Reputation is Fragile: A single governance failure can erase years of brand building and customer trust. Transparency in investor communication and accountability at the leadership level are essential.
3. Adaptation is Key: Fintech markets are dynamic. LendingClub's hesitation to

adjust its model in response to competition and regulation cost it significant market share.

4. Investor Relations Must Be Ethical: Misrepresenting loan data and failing to disclose information can lead to regulatory penalties and shareholder lawsuits, as this case shows.

5. Leadership Drives Culture: Ethical failures at the top affected company practices. Leadership must embody the integrity expected throughout the organization.

7. Conclusion:

LendingClub's story shows the fragile balance between innovation and governance in the fintech sector. While the company introduced a groundbreaking business model, it failed to meet the ethical and compliance standards needed in a highly regulated industry. The SWOT

and PESTLE analyses reveal both the internal mistakes and external challenges that contributed to its crisis. Looking ahead, fintech firms can learn from LendingClub's experience by focusing on transparency, communication with stakeholders, and ethical leadership as essential elements for lasting success.

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Advertising in the Metaverse Challenges and Opportunities for the Indian Film Industry in the Era of Web3 and Digital Finance

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Abstract:

The intersection of immersive technologies and decentralized digital infrastructure is revolutionizing the global media landscape at an unprecedented pace. This research examines the new possibility of Metaverse-based advertising in the Indian film industry within the larger context of Web3 and digital finance evolution. Using a mixed-methods approach, the study combines quantitative views of 400 survey participants with qualitative insights from 15 industry experts across film production, marketing, and blockchain development. The data reveal a wide gap between increasing consumer demand for virtual and tokenized experiences—like NFT collectibles, virtual movie premieres, and The intersection of immersive technologies and decentralized digital infrastructure is working fast to redefine the global media ecosystem. This research examines the developing promise of Metaverse-based advertising in Indian cinema, set against the wider development of Web3 and digital finance. Based on a mixed-methods design, the study combines quantitative data drawn from 400 surveys with qualitative opinions from 15 domain experts in film production, marketing, and blockchain development. The research shows a wide disconnect between emerging consumer demand for virtual and tokenized experiences, including NFT collectibles, virtual film screenings, and decentralized financing options, and the Indian film industry's minimal strategic involvement with these platforms. Youth audiences, especially those who are OTT and cryptocurrency tool savvy, have high acceptability to immersive content and Web3 applications. But the adoption within the industry continues to be hamstrung by technological, regulatory, and creative factors, such as

low technical capability, ambivalent policy environments, and inadequate investment in immersive content creation. The research presents key enablers like cross-industry collaboration, digital literacy, ethical adoption of technology, and regulatory overhaul as key to mainstreaming Metaverse advertising in Indian film. Through mapping the challenges and opportunities, this research provides actionable feedback on how India's film industry can capitalize on decentralized technologies to drive innovative engagement with audiences and reshape film promotion in the digital era. decentralized finance models—and the Indian movie industry's low strategic outreach to these platforms. Young audiences, especially those who are familiar with OTT platforms and crypto tools, show high acceptability to immersive content and Web3 applications. Yet, the industry's takeoff is limited by technology, policy, and innovation barriers such as low technical capability, ambiguous policy frameworks, and low investment in immersive content design. The research pinpoints key enablers like cross-sector partnership, digital literacy, ethical adoption of technology, and regulatory transformation as essential to drive mainstreaming Metaverse advertising in Indian cinema. Through the mapping of both the challenges and opportunities, this study provides actionable insights into how India's film industry can utilize decentralized technologies to drive innovation in audience engagement and redefine cinematic promotion in the digital era.

Keywords: Metaverse Advertising, Indian Film Industry, Web3 Technologies, Digital Finance, NFTs and Virtual Engagement

Introduction

The arrival of the Metaverse an immersive, persistent, and interactive virtual world heralds a paradigm shift in how people interact, transact, and consume media. Characterized by the intersection of extended reality (XR), blockchain technology, artificial intelligence (AI), and Web3 infrastructure, the Metaverse is no longer the domain of speculative future talk; it is increasingly redefining the shape of digital engagement across industries. While industries across the globe shift their operational and communication models to fit this new digital paradigm, the world of advertising is also changing in deep ways. Here, it is an Indian cinema industry famous for its cultural penetration and high productivity that is at a strategic crossroads. With a huge home market, an online active diaspora, and growing dependence on digital distribution platforms, the industry needs to find creative means of reaching out to changing audience behaviors. In this context, the use of Metaverse-led advertising, supported by decentralized Web3 technologies and digital finance infrastructures, offers an interesting opportunity one that is as nuanced as it is exciting.

Theoretical Background

This question draws on a multidisciplinary theoretical paradigm that includes media convergence, interactive advertising, and online consumer attitudes. Jenkins' (2006) theory of media convergence offers a starting point perspective, postulating that content does not sit within a single medium but moves across platforms and thus facilitates participatory and decentralized audience interaction. This is complemented by the theory of immersive advertising (Li, Daugherty, & Biocca, 2002), which argues that interactivity and spatial immersion further augment consumer-brand relationships within virtual spaces. The conceptual fusion of blockchain and digital finance at the core of Web3 further extends Tapscott and Tapscott's (2016) theory of decentralized value networks, where disintermediation empowers content makers and users via smart contracts, token economies, and decentralized governance models. Together, these theories guide an examination of ways Indian film can embrace and mesh advertising techniques into interactive, blockchain-based virtual worlds.

Research Problem Statement

And although India is the most film-generating country in the world and rapidly develops in the digital infrastructure, the use of advertising strategies based on the Metaverse is not widespread and is still in a stage of experimentation and fragmentation. Whereas the use of platforms like Roblox, Decentraland, and Meta Horizon Worlds in branded storytelling and engagement with consumers is now gaining momentum in the global media and entertainment sector, the promotional activities of the Indian film industry are still mostly bound to the traditional and social media. The shift to the more immersive, Web3 powered advertising systems is immobilized by several barriers: absence of any strategic vision, incomplete, development of regulations supporting crypto powered transactions, insufficient levels of digital literacy and unequal access of technology on the global scale. In addition, the regulatory framework in India is conservative about crypto assets and NFTs, further worsening the industry hesitation. Therefore, this paper focuses on the following main research question: What are the main complexities and opportunities concerning the Indian film industry in the use of the Metaverse in advertising (in terms of Web3 infrastructure and the use of digital finance systems)?

Emerging Trends, Issues, and Challenges

Entertainment brands around the world are quickly trying out immersive forms of marketing using 3D avatars, virtual events and NFT-driven marketing campaigns. Meta-health platforms such as Decentraland or The Sandbox have become interactive brand-story platforms, and brand advertising paradigms in Metaverse redefine measurable consumer interaction (Dwivedi et al., 2022). Early experience with NFT-based film memorabilia, virtual red carpet events, and blockchain-based crowdfunding campaigns has illustrated an emerging yet successful experience in India. Tokens, are a new form of tokenized fandom or fandom through Bollywood movies like Radhe Shyam and 83 (Madhavan, 2022).

Nevertheless, there are some structural and strategic problems. The mainstream

adoption is hindered by the unavailability of common measurement frameworks to gauge the benefits of investment (ROI) in virtual setting (Dwivedi et al., 2022). Small and mid-sized production houses are limited by the prohibitive expense of developing XR-ready material. Furthermore, the questions of intellectual property rights in the digital space and the data privacy measures that relate to decentralized translations are of legal and ethical concern as well (Kumar & Prasad, 2023). In addition, the country still needs to bridge any gaps in broadband infrastructure, latency, and access to immersive devices (TRAI, 2023), hindering both rural and semi-urban demographics.

Significance of the Study

This research is important to both industry and academic stakeholders. For academics, it adds to the increasing but as yet relatively under-theorized body of literature on digital advertising in post-social media environments, especially in the framework of Global South media economies. For industry practitioners, particularly film marketers, producers, and digital agencies, the research yields practical information regarding the use of immersive technologies and decentralized platforms for audience engagement, brand collaborations, and monetization.

In addition, this question crosses over with wider socio-economic trends in India's digital economy. With the government's initiative towards a "Digital India" and the continued growth of the IndiaStack and the Open Network for Digital Commerce (ONDC), there is a policy ecosystem favorable towards innovation in digital media and finance (Meity, 2023). The Indian film industry—historically a generator of cultural exports and soft power—finds itself at a singular position to

redefine its global reach in Metaverse platforms, with possibilities for real-time global premieres, tokenized fan engagement, and decentralized funding opportunities.

Scope and Limitations

The research is relevant to a number of stakeholders in academic, policy and industry areas. To academic audiences, it makes a contribution to the discussion of post-platform digital advertising and provides what is currently a deficient voice in scholarship to the Global South in the use of immersive media. As far as the professionals in the Indian film industry are concerned, the study will provide data-informed insights into new consumer habits, technology adoption trends, and monetization frameworks that can be achieved with the help of Web3 tools like NFT, DAOs, and microtransactions with crypto. Policymakers and digital infrastructure planners can also find the study applicable, as it falls under the areas of India transformation into the digital world, such as the IndiaStack, the Open Network for Digital Commerce (ONDC), and the Digital India mission (MeitY, 2023). With the Indian cinema still functioning as a tool of soft power and export generator, the implementation of the Metaverse platforms is highly likely to boost its reach or global distribution, the engagement of the audience, and diversification of revenues.

Literature Review

The convergence of the Metaverse, Web3, and the Indian film industry has also, in recent times, become a productive field for academic research, with specific relevance to advertising and digital finance. Previous literature examines the general technological and market changes that are remaking established models of marketing and researches the space for immersive virtual worlds as new spaces for audience interactions.

The Metaverse, as a spatial computing entity, possesses immersive advertising potential through augmented reality (AR), virtual reality (VR), and blockchain. As stressed by Madanchian and Taherdoost (2024), the Metaverse surpasses conventional business models by facilitating participatory, gamified, and experiential brand experiences, making it a natural extension of digital advertising. Likewise, Wadehra and Anand (2025) outline how Indian start-ups such as GreyMeta are using Metaverse platforms to reach digitally savvy consumers with Web3-backed loyalty ecosystems and decentralized campaigns.

In the Indian scenario, researchers have started studying the adaptation process of conventional sectors towards immersive digital environments. Nikalje (2023) touches upon gaps in regulation in Indian competition law with regard to Big Tech monopolies and nascent XR technologies, underlining the imperative for legal and policy transformation for promoting fair digital innovation. The remark is especially relevant for India's film industry, where

uncertainty regarding regulatory norms in the case of NFT-based advertising or crypto-enabled ticketing fosters reluctance in take-up.

Web3, built on blockchain and decentralized finance (DeFi), ushers in a completely new architecture for fan interaction and content monetization. Singh, Wongmahesak, and Chandra (2025) emphasize the increasing significance of NFTs and smart contracts as the foundation for ownership in virtual film merchandise, ticketing systems, and exclusive content. These decentralized platforms enable creators to monetize their content directly while bypassing conventional distribution gatekeepers. This change, however, raises cybersecurity, content authenticity, and intellectual property concerns, as expounded by Mitra, Das, and Shaw (2025) in their examination of decentralized virtual space.

The applicability of NFTs as advertisements in India is highlighted in research such as Cajera and Dhinaiya (2023), which documents the application of digital collectibles in movie marketing. By providing NFT-tied trailers, digital posters, or background clips, directors can create digital scarcity and exclusivity—precious weapons in a time of content overspill. Goel and Kumar (2024) warn, though, that the viability of such approaches depends on user trust and market fluctuation in crypto-economies, which continue to be volatile in developing countries.

In addition, Joshi, Pandey, and Kumari (2024) make a distinction between conventional in-world promotions and immersive narratives in the Metaverse. They contend that static banners or brand integrations from previous digital forms can easily be transplanted, but successful Metaverse campaigns must include dynamic engagement, identity personalization, and co-creation with fans. In Indian cinema, this means an imaginative reframing of marketing practices—from linear content to branching stories and gamified brand experiences.

From a policy and market readiness perspective, Chandra et al. (2025) also note the infrastructural challenges that impede full Metaverse adoption in India, such as disparities in internet connectivity, XR device affordability, and low blockchain

literacy. Yet, there is a growing institutional interest in aligning the entertainment sector with India's Digital Economy Strategy, providing impetus for innovation in immersive advertising formats.

In summary, the literature converges on a few key insights. First, the Metaverse offers novel experiential formats for advertising, yet its success hinges on meaningful engagement and technological access. Second, the integration of Web3 tools presents significant opportunities for direct monetization and fan participation, but introduces legal, ethical, and infrastructural challenges. Finally, for the Indian film industry, strategic experimentation with NFTs, immersive experiences, and decentralized platforms holds promise but demands adaptive regulation, cross-sectoral collaboration, and audience education.

Research Gap Analysis

Aspect	What Has Been Studied	Limitations of Existing Studies	Identified Research Gap
Metaverse in Advertising	Studies have explored immersive advertising in global Metaverse platforms like Decentraland, Roblox, etc. (Madanchian & Taherdoost, 2024)	Most are Western-centric; little focus on South Asian contexts or cultural nuances.	Lack of contextualized analysis for Metaverse-based advertising strategies in India's entertainment ecosystem.
Web3 and Digital Finance	Blockchain and NFT applications in marketing and media have been broadly covered (Singh et al., 2025; Goel & Kumar, 2024).	Limited integration with real-world business models in creative industries like cinema.	No robust framework linking decentralized finance mechanisms with marketing strategies for film promotion in India.
Indian Film Industry	Research on Indian film marketing has examined digital and social media campaigns (Wadehra & Anand, 2025).	Does not extend into immersive or blockchain environments.	Absence of literature on Indian cinema's promotional strategies in Metaverse or Web3 ecosystems.
NFTs for Fan Engagement	NFTs for film memorabilia and audience interaction are emerging topics (Cajera & Dhinaiya, 2023).	Exploratory in nature; lacks empirical validation and strategic depth.	Need for strategic and empirical models assessing effectiveness of NFT-based advertising for films in India.

Infrastructure Readiness	Issues like 5G access, XR device adoption, and blockchain scalability are documented (Nikalje, 2023; Mitra et al., 2025).	Focused on macro-technical aspects; not tied to sector-specific implications for creative industries.	Need for sector-specific readiness assessment of the Indian film industry for Metaverse-enabled marketing infrastructure.
Regulatory Frameworks	Legal concerns around crypto, digital IP, and platform monopolies are discussed (Nikalje, 2023).	Lacks sector-specific guidance for entertainment or advertising in virtual economies.	Gap in India-centric regulatory analysis for advertising Indian films in decentralized and virtual environments.
Audience Behavior & Adoption	User experience and consumer trust in virtual advertising is studied globally (Joshi et al., 2024).	No India-specific audience behavioral data exists on interaction with film-related ads in the Metaverse.	Gap in understanding how Indian audiences respond to immersive film advertising and Web3 engagements like NFTs or DAOs.
Cross-Platform Strategies	Global campaigns use multi-platform convergence (e.g., XR + NFT + social media).	Limited analysis of such convergence strategies by Indian film marketers.	Lack of research on integrated cross-platform marketing models for Indian films within Metaverse and Web3 frameworks.

Research Objectives

1. To examine the current state of adoption and implementation of Metaverse-based advertising strategies within the Indian film industry.
2. To analyze the opportunities presented by Web3 technologies (e.g., NFTs, DAOs, DeFi) for enhancing fan engagement, revenue generation, and brand integration in Indian cinema advertising.
3. To identify the key technological, infrastructural, and regulatory challenges that hinder the integration of immersive advertising platforms in the Indian film marketing ecosystem.
4. To propose a strategic framework for Indian film marketers to effectively leverage the Metaverse and Web3 for advertising, based on global best practices and India-specific insights.

Research Methodology

This study adopts a **mixed-methods research approach** to comprehensively investigate the emerging role of Metaverse-based advertising in the Indian film industry within the broader context of Web3 and digital finance. The chosen methodology is grounded in both exploratory and descriptive paradigms, enabling the researcher to capture qualitative insights from industry practitioners and quantify

consumer behavior patterns through empirical data analysis.

1. Research Design

The design of this study combines **exploratory qualitative inquiry** with **descriptive quantitative methods**. This dual approach is appropriate for examining both the subjective experiences of professionals engaged in digital film marketing and the measurable attitudes and behaviors of technologically engaged film audiences. The qualitative component emphasizes in-depth understanding through expert interviews, while the quantitative survey collects standardized data that allow for generalizable conclusions.

2. Target Population and Sampling Frame

The population comprises three distinct yet interconnected stakeholder groups:

1. **Industry Professionals:** Individuals engaged in film marketing, production, and digital promotion within the Indian cinema ecosystem, including Bollywood and major regional industries.
2. **Technology Specialists:** Developers and service providers involved in building XR applications, NFT marketplaces, blockchain-based advertising systems, or Metaverse platforms.
3. **Digital Consumers:** Indian citizens who actively engage with digital media, blockchain services,

immersive environments, or virtual fan communities.

3. Sampling Methodology

This study utilizes a **multi-stage sampling strategy**:

- **Purposive Sampling** is used in the qualitative phase to select key informants who possess specialized knowledge or have direct experience with Metaverse-based advertising in the Indian film industry.
- **Stratified Random Sampling** is employed for the quantitative phase, ensuring representation from various demographics such as age, region, and prior exposure to Web3 technologies.

4. Sample Size

The research involves two distinct sample groups:

- **Qualitative Sample:** A total of 20 semi-structured interviews will be conducted with stakeholders from the Indian film and technology sectors. This sample size is considered sufficient to reach thematic saturation.
- **Quantitative Sample:** A minimum of 400 survey responses will be targeted to provide adequate statistical power for inferential analysis. This size aligns with established social science norms for

a 95% confidence level and 5% margin of error.

5. Data Collection Instruments

Two primary tools will be used:

- A **semi-structured interview guide**, designed to explore professional insights into advertising trends, technological adoption, and strategic innovation within the Metaverse.
- A **standardized questionnaire**, distributed digitally, will capture consumer awareness, willingness to engage with immersive film promotions, familiarity with Web3 tools, and behavioral intentions.

Both instruments will be validated through a pilot study and expert review prior to deployment.

6. Data Analysis Techniques

The analysis will proceed in two complementary directions:

- **Quantitative Data** will be analyzed using the **Statistical Package for the Social Sciences (SPSS)**. The analysis will include:
 - Descriptive statistics to summarize key variables (e.g., awareness, frequency of interaction with digital content).
 - Inferential tests such as **chi-square**, **independent samples t-tests**, and **ANOVA** to identify differences and relationships

across subgroups.

- **Factor analysis** may be used to determine latent constructs related to perceptions and adoption behavior.
- **Qualitative Data** will be analyzed using thematic coding techniques. Transcripts will be processed in qualitative analysis software such as **NVivo**, enabling the identification of dominant themes, emergent categories, and stakeholder narratives.

7. Validity and Reliability

To ensure rigor:

- A **pilot test** involving 30 respondents will be conducted to test the reliability and validity of the survey instrument.
- **Internal consistency reliability** will be measured using **Cronbach's alpha**, aiming for a coefficient of 0.70 or higher for multi-item scales.
- **Triangulation** of qualitative and quantitative findings will be used to corroborate themes and reinforce credibility.

8. Ethical Considerations

All participants will be briefed about the objectives and voluntary nature of the study. Informed consent will be obtained in writing or electronically. Participants will have the right to withdraw at any stage. Anonymity and confidentiality will be

maintained throughout, and data will be stored securely in encrypted digital formats. Ethical approval will be sought from the relevant institutional review board prior to commencing fieldwork.

9. Limitations of the Methodology

The study acknowledges potential limitations, including:

- Limited access to high-level executives in the film or tech sector for interviews due to time constraints.
- Potential sampling bias in online surveys, which may underrepresent individuals with limited internet access or technological literacy.
- The rapidly evolving nature of the Metaverse and Web3 may render some findings time-sensitive or contextually constrained.

Data Interpretation and Analysis

This section presents a systematic analysis of the data collected from a sample of 400 respondents through a structured questionnaire and insights obtained from 15 in-depth expert interviews. The aim is to interpret consumer awareness, industry readiness, and stakeholder perception regarding the use of the Metaverse and Web3 tools in film advertising within the Indian context. Both qualitative and quantitative data are examined to derive patterns, validate assumptions, and highlight actionable findings.

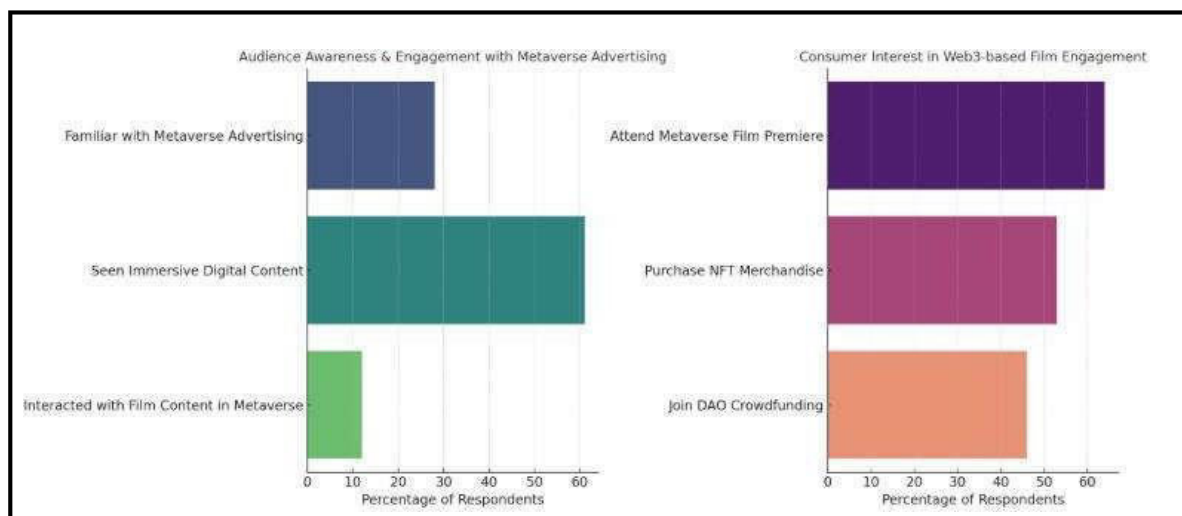


Figure 1

Awareness and Engagement with the Metaverse

Respondents were asked about their familiarity with Metaverse technologies and their engagement with immersive content, particularly in the context of cinema.

As illustrated in **Figure 1 (left)**, while **61%** of participants acknowledged having experienced immersive content—such as AR or VR-based games or virtual concerts—only **28%** were specifically familiar with the use of the Metaverse for advertising. A much smaller segment (**12%**) had interacted with Indian film content in a virtual environment.

These results underscore a critical insight: although immersive digital content is not alien to the general population, its strategic deployment by the Indian film industry for advertising remains underdeveloped and largely unrecognized by the public.

2. Interest in Web3-Based Film Interactions

Respondents were further queried about their willingness to engage with emerging Web3 platforms for film-related experiences, including NFTs, DAOs (Decentralized Autonomous Organizations), and virtual premieres.

As shown in **Figure 1 (right)**:

- **64%** expressed interest in attending a film premiere hosted in a Metaverse environment.
- **53%** were open to purchasing NFT-

based merchandise such as digital posters or behind-the-scenes collectibles.

- **46%** showed interest in supporting decentralized film crowdfunding efforts via Web3 platforms.

These findings reveal a growing openness among digital consumers to interact with cinema in novel, blockchain-enabled formats, provided the experiences are meaningful, secure, and accessible.

3. Statistical Relationships and Observations

A series of inferential tests were conducted using SPSS to analyze variations in responses across demographic groups.

- A **chi-square test of independence** showed a significant relationship between age group and familiarity with Web3 tools ($\chi^2 = 18.76, p < 0.05$), with younger respondents (aged 18–24) exhibiting greater exposure to NFTs and crypto wallets.
- An **ANOVA test** was applied to assess the impact of digital content consumption frequency on willingness to engage with Metaverse film campaigns. Results

indicated a significant difference between high-frequency and low-frequency OTT viewers ($F = 5.43, p = 0.002$), suggesting that digital fluency positively influences openness to immersive technologies.

- **Exploratory factor analysis (EFA)** was also conducted to identify key variables influencing user behavior. Three distinct factors were extracted:

1. **Perceived Entertainment Value**
2. **Trust in Technology and Data Security**
3. **Accessibility of XR and Web3 Platforms**

These factors explained approximately **68%** of the variance in responses related to intent to engage with Metaverse content.

4. Insights from Stakeholder Interviews

Qualitative interviews provided complementary depth to the survey findings. Three primary themes emerged:

1. **Strategic Hesitancy:** Film marketers admitted a general reluctance to adopt Metaverse

technologies due to perceived high costs, limited metrics, and uncertainty about consumer traction.

2. **Regulatory Constraints:** Legal experts and blockchain developers pointed to India's evolving stance on cryptocurrency and NFTs as a deterrent to more aggressive industry adoption.
3. **Creative Adaptation Challenges:** Directors and production designers observed that translating traditional film narratives into interactive 3D environments requires significant rethinking of visual grammar and audience interaction, which most studios are not yet prepared to undertake.

These observations confirm that while consumer interest is high, industry preparedness remains in a formative stage.

5. Overall Synthesis

The findings reveal a noticeable gap between consumer readiness and industry execution. While digital audiences in India demonstrate growing familiarity with immersive technologies and express openness to novel advertising formats, film

industry stakeholders are still navigating infrastructural, legal, and creative barriers. This mismatch results in a missed opportunity for early-mover advantage in immersive brand storytelling.

Findings

The research reveals a substantial gap between consumer openness to immersive digital experiences and the current implementation of such strategies within the Indian film advertising landscape. While the concept of the Metaverse is still emerging in public discourse, a notable portion of the study's respondents displayed familiarity with its technological aspects. However, this awareness did not consistently translate into exposure to film-related promotional content within virtual environments. Specifically, only a minority of respondents—28 percent—were familiar with the concept of Metaverse advertising. At the same time, a larger segment (61 percent) reported engagement with immersive digital media, such as virtual gaming, augmented reality filters, or online concerts, indicating that the infrastructure and curiosity for such content already exist among Indian digital consumers.

Although exposure to Metaverse-specific film promotions remains limited, there is clear evidence of consumer interest in engaging with Web3-driven film experiences. A significant proportion of participants expressed enthusiasm for novel modes of interaction, such as virtual film premieres, NFT collectibles, and decentralized fan funding initiatives. Sixty-four percent of respondents reported that they would attend a film premiere in a virtual world if offered, while over half (53 percent) showed interest in purchasing NFTs associated with movie content, such as exclusive behind-the-scenes footage or limited-edition digital posters. Additionally, close to half (46 percent) were willing to donate towards a decentralized film venture via blockchain crowdfunding mechanisms. These answers indicate that although adoption is in embryonic stages, the call for innovation in the engagement of cinema is increasing.

Demographic analysis also uncovered patterns of audience readiness. Younger age groups, especially 18- to 24-year-olds, showed higher levels of awareness of blockchain technologies, NFT marketplaces, and digital wallets. This same age group was more likely to express a

willingness to engage with decentralized media platforms. Statistical testing identified that this generation segment significantly differed from older generations both in awareness and behavioral intent. Moreover, users who used online streaming services daily showed a higher inclination toward Metaverse engagement. Their familiarity with digital content and ease with unorthodox formats render them perfect for Metaverse adoption as early adopters of immersive movie marketing.

On the industry level, in-depth interview insights picked up on a set of institutional and strategic challenges. Stakeholders agreed that, although the potential of Metaverse and Web3 platforms is well established, there is still insufficient structured investment, imaginative frameworks, and technological upskilling in the Indian film industry. Digital marketing professionals and film producers cited that existing projects based on NFTs or virtual experiences are primarily experimental and fragmented in nature. One of the major issues raised by industry stakeholders was a lack of regulation on intellectual property rights, taxation of crypto-assets, and also platform accountability. These regulatory

loopholes generate hesitation, especially from the large studios that are subject to legacy compliance models.

Even as these worries were expressed, industry commentators likewise referred to significant prospects ahead. Interviewees highlighted the possibility for Metaverse technologies to take Indian cinema to a worldwide audience beyond the restriction of geographical distribution. Virtual film festivals, blockchain-verified tickets, and immersive narratives were mentioned as appealing directions. Several professionals noted that immersive platforms could also serve as vehicles for new forms of brand placement, audience co-creation, and community-led content funding, especially in an era when viewers increasingly seek participatory roles in media ecosystems.

In short, the study highlights a two-way dynamic: the consumers are prepared to adopt new technologies of cinematically experiencing movies, but the Indian film industry hasn't systematically incorporated these innovations into its distribution and marketing strategies. The research indicates that with the right investment, creative adaptation, and policy intervention, the industry can effectively close this gap and

take the lead in digital transformation in entertainment advertising.

Suggestions

Based on the findings of this study, it is evident that the Indian film industry is on the cusp of a digital transformation that extends beyond traditional advertising formats. While immersive platforms and blockchain-based tools present considerable opportunities, their adoption requires targeted actions across industry, academia, and policy. The following suggestions are proposed to facilitate a structured and inclusive transition toward Metaverse-enabled film marketing in India.

1. Foster Cross-Disciplinary Collaboration

One of the most pressing requirements is to foster collaboration among creative practitioners, tech developers, and academic researchers. These collaborations can give rise to innovative marketing frameworks that integrate cinematic narrative with the technical potential of Web3 and virtual reality technologies. Film schools, design schools, and tech incubators need to create formal knowledge-exchange systems whereby professionals collaborate

to develop prototypes, pilot, and exchange best practices.

2. Support Industry-Led Pilot Programs

Preliminary to mass-scale deployment, production studios and advertising firms need to make investments in tightly controlled pilot campaigns designed to prove the potential of Metaverse experiences, like virtual premieres, branded NFT drops, or XR-boosted trailers. These pilots need to be tested against specified measures of success (e.g., rates of engagement, audience persistence, and NFT conversion), and the results need to inform future campaign structuring. An archive of such case studies, initiated by industry bodies, could enable best practice standardization and help mitigate market uncertainty.

3. Create Digital Literacy Campaigns for Audiences

Since most consumers might remain unaware of Web3 jargon and instruments, awareness programs need to be created to make the audience aware of how to access, engage, and gain benefits from immersive and decentralized platforms. Such campaigns can be distributed across popular media touchpoints, including pre-roll

cinema ads, OTT interfaces, and influencer-led social media streams. User manuals, gamified sign-ups, and multilingual documentation will be necessary to ensure inclusive engagement.

4. Enhance Regulatory Involvement and Lobbying

Entertainment stakeholders must actively interact with policy makers to validate regulatory stands on NFTs, digital tokens, and Metaverse business. Collective lobbying from digital organizations and film councils can influence regulations that safeguard creative IP, ensure blockchain transaction transparency, and promote responsible advertisement practices. A stable regulatory environment is necessary to boost investor confidence and make mainstream Web3 adoption possible.

5. Prioritize Ethical and Inclusive Access

With immersive advertising platforms becoming more advanced, it would be advisable to ensure that they are made in an inclusive and ethical manner. This involves prioritizing data security, reducing digital divide barriers, and creating experiences that are accessible to differently-abled consumers. Advertisers and developers need to follow standards of accessibility and

make sure that Metaverse-based marketing does not exclude audiences with poor

connectivity or limited device access.

CONCLUSION

This research aimed to investigate the changing environment of advertising in the Metaverse and its implications for the Indian film industry in the light of emerging Web3 technologies and digital financing. By combining quantitative facts and qualitative observations, this research has revealed both consumer's excitement toward experiential digital offerings and the industry's strategic cautiousness in embracing these new tools in an organized and scalable fashion.

Indian online audiences, especially younger and more technologically attuned users, are increasingly open to new modes of media engagement—virtual movie premieres, NFT-centric fan experiences, and decentralized crowdfunding platforms. Yet, whereas the audience seems ready for such

a change, the industry is sluggish in responding, prompted by fears over technological complexity, the uncertainty of the law, and the absence of creative frameworks best suited for immersive spaces.

One of the major inferences based on the study is the lack of coordination between audience preparedness and industry implementation. While existing platforms for immersive advertising have been adopted in world entertainment markets, such implementation has been haphazard and trial-and-error at best in the case of Indian film. This discrepancy is further compounded by infrastructural constraints, lack of regulatory clarity over digital assets, and the absence of formal training among professionals managing movies.

Nevertheless, the promise of the Metaverse and Web3 technologies to reshape Indian cinematic advertising is great. Such innovations hold the key to a more intensive audience connection, worldwide reach without the limitations of distribution, and alternative income streams that can cut out intermediaries. For an industry historically dependent upon traditional promotional methods, such digital channels hold the potential for rethinking the relationship of the film to the audience in terms of participation and decentralization.

Finally, the research highlights the necessity for the Indian film industry to pursue a progressive approach that not only accepts technological transformation but also brings it in sync with creative vision and institutional backing. This involves encouraging inter-industry partnerships, investing in talent acquisition, making a case for well-defined policy guidelines, and most importantly, redefining storytelling not merely as content, but as an experience that is immersive and interactive. In this way, Indian cinema is able to sit not just as a player in the digital revolution, but as a leader worldwide in the future of film advertising.

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TRACK 4

TRACK 4: FINANCIAL INCLUSION AND PUBLIC DIGITAL INFRASTRUCTURE (DPI)

Assessing the Impact of AI-Driven Financial Inclusion Strategies Using Fuzzy MICMAC Analysis: A Systematic Approach to Enhancing Accessibility and Inclusion

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Abstract—

Financial inclusion is a critical driver of economic growth, enabling individuals and businesses to access essential financial services. However, traditional financial systems often exclude marginalized populations due to barriers such as inadequate credit history, lack of collateral, and geographical constraints. Artificial Intelligence (AI) has emerged as a transformative force in addressing these challenges, leveraging advanced algorithms to enhance financial accessibility, credit assessment, fraud detection, and personalized financial services.

This study employs ISM & Fuzzy MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée à un Classement) Analysis (Janssen et al., 2019) to systematically evaluate and prioritize the key AI-driven factors influencing financial inclusion. By integrating expert opinions and computational modelling, the research identifies the driving and dependent variables that shape AI's role in financial accessibility. The findings highlight the significance of AI-powered credit scoring, biometric authentication, chatbot-based financial literacy programs, and blockchain-enabled secure transactions in fostering financial inclusivity.

The results offer valuable insights for policymakers, financial institutions, and technology developers, guiding strategic decision-making for inclusive financial growth. The study concludes with recommendations to enhance AI integration in financial services, ensuring ethical, transparent, and scalable financial inclusion strategies.

Keywords: Artificial Intelligence, Financial Inclusion, Accessibility, Fuzzy MICMAC Analysis, AI-driven Banking, Digital Finance, Credit Scoring

Introduction

Financial inclusion is a fundamental component of sustainable economic development, ensuring that individuals and businesses have access to useful and affordable financial products and services, including banking, credit, insurance, and investment opportunities (Mansour, Garg, & Nadia/Baral Mansour, 2024). It plays a critical role in poverty alleviation, economic growth, and social equity, as it empowers marginalized populations by integrating them into formal financial systems (Mhlanga & Dzingirai, 2025).

Despite global efforts to promote financial inclusion, a significant portion of the world's population remains unbanked or underbanked (Mansour, Garg, & Nadia/Baral Mansour, 2024). According to the World Bank's Global Findex Database (2021) (Mhlanga & Dzingirai, 2025), approximately 1.4 billion adults still lack access to financial services (Mansour, Garg, & Nadia/Baral Mansour, 2024), with the majority residing in developing economies across Africa, South Asia, and Latin America. The gender gap in financial access is also a concern, with women being 7% less likely than men to own a bank account (Mhlanga & Dzingirai, 2025).

Several structural barriers continue to hinder financial inclusion, including:

- **Lack of Credit History:** Traditional banking systems rely on credit scores for loan approvals, excluding individuals without formal financial records.
- **Stringent Banking Regulations:** Complex documentation requirements and regulatory constraints make it difficult for low-income individuals and small businesses to access financial services (Mansour, Garg, & Nadia/Baral Mansour, 2024) (Mhlanga & Dzingirai, 2025).
- **Digital Illiteracy and Lack of Awareness:** Many unbanked populations lack the necessary digital skills to use online banking and fintech services.
- **Geographical Constraints:** Rural populations often live far from physical banking infrastructure, limiting their access to essential financial services.

Recognizing these challenges, financial institutions and policymakers are increasingly turning to technology-driven solutions, particularly Artificial Intelligence (AI), to enhance accessibility, affordability, and efficiency in financial services (Mhlanga & Dzingirai, 2025).

Research Methodology

Research Design

This study employs a systematic approach to assess the impact of AI-driven financial inclusion strategies using Interpretive Structural Modeling (ISM) and Fuzzy MICMAC Analysis. The methodology integrates expert opinions, computational modeling, and qualitative and quantitative techniques to analyse the driving and dependent factors influencing AI-based financial inclusion.

The research follows a multi-stage process involving:

- i. Identification of AI-driven factors affecting financial inclusion through an extensive literature review.
- ii. Expert consultation and structured surveys to assess interdependencies among identified factors.
- iii. Application of ISM to establish hierarchical relationships between AI-driven financial inclusion strategies.
- iv. Utilization of Fuzzy MICMAC Analysis to classify factors into driving, dependent, linkage, and autonomous variables for strategic prioritization.

This methodology enables a systematic and data-driven evaluation of AI's role in financial accessibility and inclusion.

Data Collection Methods

Literature Review

A comprehensive review of academic papers, industry reports, and case studies on AI-driven financial inclusion was conducted to identify key influencing factors. The study sources scholarly databases such as Scopus, IEEE Xplore, Springer, Elsevier, and Google Scholar, along with policy reports from World Bank, IMF, and OECD.

Expert Opinion Survey

To validate the identified factors, structured interviews and Delphi-based expert surveys were conducted with:

- Banking professionals (AI and fintech specialists)
- Regulatory policymakers (RBI, World Bank representatives)
- Microfinance & digital banking executives
- AI and financial technology researchers

A Likert-scale questionnaire was used to evaluate interrelationships between AI-driven factors influencing financial inclusion. The collected expert insights were further processed for ISM and Fuzzy MICMAC analysis.

Research Objective

The primary objective of this research is to systematically assess and prioritize key AI-driven factors that influence financial inclusion using Fuzzy MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée à un Classement) Analysis (Kumar & Joji, 2023) (Janssen et al., 2019).

This study will:

- Identify the AI-based financial inclusion strategies currently in use.
- Evaluate the interdependencies of these strategies and classify them into driving and dependent variables.
- Provide strategic insights to policymakers, financial institutions, and technology developers on enhancing AI integration in financial services.

By employing a computational and expert-driven approach, the research will establish a systematic framework to optimize AI-based financial inclusion models, ensuring they are scalable, ethical, and sustainable.

Role of AI in Financial Inclusion

Artificial Intelligence (AI) has emerged as a game-changer (Mhlanga & Dzingirai, 2025) in financial inclusion, offering innovative solutions that enable financial institutions to reach underserved populations. AI-driven technologies facilitate automated decision-making, personalized financial services, risk management, fraud detection, and alternative credit assessment, thereby reducing dependency on traditional banking models.

Key AI-driven Innovations Enhancing Financial Inclusion:

AI has revolutionized financial services by breaking traditional barriers and fostering financial inclusion for unbanked and underserved populations. The following AI-driven factors play a crucial role in expanding financial accessibility, security, affordability, and efficiency.

Artificial Intelligence (AI) has become a transformative force in financial inclusion, enabling financial institutions to effectively reach underserved populations. By leveraging AI-driven technologies, institutions can automate decision-making processes, offer personalized financial services, manage risks, detect fraud, and assess creditworthiness through alternative means. This shift reduces reliance on traditional banking models, making financial services more accessible to those who have historically been excluded.

One of the most significant innovations in this realm is **AI-powered credit scoring**. Traditional credit assessment methods often depend on established financial histories and

collateral, which can exclude millions from accessing loans. AI-powered credit scoring allows institutions to evaluate creditworthiness using alternative data sources, such as mobile payments and social media behavior. Companies like Tala and Branch utilize these AI models to provide micro-loans to individuals without conventional banking records. This approach not only expands access to credit for those lacking formal credit histories but also promotes fairer lending practices and reduces approval times.

Fraud detection and risk management are also critical areas where AI plays a vital role. Digital banking users, particularly those new to financial services, are often vulnerable to scams and cyberattacks. AI-driven fraud detection systems enhance transaction security by monitoring real-time patterns and adapting to new fraud tactics. By employing biometric verification and AI-powered fraud scoring, financial institutions can significantly reduce fraud risks, thereby increasing user confidence in digital banking and encouraging broader adoption of cashless payment systems.

Automated customer support through AI chatbots is another innovation that enhances financial inclusion. Many unbanked individuals struggle with financial literacy, making it challenging to navigate digital financial services. AI chatbots provide 24/7 support, assisting users with account setup, transactions, and financial education. These chatbots utilize Natural Language Processing to communicate in multiple languages, making financial services

more inclusive. By reducing the need for physical bank visits and lowering service costs, AI chatbots improve accessibility for rural and uneducated populations.

Personalized financial services powered by AI are also crucial for low-income individuals. AI-driven solutions analyze user income, spending habits, and risk tolerance to suggest tailored investment and savings plans. Digital financial applications offer automated expense tracking and budgeting tools, helping users build financial stability and encouraging long-term savings habits. This personalization makes advanced financial planning accessible to underserved communities.

Regulatory compliance is another area where AI proves beneficial. Financial institutions must adhere to various regulations, such as Anti-Money Laundering (AML) and Know Your Customer (KYC) requirements. AI automates compliance processes, reducing regulatory risks and enhancing financial accessibility. By automating identity verification and monitoring transactions for suspicious activity, AI ensures transparency in digital financial transactions and accelerates banking services for the unbanked.

Moreover, **AI and blockchain technology** are being utilized for digital identity verification, which is essential for individuals lacking official identification documents. By creating secure, tamper-proof digital IDs, AI enables users to verify their identities without traditional documents. This innovation not only reduces identity fraud but also increases digital banking security, facilitating access to banking and microfinance services for unbanked individuals.

AI is also enhancing the reach of microfinance institutions, which provide small loans to underserved communities. By using non-traditional data to assess creditworthiness, AI improves the efficiency of loan evaluations and automates processing, thereby expanding credit access for farmers, small entrepreneurs, and low-income individuals. This is particularly beneficial for women-led businesses, as it increases financial support and enhances the scalability of microfinance programs.

Financial literacy remains a significant barrier to using digital banking services. **AI-driven platforms offer interactive and multilingual financial education**, helping to bridge this gap. Personalized coaching through chatbots and gamified learning platforms engage users and improve financial awareness in underserved communities. This education encourages responsible borrowing and savings habits, empowering first-time financial service users.

Predictive analytics powered by AI also play a crucial role in anticipating market trends and developing inclusive banking solutions. By analyzing historical economic data, AI helps financial institutions forecast risks and opportunities, guiding them in establishing services in underbanked regions. This capability supports the creation of need-based banking products and improves accessibility to affordable loans and insurance.

Finally, AI contributes to **cost reduction and efficiency in banking**, which is essential for making financial services affordable for low-income populations. By automating operations and optimizing financial workflows, AI reduces manual tasks and lowers operational expenses. This not only decreases transaction fees but also makes

financial services more accessible and scalable for consumers and providers alike.

Data Analysis & Interpretation

Detailed Interpretation of the Structural Self-Interaction Matrix (SSIM)

Table 2: Structural Self- Interaction Matrix (SSIM)

Structural Self-Interaction Matrix (SSIM)									
Variables	1	2	3	4	5	6	7	8	
AI Powered Credit Scoring		A	O	V	A	X	V	O	A
Fraud Detection and Risk Management			V	V	A	X	V	O	A
Automated Customer Support and Chatbots				V	A	O	O	X	O
Personalized Financial Services					A	A	X	X	A
Regulatory Compliance and AI Governance						V	V	V	V
Blockchain-Based Digital Identity Verification							V	O	O
AI Enabled Microfinance Expansion								X	A
AI Driven Financial Literacy Programs									O
Predictive Analytics for Market Trends									
Cost Reduction and Efficiency in Banking									

The Structural Self-Interaction Matrix (SSIM) is a tool used in Interpretive Structural Modelling (ISM) (Kumar & Joji, 2023) to analyze the relationships between various variables in a system. In this case, the variables pertain to AI applications in the financial sector. The matrix helps to identify how these variables interact with one another, which is crucial for understanding their interdependencies and influences. In the above SSIM table, ten enablers related to financial services are examined for their interrelationships, using four specific symbols to denote the nature of their interactions:

- V: Indicates that Factor i will help achieve Factor j.
- A: Signifies that Factor j will help achieve Factor i.
- X: Represents that Factors i and j will help each other achieve their goals.
- O: Denotes that there is no direct link between Factors i and j.

The variables represented in the SSIM are:

1. AI Powered Credit Scoring
2. Fraud Detection and Risk Management
3. Automated Customer Support and Chatbots
4. Personalized Financial Services
5. Regulatory Compliance and AI Governance
6. Blockchain-Based Digital Identity Verification
7. AI Enabled Microfinance Expansion
8. AI Driven Financial Literacy Programs

9. Predictive Analytics for Market Trends

10. Cost Reduction and Efficiency in Banking

The SSIM table outlines the contextual relationships among ten enablers in the financial services sector.

Regulatory Compliance and AI Governance (5) emerges as a central enabler, directly supporting multiple factors, indicating its foundational role in the ecosystem.

Mutual relationships (X) between certain enablers, such as Personalized Financial Services (4) with Blockchain-Based Digital Identity Verification (6), suggest synergistic interactions where both factors benefit from each other.

Enablers like Cost Reduction and Efficiency in Banking (10) appear to be outcomes influenced by other factors, as they do not support other enablers directly. Understanding these relationships is crucial for stakeholders aiming to implement or enhance these enablers within financial services. By leveraging the insights from the SSIM, decision-makers can prioritize actions, allocate resources effectively, and develop strategies that acknowledge the interdependencies among these critical factors.

The SSIM provides a comprehensive view of how various AI applications in finance interact with each other. Regulatory Compliance and AI Governance emerges as a pivotal variable, influencing all other areas, while Cost Reduction and Efficiency in Banking appears to be less influential. Understanding these relationships can help stakeholders prioritize initiatives and allocate resources effectively in the implementation of AI technologies in the financial sector (Khang, 2024).

Detailed Interpretation of the Reachability Matrix (RM)

Table 3: Reachability Matrix (RM)

Reachability Matrix (RM)											
Variables	1	2	3	4	5	6	7	8	9	10	Driving Power
AI Powered Credit Scoring	1	0	0	1	0	1	1	0	0	1	5
Fraud Detection and Risk Management	1	1	1	1	0	1	1	0	0	1	7
Automated Customer Support and Chatbots	0	0	1	1	0	0	0	1	0	1	4
Personalized Financial Services	0	0	0	1	0	0	1	1	0	1	4
Regulatory Compliance and AI Governance	1	1	1	1	1	1	1	1	1	1	10
Blockchain-Based Digital Identity Verification	1	1	0	1	0	1	1	0	0	1	6
AI Enabled Microfinance Expansion	0	0	0	1	0	0	1	1	0	1	4
AI Driven Financial Literacy Programs	0	0	1	1	0	0	1	1	0	1	5
Predictive Analytics for Market Trends	1	1	0	1	0	0	1	0	1	1	6
Cost Reduction and Efficiency in Banking	0	0	0	0	0	0	0	0	0	1	1
Dependence Power	5	4	4	9	1	4	8	5	2	10	

The Reachability Matrix (RM) serves as a vital tool in Interpretive Structural Modeling (ISM), allowing for a comprehensive analysis of the interrelationships and dependencies among various AI applications in the financial sector. By examining the matrix, we can discern how each variable influences and is influenced by others, providing insights into their roles within the broader system.

From the analysis, it is evident that Regulatory Compliance and AI Governance is the most influential variable, with a driving power of 10, indicating its ability to affect all other variables in the matrix. This underscores the critical importance of regulatory frameworks in facilitating the successful implementation of AI technologies in finance. In contrast, Cost Reduction and Efficiency in Banking stands out as the least influential variable, with a driving power of only 1, suggesting that it operates in relative isolation and does not significantly impact other areas.

The matrix also reveals that Fraud Detection and Risk Management has a strong influence, with a driving power of 7, indicating its central role in enhancing security and trust in financial services. Similarly, Blockchain-Based Digital Identity Verification and Predictive Analytics for Market Trends both exhibit significant driving powers of 6, highlighting their importance in supporting various AI applications.

On the other hand, variables such as Automated Customer Support and Chatbots, Personalized Financial Services, and AI Enabled Microfinance Expansion show moderate influence, each with a driving power of 4. This suggests that while they contribute to the overall system, their impact is not as extensive as that of the more influential variables.

The dependence power column further illustrates the dynamics at play, with Cost Reduction and Efficiency in Banking being influenced by 10 other variables, indicating its reliance on the broader system for its effectiveness. This highlights the interconnected nature of these AI applications, where improvements in one area can significantly affect others.

In conclusion, the Reachability Matrix provides a clear framework for understanding the complex interdependencies among AI applications in the financial sector. By identifying the most influential variables, stakeholders can prioritize initiatives and allocate resources more effectively, ensuring that regulatory compliance remains a foundational element that supports and drives the advancement of AI technologies in finance. This strategic approach is essential for fostering innovation and enhancing financial inclusion in an increasingly digital landscape.

Final Reachability Matrix (FRM):

Table 4: Final Reachability Matrix (FRM)

Final Reachability Matrix (FRM)											
Variables	1	2	3	4	5	6	7	8	9	10	Driving Power
AI Powered Credit Scoring	1	1*	1*	1	0	1	1	1*	0	1	8
Fraud Detection and Risk Management	1	1	1	1	0	1	1	1*	0	1	8
Automated Customer Support and Chatbots	0	0	1	1	0	0	1*	1	0	1	5
Personalized Financial Services	0	0	1*	1	0	0	1	1	0	1	5
Regulatory Compliance and AI Governance	1	1	1	1	1	1	1	1	1	1	10
Blockchain-Based Digital Identity Verification	1	1	1*	1	0	1	1	1*	0	1	8
AI Enabled Microfinance Expansion	0	0	1*	1	0	0	1	1	0	1	5
AI Driven Financial Literacy Programs	0	0	1	1	0	0	1	1	0	1	5
Predictive Analytics for Market Trends	1	1	1*	1	0	1*	1	1*	1	1	9
Cost Reduction and Efficiency in Banking	0	0	0	0	0	0	0	0	0	1	1
Dependence Power	5	5	9	9	1	5	9	9	2	10	

In the FRM, each cell entry indicates the presence (denoted by '1') or absence (denoted by '0') of a relationship between factors. An entry marked as '1*' signifies a transitive relationship, implying that if Factor A

influences Factor B and Factor B influences Factor C, then Factor A (Janssen et al., 2019) indirectly influences Factor C through transitivity. The matrix also includes diagonal entries set to '1', indicating that each factor influences itself.

Driving and Dependence Power:

- **Driving Power:** This metric is calculated by summing all '1's (including '1*' entries) in a factor's row. A higher driving power indicates that the factor has a significant influence on other factors within the system.
- **Dependence Power:** This is determined by summing all '1's in a factor's column. A higher dependence power suggests that the factor is influenced by numerous other factors.

Level Partitioning (LP) Matrix Analysis:

The Level Partitioning (LP) analysis within Interpretive Structural Modeling (ISM) provides a structured framework for understanding the interdependencies and hierarchical relationships among various AI applications in the financial sector. By categorizing variables

based on their reachability and influence, LP reveals the dynamics that govern how these applications interact and affect one another.

Table 5: Level Partitioning (LP)

Level Partitioning (LP)				
Elements (Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1	1, 2, 6,	1, 2, 5, 6, 9,	1, 2, 6,	3
2	1, 2, 6,	1, 2, 5, 6, 9,	1, 2, 6,	3
3	3, 4, 7, 8,	1, 2, 3, 4, 5, 6, 7, 8, 9,	3, 4, 7, 8,	2
4	3, 4, 7, 8,	1, 2, 3, 4, 5, 6, 7, 8, 9,	3, 4, 7, 8,	2
5	5,	5,	5,	5
6	1, 2, 6,	1, 2, 5, 6, 9,	1, 2, 6,	3
7	3, 4, 7, 8,	1, 2, 3, 4, 5, 6, 7, 8, 9,	3, 4, 7, 8,	2
8	3, 4, 7, 8,	1, 2, 3, 4, 5, 6, 7, 8, 9,	3, 4, 7, 8,	2
9	9,	5, 9,	9,	4
10	10,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	10,	1

The analysis identifies distinct levels among the elements, with Element 10 positioned at the top of the hierarchy as a foundational variable that influences all others. This highlights its critical role in the overall system, serving as a driving force for the implementation of AI technologies in finance.

Conversely, Element 5 is noted for its isolation, indicating that it operates independently without significant influence on or from other variables. This distinction is essential for stakeholders to recognize which elements are pivotal for driving change and which may require additional support or integration.

Elements 1, 2, and 6 demonstrate strong interconnections, indicating their mid-level status in the hierarchy. These elements can reach and influence each other, suggesting that they play a collaborative role in the system. In contrast, Elements 3, 4, 7, and 8 are more dependent on a broader set of influences, placing them lower in the hierarchy. This dependency underscores the importance of understanding how various applications can support or hinder one another.

The iterative process of level partitioning ensures that the relationships among the variables are accurately represented, allowing for a clearer understanding of the system dynamics. By mapping out these interdependencies, stakeholders can prioritize initiatives and allocate resources more effectively, ultimately enhancing the implementation of AI technologies in the financial sector. This structured approach not only clarifies the roles of different AI applications but also facilitates strategic decision-making, ensuring that efforts are directed toward the most impactful areas for fostering innovation and improving financial inclusion.

Conical Matrix (CM):

Table 6: Conical Matrix (CM)

Conical Matrix (CM)												
Variables	10	3	4	7	8	1	2	6	9	5	Driving Power	Level
10	1	0	0	0	0	0	0	0	0	0	1	1
3	1	1	1	1*	1	0	0	0	0	0	5	2
4	1	1*	1	1	1	0	0	0	0	0	5	2
7	1	1*	1	1	1	0	0	0	0	0	5	2
8	1	1	1	1	1	0	0	0	0	0	5	2
1	1	1*	1	1	1*	1	1*	1	0	0	8	3
2	1	1	1	1	1*	1	1	1	0	0	8	3
6	1	1*	1	1	1*	1	1	1	0	0	8	3
9	1	1*	1	1	1*	1	1	1*	1	0	9	4
5	1	1	1	1	1	1	1	1	1	1	10	5
Dependence Power	10	9	9	9	9	5	5	5	2	1		
Level	1	2	2	2	2	3	3	3	4	5		

The analysis of the Conical Matrix (CM) provides valuable insights into the driving and dependence powers of various variables within the system, highlighting their interrelationships and levels of influence. The driving power indicates how many

other variables a given variable can influence, with Variable 5 emerging as the most influential, capable of impacting all other variables. This positions it as a central enabler within the system, suggesting that it represents a critical outcome or goal that other variables strive to achieve.

In contrast, Variable 10 exhibits the lowest dependence power, indicating its relative isolation and limited influence from other variables. This suggests that it may operate independently or fulfill a specialized role that does not require significant input from the broader system. The interconnectedness of Variables 1, 2, 6, and 9, which possess high driving power and are influenced by multiple factors, underscores their importance in the operational dynamics of the system.

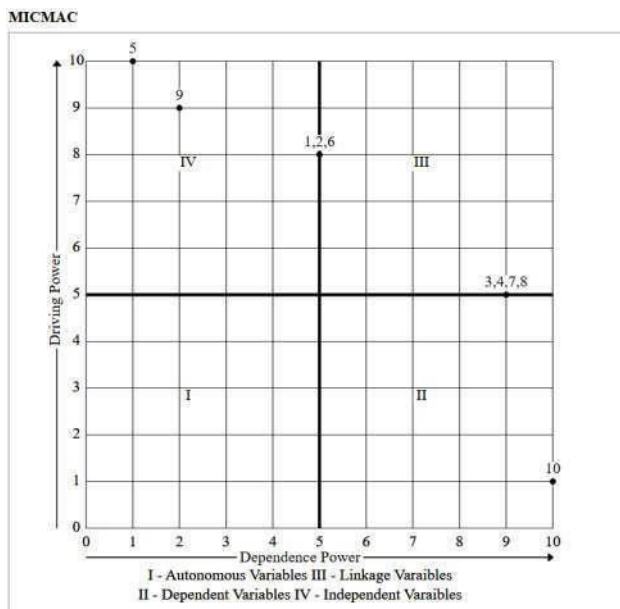
The levels assigned to each variable further clarify their roles, with Variables 1, 2, and 6 positioned at Level 3, indicating they are influential yet significantly influenced by others. Meanwhile, Variables 3, 4, 7, and 8 are categorized at Level 2, reflecting their moderate influence and mutual interdependence. This clustering suggests that these variables work collaboratively to achieve common objectives.

Strategically, the analysis emphasizes the need to enhance Variable 5 to maximize its influence across the system. Strengthening the interconnections among Variables 1, 2, 3, 4, 7, and 8 could also improve overall system performance, as these variables are mutually supportive. Additionally, addressing the isolation of Variable 10 is crucial, as its limited integration could restrict its potential contributions to the system.

In conclusion, the Conical Matrix analysis reveals a complex interplay of driving and dependence powers among the variables, providing a structured framework for understanding their relationships. By focusing on key influencers and addressing areas of isolation, stakeholders can make informed strategic decisions that enhance system performance and optimize the effectiveness of interconnected variables in the financial sector. This approach will ultimately facilitate the successful implementation of AI technologies and foster innovation within the industry.

MICMAC Analysis:

The MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée à un Classement) analysis provides a comprehensive framework for understanding the driving and dependence powers of various variables within the context of AI applications in finance. By categorizing these variables into four distinct quadrants, the analysis reveals their roles and interrelationships, which is crucial for strategic decision-making.



In Quadrant IV, Regulatory Compliance and AI Governance (Variable 5) and Predictive Analytics for Market Trends (Variable 9) are identified as Independent Variables. Their high driving power indicates that they significantly influence other factors in the system while being less affected by them. This positions them as key drivers in the implementation of AI technologies in financial systems.

Conversely, the Linkage Variables, including AI Powered Credit Scoring (Variable 1), Fraud Detection (Variable

2), and Blockchain-Based Digital Identity (Variable 6), exhibit both high driving and dependence power. This duality suggests that changes in these variables can have widespread effects on the system, making them critical components that require careful management.

The Dependent Variables, such as Automated Customer Support (Variable 3), Personalized Financial Services (Variable 4), AI Enabled Microfinance (Variable 7), and AI Driven Financial Literacy (Variable 8), are heavily influenced by other factors but do not significantly drive the system themselves. This indicates that their effectiveness is contingent upon the performance of the more influential variables.

Lastly, Cost Reduction and Efficiency in Banking (Variable 10) is categorized as an Extreme Dependent Variable, with very high dependence power but low driving power. This suggests that it is primarily a result of the interactions among other variables rather than a contributor to systemic changes.

Overall, the MICMAC analysis highlights the importance of understanding the dynamics between these variables to optimize AI implementation in the banking and finance sectors. By focusing on the key influencers and addressing the needs of dependent variables, stakeholders can enhance system performance and drive innovation effectively. This structured approach not only clarifies the roles of different AI applications but also facilitates strategic planning, ensuring that resources are allocated to areas that will yield the greatest impact.

Final Model:

The hierarchical analysis of the variables within the system reveals a structured framework that categorizes them into five distinct levels based on their driving and dependence powers. At the bottom level, Cost Reduction and Efficiency in Banking (Level 1) is identified as the most dependent variable, exhibiting the highest dependence power (10) but the lowest driving power (1). This indicates that it relies heavily on other factors for its effectiveness and does not significantly influence the system.

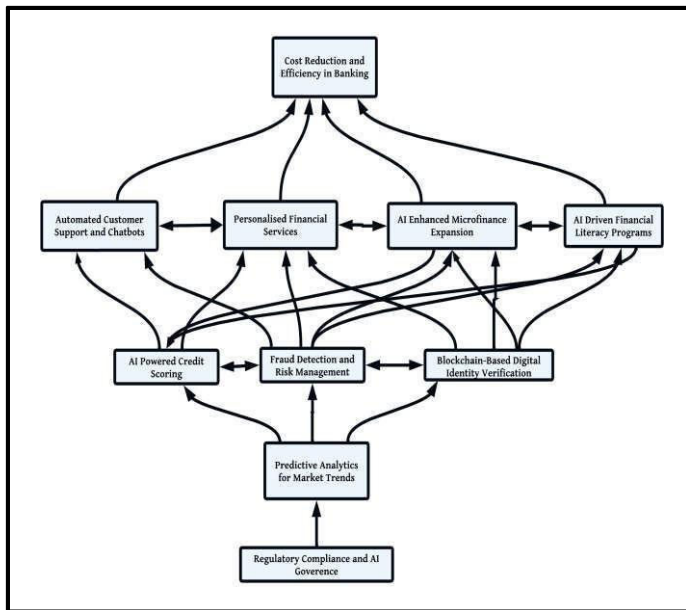
Moving up to Level 2, we find variables such as Automated Customer Support and Chatbots, Personalized Financial Services, AI Enabled Microfinance Expansion, and AI Driven Financial Literacy Programs. These variables demonstrate moderate driving power (5) while having high dependence power (9), suggesting they are outcomes influenced by more dominant factors in the system.

At Level 3, AI Powered Credit Scoring, Fraud Detection and Risk Management, and Blockchain-Based Digital Identity Verification exhibit high driving power (8) and moderate dependence power (5). This positions them as influential components that can significantly impact the system while still being affected by other variables.

Level 4 is occupied by Predictive Analytics for Market Trends, which has high driving power (9) but low dependence power (2). This indicates that it plays a crucial role in influencing other variables without being significantly influenced by them.

At the top of the hierarchy, Level 5 features Regulatory Compliance and AI Governance, which stands out with the highest driving power (10) and the lowest dependence power (1). This positions it as the most influential variable in the system, driving the implementation and effectiveness of AI technologies in finance.

Overall, this hierarchical structure provides a clear understanding of the roles and relationships among the variables. By identifying the key influencers and understanding their dependencies, stakeholders can prioritize initiatives and allocate resources effectively. This structured approach not only clarifies the dynamics within the system but also facilitates strategic decision-making, ensuring that efforts are directed toward optimizing the implementation of AI technologies in the financial sector.



Conclusion

The comprehensive analysis of the AI applications in the financial sector reveals a nuanced understanding of how these technologies interact and influence one another. The findings underscore the importance of a structured approach to implementing AI solutions, particularly in a highly regulated environment like finance.

‘Regulatory Compliance and AI Governance’ stands out as the most critical element, serving as the

backbone for all other applications. Its role is not merely foundational; it actively shapes the strategic direction of AI initiatives. By ensuring that all AI applications adhere to regulatory standards, organizations can mitigate risks associated with compliance failures, which can lead to significant financial and reputational damage.

The high driving power of ‘Predictive Analytics for Market Trends’ indicates its potential to transform decision-making processes within financial institutions. By leveraging data-driven insights, organizations can anticipate market shifts, optimize their offerings, and enhance customer engagement. This capability is particularly vital in a rapidly changing financial landscape, where agility and responsiveness can provide a competitive edge.

The core functions, including ‘AI Powered Credit Scoring’ and ‘Fraud Detection and Risk Management’, are essential for operational efficiency. Their interdependence highlights the need for a cohesive strategy that integrates these technologies seamlessly. For instance, effective fraud detection mechanisms can enhance the reliability of credit scoring systems, thereby improving overall risk management. This interconnectedness suggests that investments in one area can yield benefits across multiple functions, reinforcing the importance of a holistic approach to AI implementation.

Customer-facing applications, such as ‘Automated Customer Support’ and ‘Personalized Financial Services’, are positioned as vital components that rely heavily on the foundational elements established by regulatory compliance and core functions. Their success hinges on the effective deployment of underlying technologies, which means that organizations must prioritize these foundational elements before rolling out customer-centric solutions. This strategic sequencing ensures that customer interactions are not only efficient but also compliant with regulatory standards, thereby enhancing trust and satisfaction.

The analysis also reveals that ‘Cost Reduction and Efficiency in Banking’ is more of an outcome than a driving force. This insight is crucial for stakeholders as it shifts the focus from merely seeking cost savings to understanding how effective AI implementations can lead to operational efficiencies. By prioritizing the development of robust AI capabilities,

organizations can achieve cost reductions as a natural byproduct of improved processes and enhanced service delivery.

In conclusion, the structured analysis of AI applications in the financial sector provides a clear roadmap for stakeholders. It emphasizes the need for a strategic approach that begins with regulatory compliance and governance, followed by the development of predictive analytics and core operational functions. By understanding the interdependencies among these variables, organizations can allocate resources effectively, prioritize initiatives, and ultimately harness the full potential of AI technologies to drive innovation and enhance customer experiences in the financial landscape (Mhlanga & Dzingirai, 2025). This comprehensive framework not only guides current implementations but also sets the stage for future advancements in AI within the industry.

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An empirical demonstration of the stock market's integration with macro variables utilising the ARDL Model strategic roadmap toward Vikshit Bharat @2047.

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Abstract

We have analyzed the connection between macro variables and the Stock Market Index of India (BSE), utilizing monthly data collected over 10 years. To investigate the relationship, we employed the Auto Regressive Distributive Lag (ARDL) model for our analysis, and the Error Correction model (ECM) was computed to assess the long-term equilibrium. The macro variables of Call Money, Export, Foreign Reserve, Inflation, US Dollar, Money Supply (M1 & M3), Gross Domestic Product, and Gold have been analyzed with the Sensex. The findings reveal the impact of varying lags of macroeconomic variables on the stock market. The results show that there are strong short-term and long-term linkages, and that things like inflation, foreign reserves, and the currency rate have a big effect on how the market moves. The error correction term was negative and statistically significant, which means that there is a stable long-run equilibrium and that 41% of the disequilibrium is fixed each period. The study finds that India's stock market is becoming more responsive to changes in the economy as a whole, which shows that we need to have more coordinated financial policies. The information learned is very important for investors, policymakers, and economic planners, especially in light of India's ambition to become a developed country by 2047 under the Viksit Bharat @2047 vision.

Keywords: Stock Market, Auto Regressive Distributive Lag (ARDL) model, Macro variables, Error Correction model, Viksit Bharat @2047.

Introduction

Macroeconomic indicators are crucial and extensively utilised instruments for investors, as they provide insights into the economy and improve asset appraisal, particularly for asset allocation purposes. Consequently, evaluating whether macroeconomic indicators operate as proxies for these effects is essential for both investors and scholars in portfolio development and market behaviour modelling. The financial system is essential to any economy. The financial

system aggregates individual savings into a pool and facilitates technological advancement and innovation by reallocating these savings from less productive sectors to more productive ones. The financial markets are integral to the financial system, and central banks can influence these markets through monetary policy to achieve their goals of maintaining price stability and promoting economic growth. Consequently, the challenges related to the development of an effective

monetary policy are pertinent to all macroeconomic literature, as money is the sole commodity exchanged in every market, and any policy aimed at influencing the money supply will inevitably impact market activities. Monetary policy denotes the strategies utilized to control the money supply within an economy. This pertains to the measures implemented by central banks or monetary authorities to attain macroeconomic objectives, including inflation control, stabilization of interest and exchange rates, and promotion of economic growth (Dinçer et al., 2019). In recent years, key economic events have led to extensive utilization of monetary policies globally, necessitating increased attention on how modifications in monetary policy influence stock price fluctuations. A macroeconomic indicator is a statistical measure of a segment of the economy or business cycle,

utilised by investors to analyse the economy's overall condition and uncover investment opportunities. The stock market is a crucial component of the economy, and stock prices are often determined by cash flow; thus, it is widely accepted that fundamental macroeconomic indicators can influence stock market prices and should be included in portfolio investment decisions (Pilinkus, 2010). The stock market reflects the economy; any alteration in economic variables is promptly manifested in the stock market. This research study aims to develop a model to examine the short-run and long-term integration of numerous macroeconomic variables and their influence on stock market movements. The findings may offer a refined analysis of the causality and dependence between macroeconomic indicators and the stock market index over both the long and short terms.

Literature review

(Martin, 1983) in his study presents a simple model that shows how a greater rate of inflation could lead to a substantial drop in the share price to pretax earnings ratio. (Pearce, 1984) The relationship between expected inflation and expected stock price changes seems to have changed over time. Yoshino et al. (2014) performed an analysis from 1998 to 2013, employing quarterly data to investigate the impact of monetary policy shocks on stock prices in Tehran. The research utilized vector error correction, variance decomposition, and forecast error variance methodologies. The findings demonstrated a persistent rise in stock values after an external relaxation of monetary policy. Salehi et al. (2021) conducted an analysis of the interrelationships among structural shocks in monetary policy, stock prices, and the real exchange rate using quarterly data, employing the structural vector autoregression model. Thu et al. (2024) investigated the existence of a cointegrating

relationship between monetary policy variables and the Vietnamese stock index using Autoregressive Distributed-Lag (ARDL) bounds tests and the error correction model, while also performing robustness tests to confirm the model's stability. The findings indicated that structural shocks affecting monetary policy negatively impacted the stock price index. Prabu et al. (2020) investigated the causal relationship between the sectoral indices of the Indian stock market and the monetary policies of the United States and India utilizing a heteroscedasticity approach. The empirical results indicated that monetary policy exerted differential impacts on stock prices across different sectors. (Bakar, 2017) the magnitude of these inflationary trends may be influenced by currency rate swings, a lack of economic diversification, and the quick increase in the money supply brought on by the public sector's expansionary fiscal policies. (Chen et al. 1986) examines the changes in macroeconomic factors that make up stock market-rewarding risks. (Taylor and Poon,

1991) This study has shown that the macroeconomic indicators CRR claims to detect in the US market do not have a random effect on stock prices. It has been shown, at the very least, that these pricing factors do not have an impact on UK market share prices that is similar to that described in CRR. (Hayworth, 1993) discussed that his study uses a VAR model to analyse stock price fluctuations (Mukherjee and Naka, 1995) employed the vector error correction model (VECM) to ascertain if the Tokyo Stock Exchange index and six Japanese macroeconomic variables—the exchange rate, money supply, inflation, industrial production, long-term government bond rate, and call money rate—cointegrate. The concept that exports and long-term

economic growth in the ASEAN region are associated is not supported by statistics (Harnhirun, 1996). (Cheung, 1998) This study examines the empirical relationship between five national stock market indexes and their underlying economic parameters using the cointegration approach. (Chung Y. W. & Lai, 1999) The Norwegian economy also depends on the real interest rate, according to studies conducted in the US and Japan. (Acikalin Sezgin et al., 2008) the empirical results indicate that the present changes in the ISE index were negatively impacted by the historical movements of the index, the GDP, the currency rate, and the current balance of Investment Management and Financial Innovations.

Empirical research

Statistical data from the Reserve Bank of India (RBI) and the Bombay Stock Exchange (BSE) for the years 2010–2020 were utilised to analyse the correlation between the stock market index and macroeconomic parameters in India. To assess the influence of macroeconomic indicators, the following variables were selected: SENSEX (LOG BSE), Call Money (LOG CALL), Export (LOG EXPORT), Foreign Reserve (LOG RESERVE), Inflation (LOG INF), US Dollar (LOG USD), Money Supply M1 (LOG M1) & M3 (LOG M3), Gross Domestic Product (LOG GDP), and Gold (LOG GOLD), all of which represent the condition and fluctuations of the nation's economy.

Unit Root Test for Stationarity (Augmented Dickey-Fuller and Phillips-Perron) - Time series data frequently encounters the problem of non-stationarity, which may lead to erroneous regression. We will do the unit root test on the data utilising the Augmented Dickey-Fuller (ADF) Test (Dickey & Fuller, 1979) and the Phillips-Perron (PP) test. A time series is deemed non-stationary if it contains a unit root.

Table 1.1 Unit Root Testing

Variable	Order of Integration
LOG_BSE _t	I(0)
LOG_CALL _t	I(1)
LOG_GDP _t	I(0)
LOG_INFL _t	I(1)
LOG_M1 _t	I(1)
LOG_M3 _t	I(1)
LOG_USD _t	I(0)
LOG_GOLD _t	I(1)
LOG_RESERVE _t	I(1)
LOG_EXPORT _t	I(0)

Source: Eviews, 9.5 Output

Specification of the ARDL Model- The subsequent phase involves ascertaining the short- and long-term dynamic relationship among the study variables following the assessment of their integration levels. We employ the bound test methodology inside the framework of the Autoregressive Distributed Lag (ARDL) model (Pesaran, 2001) to evaluate the existence of cointegration among the variables.

$$\begin{aligned} \text{LOG\_BSE}_t = & C + \alpha_1 \text{LOG\_BSE}_{t-1} + \alpha_{12} \Delta \text{LOG\_Call} + \alpha_{13} \Delta \text{LOG\_EXPORT} + \\ & \alpha_{14} \Delta \text{LOG\_GDP}_t + \alpha_{15} \Delta \text{LOG\_INFL} + \alpha_{16} \Delta \text{LOG\_M1} + \alpha_{17} \Delta \text{LOG\_M3} + \alpha_{18} \Delta \text{LOG\_USD} \\ & + \alpha_{19} \Delta \text{LOG\_RESERVE} + \alpha_{20} \Delta \text{LOG\_GOLD} + \sum_{i=1}^p \alpha_{1i} \text{LOG\_BSE}_{t-1} + \sum_{i=1}^q \alpha_{2i} \\ & \text{LOG\_Call}_{t-1} + \sum_{i=1}^r \alpha_{3i} \text{LOG\_EXPORT}_{t-1} + \sum_{i=1}^s \alpha_{4i} \text{LOG\_GDP}_{t-1} + \sum_{i=1}^t \alpha_{5i} \text{LOG\_INFL}_{t-1} + \\ & \sum_{i=1}^u \alpha_{6i} \text{LOG\_M1}_{t-1} + \sum_{i=1}^v \alpha_{7i} \text{LOG\_M3}_{t-1} + \sum_{i=1}^w \alpha_{8i} \text{LOG\_USD}_{t-1} + \sum_{i=1}^x \alpha_{9i} \\ & \text{LOG\_RESERVE}_{t-1} + \sum_{i=1}^y \alpha_{20i} \text{LOG\_GOLD}_{t-1} + \mu_t \end{aligned}$$

Dependent Variable: LOG_BSE

Method: ARDL

Maximum dependent lags: 2 (Automatic selection)

Dynamic regressors (2 lags, automatic): LOG_CALL LOG_EXPORT LOG_GDP

LOG_INFL LOG_M1 LOG_M3, LOG_USD LOG_RESERVE LOG_GOLD

Selected Model: ARDL (1, 0, 2, 2, 0, 2, 1, 0, 2, 2)

Table 1.2 ARDL Model

Variable	Coefficient	Prob.*
LOG_BSE(-1)	-0.30294	0.0005
LOG_CALL	-0.025191	0.456
LOG_EXPORT	-0.048647	0.4888
LOG_EXPORT(-1)	-0.013507	0.8469
LOG_EXPORT(-2)	0.112301	0.0795
LOG_GDP	-0.208828	0.5733
LOG_GDP(-1)	0.83091	0.0004
LOG_GDP(-2)	-0.55537	0.0016
LOG_INFL	1.500633	0.0042
LOG_M1	0.103196	0.5535
LOG_M1(-1)	0.08312	0.6859
LOG_M1(-2)	-0.298625	0.02
LOG_M3	-0.091931	0.3643
LOG_M3(-1)	0.118171	0.2407
LOG_USD	-1.084842	0
LOG_RESERVE	1.015054	0.0016
LOG_RESERVE (-1)	-2.313413	0
LOG_RESERVE (-2)	1.252019	0
LOG_GOLD	-0.083753	0.3032
LOG_GOLD (-1)	-0.033302	0.06905
LOG_GOLD (-2)	-0.108615	0.10927
C	0.608351	0.1073
R-squared	0.54946	0

Source: Eviews, 9.5 Output

The model illustrates the lag effects of key macroeconomic variables within the ARDL (1, 0, 2, 2, 0, 2, 1, 0, 2, 2) framework, indicating that exports, GDP, money supply (M2), reserves, and gold exert influence for up to two lag periods, while the Bombay Stock Exchange (BSE) and money supply (M3) affect outcomes for one lag period. The model's R Square value is approximately 55%.

Model for Error Correction- The error correction model (ECM) among co-integrated variables elucidates the variation in dependent variables resulting from independent variables. The connection and ECM were presented by Engle and Granger (Granger & Weiss, 1983). The primary objective of ECM is to identify causal factors that may influence the variables.

Short-Term and Long-Term Results of the Model.

Table 1.3 Regression Output

Dependent Variable: LOG_BSE		
Method: Least Squares		
Variable	Coefficient	Prob.
C	0.044412	0.3741
D (LOG_BSE (-1))	0.118904	0.2621
D(LOG_CALL)	-0.114126	0.1926
D (LOG_CALL (-1))	0.009186	0.9106
LOG_EXPORT	0.003264	0.9634
LOG_EXPORT (-1)	-0.054632	0.4826
LOG_GDP	-0.537481	0.2062
LOG_GDP (-1)	0.294646	0.4711
D(LOG_INFL)	1.183883	0.0173
D (LOG_INFL (-1))	0.119072	0.08068
D(LOG_M1)	0.113758	0.5524
D(LOG_M1(-1))	0.419824	0.0289
D(LOG_M3)	-0.199547	0.081
D(LOG_M3(-1))	-0.078044	0.474
LOG_USD	-1.084842	0
LOG_USD	-1.584632	.02
D(LOG_RESERVE)	1.481884	0
D (LOG_RESERVE (-1))	-1.143633	0.0004
LOG_GOLD	-0.114468	0.021
LOG_GOLD (-1)	-0.59012	0.05486
ECT (-1)	-0.415181	0.0196
R-squared	0.390384	0

Source: Eviews, 9.5 Output

Consistent with the idea, the ECM was determined to be (-0.4151), indicating a negative and statistically significant result at the 5% significance level. The negative sign of the error component indicates the existence of an automatic equilibrium, which converges or adjusts at a rate of 41% towards the long-run equilibrium in the short run. In other words, errors are rectified in the present age, with 41 percent of these instances resulting in long-term equilibrium. The Durbin-Watson value is 2.003, signifying the absence of autocorrelation between the variables.

Finding of the Study

The empirical investigation using ARDL and Error Correction Model (ECM) methodologies demonstrates a complex yet statistically significant association between the Indian stock market (as indicated by the BSE index) and essential macroeconomic indicators from 2010 to 2020. The results show that factors like inflation, the money supply (M1), foreign reserves, the exchange rate of the US dollar, and gold prices have a big effect on how the stock market moves. Inflation ($p = 0.0042$) and foreign reserves ($p = 0.0016$) had a positive and significant short-term effect on BSE returns. This suggests that investors react quickly to changes in macro-level liquidity and price stability. On the other hand, the US dollar had a strong and constant negative association ($p = 0.0000$), which shows how sensitive the Indian stock market is to changes in currency and global capital flows. The effects of exports and GDP appeared with lagged coefficients, showing that trade and output indicators take a while to show up in market valuations. The ARDL model showed moderate explanatory power ($R^2 = 0.55$), and exports, GDP, reserves, and gold all had significant lag structures that lasted up to two periods. The importance of several lagged factors highlights how macroeconomic signals affect market behavior over time. The ECM results confirmed the existence of long-run equilibrium among the variables. The error correction term ($ECT = -0.4151$) was negative and significant at the 5% level, which means that around 41% of the disequilibrium moves back toward the long-run route each period. This research indicates a reliable reversion process in India's stock market, wherein transitory shocks or volatility are gradually rectified. The Durbin-Watson value of 2.003 also proved that there was no autocorrelation, which made the model's reliability even

stronger. The study offers significant evidence of stock market integration with macroeconomic fundamentals, corroborating the theoretical framework that financial markets in emerging economies, such as India, are becoming more responsive to both domestic and global macroeconomic dynamics.

Future Direction and Implication

Subsequent study should endeavor to enhance the existing model by integrating macroeconomic data from post-2020, particularly considering significant occurrences such as the COVID-19 recovery phase, digital financial inclusion, and global geopolitical realignments. Additionally, examining sector-specific stock indexes (e.g., IT, pharmaceuticals, infrastructure) in conjunction with macroeconomic variables might provide more detailed policy insights. India's goal under the *Viksit Bharat @2047* aim is to become a developed country with digital transformation, resilient financial institutions, and economic growth that includes everyone. This kind of research is very important. Incorporating factors such as digital payments adoption, fintech indices, green economy indicators, and sustainable investment flows into ARDL-based models can assist policymakers in predicting and directing financial market reactions in accordance with long-term national objectives. Empirical models can therefore function as decision-support instruments, allowing the government and institutional investors to enhance economic planning, maintain monetary stability, and fortify capital markets as facilitators for realizing a *Viksit Bharat*—a resilient, self-sufficient, and globally competitive India by 2047.

Conclusion

This paper's analysis reveals that numerous studies in economic literature examine methodological approaches regarding the relationship between stock and stock market appraisal. Researchers predominantly focus on Indian stock markets when analysing the correlation between the country's macroeconomic indicators and the stock market index. This article has resulted in the development of a model illustrating the impact of macroeconomic data on the stock market index. The short- and long-term interdependence of the link between the stock market index and macroeconomic variables. The model indicates that the error correction model achieves long-term equilibrium and rectifies shocks at a rate of 41%. The money supply, inflation, foreign exchange reserves, gold, and exchange rates significantly influence the model, which explains 40% of the volatility in the BSE (White, 1910) (Anjuman, 2013) (Vinayagathan, 2013). The prior researcher has examined the correlation of macro factors (Hasanujjaman, 2016) (Eiteman, 1933), although our study refutes the influence of exports and call money, as the association in our analysis is insignificant. The research empirically substantiates the long-term and short-term correlations between India's stock market and fundamental macroeconomic factors through the application of ARDL and ECM methodologies. The findings confirm that inflation, foreign reserves, the US dollar exchange rate, money supply, and gold prices significantly influence stock market dynamics in India. Cointegration across variables is shown by the considerable error correction term. This means that there is a stable long-run equilibrium, with around 41% of short-term disequilibrium being corrected each period. These results show that India's financial markets are becoming more connected to macroeconomic trends and outside shocks, which is what we would expect to happen in rising nations. The models' modest explanatory power shows that, in addition to macroeconomic fundamentals, investor psychology, global cues, and sectoral dynamics also have a big effect on market movements. This study enhances the field of financial econometrics and provides significant insights for investors, policymakers, and financial regulators in developing policies that guarantee market stability, encourage educated investment choices, and cultivate a more robust economy. As India moves toward the Viksit Bharat @2047 vision, it is important to grasp these macro-financial connections in order to plan for long-term economic growth and strong capital market growth.

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The Role of Central Bank Digital Currencies in the Revolution of Payment Systems: A Focus on the ASEAN countries"

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Abstract

The emergence of Central Bank Digital Currencies (CBDCs) has reshaped the global financial landscape, with ASEAN countries actively exploring their adoption. The study focuses on the role of CBDCs in modern payment systems, analysing their impact on financial inclusion, transaction efficiency, and regulatory challenges. Key statistics on ASEAN economies highlight the rapid digitalization trends driving this transformation.

The primary objective of this research is to assess the economic implications of CBDCs, including their influence on monetary policy, cross-border transactions, and traditional banking frameworks. This study aims to identify the potential challenges and opportunities that CBDC adoption presents for financial stability and innovation.

A mixed-method research approach is employed, utilizing quantitative models such as time-series analysis and qualitative assessments. Tools including regression analysis, SWOT framework, and policy evaluation methods are applied to examine CBDC adoption trends across ASEAN nations.

The findings suggest that CBDCs enhance payment system efficiency but require robust regulatory frameworks to mitigate risks. The study provides insights for policymakers and financial institutions, paving the way for strategic implementation. Future research could explore interoperability solutions and cross-border collaboration to enhance CBDC effectiveness in global markets.

Key words: Central Bank Digital Currency (CBDC), Digital Payments, Payment Systems, ASEAN Economy, Financial Innovation, Monetary Policy, Financial Inclusion, Cross-Border Transactions, Digital Currencies and Regulation, Blockchain and CBDC, Cashless Economy, CBDC Adoption, Cryptocurrency vs. CBDC, CBDC Implementation Challenges, Digital Financial Ecosystem.

Introduction

The rapid digital transformation of global financial systems has led to increased interest in Central Bank Digital Currencies (CBDCs). CBDCs represent a digital form of a country's fiat currency, issued and regulated by the central bank, with the potential to enhance transaction efficiency, financial inclusion, and monetary policy execution. Various central banks, including those in ASEAN countries, have launched pilot projects to explore the feasibility of CBDCs in their respective economies.

Academic discussions on CBDCs have evolved over the years. Early studies, such as those by Tobin (1985), proposed the idea of central banks issuing digital money to improve monetary

stability. With the advent of blockchain and distributed ledger technology, researchers such as Auer & Böhme (2020) examined how digital currencies could reshape banking structures. More recent literature, including work by Prasad (2021), highlights the implications of CBDCs on financial intermediation and cross-border transactions. The Bank for International Settlements (BIS, 2023) suggests that CBDCs can enhance global payments by reducing transaction costs and settlement times.

ASEAN countries have diverse approaches to CBDC adoption. Singapore's Project Ubin and Thailand's Project Inthanon focus on wholesale CBDCs, whereas Cambodia's Project Bakong implements a retail model to improve financial accessibility. Given ASEAN's economic and technological diversity, understanding CBDC adoption requires a comprehensive analysis of technological, economic, and regulatory factors shaping these digital currencies.

Problem Statement

This study examines the transformative role of Central Bank Digital Currencies (CBDCs) in the payment systems of ASEAN countries. With increasing digitalization, CBDCs offer the

potential to enhance payment efficiency, reduce transaction costs, promote financial inclusion, and facilitate cross-border payments. Despite pilot initiatives in countries like Singapore, Malaysia, and Thailand, the broader implications of CBDC adoption remain underexplored.

The research addresses key challenges, including the impact of CBDCs on payment system efficiency, financial inclusion, cross-border integration, monetary policy effectiveness, and financial stability. Additionally, it evaluates technological, regulatory, and cybersecurity concerns in ASEAN's diverse economic landscape. Using a mixed-methods approach with quantitative surveys and qualitative interviews, the study gathers insights from stakeholders to assess user perceptions, cost implications, regulatory considerations, and security risks.

The findings aim to provide actionable insights for central banks and policymakers, contributing to the development of secure, efficient, and inclusive digital financial systems. This research also enhances academic discourse on digital finance, offering valuable perspectives for future studies on CBDCs in emerging markets.

Literature Review

Early discussions on digital currencies date back to Tobin (1985), who suggested that central banks should issue digital money to enhance monetary policy transmission. With the rise of digital payment technologies in the 2000s, scholars such as Rogoff (2016) explored the **macroeconomic implications of a cashless society**.

As blockchain technology gained prominence, Narula (2018) examined the **technical feasibility of digital currencies**, while Auer & Böhme (2020) discussed the **impact of CBDCs on banking stability**. More recent studies, such as Prasad (2021), argue that CBDCs can **enhance financial inclusion while posing risks to commercial banks' deposit-taking functions**.

In the context of ASEAN, **the Monetary Authority of Singapore (MAS, 2022)** has conducted research on how CBDCs can facilitate **cross-border transactions**. **The Bank of Thailand**

(BOT, 2023) explored the risks and opportunities associated with CBDC deployment. Recent papers by the **Asian Development Bank (ADB, 2024)** suggest that regulatory alignment is crucial for CBDC success in ASEAN economies.

Objectives of the Study & Hypotheses

Research objective

The objectives of this study are to analyse the transformative role of Central Bank Digital Currencies (CBDCs) in the payment systems of ASEAN countries and investigate their potential to enhance financial inclusion and payment efficiency. It aims to compare public perception and acceptance of CBDCs in ASEAN countries with that of Indian respondents, while also examining the impact of CBDCs on traditional banking systems and financial intermediaries. Additionally, the study evaluates the influence of regulatory frameworks on CBDC implementation and scalability, explores security and privacy concerns affecting consumer confidence, and assesses the cross-border payment implications of CBDC adoption. It further investigates the role of CBDCs in enhancing monetary policy effectiveness and financial stability, identifies challenges and opportunities in their adoption, and provides strategic insights for policymakers to facilitate effective implementation.

The research also delves into the technological infrastructure requirements for CBDC deployment, examines their impact on reducing transaction costs and improving payment speeds, and investigates their role in curbing illicit financial activities. Furthermore, it assesses the competitive dynamics between CBDCs, cryptocurrencies, and other digital payment systems, evaluates the readiness of financial institutions and fintech companies for CBDC integration, and studies user experience factors influencing adoption and usage frequency. The study also seeks to understand the influence of cultural and socioeconomic factors on CBDC acceptance, assess scalability and interoperability for cross-border transactions, explore the impact on cash usage and digital economy growth, and identify strategic partnerships and collaborations necessary for successful CBDC implementation.

Hypotheses

In line with the objectives of this study, this research seeks to examine the role of Central Bank Digital Currencies (CBDCs) in transforming the payment systems of ASEAN countries. Given the increasing digitalization of financial transactions, CBDCs have been positioned as a key innovation that can potentially enhance transaction efficiency, financial inclusion, and monetary policy effectiveness. However, their implementation also presents challenges in terms of technological infrastructure, security risks, and regulatory considerations. This study hypothesizes that the introduction of CBDCs will significantly influence the evolution of payment systems in ASEAN countries.

Null Hypotheses (H₀):

The implementation of Central Bank Digital Currencies (CBDCs) has no significant impact on the efficiency, financial inclusion, and stability of payment systems in ASEAN countries.

Alternative Hypotheses (H₁):

The implementation of Central Bank Digital Currencies (CBDCs) significantly enhances the efficiency, financial inclusion, and stability of payment systems in ASEAN countries.

Supporting Sub-Hypotheses:

To provide a structured approach to testing the primary hypothesis, the study further proposes the following sub-hypotheses:

H1a: CBDCs improve transaction speed and reduce costs in ASEAN payment systems.

H1b: CBDCs promote financial inclusion by increasing digital payment adoption among the unbanked population.

H1c: CBDCs enhance monetary policy effectiveness and financial stability in

ASEAN countries.

1. Are you aware of the concept of Central Bank Digital Currencies (CBDCs)? * 7. Would you be willing to use CBDCs for daily transactions if introduced in India? Cross-tabulation			7. Would you be willing to use CBDCs for daily transactions if introduced in India?					Total
			Definitely No	Definitely Yes	Not Sure	Probably No	Probably Yes	
1. Are you aware of the concept of Central Bank Digital Currencies (CBDCs)?	No	Count	0	6	99	6	58	169
		% within 1. Are you aware of the concept of Central Bank Digital Currencies (CBDCs)?	0.0%	100%	62.2%	6.2%	41.4%	45.7%
	Yes	Count	12	95	99	8	67	193
		% within 1. Are you aware of the concept of Central Bank Digital Currencies (CBDCs)?	100%	99.1%	38.6%	100%	53.6%	54.3%
Total		Count	12	95	198	14	125	360
		% within 1. Are you aware of the concept of Central Bank Digital Currencies (CBDCs)?	100%	100%	100%	100%	100%	100.0%

Case Processing Summary						
	Valid		Cases Missing		Total	
	N	Percent	N	Percent	N	Percent
1. Are you aware of the concept of Central Bank Digital Currencies (CBDCs)? * 7. Would you be willing to use CBDCs for daily transactions if introduced in India?	350	100.0%	0	0.0%	350	100.0%

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	60.667 ^a	4	<.001
Likelihood Ratio	72.018	4	<.001
Invalid Cases	350		
a. 2 cells (20.0%) have expected count less than 5. The minimum expected count is 2.74.			

Key Results from the Chi-Square Test Output:

- Pearson Chi-Square Value: 60.667
- Degrees of Freedom (df): 4
- Significance Level (p-value): < 0.001

Interpretation of the Results: The standard significance level of 0.05 is significantly higher than the p-value (< 0.001). This indicates that the null hypothesis (H_0), which postulated that knowledge of CBDCs and readiness to utilize them are unrelated, can be assertedly rejected. There is a significant association between awareness of CBDCs and willingness to use them. People who are aware of CBDCs are more likely to be open to using them for daily transactions. Conversely, those unaware of CBDCs tend to be more hesitant or uncertain about adopting them. From the contingency table, a higher proportion of aware respondents chose "Probably Yes" or "Definitely Yes" for using CBDCs. In contrast, those who were not aware showed greater hesitation, with many selecting "Not Sure" or "Probably No."

Research Methodology

Aim of the study and Research Design

The aim of the study is to analyse public perceptions, preferences, and concerns regarding digital payment systems, with a specific focus on Central Bank Digital Currencies (CBDCs). It seeks to assess the reliability of various payment methods, evaluate the efficiency and security of digital transactions, and explore key concerns related to CBDCs, including trust, privacy, technological complexity, and government surveillance. By examining these factors, the study aims to provide insights into consumer attitudes toward digital financial systems and the potential challenges in adopting CBDCs. The Chi-square test is used to analyse the result and hypotheses and questionnaire is prepared to analyse the respondents view on CBDC as a payment system.

Sampling Population and Sample size calculation

To ensure statistical reliability, a total of 350 respondents is targeted for survey participation. And response is collected using a structured questionnaire containing 24 questions via google forms. In which 27.4% are corporate employee, 1.7% are finance professional, 5.1% are others,

3.4% are self employed, 62.3% are students. This sample size offers a fair representative of various taxpayer groups, which aids in examining how tax laws affect financial planning techniques.

Pilote study

The survey instrument was validated by a pilot study with 350 participants. Survey samples served as the study's framework.

Limitations

- **Limited Sample Representation:** People who live in rural areas who are unbanked and have little access to digital resources may not be fully represented in the study.
- **Data Collection Constraints:** Surveys and interviews depend on participant responses, which may be biased, incomplete, or influenced by misunderstandings.
- **Technological Variability:** Differences in digital infrastructure across ASEAN countries, This may impact the generalizability of the findings.
- **Limited Access to Institutional Data:** Confidentiality restrictions may prevent access to central bank reports and policy documents.
- **Time and Resource Constraints:** The study is limited by time and resources, restricting long-term tracking of CBDC adoption.
- **Potential Response Bias:** Participants might give socially desirable responses or possess limited knowledge about CBDCs, which could introduce bias into the analysis.

Data Analysis

Survey Results and Demographic Analysis

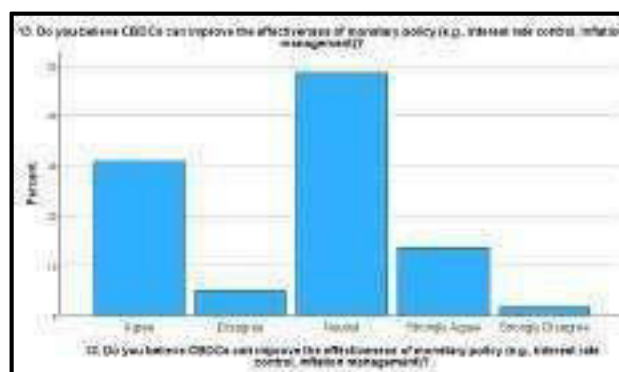
Category	Options	Percentage (%)
Gender	Male/ Female/ prefer not to say	93%/6%/1%
Occupation	Corporate employee/finance prof/ others / self-employed/ student	27%/1%/5%/3%/62%
Age group	Below 20/20-30/31-40/41-50	5.4%/79.1%/12%/3.4%
Annual Income	Below 30K/30K-60K/60K-1L/Above 1L/Prefer not to disclose	34.3%/26%/3.4%/1%/29%
Awareness of CBDCs	Yes/ no	54.3%/45.7%

Summary of Primary Data Analysis:

The primary data analysis reveals that the majority of respondents are students (62.3%), followed by corporate employees (27.4%), with a smaller share comprising self-employed individuals (3.4%) and finance professionals (1.7%). Most respondents hold postgraduate (54.3%) or undergraduate (42%) degrees, with a minimal percentage having high school (2%) or other qualifications (1.7%). Digital payments are widely used, with 49.1% of respondents always relying on them and 31.1% using them frequently, while only a small percentage use them occasionally (12.9%) or rarely (6.9%). Awareness of Central Bank Digital Currencies (CBDCs) is moderate, as 54.3% of respondents are familiar with the concept, whereas 45.7% are not, indicating a need for awareness campaigns to drive adoption. UPI emerges as the most preferred digital payment method, used by 31.4% of respondents, followed by mobile wallets (8.6%) and various combinations of UPI with credit/debit cards, internet banking, or cash. Standalone usage of credit/debit cards and internet banking remains low at 1.7% each, underscoring a strong shift toward UPI-based transactions due to their convenience and zero-cost transfers. The findings highlight the increasing adoption of digital-first financial solutions and the potential for CBDCs to integrate into the evolving payment ecosystem.

13. Do you believe CBDCs can improve the effectiveness of monetary policy (e.g., interest rate control, inflation management)?

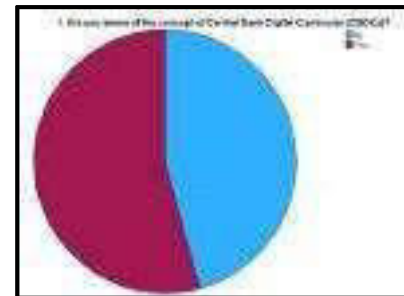
	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Agree	108	30.9	30.9	30.9
Disagree	18	5.1	5.1	36.0
Neutral	170	48.6	48.6	84.6
Strongly Agree	48	13.7	13.7	98.3
Strongly Disagree	6	1.7	1.7	100.0
Total	350	100.0	100.0	



Survey analysis using pie chart and bar graph

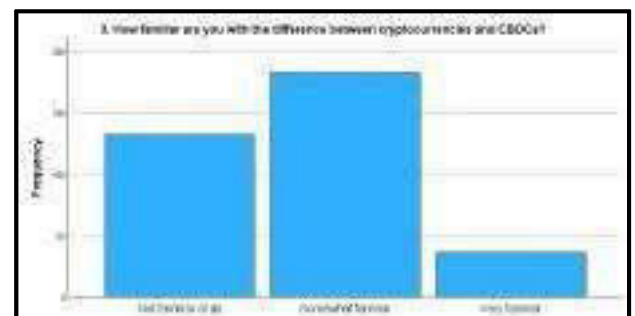
1. Are you aware of the concept of Central Bank Digital Currencies (CBDCs)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	160	45.7	45.7	45.7
	Yes	190	54.3	54.3	100.0
	Total	350	100.0	100.0	



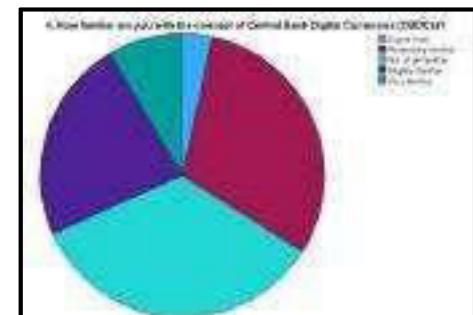
3. How familiar are you with the difference between cryptocurrencies and CBDCs?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not familiar at all	132	37.7	37.7	37.7
	Somewhat familiar	182	52.0	52.0	89.7
	Very familiar	36	10.3	10.3	100.0
	Total	350	100.0	100.0	



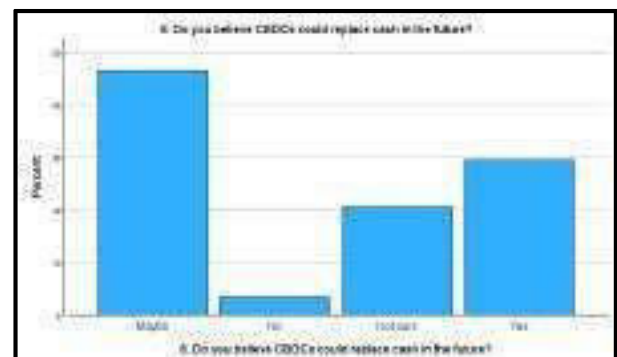
4. How familiar are you with the concept of Central Bank Digital Currencies (CBDCs)?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Expert level	12	3.4	3.4	3.4
	Moderately familiar	107	30.6	30.6	34.0
	Not at all familiar	120	34.3	34.3	68.3
	Slightly familiar	81	23.1	23.1	91.4
	Very familiar	30	8.6	8.6	100.0
	Total	350	100.0	100.0	



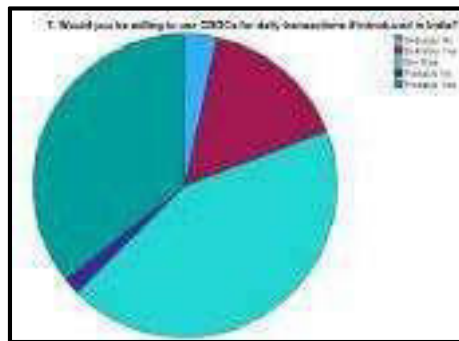
6. Do you believe CBDCs could replace cash in the future?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Maybe	163	46.6	46.6	46.6
	No	12	3.4	3.4	50.0
	Not sure	72	20.6	20.6	70.6
	Yes	103	29.4	29.4	100.0
	Total	350	100.0	100.0	



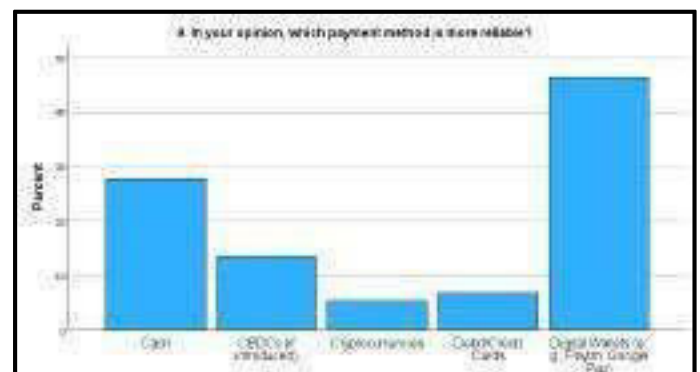
7. Would you be willing to use CBDCs for daily transactions if introduced in India?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Definitely No	12	3.4	3.4	3.4
	Definitely Yes	55	15.7	15.7	19.1
	Not Sure	152	43.4	43.4	62.6
	Probably No	8	1.7	1.7	64.3
	Probably Yes	125	35.7	36.7	100.0
	Total	350	100.0	100.0	



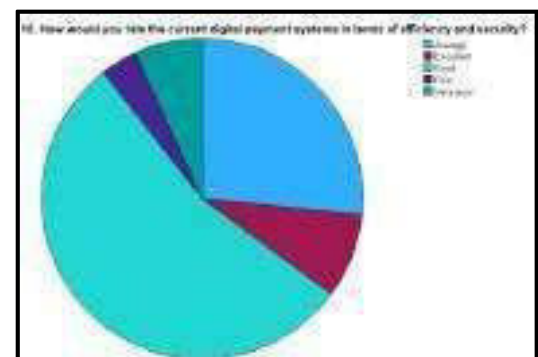
8. In your opinion, which payment method is more reliable?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cash	97	27.7	27.7	27.7
	CBDCs if introduced	46	13.7	13.7	41.4
	Cryptocurrencies	19	5.4	5.4	46.9
	Debit/Credit Cards	24	6.9	6.9	53.7
	Digital Wallets (e.g., Paytm, Google Pay)	162	46.3	46.3	100.0
	Total	350	100.0	100.0	



10. How would you rate the current digital payment systems in terms of efficiency and security?

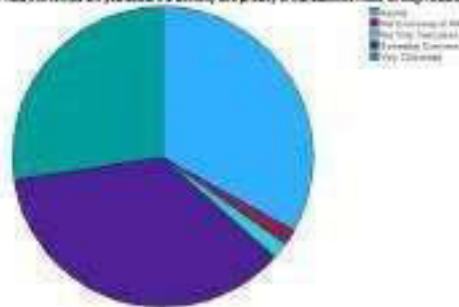
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Average	93	26.6	26.6	26.6
	Excellent	30	8.6	8.6	35.1
	Good	190	54.3	54.3	89.4
	Poor	13	3.7	3.7	93.1
	Very poor	24	6.9	6.9	100.0
	Total	350	100.0	100.0	



17. How concerned are you about the security and privacy of transactions made through CBDCs?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	118	33.1	33.1	33.1
	Not Concerned at All	6	1.7	1.7	34.9
	Not Very Concerned	6	1.7	1.7	36.6
	Somewhat Concerned	126	36.0	36.0	72.6
	Very Concerned	95	27.4	27.4	100.0
Total		350	100.0	100.0	

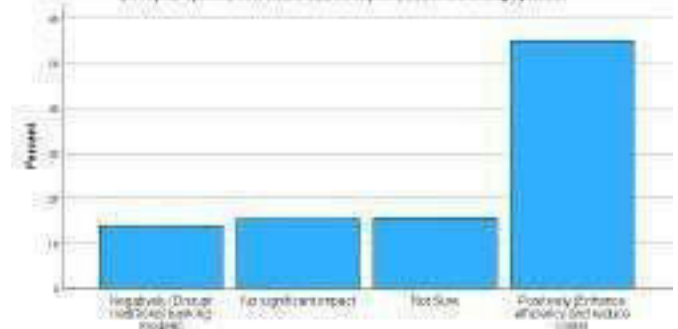
17. How concerned are you about the security and privacy of transactions made through CBDCs?



21. In your opinion, how would CBDCs impact traditional banking systems?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Negatively (Disrupt traditional banking models)	49	14.0	14.0	14.0
	No significant impact	54	15.4	15.4	29.4
	Not Sure	55	15.7	15.7	45.1
	Positively (Enhance efficiency and reduce costs)	152	44.0	44.0	100.0
Total		350	100.0	100.0	

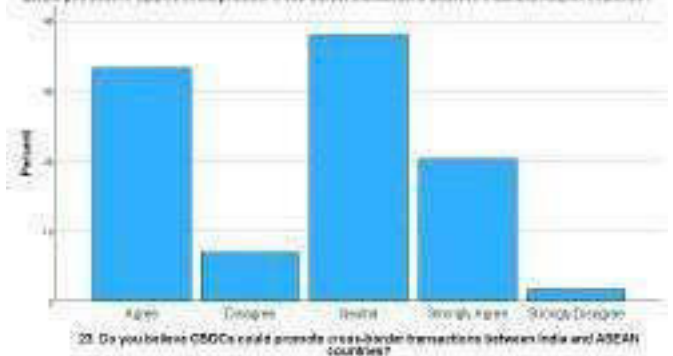
21. In your opinion, how would CBDCs impact traditional banking systems?



23. Do you believe CBDCs could promote cross-border transactions between India and ASEAN countries?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	116	33.1	33.1	33.1
	Disagree	24	6.8	6.8	40.0
	Neutral	133	38.0	38.0	78.0
	Strongly Agree	71	20.3	20.3	98.3
	Strongly Disagree	6	1.7	1.7	100.0
Total		350	100.0	100.0	

23. Do you believe CBDCs could promote cross-border transactions between India and ASEAN countries?



Interpretation

The survey analysis highlights key trends in digital payment adoption and awareness of Central Bank Digital Currencies (CBDCs). A significant portion of respondents, primarily students and corporate employees with higher education qualifications, actively use digital payment methods, with UPI being the most preferred. While awareness of CBDCs is moderate, detailed understanding remains limited. Social media plays a crucial role in spreading awareness, but misconceptions persist regarding the distinction between CBDCs and cryptocurrencies.

Respondents recognize the potential benefits of CBDCs, such as enhanced security, financial inclusion, and reduced transaction costs. However, concerns related to privacy, data security, and technological challenges indicate a need for more education and policy clarity to encourage broader adoption.

Discussion

Key Findings

The survey reveals moderate public awareness of CBDCs (52.6% familiar, 47.4% unaware), with news articles (29.7%) and social media (24.9%) being the primary information sources. Key benefits include financial inclusion (34%), reduced transaction costs (27.7%), and faster payments (21.7%), but major concerns revolve around security (37.1%), cyber threats (25.4%), and trust issues. While 44.6% believe CBDCs can improve monetary policy, 48.6% remain uncertain. The banking (17.1%) and e-commerce (17.1%) sectors are expected to benefit the most. Trust and adoption remain critical, with 63.4% concerned about security and 56.9% supporting strong regulations. 53.4% see potential for cross-border transactions, though 38% remain neutral. Overall, CBDCs hold promise, but adoption depends on awareness, security measures, and regulatory clarity.

Stakeholder Implication

The introduction of Central Bank Digital Currencies (CBDCs) in ASEAN countries carries significant implications for various stakeholders, including governments, financial institutions, businesses, and consumers. For central banks and policymakers, CBDCs offer enhanced monetary policy tools, improved financial inclusion, and greater control over cross-border transactions. However, they must address regulatory challenges, cybersecurity risks, and public trust concerns. Commercial banks and financial institutions may experience shifts in their business models due to potential disintermediation but could benefit from reduced transaction costs and increased efficiency. Businesses and e-commerce sectors stand to gain from faster, cost-effective digital transactions, improving economic efficiency. Consumers may benefit from enhanced payment security, lower costs, and broader financial access, though concerns regarding privacy and digital literacy must be addressed. Regulatory bodies need to ensure a balanced approach that fosters innovation while mitigating financial risks. Overall, successful CBDC adoption will depend on collaborative efforts among stakeholders to build trust, implement strong security measures, and establish clear regulatory frameworks.

Conclusion

The study highlights optimism about CBDCs enhancing monetary policy, financial inclusion, and cross-border transactions, especially in ASEAN nations. However, concerns over security, data privacy, and financial stability persist. Successful adoption requires clear regulations, strong cybersecurity, and collaboration between governments, financial institutions, and tech providers. Financial institutions can leverage CBDCs to reduce costs and expand access, while public awareness campaigns and pilot programs can build trust. Improved cross-border payment systems could also strengthen ASEAN economic ties. A balanced approach addressing regulatory, technological, and cultural challenges is essential for maximizing CBDC benefits while ensuring stability and trust.

Key words

ASEAN countries, cross border transactions, regulatory frameworks, traditional banking systems, Public Awareness and Adoption, Central Bank Innovation, E-Governance and Policy Implementation, Financial Sector Transformation.

Scope for Further Research

Future research on CBDCs in ASEAN should focus on their long-term impact on financial systems, monetary policy, and economic stability. Comparative studies across regions with different economic structures can offer insights into adaptability, while consumer behaviour research can explore adoption factors like digital literacy and trust. Cybersecurity risks, privacy concerns, and blockchain-based solutions require further analysis. Additionally, studies on regulatory frameworks and cross-border coordination can enhance policy harmonization. An interdisciplinary approach combining finance, technology, law, and economics will be essential to understanding CBDCs' evolving role in global financial ecosystems.

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Performance Evaluation in Indian General Insurance Sector: An Empirical Study using DEA and Superefficiency DEA Method

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Abstract:

In order to understand the performance in India general insurance sector, this study is being conducted to benchmark all the companies working in this sector excluding standalone health insurer and specialized insurer. Data Envelopment Method (DEA) and Super Efficiency methods were employed to rank performing companies. It was found that non efficient firms compared to benchmarked firms need to improve their performance.

Keywords: Data Envelopment Analysis (DEA), Slack Based Method (SBM), Super Efficiency, General Insurance, Performance, Benchmarking

Introduction

Foreign direct investment (FDI), openness towards trade and financial sector development boosts economic development in all types of economies (Radmehr et al., 2022). What factors contribute to economical development have become the important concepts being explored (Paun et al., 2019). This concept touches almost all the sectors namely shared economy (Veretennikova & Selezneva, 2023), digital economy (Zou et al., 2024), agricultural activity (Khan et al., 2019) to traditional economic activity like construction (Oladinrin et al., 2012) etc. Prelude to effective utilization of resources like technology and human resource is sufficient accumulated capital which determines sustainable growth (Paun et al., 2019). For any nation to progress, its financial sector holds high importance, which in turn is dependent on accessibility and cost of capital (Paun et al., 2019). A

part of financial sector is general insurance sector, which impacts development of economy although slowly and holds long term view (Tran & Huynh, 2023). Insurance sector generates funds which in turn are used for various types of developments in economy like social and infrastructure by bolstering risk taking capabilities (Vadlamannati, 2008). Which in turn leads to generation of income, protects life and property and generates savings for after retirement life (Apergis & Poufinas, 2020). Few growing economies like India and Vietnam have experienced positive impact from insurance related activities (Tran & Huynh, 2023; Vadlamannati, 2008). In a study conducted by Ilyas & Rajasekaran in 2019, it was found that public general insurers were more cost efficient than private insurers and Indian sector had moderate efficiency and productivity. Even during

global crisis of 2008, Indian general insurers were unaffected in terms of production (Ilyas & Rajasekaran, 2019). Insurance sector very much influence economy and plays a key role in its upgradation (Ajide et al., 2023). To make healthcare accessible, affordable and available, a scheme called as Ayushman Bharat was launched (Lahariya, 2018) for universal healthcare coverage (Pandey et al., 2021). Ambitious plan to develop 175 GW of renewable energy has been laid out by NITI Aayog and Ministry of New and Renewable energy (Elavarasan et al., 2020). Another project in progress is Swachh Bharat Mission and Jal Jeevan Mission for adequate water and sanitation (Sarkar & Bharat, 2021). UN has adopted 17 sustainable development goals in 2015 for sustainable development in terms of economy, environment and society (Swamy et al., 2017). These universal goals include important issues like reduction of poverty, sustainable energy, health, education and climate action (Agbakwuru et al., 2024). It has been found that disarray causes deterioration of environment, unequal social strata and adverse health risk for the masses (Liu et al., 2024). The good affects of such initiative is evident from increased coverage of health insurance particularly in

rural areas due to Ayushman Bharat-Pradhan Mantri Jan Arogya Yojana (PM-JAY) (Mohanty et al., 2023). Enrolment in government backed health insurance has reduced expenses of individuals totaling to Rs.3314 (Aashima & Sharma, 2023). Inspite of these many efforts by the government, only 37.2% of the entire populace is adequately covered under health insurance out of which public insurer covers majority i.e. 78% (Ghia & Rambhad, 2023). In line with this vision is the ambition of insurance for all by 2047 by Indian government. Part of which is to increase spending in health sector, improvement of its facilities, improved regulation for private healthcare providers (Aashima & Sharma, 2023) and expansion of health insurance for both inpatient and outpatient (Thakur & Faizan, 2023). These plans would lead to Vikshit Bharat in due course of time.

We first review the literature to understand DEA method and performance parameters for inputs and outputs for the DMUs. Then, we introduce our sample, methodology, and calculations, followed by results, conclusions and finally, we draw inferences from our findings.

Literature Review

Business success is defined by various aspect of an organization and how well the policies are implemented in the organization. It is usually measured by Key Performance Indicators (KPI) which encompasses both financial and non-financial outcomes (Anjomshoa, 2024; Bishop, 2018). Any organizations success can be defined in terms of three important parameters like profitability, growth and market share (Acar & Özşahin, 2018; Poursoleyman et al., 2022). Further

performance dimensions include satisfaction of employees, its customers, how efficient operations are, how much innovation in an organsition and how much socially responsible it is (Bhatti et al., 2013; Stainer, 2006). Business environments are complex hence organization need a balanced approach effectively utilizing KPI for various aspects for long term growth and success (Anjomshoa, 2024; Bishop, 2018; Stainer, 2006). Operational efficiency is highly

important for any organization to determine its success. Highly efficient organization generates higher revenue at lower expenses (Beracha et al., 2018). Performance in terms of operations of an organization is also influenced by strategic planning (Philip, 2007), data assets (Hu et al., 2022) and technology adoption (Beheshti & Beheshti, 2010; Molete et al., 2025). Now the question arises, why do we need to improve operational performance? It is required for being competitive and effective in long term as it leads to better financials and customer satisfaction (Baik et al., 2013; Beheshti & Beheshti, 2010).

How do we measure operational performance and quantify it? It is measured in terms of efficiency which indicates how effectively resources are being converted into outputs. Efficiency is measured using Data Envelopment Analysis (DEA) using multiple inputs and outputs for various decision making units (DMUs) and to assess how efficient they are. In our study DMUs are various insurance companies (Emrouznejad et al., 2013; Thanassoulis & Allen, 1998). The advantage of DMU is that it does not require any prior relationships between parameters and calculates efficiency using linear programming (Martić et al., 2009). DMUs can be colleges, schools, cities, banks etc. whose efficiency we want to calculate (Abdullah et al., 2018; Thanassoulis & Allen, 1998; Zhu, 1996). The ability to convert input into outputs defines efficiency of a DMU the most efficient lie on the efficiency frontier (Martić et al., 2009). There are two types of DEA models namely CCR (Charnes, Cooper, and Rhodes) model which assumes constant return to scale (Martić et al., 2009) and other is BCC (Banker, Charnes, and Cooper) model which assumes variable returns to scale. The model can be either input or output oriented so as to either minimize inputs or maximize outputs (Cooper et al.,

2011; Martić et al., 2009). BCC model specializes in measuring pure technical efficiency by variable returns to scale method (Sun, 2002). This model is good for DMUs operating at varying rate of scale namely water usage efficiency across various cities (Pan et al., 2020; Sun, 2002). Further concept includes finding cost efficiency of a DMU. It was found to be 80.08% in a South African general insurance market which is a good level of efficiency (Alhassan & Biekpe, 2016). A study in Thai general insurance market found that profit measures such as return on equity is inversely proportional to cost efficiency (Greene & Segal, 2004). Similar study was conducted in US life insurance segment which found high cost inefficiencies wr.t earnings (Greene & Segal, 2004).

Small sized insurance companies are found to be more cost-efficient than larger firms (Rai, 1996). In another study, it was found that specialized firms were more cost efficient compared to general insurers or life insurers (Kader et al., 2010; Rai, 1996). Similarly, it was found that if financial leverage is effectively managed or specialized insurance product can lead to better cost efficiency (Luhnen, 2009). Cost efficiency alongwith good risk assessment is important for an insurance firm to be profitable and have sustainable growth (Radosavljević, 2023). Cost efficiencies can vary from region to region. Fenn et al. (2008) found using SFA method that in Netherlands cost efficiency was around 94% however in Dutch it was 63% for the period 1988-1992.

Various studies have analyzed performance and efficiencies of various companies using various inputs and outputs on the basis of objective of the study and literature review. In a study conducted by Ilyas & Rajasekaran in 2019, the inputs were count of employees, branches, administration costs etc. Yet, in another study, commission was included as

input specifically commission to premium ratio was considered Ghosh, A., Sarkar, A., Dey, M., Guha, B., Jana, S. and Ghorui, N., 2021). One of the study considered effect of ownership, time, incurred claims ratio reciprocal and solvency ratio on the efficiency performance (Sinha, R.P., 2019). As far as outputs are various studies have analyzed different factors.

One of the study used ratio of liquid assets to liabilities as one of the output; since it conveys about claims paying ability of an organization (Leverty, J.T. and Grace, M.F., 2010). One of the studies by Cummins and VanDerhei (1979) used a

proxy for number of policies as an output by replacing it with direct premium written as an indicator of output. A study was conducted in Nigeria using DEA method. The inputs considered were net premium, management costs, total assets etc. and outputs were return on investment, net claims, profit after tax and market share (Smętek, K., Zawadzka, D. and Strzelecka, A., 2022, Ogieva, Osazee Frank, and Omorodion Omoregbe. (2017). In line with these findings, we have considered some of these inputs and outputs for our study.

Methodology

DEA has been used in this research for analysing performance parameters and to differentiate efficient firms from inefficient firms based on the efficiency frontier. However, in order to rank efficient firms, Super Efficiency method has been used.

On the basis of above literature review and as per various other studies and performance parameters as mentioned in various studies highlighted in Annexure. Three input variables have been highlighted and three output variables are highlighted and selected for our current research. Only General insurers based out of India have been used in our study and SAHI (Standalone Health Insurers) and specialised insurers have been excluded from our study to analyse and companies in the same category and sector so as to keep most of the performance conditions similar. The following performance parameters have taken up for efficiency comparison in our study.

Performance Parameters

Table 1: Input Efficiency Parameters

Commission	Mgmt Expenses	Net Incurred Claims Ratio

Input Parameters: As shown in table 2; the input parameters considered are Management expenses (ZL Wang et al., 2019), Net commissions (ZL Wang et al., 2019) and Net Incurred Claims Ratio (Malya, S. and George, S.A., 2024)

Table 2: Output Efficiency Parameters

Liquid Assets to Liabilities	Gross Direct Premium Growth Rate	Profit After Tax (PAT)

Output Parameters: As shown in Table 2; the output parameters considered for our study are Profit After Tax (PAT) (Osazee Frank Ogieva et al., 2017), Gross Direct Premium Growth Rate Nourani, M., Devadason, E.S., Kweh, Q.L. and Lu, W.M., 2017) and Liquid Assets to Liabilities (Leverty, J.T. and Grace, M.F., 2010).

BCC model of DEA with input orientation have been used in our current research so as to calculate relative efficiency in terms of variable return to scale. DEA-SOLVER-LV8 (2014-12-05) was used for analysis and result findings of BCC models and Superefficiency was computed using Efficiency Measurement System (EMS) developed by Holger Scheel. These are a free open source software easily available on internet.

Number of DMUs

DMUs stand for Decision Making Unit i.e. the number of general insurance companies in our study. There are 25 general insurance companies in India selling diversified products. We have not considered specialized general insurers. Considering if number of inputs are 'm' and outputs as 's' then number of DMUs should be either greater than $m*s$ or $3*(m+s)$. Hence number of inputs and outputs should be less than or equal to total of 8 parameters accordingly we can decide the number of input and output parameters for our study.

Result

Table 3: Descriptive Statistics

Statistics on Input/Output Data

	Comission	Mgmt Expenses	Net Incurred Claims Ratio	Liquid Assets to Liabilities	Gross Direct Premium Growth Rate	PAT
Max	3089.01	5081.81	33128.3	1.16	1	1918.59
Min	-0.82	31.16	42.31	0.005	-0.221	-803.71
Average	886.774	1285.54	6042.42	0.21762	0.19513	256.684
SD	828.997	1276.85	7276.59	0.22344	0.22191	555.365

Correlation

	Comission	Mgmt Expenses	Net Incurred Claims Ratio	Liquid Assets to Liabilities	Gross Direct Premium Growth Rate	PAT
Comission	1	0.76613	0.74987	-0.2091	-0.1974	0.5593
Mgmt Expenses	0.76613	1	0.96263	-0.0892	-0.2251	0.3075
Net Incurred Claims Ratio	0.74987	0.96263	1	-0.0154	-0.2315	0.3084
Liquid Assets to Liabilities	-0.2091	-0.0892	-0.0154	1	0.61464	-0.097
Gross Direct Premium Growth Rate	-0.1974	-0.2251	-0.2315	0.61464	1	0.00842
PAT	0.5593	0.3075	0.3084	-0.097	0.00842	1

Table 4: Return to Scale (RTS) For BCC_Input Orientation

DMU	Score	RTS of Projected DMU
Acko General Insurance Ltd	0.1132	Constant
Bajaj Allianz General Insurance Co Ltd	1	Decreasing
Cholamandalam MS General Insurance Co Ltd	0.3372	Decreasing
Edelweiss General Insurance Co Ltd	0.5092	Constant
Future Generali India Insurance Co Ltd	0.1796	Decreasing
Go Digit General Insurance Ltd	0.039	Constant
HDFC Ergo General Insurance Co Ltd	0.2872	Decreasing
ICICI Lombard General Insurance Co Ltd	1	Decreasing
IFFCO-Tokio General Insurance Co Ltd	0.2579	Decreasing
Kotak Mahindra General Insurance Co Ltd	0.2314	Constant
Kshema General insurance	1	Constant
Liberty General Insurance Co. Ltd	0.1032	Constant
Magma HDI General Insurance Co Ltd	0.1116	Constant
National Insurance Co Ltd	0.0102	Constant
Navi General Insurance Co. Ltd	1	Constant
Raheja QBE General Insurance Co Ltd	0.5034	Constant
Reliance General Insurance Co Ltd	0.2027	Decreasing
Royal Sundaram General Insurance Co Ltd	0.2099	Decreasing
SBI General Insurance Co Ltd	0.2061	Decreasing
Shriram General Insurance Co Ltd	1	Decreasing
Tata AIG General Insurance Co Ltd	0.4025	Decreasing
The New India Assurance Co Ltd	0.3161	Decreasing
The Oriental Insurance Co Ltd	0.0136	Constant
United India Insurance Co Ltd	0.0095	Constant
Universal Sompo General Insurance Co Ltd	1	Decreasing

No. of Increasing RTS=0

No. of Constant RTS=12

No. of Decreasing RTS=13

From the table above we can see that no company is operating at increasing RTS. Whereas, 12 companies are operating at increasing RTS and 13 are operating at decreasing RTS.

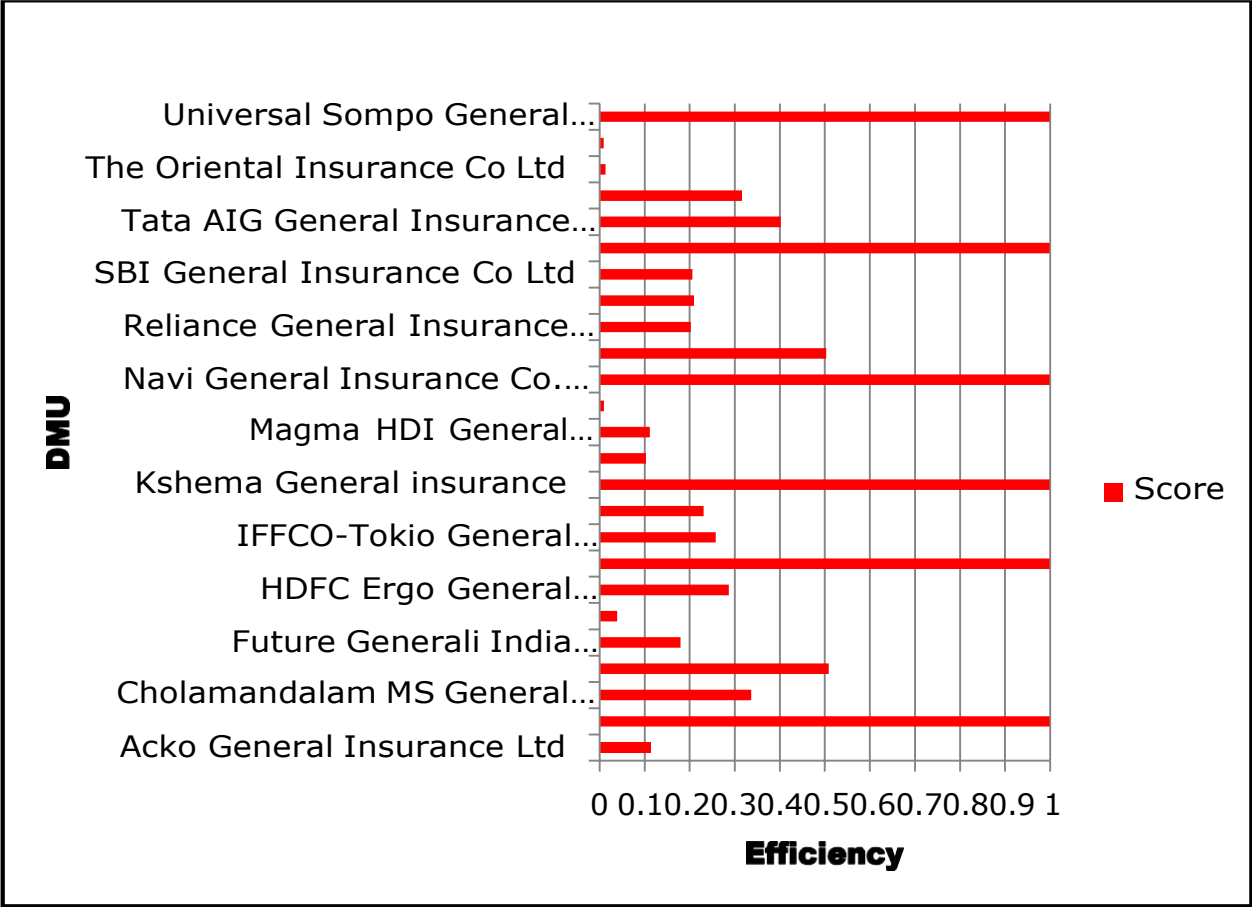
Table 5: Pure Technical Efficiency using BCC_Input Orientation

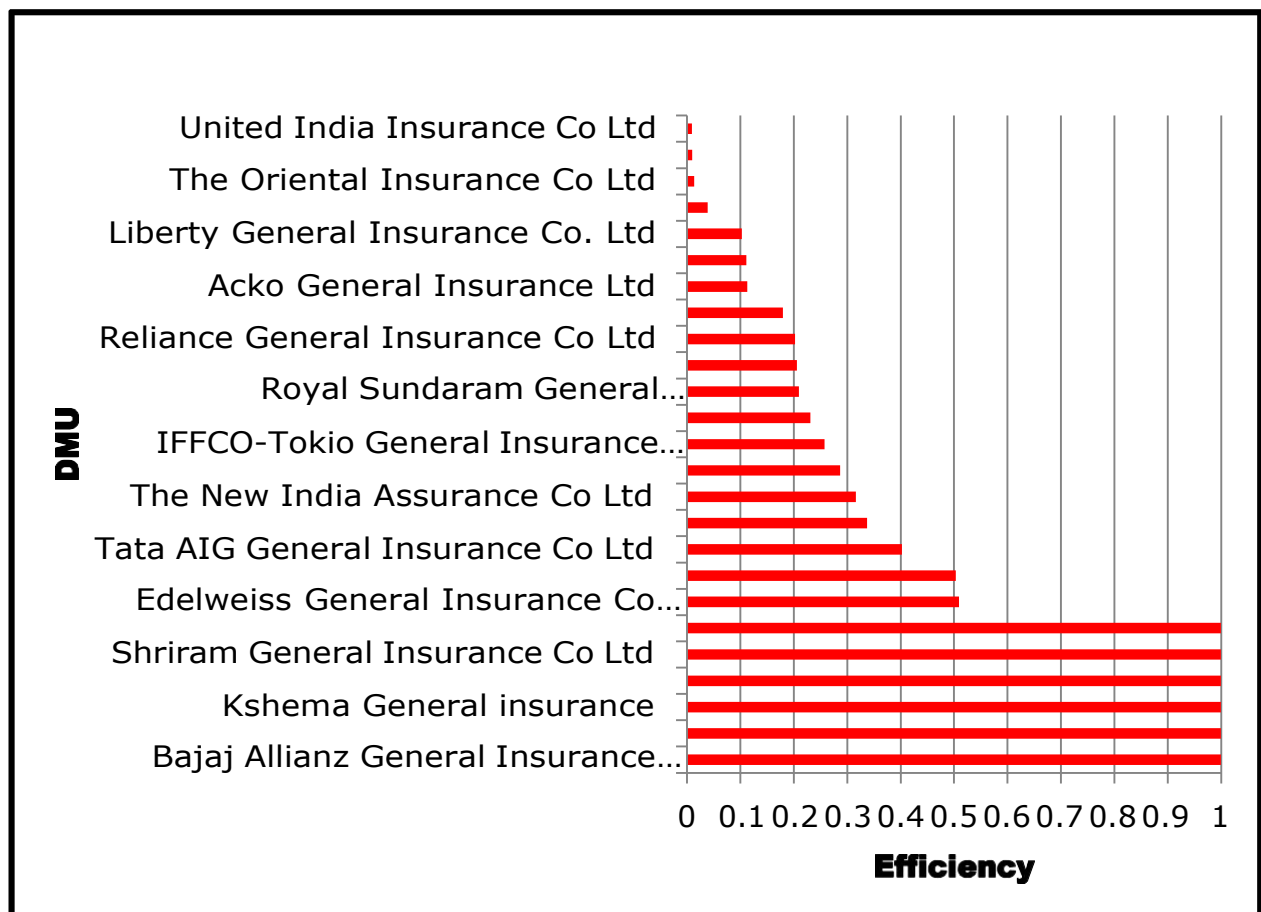
No.	DMU	Score	Rank
2	Bajaj Allianz General Insurance Co Ltd	1	1
8	ICICI Lombard General Insurance Co Ltd	1	1
11	Kshema General insurance	1	1
15	Navi General Insurance Co. Ltd	1	1
20	Shriram General Insurance Co Ltd	1	1
25	Universal Sompo General Insurance Co Ltd	1	1
4	Edelweiss General Insurance Co Ltd	0.5092	7
16	Raheja QBE General Insurance Co Ltd	0.5034	8
21	Tata AIG General Insurance Co Ltd	0.4025	9
3	Cholamandalam MS General Insurance Co Ltd	0.3372	10
22	The New India Assurance Co Ltd	0.3161	11
7	HDFC Ergo General Insurance Co Ltd	0.2872	12
9	IFFCO-Tokio General Insurance Co Ltd	0.2579	13
10	Kotak Mahindra General Insurance Co Ltd	0.2314	14
18	Royal Sundaram General Insurance Co Ltd	0.2099	15
19	SBI General Insurance Co Ltd	0.2061	16
17	Reliance General Insurance Co Ltd	0.2027	17
5	Future Generali India Insurance Co Ltd	0.1796	18
1	Acko General Insurance Ltd	0.1132	19
13	Magma HDI General Insurance Co Ltd	0.1116	20
12	Liberty General Insurance Co. Ltd	0.1032	21
6	Go Digit General Insurance Ltd	0.039	22
23	The Oriental Insurance Co Ltd	0.0136	23
14	National Insurance Co Ltd	0.0102	24
24	United India Insurance Co Ltd	0.0095	25

Average PTE: 0.40174 = 40.17%

From the table 5 above we can see that only 6 companies are operating at efficient level and are on efficiency curve. Rests of the companies are operating below efficient level and are not on the efficiency curve. The average pure technical efficiency is 40.17% of all the companies combined.

Graph 1: Efficiency Score of Companies





The above graph1 depicts the efficiency level of various companies considering BCC-I model.

Super Efficiency:

Table 6: SuperEfficiency Score using BCC Input Orientation

Rank	DMU	Score
1	Navi General Insurance Co. Ltd	7.027124085
2	Bajaj Allianz General Insurance Co Ltd	3.852679136
3	Universal Sampo General Insurance Co Ltd	2.894684746
4	Shriram General Insurance Co Ltd	1.472803327
5	Kshema General insurance	1
5	ICICI Lombard General Insurance Co Ltd	1
7	Edelweiss General Insurance Co Ltd	0.509238624
8	Raheja QBE General Insurance Co Ltd	0.5033745
9	Tata AIG General Insurance Co Ltd	0.402550181
10	Cholamandalam MS General Insurance Co Ltd	0.337149138
11	The New India Assurance Co Ltd	0.31608851
12	HDFC Ergo General Insurance Co Ltd	0.287210828
13	IFFCO-Tokio General Insurance Co Ltd	0.257838731
14	Kotak Mahindra General Insurance Co Ltd	0.231419889
15	Royal Sundaram General Insurance Co Ltd	0.209862177
16	SBI General Insurance Co Ltd	0.206129258
17	Reliance General Insurance Co Ltd	0.202649515
18	Future Generali India Insurance Co Ltd	0.179595479
19	Acko General Insurance Ltd	0.113175665
20	Magma HDI General Insurance Co Ltd	0.111558923
21	Liberty General Insurance Co. Ltd	0.103166816
22	Go Digit General Insurance Ltd	3.90E-02
23	The Oriental Insurance Co Ltd	1.36E-02
24	National Insurance Co Ltd	1.02E-02
25	United India Insurance Co Ltd	9.52E-03

The Super Efficiency from above table 6 also depicts only 6 companies are efficient in Indian General Insurance sector considering input model operating at BCC. Navi leading the ranks followed by Bajaj Allianz, Universal Sampo, Shriram General, Kshema and ICICI Lombard.

Conclusion

As far as controlling cost and reducing input to produce the same level of output no firm is operating at increasing return to scale. 12 firms are operating at constant return to scale whereas, remaining 13 are operating at decreasing return to scale. Not many firms are able to control their input costs to the level required for being efficient. Moreover, only 6 companies are found to be operating on efficiency curve for BCC-Input model where minimizing costs are involved to produce same level of output. Remaining companies fail to be efficient in controlling their costs. Pure Technical efficiency is found to be 40.17% in Indian general insurance sector as far as input costs are concerned. Super Efficiency results also present the ranking of the firms which are able to outperform their peers. Only 6 companies are superefficient and performing at more than 100% level. Rest of the companies fails to reach efficiency frontier level. Among all companies, private insurers are only present on the efficiency frontier.

Inference

In Indian General Insurance sector only 6 companies are able to decrease their input costs implying that sector still needs to learn and adapt to cost control techniques and strategies it needs to adopt. The sector is operating at only 40.17% which it needs to improve upon so as to be more productive and hence more profitable. Similar results follows in superefficiency model where only 6 companies are performing beyond par and rest of the companies are still struggling to control their input costs. Public sector companies need to gear up for being more efficient in controlling input cost in a fast paced dynamic competitive world. The firms can think of improving their output only instead of focusing on reducing their costs but still their profitability will be limited in scope unless and until various strategies are employed to keep their costs also on check. Initially sector can look at increasing 40% efficiency level to 60% to be more productive. The importance of this study emanates from the fact that this sector is capital intensive sector more the inefficiencies more will be capital outgo in terms of claims, claims management cost, commission cost, employees salaries and administrative costs. Hence, better the cost efficient level of a company better will be its performance. Future studies can look at panel data or longitudinal data for comparing cost efficient level of the firms. It can also expand the width of the study by including specialized insurer also in this study, which is a limitation in our study.

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Annexure

Table 1: Input and Output Parameters for various general insurance companies in India

	(I) Comission	(I) Mgmt Expenses	(I) Net Incurred Claims Ratio	(O) Liquid Assets to Liabilities	(O) Gross Direct Premium Growth Rate	(O) PAT
Acko General Insurance Ltd	167.08	829.29	850.19	0.29	0.24	15.33
Bajaj Allianz General Insurance Co Ltd	643.89	1849.54	6555.93	0.08	0.33	1550.33
Cholamandalam MS General Insurance Co Ltd	1151.65	844.66	3741.42	0.01	0.22	331.37
Edelweiss General Insurance Co Ltd	57.75	220.52	334.07	0.47	0.56	-124.69
Future Generali India Insurance Co Ltd	622.77	599.56	2398.57	0.11	0.08	133.31
Go Digit General Insurance Ltd	1888.46	1080.17	4990.20	0.07	0.29	0.05
HDFC Ergo General Insurance Co Ltd	915.31	1635.32	8396.44	0.13	0.12	437.67

ICICI Lombard General Insurance Co Ltd	3089.01	2817.73	11939.47	0.09	0.18	1918.59
IFFCO-Tokio General Insurance Co Ltd	894.13	918.14	5969.15	0.21	0.01	254.90
Kotak Mahindra General Insurance Co Ltd	218.16	308.91	575.90	0.04	0.40	-88.95
Kshema General insurance	-0.82	69.56	271.45	1.16	1.00	43.25
Liberty General Insurance Co. Ltd	385.24	337.57	1424.30	0.12	0.10	20.90
Magma HDI General Insurance Co Ltd	659.97	347.22	1810.48	0.12	0.20	-141.22
National Insurance Co Ltd	1200.17	3044.49	13094.56	0.15	0.01	-243.86
Navi General Insurance Co. Ltd	6.75	31.16	42.31	0.15	0.01	51.94
Raheja QBE General Insurance Co Ltd	75.33	70.21	174.91	0.26	-0.22	-41.39
Reliance General Insurance Co Ltd	863.62	1425.15	5420.94	0.21	0.13	280.27
Royal Sundaram General Insurance Co Ltd	685.59	412.45	2190.17	0.23	0.08	114.15
SBI General Insurance Co Ltd	720.41	1177.34	6056.05	0.19	0.16	239.84
Shriram General Insurance Co Ltd	659.27	361.07	1495.69	0.04	0.34	454.50
Tata AIG General Insurance Co Ltd	2017.40	1770.50	6641.17	0.21	0.15	684.92
The New India Assurance Co Ltd	3007.82	5081.81	33128.26	0.44	0.08	1129.33
The Oriental Insurance Co Ltd	880.49	2764.77	15719.62	0.17	0.18	18.61
United India Insurance Co Ltd	1339.72	3760.93	16033.69	0.15	0.13	-803.71
Universal Sompo General Insurance Co Ltd	20.17	380.43	1805.68	0.35	0.13	181.65

Can Financial Inclusion Improve the Quality of Life ? – A Study on Unorganised Sector of Kolkata

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Abstract

This study looks into the relevance between quality of life and financial inclusiveness for informal sector workers in Kolkata, West Bengal. It specifically focuses on "financial joy," which refers to the personal satisfaction derived from having access to financial services. The research used a quantitative approach, gathering primary data through surveys. 164 respondents were interviewed and the data was then analyzed using cross-tabulation to understand demographic variations, correlation analysis to identify relationships, and linear regression to determine how financial inclusion predicts both objective measures of quality of life and that subjective feeling of financial joy. The findings reveal a prominent positive relationship between and both quality of life, financial inclusion and financial joy. This suggests that when people associated with unorganised sectors have better access to financial services, it not only improves their quality of life, but also contributes to their overall financial contentment. These insights are crucial for policymakers aiming to create holistic well-being through financial inclusion initiatives in urban informal sectors.

Keywords: Financial Inclusion, Quality of Life, Regression, Financial Joy

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Introduction

Financial Inclusion, according to the Rangarajan Committee (2008), refers to providing vulnerable groups, such as the economically disadvantaged and low-income individuals, with accessible financial services and appropriate credit facilities at affordable rates. This inclusion is crucial for a holistic growth trajectory among all sectors of the economy, with mainstream financial institutions playing a pivotal role in driving this inclusive

development agenda. Individuals lacking a bank account face barriers such as saving for future expenses, for children's education, and accessing healthcare facilities along with other problems. Financial inclusion hinges significantly on access and usage of banking services. Enhancing financial inclusion can be achieved if number of bank branches can be significantly increased, including formal financial bodies, expanding

technology-driven banking , and eliminating hurdles in reaching out to financial services. A refuted bank account can promote saving for the future and facilitate loans (Agarwala *et al.*, 2022)(Chibba ,2009) . The effective management of earnings presents a significant challenge for urban poor people, who primarily rely on daily income to sustain their livelihood. In light of the crucial role of financial inclusion,

Literature Review

The persistent challenge of financial exclusion in rural and semi-urban areas, as well as among marginalized populations, has stimulated extensive academic inquiry. Scholars and experts globally have undertaken numerous investigations into various dimensions of financial inclusion. Illustratively, Fayyaz & Khan (2021) explored the impact of microfinance as a financial inclusion strategy on the quality of life (QOL), personal empowerment, and familial harmony of female borrowers. Their multinomial logistic regression model indicated a prominent positive influence of microfinance on enhanced well being among Pakistani women.

Examining data from 1990 to 2018, Audi, Bibi, and Ahmed (2019) conducted a study on the implications of financial inclusion for financial growth and overall well-being in South Asian countries. Their panel pooled regression results indicated a statistically negligible and negative effect of financial development on economic growth. However, they identified a statistically prominent and negative impact on human well-being within these nations. Notwithstanding these findings, the study stressed the essential

this study investigates into the financial habits of people associated for livelihood in the unorganised sector as domestic help, rickshaw puller, daily waged labour and hawker in the city of Kolkata. It also looks into the impact of financial inclusion and services in improvement of their well being, looking into the ecstasy or fulfillment of the people associated with the unorganised sector in Kolkata.

contribution of financial inclusion to achieving enhanced economic growth and human well-being in the selected Asian economies.. Vinay Bhushan & Manjunath (2021) investigated the effect of diverse financial inclusion schemes on the financial well being of people residing in rural areas in 10 villages of Karnataka. Their study, which introduced a novel economic satisfaction scale, utilized a structured questionnaire to analyze the correlation between financial inclusion programs and rural livelihood. The findings inferred a positive contribution of JAM (Jan Dhan Yojana - Mobile phone - Aadhar) to economic well-being. Sen & Laha (2021) conceptually linked Financial Inclusion and Quality of Life, relying on secondary data from major Indian states for 2001 and 2011. Canonical correlation analysis demonstrated that northern Indian states exhibited strong performance in both financial inclusion and quality of life .Southern states, while possessing high quality of life, displayed moderate financial inclusion development, whereas eastern states underperformed in both aspects. The study concluded that financial inclusion policy measures should prioritize increasing awareness of financial services through financial

literacy to stimulate demand and subsequently enhance QOL as opined by Warhamni, R. N. (2021), Meher, S. (2014). Research specifically addressing the financial inclusion of workers in the unorganized sector, particularly cycle rickshaw pullers, remains limited. The proposed study aims to bridge this literature gap by examining the reach, awareness, and utilization of financial services among unorganized sector workers in Kolkata, along with their

impact on quality of life and perceived financial joy.

Objectives

The objective of this article is to study how financial inclusion impacts the quality of life of people of Kolkata associated with the unorganised sector. It also explores the level of financial joy experienced by the people linked with the unorganised sector in Kolkata.

Data & Methodology

The research for this study is grounded in primary data, specifically collected through structured questionnaires administered during personal interviews. The sample comprised 164 individuals from various unorganized sectors across Kolkata, including domestic helpers, rickshaw pullers, hawkers, daily wage laborers, and small business owners.

The study aimed to identify and measure several determinants across three core constructs:

Financial Inclusion: This included indicators such as having a bank account, frequency of number of visits to the bank, availability and use of debit cards, loans, and the use of mobile in banking transactions.

Quality of Life: Factors here encompassed home ownership, access to healthcare and education, reliable access to water and electricity, and vehicle ownership.

Financial Joy: This was measured by subjective feelings, such as joy experienced after opening a bank account, pleasure from receiving a loan, or satisfaction from achieving savings targets.

Based on the information gathered, scores were assigned to respondents for each determinant, which were then aggregated to construct indices for financial inclusion, quality of life, and financial joy. These indices subsequently categorized respondents into "high," "medium," and "low" groups. For data analysis, Cronbach's alpha was employed to ensure reliability, while correlation and multiple linear regression were utilized to establish the relationships between financial inclusion, quality of life, and financial joy.

Discussion

Table 1: Cross-tabulation between Financial Inclusion Index & Quality of Life Index

FII	QOLI				
		HIGH	MEDIUM	LOW	TOTAL
	HIGH	22.95%	67.21%	9.84%	100.00%
	MEDIUM	7.50%	61.25%	31.25%	100.00%
	LOW	9.09%	36.36%	54.55%	100.00%

It can be observed from Table 1 given below that respondents, who have high financial inclusion, have high to medium quality of life. Similarly low financial inclusion indicates medium to low quality of life which signifies that financial inclusion plays a pivotal role in the quality of life of people.

Table 2: Cross-tabulation between Financial Inclusion Index & Financial Joy Index

FII	FJI				
		HIGH	MEDIUM	LOW	TOTAL
	HIGH	65.57%	32.79%	1.64%	100.00%
	MEDIUM	6.25%	65.00%	28.75%	100.00%
	LOW	0.00%	18.18%	81.82%	100.00%

From Table 2 we can observe that respondents, who have high financial inclusion, have high to medium financial joy. Similarly low financial inclusion indicates that financial joy felt by respondents ranges from medium to low.

Table 3: Cross-tabulation between Quality-of-Life Index and Financial Joy Index

QOLI	FJI				
		HIGH	MEDIUM	LOW	TOTAL
	HIGH	52.38%	28.57%	19.05%	100.00%
	MEDIUM	31.91%	51.06%	17.02%	100.00%
	LOW	10.81%	54.05%	35.14%	100.00%

Table 3 represents the cross-tabulation between quality of life and financial joy and the data clearly indicates that having a high quality of life, an individual can experience better financial joy, similarly experience of financial joyfulness decreases with a decrease in quality of life.

	LEVEL OF FINANCIAL JOY			
GENDER	HIGH	MEDIUM	LOW	TOTAL
Male	35.14%	45.95%	18.92%	100%
Female	24.36%	51.28%	24.36%	100%

Table 4: Cross-tabulation between Gender of the respondent and Financial Joy (in percentage)

As per Table 4, we can say male respondents reported a higher feeling of financial joy as compared to females. The data reveals that males report higher levels of financial joy (35.14%) compared to females (24.36%), while females report medium levels of financial joy (51.28%) more often than males (45.95%). Additionally, females experience lower levels of financial joy (24.36%) than males (18.92%). This indicates that males tend to experience more polarized financial joy, with higher highs and lower lows, whereas females report more moderate financial joy overall.

	LEVEL OF FINANCIAL JOY			
OCCUPATION	HIGH	MEDIUM	LOW	TOTAL
Small Business Owners	38.10%	38.10%	23.81%	100%
Domestic Help	23.81%	52.38%	23.81%	100%
Daily Wage Employee	44.83%	41.38%	13.79%	100%
Hawker	22.22%	44.44%	33.33%	100%
Ricksaw Puller	23.33%	56.67%	20.00%	100%

Table 5: Cross-tabulation between Occupation of the respondent and Financial Joy (in percentage)

Table 5; people in different jobs feel differently about their finances. Daily wage employees are the happiest, with 44.83% feeling high financial joy, while hawkers feel the least happy, with only 22.22% feeling high financial joy. Small business owners also feel quite happy, with 38.10% reporting high financial joy. Domestic helpers and rickshaw pullers mostly feel medium financial joy, with 52.38% and 56.67% respectively. Hawkers are the most likely to feel low financial joy at 33.33%. These differences suggest that occupation can greatly affect how people feel about their financial situation.

Table 6: Cross-tabulation between Education Level of the respondent and Financial Joy (in percentage)

	LEVEL OF FINANCIAL JOY			
LEVEL OF EDUCATION	HIGH	MEDIUM	LOW	TOTAL
No Formal Educatuon	19.23%	53.85%	26.92%	100.00%
Primary	23.64%	41.82%	34.55%	100.00%
Secondary	33.93%	55.36%	10.71%	100.00%
Higher Secondary	50.00%	42.86%	7.14%	100.00%
Graduation	100.00%	0.00%	0.00%	100.00%

We can observe from Table 6, that education level plays a key role in determining the sense of financial joy with the individual. People with different levels of education feel differently about their finances. Those with no formal education feel the least happy, with only 19.23% reporting high financial joy and 26.92% feeling low financial joy. As education levels increase, financial joy also increases. For example, 33.93% of people with secondary education and 50% of those with higher secondary education feel high financial joy. Remarkably, everyone with a graduation degree feels high financial joy (100%). This suggests that higher education is linked to greater financial happiness.

Table 7: Cross-tabulation between the Family Structure of the respondent and Financial Joy (in percentage)

FAMILY STRUCTURE	LEVEL OF FINANCIAL JOY			TOTAL
	HIGH	MEDIUM	LOW	
Alone	0.0%	25.0%	75.0%	100.0%
With Spouse	35.7%	50.0%	14.3%	100.0%
With Spouse And Children	28.9%	50.0%	21.1%	100.0%
With Spouse Children And Parent	33.3%	33.3%	33.3%	100.0%

Table 7; People with different family structures experiences different levels of financial joy. Those living alone are the least happy, with 75% feeling low financial joy and none feeling high financial joy. People living with a spouse are the happiest, with 35.7% feeling high financial joy and only 14.3% feeling low financial joy. Those living with a spouse and children feel a bit less happy, with 28.9% feeling high financial joy. People living with a spouse, children, and parents have a more balanced distribution, with 33.3% feeling high, medium, and low financial joy each. This shows that living with family, especially just with a spouse, is linked to higher financial happiness.

Table 8: Cross-tabulation between Amount of income of the respondent and Financial Joy (in percentage)

LEVEL OF INCOME	LEVEL OF FINANCIAL JOY			TOTAL
	HIGH	MEDIUM	LOW	
LESS THAN Rs. 5000	0%	0%	0%	0%
Rs.5000-10000	26.3%	51.3%	22.4%	100%
Rs.10000-20000	28.6%	49.2%	22.2%	100%
Rs.20000-30000	53.8%	30.8%	15.4%	100%

Table 8 is indicating that income plays a key role in the determination of financial joy among the respondents which can be observed that for those earning between Rs. 5000 and 10000, 26.3% feel very happy about their finances, while 22.4% feel unhappy. Among those earning Rs. 10000 to 20000, 28.6% feel very happy, and 22.2% feel unhappy. People earning

between Rs. 20000 and 30000 are the happiest, with 53.8% feeling very happy and only 15.4% feeling unhappy. This shows that people tend to feel happier with their finances as their income increases.

Table 9: Reliability Analysis

Cronbach's Alpha	N of Items
.836	20

The reliability of the data was measured using Cronbach's Alpha, which yielded a value of **0.836** for the 20 items included in the measurement. This indicates a **high level of internal consistency**, suggesting that the items are well-correlated and collectively measure the same underlying construct as per **Table 9**.

Table 10: Correlation between Financial Inclusion Index (FII), Quality of Life Index (QOLI) & Financial Joy Index (FJI)

Correlations				
		FII	QOLI	FJI
FII	Pearson Correlation	1	.351**	.784**
	Sig. (2-tailed)		.000	.000
	N	164	164	164
QOLI	Pearson Correlation	.351**	1	.273**
	Sig. (2-tailed)	.000		.001
	N	164	164	164
FJI	Pearson Correlation	.784**	.273**	1
	Sig. (2-tailed)	.000	.001	
	N	164	164	164
**. Correlation is significant at the 0.01 level (2-tailed).				

The correlation analysis reveals strong and statistically significant relationships among the variables. Specifically, there are significant positive correlations between Financial Inclusion Index (FII) and both Quality of Life Index (QOLI) ($r = 0.351$, $p < 0.01$) and Financial Joy Index (FJI) ($r = 0.784$, $p < 0.01$). Additionally, a positive correlation exists between Quality of Life Index (QOLI) and Financial Joy Index (FJI) ($r = 0.273$, $p < 0.01$). These findings suggest that people with higher levels of financial inclusion tend to experience improved quality of life and greater financial satisfaction. Moreover, people with higher quality of life also tend to experience higher levels of financial joy.

Table 11: Regression between Financial Inclusion Index (FII), Demographic Variables & Quality of Life Index (QOLI)

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.530 ^a	.281	.240	.20630

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.373	8	.297	6.970	.000 ^b
	Residual	6.086	143	.043		
	Total	8.459	151			

Coefficients ^a								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	1.409	.153		9.229	.000		
	GENDER	.018	.038	.038	.472	.638	.772	1.295
	AGE	-.001	.002	-.025	-.322	.748	.834	1.198
	EDUCATION	-.061	.021	-.232	-2.948	.004	.810	1.235
	OCCUPATION	.034	.052	.049	.660	.510	.913	1.095
	MARITAL STATUS	-.142	.071	-.156	-1.987	.049	.817	1.224
	FAMILY STRUCTURE	.116	.035	.266	3.341	.001	.796	1.256
	INCOME	6.336E-6	.000	.143	1.711	.089	.722	1.385
	FII	.263	.060	.343	4.422	.000	.835	1.198
a. Dependent Variable: QOLI								

From Table 11, we can observe that education, marital status family structure and financial inclusion index are highly significant at 0.05 level and play a key role in determining the dependent variable i.e.; quality of life. Family structure (B = 0.116, p = 0.001) and FII (B = 0.263, p = 0.000) positively impact the quality of life, indicating that certain family structures and financial independence enhance the quality of living among the respondents. Gender, age, occupation, and income do not significantly predict quality of life. Collinearity statistics show that all predictors have VIF values are less than 10, indicating no multicollinearity.

Conclusion

Financial inclusion is vital not only for economic growth but also for improving the quality of life, specifically in the informal sector. By ensuring financial services, governments can accelerate the development marginalized groups, support small businesses, and enhance sustainable development. This access boosts financial strength for individuals and society. "Financial joy" refers to the satisfaction which is gained from having access to these services, eventually which improves life quality. Thus, financial inclusion directly leads to financial happiness. When individuals can effectively manage their finances, it enhances their well-being and security. Governments are key to this, needing to prioritize policies that enhances financial access, literacy, and inclusiveness as a laying stone for prosperous and social fairness.

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India's Economic Transformation: Leveraging Financial Inclusion and Digital Public Infrastructure

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Abstract:

India's economy is undergoing a significant transformation, driven by financial inclusion and digital public infrastructure. The Pradhan Mantri Jan -Dhan Yojana (PMJDY), the national mission for financial inclusion to ensure access to financial services, namely , a basic saving & deposit account, remittance, credit, insurance, and pension in an affordable manner. As one of the largest financial inclusion drives in the world and completed in record time, PMJDY is an indicator of the pulse of the bottom of the pyramid as it brings the poor within the fold of the formal financial system. PMJDY has brought the unbanked into the banking system, expanded the financial architecture of India, and brought financial inclusion to almost every adult with 55.6 per cent women account holders. This research paper explores the impact of financial inclusion and digital public infrastructure on India's economic growth, poverty reduction, and increased access to financial services. The study examines the role of initiatives such as Jan Dhan Yojana, Aadhaar, and UPI in promoting financial inclusion and digital payments. The findings suggest that financial inclusion and digital public infrastructure have contributed significantly to India's economic growth and poverty reduction. The research highlights the importance of continued investment in digital infrastructure and financial inclusion initiatives to promote sustainable economic development in India.

Keywords: Economic Transformation, Leveraging, Financial Inclusion, Digital Public Infrastructure, Digital Payment, Sustainable economic development.

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THE ROLE OF DIGITAL PUBLIC INFRASTRUCTURE (DPI) IN ADVANCING FINANCIAL INCLUSION IN RURAL INDIA

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Abstract

This study explores the impact of Digital Public Infrastructure (DPI) such as Aadhaar, Unified Payments Interface (UPI), and Jan Dhan Yojana in enhancing financial inclusion in rural India. DPI has significantly improved access to financial services for underbanked populations by providing a secure, scalable, and interoperable platform for identity verification and digital transactions. Using secondary data, reports, and case studies, the paper evaluates the efficiency and outreach of DPI initiatives and identifies key barriers and enablers to rural financial inclusion.

Keywords: Digital Public Infrastructure, Financial Inclusion, Rural India, Aadhaar, UPI, Jan Dhan Yojana, Digital Payments

Introduction:

Financial inclusion is vital for achieving inclusive economic growth, especially in a country as diverse and populous as India. Rural populations, which make up a significant portion of the country, have historically faced barriers to accessing formal banking, credit, and insurance services. These challenges stem largely from inadequate infrastructure, limited financial literacy, and geographical isolation. The emergence of Digital Public Infrastructure (DPI) marks a significant shift in addressing these gaps. Key components such as Aadhaar (a digital identity system), Unified Payments Interface (UPI), and the Pradhan Mantri Jan Dhan Yojana (PMJDY) have collectively laid the groundwork for a more inclusive financial system. These initiatives simplify authentication, enable seamless digital transactions, and facilitate access to zero-balance bank accounts. This paper seeks to explore the transformative impact of DPI on rural financial inclusion, analyzing how these tools have redefined accessibility, transparency, and participation in the formal financial ecosystem.

Review of Literature:

Ghosh and Vinod (2022) In their study, Ghosh and Vinod emphasized that Aadhaar, India's biometric digital identity system, has played a pivotal role in simplifying the Know Your Customer (KYC) process. This has enabled millions of rural residents to open bank accounts with ease, contributing directly to the growth of financial inclusion.

Reserve Bank of India (2023) The RBI's annual report highlighted a significant surge—over 80% year-on-year—in UPI transactions in rural areas. This data reflects growing trust and familiarity with digital payments in underserved regions, driven by smartphone penetration and user-friendly DPI platforms.

Mehta and Sharma (2021) this study found that the Jan Dhan Yojana, when integrated with Aadhaar and mobile banking, has facilitated large-scale Direct Benefit Transfers (DBT). The result has been a marked reduction in fund leakages and an improvement in subsidy disbursal efficiency.

Basu (2020) Basu raised critical concerns around DPI adoption, especially in rural India. While acknowledging its benefits, the study noted key limitations such as poor digital literacy, weak digital infrastructure, and growing data privacy risks due to centralized identity and transaction data.

IFMR LEAD (2019) A field-based study conducted by IFMR LEAD explored the usage of digital identity in rural finance. It concluded that while DPI offers enormous potential, its impact is uneven due to socio-economic disparities, and that enabling support systems—such as training and grievance redressal—are crucial for success.

1. Need for the Study:

While financial inclusion has improved in urban areas, rural regions still face challenges such as low banking penetration, limited access to credit, and digital illiteracy. This study is needed to evaluate whether DPI tools are addressing these gaps effectively.

2. Scope of the Study:

The scope includes rural regions of India with a focus on the use of Aadhaar, UPI, and Jan Dhan Yojana from 2015 to 2024. The study covers financial inclusion parameters such as bank account access, transaction volume, and use of digital payment platforms.

3. Objectives of the Study:

- To assess the impact of DPI on financial inclusion in rural India.
- To identify the benefits and challenges of using DPI in financial services.
- To suggest policy interventions to strengthen DPI adoption in rural areas.

4. Research Methodology:

This study uses a qualitative approach based on secondary data analysis. Sources include government reports, academic journals, policy papers, and RBI and NPCI data. Case studies from states like Uttar Pradesh, Bihar, and Tamil Nadu are included to assess regional variations. Content analysis is used to evaluate the effectiveness of DPI tools in achieving financial inclusion.

5. Limitations of the Study:

- The study relies on secondary data, which may not fully reflect ground-level realities.
- Regional disparities may limit the generalizability of findings.
- Rapid changes in technology may affect the long-term relevance of the results.

Theoretical Framework

The study is grounded in three interrelated theoretical models: the Technology Acceptance Model (TAM), Financial Inclusion Theory, and the Public Infrastructure Theory. These frameworks collectively help explain how Digital Public Infrastructure (DPI) influences financial behavior, accessibility, and inclusion in rural India.

Technology Acceptance Model (TAM)

Developed by Davis (1989), the TAM suggests that two key factors—Perceived Usefulness (PU) and Perceived Ease of Use (PEOU)—determine users' acceptance of a new technology. In the context of rural India, DPI platforms such as UPI, Aadhaar-enabled Payment Systems (AePS), and mobile banking apps are adopted when users find them beneficial and easy to operate. Many rural users, especially those new to digital tools, make adoption decisions based on how well these platforms simplify transactions, reduce the need for travel to bank branches, and allow quick access to funds.

Financial Inclusion Theory

This theory emphasizes that greater access to formal financial services leads to improved economic participation, poverty reduction, and social empowerment. DPI directly aligns with this theory by removing traditional access barriers. Aadhaar simplifies identity verification, Jan Dhan provides zero-balance accounts, and UPI offers seamless peer-to-peer and merchant payments. These innovations enable individuals to save securely, receive government subsidies, and participate in formal markets—thus furthering the cause of financial inclusion.

Public Infrastructure Theory

Public Infrastructure Theory posits that state-sponsored infrastructure—when designed as a public good—can generate widespread socio-economic benefits. DPI, functioning as open digital infrastructure, plays a foundational role in enabling private innovation and public service delivery. Platforms such as Aadhaar and UPI are interoperable and accessible, fostering an ecosystem where banks, fintechs, and government agencies can offer targeted financial services at scale. This theory helps understand how DPI acts as a digital backbone that supports inclusive finance, much like physical infrastructure supports economic activity.

Findings

The study aimed to evaluate the role of Digital Public Infrastructure (DPI) in promoting financial inclusion in rural India, focusing on its impact, benefits, challenges, and policy needs. The findings are structured in relation to each objective:

1. Impact of DPI on Financial Inclusion in Rural India

- DPI platforms such as Aadhaar, Unified Payments Interface (UPI), and the Jan Dhan Yojana (PMJDY) have significantly increased access to formal financial services in rural areas.
- As of recent data, over **80% of rural households** now have at least one bank account, largely facilitated by the seamless integration of biometric authentication and simplified KYC norms via Aadhaar.
- UPI transactions in rural and semi-urban areas have seen a **year-on-year growth of over 50%**, indicating increasing trust and digital literacy among users.
- DPI has enabled more efficient **Direct Benefit Transfers (DBTs)**, reducing leakages in subsidy and welfare distribution.

2. Benefits and Challenges of DPI in Financial Services

Benefits:

- **Accessibility:** Mobile banking apps and UPI have made banking services available even in remote villages with limited physical infrastructure.
- **Transparency and Speed:** Real-time transfers and digital transaction records enhance accountability in financial dealings.
- **Cost-effectiveness:** Digital systems reduce the operational costs of financial institutions, encouraging them to expand services to underserved areas.

Challenges:

- **Digital Divide:** Inadequate internet connectivity, low smartphone penetration, and limited digital literacy in some regions hinder full adoption.
- **Cyber security Concerns:** Increased digitization has raised risks related to data privacy and fraud.
- **Last-mile delivery:** Dependence on banking correspondents (BCs) and agents still persists, and their coverage is not uniformly efficient across regions.

3. Suggested Policy Interventions

- **Infrastructure Development:** Investment in rural digital connectivity, especially through BharatNet and 5G expansion, is critical.

- **Capacity Building:** Regular digital literacy drives and training programs for users and banking agents are essential.
- **Regulatory Support:** Strengthening data protection laws and ensuring interoperability between platforms will improve user confidence.
- **Incentivizing Innovation:** Encouraging fintech startups to build region-specific solutions and local language interfaces will deepen DPI penetration.

Suggestions

To enhance the effectiveness and reach of Digital Public Infrastructure (DPI) in promoting financial inclusion in rural India, several key measures are recommended. Firstly, there is an urgent need to strengthen the digital infrastructure in rural areas by accelerating the rollout of BharatNet, expanding 5G networks, and ensuring affordable internet access, along with a stable power supply to support uninterrupted digital banking services. Secondly, promoting digital literacy is crucial—village-level campaigns targeting vulnerable groups such as women, farmers, and the elderly should be implemented in collaboration with schools, NGOs, and local bodies to raise awareness about safe and effective use of digital tools like UPI and Aadhaar-enabled payment systems. Thirdly, developing user-friendly digital platforms in regional languages, supported by voice-based or icon-driven interfaces, will greatly aid low-literate populations. Simplified onboarding and KYC processes are also needed to ease entry into the digital financial ecosystem. Fourth, last-mile service delivery can be improved by strengthening the Business Correspondent (BC) network through training, performance incentives, and better devices, while deploying mobile banking units in underserved areas. Fifth, robust cyber security measures must be implemented to protect users, including multi-factor authentication and grievance redressal systems, along with basic fraud protection coverage for rural digital users. Sixth, public-private partnerships should be actively fostered to leverage the expertise of fintech firms, telecom companies, and microfinance institutions in creating tailored financial solutions. Innovation should be encouraged through regulatory support and funding mechanisms for startups focused on DPI.

Finally, regular monitoring and policy review are essential—this includes establishing real-time monitoring systems, feedback channels for rural users, and timely updates to regulatory frameworks to keep pace with technological evolution and user needs. Together, these measures can significantly deepen financial inclusion and ensure that DPI reaches its full potential in transforming rural India's financial landscape.

Conclusion

Digital Public Infrastructure has played a transformative role in bridging the financial inclusion gap in rural India. Through platforms like Aadhaar, UPI, and Jan Dhan, millions have been brought into the formal financial system. However, to achieve holistic and sustainable inclusion, it is essential to invest in digital literacy, infrastructure, and inclusive

technology design. With sustained government and private sector collaboration, DPI has the potential to reshape rural economic participation and social equity.

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DIGITAL PUBLIC INFRASTRUCTURE: CONCEPTS, GLOBAL EFFORTS, BENEFITS, CHALLENGES, AND SUCCESS STORIES

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ABSTRACT

Digital Public Infrastructure (DPI) is a rising innovation that leverages open virtual technologies to enhance get admission to public and social services, thereby improving welfare and livelihoods. It accommodates systems like digital identity, price structures, and data exchanges that join individuals and establishments to critical offerings and economic possibilities securely and correctly. This paper explores the idea of DPI, its worldwide trends, blessings, and challenges, along achievement and failure stories from one-of-a-kind countries. DPI is remodeling carrier transport for underserved populations but additionally gives risks inclusive of cybersecurity threats, lack of interoperability, virtual exclusion, susceptible public-non-public collaboration, and moral worries. These demanding situations should be addressed to completely realise DPI's societal impact. The observe contributes to the wider virtual governance discourse by means of displaying that when implemented inclusively, DPI can be a cornerstone of equitable virtual societies.

Keywords: virtual public infrastructure, digital ID, digital payment, records trade, interoperability, public-private partnerships, cybersecurity, digital society.

INTRODUCTION

Digital Public Infrastructure (DPI) refers to open-source, networked digital systems designed to supply important public offerings to citizens, corporations, and governments. The concept received worldwide visibility throughout India's G20 presidency in 2023, highlighting its ability to power inclusive virtual transformation.

The COVID-19 pandemic (2020–2022) underscored the urgency and fee of DPI. Countries with mature DPI systems, which include India, fast dispensed welfare benefits via virtual

channels (Kumar, 2020). In evaluation, countries without such infrastructure confronted delays and inefficiencies in achieving their citizens (Ozili, 2021), emphasizing the position of DPI in emergency reaction and monetary inclusion.

Beyond crisis control, DPI is essential for accelerating digital inclusion, particularly in growing international locations that lack assets to construct incorporated structures (Webber et al., 2022; Dahlman et al., 2016). Even wealthier international locations face fragmentation due to non-interoperable legacy systems. Many African nations have partial digital systems but lack foundational additives like a unified virtual identification—proscribing get entry to digital markets and public offerings (Williams et al., 2016; Holmes)

THEORY AND RELATED LITERATURE

Theoretical Foundation

An extensively used framework to give an explanation for the adoption of virtual technologies which includes DPI is the Technology Acceptance Model (TAM) (Davis et al., 1989). This version posits that people undertake a technology based on two key perceptions: ease of use and value. If a digital device is perceived as both smooth and useful, customers are more likely to simply accept it (Schmidhuber et al., 2020; Rabe & Kostka, 2024). In the context of DPI, this implies that widespread adoption depends on public perception of its utility and user-friendliness.

Empirical and Theoretical Support for DPI

Several research have analyzed the promise and overall performance of DPI:

- **Goldsmith & Gardner (2022)** emphasize that digital infrastructure can improve public asset management, protection, sustainability, and equity. They endorse for investments in platforms, facts systems, and clever governance.
- **Hanna et al. (2020)** argues for democratic public ownership of digital infrastructure, highlighting 5 standards: commonplace access, citizen empowerment, decreased corporate control, ecological sustainability, and facts sovereignty.
- **Hustad & Olsen (2021)** cognizance on provider-oriented, sustainable infrastructure, underscoring flexibility, reuse, enterprise-IT alignment, and sturdy governance as key layout factors.

Sectoral and Country-Specific Evidence

- **China:**
 - **Liu et al. (2024)** locate that the Broadband China policy considerably progressed public fitness results through better healthcare access and healthier existence.
 - **Zhou (2022)** hyperlinks virtual infrastructure to financial boom, reduced inflation, and hard work performance, but warns of monopolistic practices with the aid of tech oligarchs.

- **Tang & Yang (2023)** show accelerated carbon emissions from infrastructure enlargement and suggest emissions trading schemes for mitigation.
- **Tang & Zhao (2023)** conclude that virtual infrastructure boosts overall component productiveness, especially in areas with sturdy R.

Global South and Equity Concerns

- **Ayodele (2024)** argues that DPI is essential for Africa's continental integration and development, complementing conventional infrastructure like roads and power.
- **Finger & Montero (2022)** suggest that virtual structures performing as intermediaries for public offerings may want to qualify as public utilities—if regulated to uphold public interest.
- **Webber et al. (2022)**, primarily based on interviews in New Zealand, identify stakeholder concerns about digital inequality—highlighting troubles round internet get entry to, inclusion, and affordability of virtual competencies training.

CRITICAL PERSPECTIVES, RESEARCH GAP, AND CONCEPTUAL FOUNDATIONS OF DPI

Critical Perspectives on DPI

While virtual public infrastructure offers several blessings, the literature also highlights numerous essential issues:

- **Privacy and Exclusion:**

Bentley et al. (2024) note that virtual technologies, inclusive of DPI, are frequently criticized for susceptible privateness protections and for exacerbating digital exclusion, thereby widening the digital divide.

- **Digital Literacy and Access:**

Lythreatis et al. (2022) warn that virtual illiteracy may restriction DPI adoption, especially amongst marginalized groups, eroding its meant blessings.

- **Governance Risks:**

Eaves et al. (2024) caution that integrating small structures into a big DPI can undermine transparency and accountability, especially when scaling fast.

- **Marginalization and AI Integration:**

Nagar and Eaves (2024) highlight the chance of layering AI on top of DPI systems without first making sure equitable access. They argue that historically marginalized agencies may also mistrust or avoid government-led virtual systems due to systemic inequities.

Case from Singapore:

Zhuang et al. (2025) emphasize that whilst DPI can decorate resilience and competitiveness, it also dangers except susceptible populations consisting of visually impaired individuals.

Dependency and Digital Insecurity:

Hardy (2024) factors out that even in digitally advanced nations like Estonia (e.g., the X-Road gadget), people increasingly sense depending on being on line, growing vulnerability within the face of capacity virtual disruptions.

Gap in the Literature

Most existing research recognition on the possibilities or zone-particular benefits of virtual infrastructure. However, there is confined studies on the worldwide tendencies, possibilities, and systemic challenges of DPI. This looks at contributes by means of:

- Clarifying the definition and key additives of DPI,
- Highlighting stakeholder roles and examples of DPI tasks,
- Exploring global advantages and risks, and
- Bridging the theoretical with the practical across diverse contexts.

CONCEPTUAL UNDERPINNINGS OF DPI

Analogy for Understanding DPI

Digital public infrastructure can be as compared to physical roads. Just as roads enable movement and connectivity throughout a rustic, DPI allows digital connections that facilitate get admission to offerings, records, and financial structures.

- Physical infrastructure connects people and goods.
- Digital infrastructure connects humans, information, and cash across the virtual economic system.

Therefore, DPI may be seemed because the infrastructure of the virtual global, critical for participation in contemporary society.

Definition of DPI

The definition of DPI maintains to evolve. Some time-honored definitions include:

- **Eaves et al. (2024):** DPI is a hard and fast of digital systems enabling international locations to supply social offerings and monetary possibilities effectively and appropriately.
- **G20 New Delhi Leaders' Declaration (2023):** DPI is a “set of shared digital systems that are secure and interoperable, built on open technologies, to deliver equitable access to public and/or private services at societal scale.”

- **Zuckerman (2020):** DPI is a central authority-led, open-supply digital network that encourages private sector innovation at the same time as serving public interest.

Thus, DPI combines two center factors:

1. Open, interoperable virtual systems designed for public gain.
2. An atmosphere of public-personal collaboration to decorate innovation and service transport.

Components and Stakeholders of Digital Public Infrastructure (DPI)

Core Components of DPI

For a DPI to characteristic effectively and inclusively, several technological and institutional components must be in area (see Figure 1):

1. **Digital Identity System**
 - Provides specific, verifiable digital identities for people.
 - Facilitates stable authentication and get entry to throughout diverse services.
 - Source: Singh et al. (2019); Giannopoulou (2023)
 - Enables inclusive participation and helps aggressive digital surroundings.
 - Source: Rukanova et al. (2023)
2. **Digital Payment System**
 - Enables actual-time digital switch of money and close to-cash devices.
 - Supports transactions among people, agencies, and governments.
 - Source: Singh et al. (2019)
3. **Data Exchange and Integration System**
 - Facilitates seamless sharing and interoperability amongst unbiased virtual systems.
4. **Consent Networks**
 - Allows users to authorize or limit get right of entry to their private records.
 - Ensures privacy and user manage over facts usage.
 - Source: Eaves et al. (2024)
5. **Credentials**
 - Facilitates secure virtual sharing of professional files (e.g., certificates, licenses).
 - Supports each government-issued and personal credentials.
 - Source: Hobson et al. (2023)
6. **Registries**

- Verifies and continues information of ownership or entitlement (e.g., land, identity, licenses).
- Serves as an authoritative supply for digital claims and assets.

7. Digital Signatures

- Ensures the felony validity of digital transactions and documents.
- Enables authentication and non-repudiation of digital content.
- Source: Brands (2000)

8. National Digital Strategies, Roadmaps, and Blueprints

- Provides strategic path for the rollout and governance of DPI.
- Helps become aware of and address gaps inside the infrastructure.
- Supports pass-sectoral coordination for national integration.

STAKEHOLDERS DRIVING DPI DEVELOPMENT

Digital public infrastructure improvement is a collaborative attempt related to a big selection of stakeholders (see Figure 2):

1. Public Sector

- Roles:
 - Develops felony and regulatory frameworks.
 - Ensures moral and stable use of technologies.
 - Provides seed investment and promotes innovation.
- Examples: Government ministries, departments, and regulatory groups.
- Source: Selim and ElGohary (2020)

2. Private Sector

- Roles:
 - Innovates with technology for DPI solutions.
 - Provides financial help and task expertise.
 - Contributes to team of workers development and nearby capability building.
- Examples: Tech organizations, commercial enterprise agencies, consultancies.
- Source: Selim and ElGohary (2020)

3. Academia

- Roles:
 - Develops conceptual frameworks and taxonomies for DPI.
 - Hosts forums to bridge research, coverage, and practice.
 - Publishes proof-based research to tell selection-makers.
- Examples: Universities, research institutes, instructional suppose tanks.

4. Civil Society Organizations (CSOs)

- Roles:
 - Raise public recognition approximately DPI advantages and rights.
 - Advocate for inclusive regulations and statistics protections.
 - Offer professional insights into societal and moral dimensions.
- Examples: NGOs, advocacy networks, philanthropic corporations.

5. International Development Organizations

- Roles:
 - Provide technical guide and coverage guidance.
 - Offer investment, grants, and loans for DPI initiatives.
- Examples: World Bank, UNDP, Gates Foundation, and so forth.

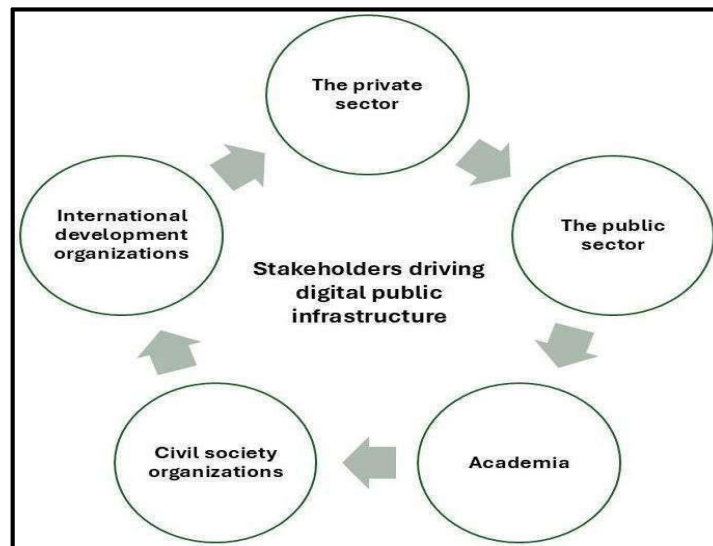


Figure 1. Stakeholders driving digital public infrastructure

PUBLIC-PRIVATE PARTNERSHIPS IN FINANCING DIGITAL PUBLIC INFRASTRUCTURE (DPI)

● High-Income Countries:

Governments in countries along with the Netherlands, Finland, Norway, the US, and Germany usually fund a majority of DPI projects directly.

- These nations possess:

- Strong economies
- Robust governance frameworks
- Advanced technological infrastructure
- Sufficient financial capacity

- Example: Government-led country wide digital identity systems in Europe and North America.

● Low- and Middle-Income Countries (LMICs):

- These countries regularly lack the financial capability to fund DPI initiatives independently.

- They rely on:

- Domestic resources (e.g., national budgets)

- International support (e.g., World Bank, Gates Foundation)
- Philanthropic resource

Why Public-Private Partnerships (PPPs) Are Essential in LMICs

- DPI structures require sizable, long-term funding because of their complexity and scope.
- Governments alone can't endure the total financial burden; for this reason, PPP models are maximum appropriate (Ma et al., 2023).
- PPPs permit pooling of public and private resources, enabling sustainable improvement.

SOURCES OF FUNDING IN A PPP MODEL

Sector	Funding Sources
Public Sector	- Tax revenues- Budgetary allocations to digital infrastructure
Private Sector	- Domestic private investors- Loans from financial institutions- Grants/donations from philanthropists- Loans from international private finance bodies

GLOBAL INITIATIVES SUPPORTING DPI DEVELOPMENT

Several global initiatives and coalitions are actively operating to sell and aid DPI globally. These applications provide investment, technical aid, and expertise-sharing structures.

1. 50-in-5 Initiative

- **Led through:** Country coalitions with aid from World Bank and Gates Foundation
- **Goal:** Help 50 countries put in force DPI properly and inclusively by using 2028
- **Focus Areas:**
 - Design, release, and scale DPI additives
 - Share high-quality practices and open-source technology
 - Build local capacity and reduce costs
- **Source:** Duliev (2023)

2. ID4D Initiative (Identification for Development)

Led by: World Bank

Objective: Advocate for secure and inclusive national ID systems

Core Principles:

Privacy-by-design

User control over data

Strong legal and regulatory safeguards

Source: Musoni et al. (2023)

3. AfricaNenda

- **Focus:** Expand on the spot and inclusive fee structures across Africa
- **Objective:** Achieve universal economic inclusion with the aid of 2030
- **Support Offered:**
 - Technical pre-task assistance
 - Institutional ability constructing

- **Source:** Domingo et al. (2023)

4. MOSIP (Modular Open-Source Identity Platform)

- **Type:** Not-for-profit, college-incubated basis
- **Supporter:** Gates Foundation
- **Role:**
 - Provide modular, open-supply foundational ID systems
 - Help governments design and own price-effective, scalable ID structures
- **Source:** Martin (2021)

5. Digital Public Goods Alliance (DPGA)

- **Endorsed by way of:** United Nations
- **Purpose:** Promote digital public items (e.g., open-source software) to help obtain SDGs
- **Mission:**
 - Facilitate discovery and use of virtual public items
 - Promote equitable worldwide virtual transformation

6. Digital Impact Alliance (DIA)

- **Objective:** Equip stakeholders with insights and equipment for sustainable virtual development
- **Activities:**
 - Research and understanding dissemination
 - Connect governments, funders, and improvement actors
 - Ensure digital systems are inclusive and evidence-based

This section gives a comprehensive evaluate of both the financing mechanisms (in particular PPPs) and the key global tasks helping DPI development worldwide. Let me understand if you'd like a visual precis (along with a chart or mind map) or circulate directly to the opportunities and demanding situations of DPI. Here's a properly-dependent, factor-smart version of the topic

“Opportunities of Digital Public Infrastructure”, accompanied via decided on achievement testimonies from international locations implementing DPI efficaciously. This layout improves clarity, retention, and replica-paste usability for academic functions.

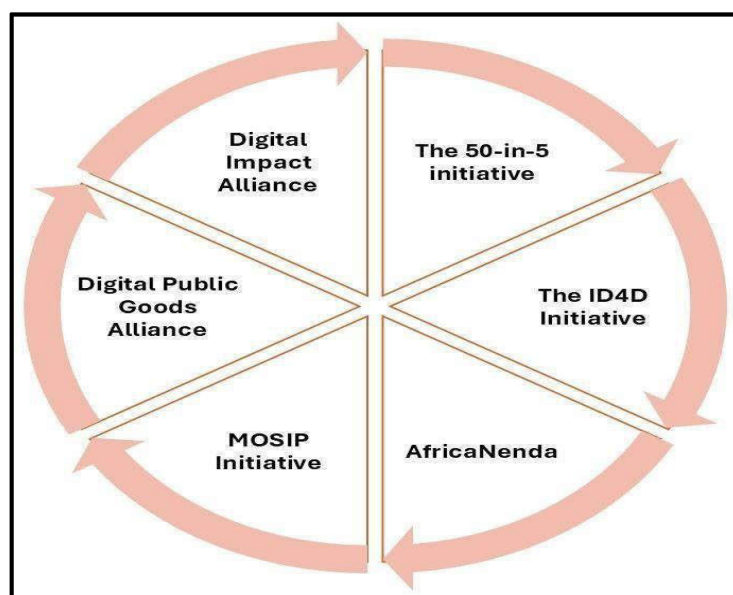


Figure 2. Global Initiatives Supporting Digital Public Infrastructure

OPPORTUNITIES OF DIGITAL PUBLIC INFRASTRUCTURE

1. Economic Growth & Competitiveness

- DPI supports the advent of a vibrant and competitive financial system with the aid of growing connectivity and digital get admission to.
- Encourages the development of virtual markets, boosting productiveness.

2. Trust in Governance.

1. Sustainable Development Goals (SDG) Advancement

- DPI accelerates development toward SDGs, especially inclusive prosperity for ladies and the poor.
- Source: Choudhuri et al., 2021

2. Financial Inclusion

- Expands access to banking, credit, and charge structures, specifically among underserved populations.
- Example: Aadhaar UPI in India enabled banking get entry to for hundreds of thousands.
- Source: D’Silva et al., 2019

3. Healthcare Access and Outcomes

- Enables virtual fitness records, far off consultations, and higher information sharing.
- Improves healthcare get admission to specifically in rural communities.
- Source: Choudhuri et al., 2021

CLIMATE RISK MITIGATION

- Facilitates actual-time weather statistics change for faster disaster response and resilience making plans.
- Helps in forecasting, early warning, and response coordination.

BOOSTING INNOVATION AND COMPETITION

- DPI allows private area innovation, faster product development, and activity creation.
- Source: Zuckerman, 2020

ACCESS TO GOVERNMENT AND FINANCIAL SERVICES

- Simplifies access to wages, payments, social benefits, identification offerings authorities' schemes.
- Works irrespective of earnings or vicinity.

ENTREPRENEURSHIP AND BUSINESS GROWTH

- DPI opens virtual markets, enabling startups and SMEs to thrive.
- Equal opportunities for virtual service carriers to attain customers.
- Source: Zuckerman, 2020; Henry et al., 2025

DPI SUCCESS AND FAILURE STORIES: COUNTRY CASES

Country	DPI System	Highlights
Brazil	Pix Payment System (2020)	- Cost: USD 4 million- Savings: USD 5.7 billion in 2021- Users: 149 million individuals & 15 million firms (Sampaio & Ornelas, 2024)
Peru	Yape (2017)	- Launched by BCP- 12 million users (35% of population)- Widely accepted as payment mode- Peru's first super app (Aurazo & Gasmi, 2024)
Singapore	Singpass	- National digital identity ecosystem- Used for public and private services- Allows federated data sharing with consent (Hoe, 2018)
India	Aadhaar + UPI	- 1.365 billion Aadhaar users- Enables G2P payments- Aadhaar Payment Bridge: DBT (direct benefit transfer) authentication- UPI: 8 billion transactions/month; 65% of GDP (Maheshwari, 2023)
Kenya	Inua Jamii Program	- Digital identity + biometric G2P payments- KES 8.54 billion to 1.07 million beneficiaries in Jan 2022- Uses Single Registry

		+ IPRS (McKay et al., 2020)
Zambia	Meheba Refugee Camp DPI	- Cash-based aid via digital wallets, SIMs, and PINs- Collaboration with UNHCR, UNCDF, MSC (Abdelgawad et al., 2023)

CHALLENGES OF DIGITAL PUBLIC INFRASTRUCTURE

1. Difficulty in Evaluating Impact

- No standardized international framework to measure the actual impact of DPI.
- Lacks metrics for:
 - User adoption rates
 - Service delivery efficiency
 - Safeguard adequacy
 - Economic impact on stakeholders

2. Cybersecurity Risks

Vulnerability to:

- Data privacy breaches
 - Hacking and unauthorized access
- Often lacks enough safety safeguards

3. Lack of Interoperability

- Government and business enterprise systems regularly do no longer integrate seamlessly.
- Results in inefficiencies and fragmented person reviews.

4. Digital Exclusion & Low Literacy

- Affects people without digital IDs or literacy.
- Excludes prone populations: elderly, rural, low-income users.
- Lack of agree with in virtual systems worsens the issue.

5. Poor Public–Private Collaboration

- Resistance due to:
 - Conflicting statutory roles in public quarter
 - Market opposition in non-public region
- Hinders incorporated DPI improvement.

6. Lack of Accountability Mechanisms

- Inadequate structures for oversight and remediation.
- Weak felony or institutional frameworks in some areas.

7. Algorithmic Bias

- Biases in choice-making algorithms.
- Can cause discriminatory get entry to services.

8. Ethical Dilemmas

- Balancing digital get entry to with:
 - User privacy
 - Consent for statistics usage
- Issues of surveillance vs carrier transport.

9. Geopolitical Constraints

- Affects global DPI improvement and support:
 - Export regulations
 - Sanctions
 - Cross-border skills shortages
- Developing international locations may face limitations in having access to technology or knowledge.

CONCLUSION:

A compelling concept at the core of digital public infrastructure is that everyone should have equal access to digital services and financial tools, regardless of where they live or their income. DPI has unobtrusively emerged as the foundation of inclusion, whether it is through instantaneous money transfers via UPI or the direct deposit of government benefits into a bank account. Even though the technology may seem complicated, the effects are straightforward and relatable: millions of people can now open bank accounts with just their fingerprints, a farmer in a village can now receive subsidies instantly, and students can now obtain certificates without any red tape. DPI therefore thrives under the umbrella of "Financial Inclusion" and does not fit under terms like "metaverse" or "blockchain" alone.

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Digital Marketing Communication in Indian Banking: A Critical Review

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Abstract

India's banking industry is witnessing a dynamic shift, evolving far beyond its traditional roles of deposits and lending. In today's competitive environment, Indian banks are actively adopting innovative marketing approaches to build stronger, more meaningful connections with their customers. Digital Marketing Communication (DMC) has emerged as a strategic tool, enabling banks to transition from conventional outreach to more interactive, personalized, and customer-centric communication. This study critically reviews the adoption and application of DMC within the Indian banking sector. It provides insights for banks to improve communication, ensure digital inclusion, and enhance staff training in digital tools to boost overall service effectiveness.

Keywords: Digital Marketing Communication, Indian Banking, Customer Engagement, Digital Strategy, Banking Innovation

Examining the Role of Public Digital Infrastructure in Advancing Digitally Empowered Financial Inclusion in India

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Abstract:

Financial inclusion is increasingly recognized as a driver of equitable economic development, particularly in emerging economies like India. With traditional banking systems often unable to reach rural and underserved populations, India has pioneered a unique model of financial inclusion through its Public Digital Infrastructure (PDI). This paper explores the conceptual and empirical dimensions of the JAM trinity—Jan Dhan Yojana, Aadhaar, and the Unified Payments Interface (UPI)—as a cohesive ecosystem that has redefined financial access, efficiency, and transparency. It examines how the synergy of biometric identity, mobile connectivity, and direct benefit transfers has significantly lowered the barriers to financial participation for low-income and marginalized groups. The study also critically evaluates persistent challenges such as digital literacy gaps, infrastructure constraints, and socio-economic disparities, while highlighting policy recommendations for building a more resilient, inclusive, and trust-based digital financial ecosystem.

Keywords: *Financial Inclusion, Public Digital Infrastructure, JAM Trinity (Jan Dhan–Aadhaar–UPI), Digital Literacy, Inclusive Development*

Introduction

Financial inclusion plays a vital role in promoting equitable economic development and driving overall economic growth, particularly when reinforced by digital technologies and sound policy frameworks. It involves providing accessible and affordable financial services to every individual. As a key priority for policymakers, financial inclusion is seen as a catalyst for inclusive growth. In a country like India, with a population surpassing 1.4 billion—many of whom live in rural or semi-urban areas—traditional banking systems have struggled to reach underserved

communities. In this context, Public Digital Infrastructure (PDI) has become a crucial tool in expanding financial access and supporting inclusive financial ecosystems. The convergence of financial inclusion efforts with digital public goods such as Aadhaar, Jan Dhan Yojana (JDY), and the Unified Payments Interface (UPI)—collectively referred to as the JAM trinity—has revolutionized access to financial services in India. These digital tools have played a pivotal role in broadening financial access for economically disadvantaged and low-income groups by making banking and

payment systems more accessible, transparent, and efficient. The synergy between biometric identification (Aadhaar), bank accounts (Jan Dhan), and mobile connectivity has facilitated large-scale account openings, seamless direct benefit transfers, and effective last-mile delivery of financial services. As a result, it has lowered entry barriers for both rural and urban poor populations and enhanced the reliability of welfare disbursements. (Panse et al., 2021) Likewise, the Unified Payments Interface (UPI) has transformed the digital payments landscape by allowing quick, seamless, and secure money transfers between individuals and businesses. Its extensive adoption has brought digital transactions into the mainstream, thereby advancing financial

inclusion and encouraging broader economic engagement (Azimi, 2022). Enhancing the accessibility and fairness of financial services through digital public goods requires sustained efforts in promoting digital literacy, ensuring robust security, and implementing targeted outreach to achieve inclusive impact and prevent marginalization. This paper conceptually examines the convergence of financial inclusion and digital public goods like Aadhaar, Jan Dhan Yojana, and the Unified Payments Interface (UPI). It underscores the transformative power of these systems while critically analysing the challenges, opportunities, and future pathways toward building a more inclusive financial landscape.

Methodology

This study adopts a **mixed-methods approach**, integrating both qualitative and quantitative research methods to comprehensively explore the impact of Public Digital Infrastructure (PDI) on financial inclusion in India. A theoretical framework will be constructed by reviewing key academic literature on financial inclusion, digital public goods, and digital governance. This framework will help map the interactions between digital identity, financial access, and economic participation. Quantitative data will be sourced from **reputed institutions** such as: **Reserve Bank of India (RBI)**,

National Payments Corporation of India (NPCI), **NABARD**, **Ministry of Finance** and **TRAI**. Variables of interest may include Number of Jan Dhan accounts opened, UPI transaction volumes, DBT (Direct Benefit Transfer) disbursement efficiency, Gender-disaggregated usage rates, Rural vs urban adoption metrics. The study will offer insights into real-world challenges in outreach, trust-building, and usability of services. Limitations of the study will include data availability, regional generalizability, and reliance on secondary sources where primary fieldwork is not feasible.

Literature review

Recent research explores how expanding financial access impacts economic development across different countries and

contexts. The dominant evidence shows that increased financial inclusion leads to greater financial and economic development,

particularly in developing and emerging economies.

- **Positive Relationship Between Financial Inclusion and Economic Growth:** A substantial body of empirical research establishes a robust positive association between financial inclusion and economic growth. This relationship is especially salient in low-income and emerging market economies, where enhanced access to financial services serves as a catalyst for entrepreneurial activity, capital formation, and increased household consumption. (Daud & Ahmad, 2022) Empirical evidence indicates the presence of a bidirectional causal relationship between financial inclusion and economic growth. Financial inclusion not only contributes to economic expansion, but sustained economic growth also facilitates broader financial inclusion, thereby establishing a mutually reinforcing cycle (Azimi, 2022).
- **Digital Financial Inclusion and Technology:** The advancement of digital financial inclusion has significantly contributed to accelerating economic growth, notably in countries such as China (Ahmad et al., 2021). The integration of digital technologies enhances both the accessibility and cost-effectiveness of financial services, thereby extending financial access to historically marginalized and underserved populations. Information

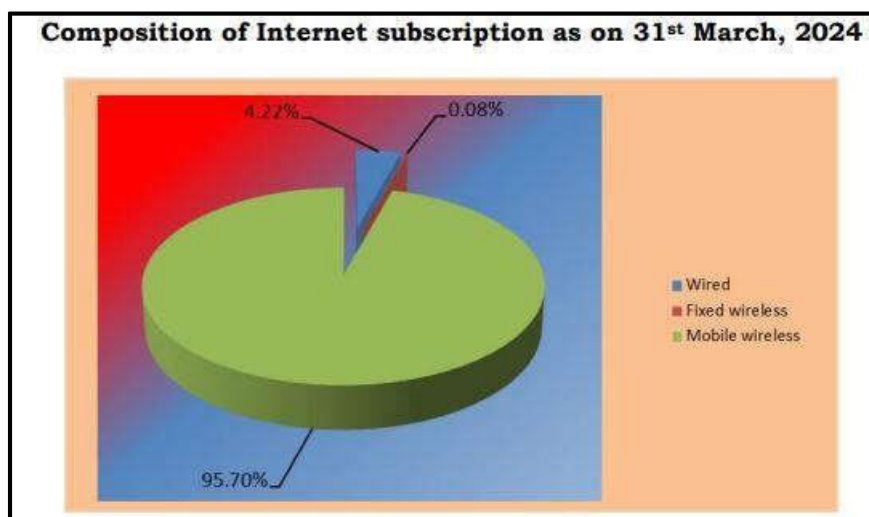
and Communication Technology (ICT) serves as a complementary factor in amplifying the impact of financial inclusion on economic growth. However, its effectiveness is contingent upon adequate user education and the presence of supportive infrastructure, particularly within the context of developing economies (Chatterjee, 2020).

- **Mechanisms and Broader Socio-Economic Effects:** Financial inclusion serves as a catalyst for economic growth by fostering small and medium-sized enterprise (SME) development and stimulating household-level consumption, thereby promoting entrepreneurial activity and reinforcing domestic demand within the economy. (Eziamaka et al., 2024) It also helps reduce income inequality, which in turn positively affects GDP growth, particularly in high-fragility and low-income countries (Arakelyan, 2024). Although financial inclusion is generally associated with poverty reduction, its impact on income inequality is complex and context-dependent. In certain regions, increased financial inclusion has been correlated with rising income disparities, underscoring the necessity for targeted policy interventions to ensure equitable outcomes (Ololade, 2024) and Access to finance for previously marginalized populations promotes sustainable development and contributes to the empowerment and resilience of communities (Ibeh et al., 2024).

Key Achievements

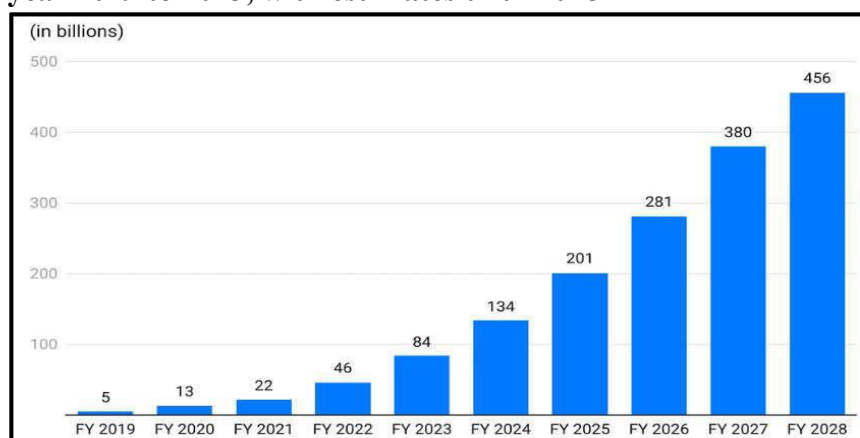
India has made substantial progress in extending financial services through digital means:

- Digital Penetration:** The adoption of mobile-based banking and digital payment systems has witnessed substantial growth in India, particularly within Tier II and Tier III cities. As of 2023, the country hosts over 900 million internet users, positioning it as the second-largest digital market globally, following China (TRAI, 2024). Projections suggest that this user base will surpass 1.6 billion by 2050, with anticipated growth across both urban and rural regions. This trend reflects a dynamic and expanding landscape of internet accessibility and digital connectivity nationwide. (*India, n.d.*)



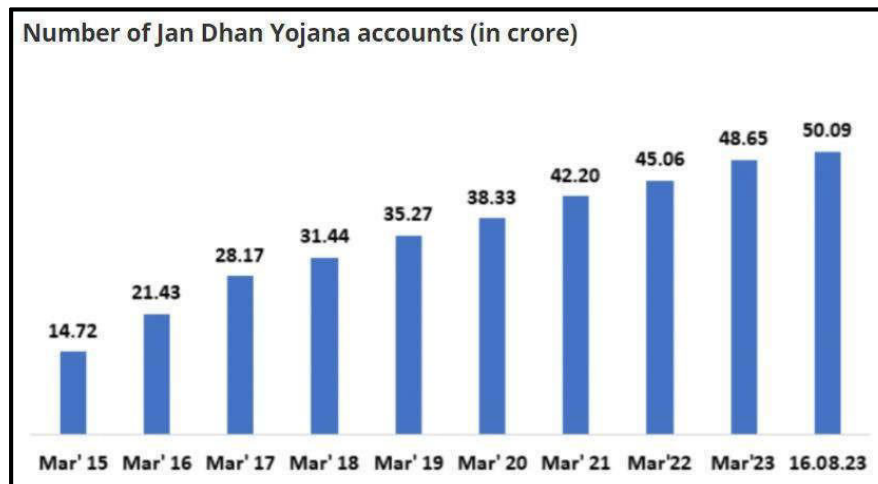
Source: The Indian Telecom Services Yearly Performance Indicators 2023-2024

- UPI Transactions:** UPI was introduced on April 11, 2016, by the National Payments Corporation of India (NPCI). According to the National Payments Corporation of India (NPCI), monthly UPI transactions crossed 10 billion in mid-2024, reflecting massive adoption even among the informal sector.
- Number of unified payments interface transactions across India from financial year 2019 to 2023, with estimates until 2028**



(source: coolest gadgets, reference: statista.com)

- Jan Dhan Yojana:** As of late 2023, more than 500 million bank accounts had been opened under this initiative, with approximately 55% held by women. Furthermore, nearly 67% of these accounts are classified as active, according to data from the Ministry of Finance.



(source: polycircle.org)

- Direct Benefit Transfer (DBT):** Since its launch in 2013, India's Direct Benefit Transfer (DBT) system has fundamentally transformed the delivery of welfare programs by disbursing over ₹29 lakh crore directly into beneficiaries' bank accounts. This mechanism has substantially minimized inefficiencies, including leakages, corruption, and administrative delays, thereby enhancing the transparency and effectiveness of government schemes. (Singh & Mishra, 2024). DBT covers a wide range of programs, including subsidies, scholarships, pensions, and nutritional support, with more than 314 schemes and over 693 crore transactions recorded by 2022-23. (Google Search, n.d.)
- NABARD:** Through its Financial Inclusion Fund (FIF), NABARD has significantly contributed to strengthening digital infrastructure at the grassroots level by financing rural kiosks, supporting Business Correspondent (BC) training initiatives, and facilitating Wi-Fi connectivity in rural banking branches particularly

through support of Self-Help Groups (SHGs) and the SHG-Bank Linkage Programme. As of March 31, 2020, the number of SHGs linked to formal banking institutions had reached 5.577 million, marking substantial growth from the program's inception in 1992, when only 500 SHGs received financial support (Jayant & Bhatt, 2021). Moreover, NABARD's partnerships with Regional Rural Banks (RRBs) have been instrumental in extending affordable credit and formal banking services to economically disadvantaged segments, thereby enhancing the outreach of institutional finance in rural India (Ramakrishna, 2018).

Emerging Trends

Several technological and regulatory innovations are rapidly shaping the next wave of financial inclusion, making financial services more accessible, affordable, and secure for underserved populations.

Technological Innovations:

- Fintech Solutions:** Mobile banking, digital wallets, peer-to-peer lending, and online banking platforms are

progressively dismantling conventional barriers to financial access, thereby facilitating the inclusion of millions of unbanked and underbanked individuals into the formal financial system.

- **Advanced Technologies:** Blockchain technology enables secure, transparent, and cost-efficient transactions, whereas artificial intelligence (AI) and machine learning facilitate the delivery of personalized financial services and continuous customer support through automated systems such as chatbots and virtual assistants.
- **Software Engineering:** Robust, scalable, and secure software architectures are crucial for ensuring the efficient and uninterrupted delivery of digital financial services, especially in remote and underserved regions.
- **User Experience:** Performance efficiency and user-friendliness are critical determinants of fintech adoption. Mobile money services and digital platforms tend to achieve broader acceptance in contexts where they are perceived as intuitive, dependable, and convenient.

Regulatory Innovations:

- **Responsive Regulation:** Adaptive, activity-based, and technology-neutral regulatory frameworks are increasingly recognized as best practices in the evolving financial

landscape. Such approaches aim to strike an appropriate balance between fostering innovation and ensuring financial stability, consumer protection, and the integrity of financial markets.

- **Regulatory Sandboxes:** Regulatory mechanisms such as sandboxes provide fintech enterprises with the opportunity to test and pilot novel financial products within a controlled and supervised environment. This approach promotes innovation while simultaneously enabling effective risk management and regulatory oversight.
- **Innovation Hubs:** Regulatory bodies are developing innovation hubs to provide guidance to fintech firms, facilitate regulatory compliance, and promote responsible and sustainable entry into the financial marketplace.
- **Proportional Regulation:** The implementation of risk- and activity-based regulatory frameworks enables the development of inclusive non-bank financial services while preserving the space for innovation and technological advancement.

Challenges and Limitations

Financial inclusion via digital platforms and digital public infrastructure (PDI) has expanded rapidly, but several systemic challenges persist that limit its transformative potential, especially in developing countries.

Key Systemic Challenges

- **Digital Divide:** A persistent disparity exists in the access to and utilization of digital financial services between urban and rural regions, as well as across various income levels and gender groups. This digital divide constrains the overall effectiveness and inclusivity of digital financial inclusion initiatives, resulting in the continued exclusion of marginalized and underserved populations. (Omar & Inaba, 2020). The digital divide along rural-urban and gender lines continue to pose a significant challenge. According to the GSMA Mobile Gender Gap Report (2023), women in India are 41% less likely than men to access mobile internet services, highlighting persistent gender-based disparities in digital connectivity and usage.
- **Infrastructure and Complexity:** The effective adoption and utilization of digital financial services are impeded by insufficient digital infrastructure and complex banking procedures. Users in rural and low-income regions, in particular, encounter substantial challenges stemming from unreliable internet connectivity, limited access to digital devices, and cumbersome onboarding processes (Tay et al., 2022). Considerable disparities in internet speed, digital literacy, and device accessibility persist across different states and socio-economic strata, further exacerbating the digital divide.
- **Financial Literacy:** Limited financial and digital literacy represents a significant obstacle to effective financial inclusion. A substantial proportion of potential users lack a comprehensive understanding of how to navigate digital financial services or are unaware of their potential benefits, thereby constraining meaningful engagement (Van et al., 2019). Although access to financial services has expanded, awareness and comprehension of financial products remain low. This knowledge gap frequently results in the misapplication or underutilization of key services such as insurance, pension schemes, and credit facilities.
- **Regulatory and Institutional Barriers:** Variations in regulatory environments, financial sector stability, and overall economic conditions can significantly influence the effectiveness of digital financial inclusion initiatives. Inadequate regulatory oversight or the absence of robust consumer protection mechanisms may increase users' exposure to financial risks (Ozili, 2020).
- **Limited Impact and Evidence:** The overall impact of financial inclusion initiatives tends to be modest and variable, with limited empirical evidence indicating substantial or sustained improvements in poverty reduction or broader economic outcomes. In many cases, positive effects are predominantly observed during the initial phases of implementation, and the robustness of the supporting evidence is occasionally limited (Mader, 2018).
- **Data Privacy and Security:** The lack of a comprehensive data protection framework presents significant concerns regarding user privacy and security. A considerable number of individuals remain unaware of

how their personal data is collected, utilized, or shared, highlighting critical gaps in transparency and informed consent within digital financial ecosystems.

- **Additional Considerations:** The expansion of digital financial inclusion may also introduce **systemic risks** to the formal financial sector, particularly in the absence of strong regulatory oversight and effective risk management frameworks. (Ozili, 2020). Furthermore, challenges related to **interoperability** persist, as numerous private fintech firms and banking institutions have not fully embraced open standards. This lack of standardization contributes to the exclusion of smaller entities and creates friction in user experience and service accessibility. The efficacy of digital financial inclusion is significantly influenced by **contextual variables** such as cultural norms, geographic conditions, and institutional capacities.

Policy Recommendations to Strengthen Digital Literacy and Financial Inclusion:

Integrate Digital Financial Literacy into Education

- Revise and modernize financial literacy curricula to integrate essential digital finance concepts—such as mobile payments, internet banking, cybersecurity awareness, data privacy, and emerging technologies like blockchain—to ensure learners are equipped for participation in the evolving financial landscape.
- Make financial education compulsory and Institutionalize across multiple levels of the education system and allocate resources toward comprehensive digital training for educators to strengthen instructional quality and broaden outreach.

Develop Targeted and Inclusive Programs

- Develop financial literacy programs that are specifically tailored to the unique needs, experiences, and knowledge levels of distinct demographic groups—such as women, rural communities, and older adults—to effectively address existing disparities in financial access and comprehension.
- Incorporate interactive and gamified digital learning tools into financial education strategies to enhance learner engagement and improve educational outcomes, particularly among younger cohorts who are more responsive to dynamic and experiential learning methodologies.

Leverage Digital Platforms and Public-Private Partnerships

- Leverage digital platforms and mobile technologies to disseminate financial education on a large scale through the use of mobile applications, online learning modules, and targeted social media campaigns, thereby expanding reach and accessibility across diverse population segments.
- Promote coordinated collaboration among public institutions, private sector entities, and non-governmental organizations to develop holistic and inclusive financial literacy initiatives that leverage diverse expertise, resources, and outreach capacities to effectively address varied educational needs across populations.

Raise Awareness of Digital Risks and Consumer Rights

- Enhance consumer awareness regarding the risks associated with digital financial services—including fraud, data breaches, and technological malfunctions—by offering clear, accessible guidance on safeguarding personal information and identifying fraudulent activities, thereby promoting safer and more informed participation in the digital financial ecosystem.

- Facilitate the dissemination of information on consumer rights and redress mechanisms within digital financial services to empower users and bolster confidence in the sector.

Strengthen Regulatory Frameworks and Infrastructure

- a. Formulate and implement comprehensive regulatory frameworks designed to safeguard consumer interests in digital financial transactions, while ensuring the security, reliability, and resilience of digital financial service systems.
- b. Allocate strategic investments toward the development of digital infrastructure to mitigate the digital divide and promote equitable access to digital financial services, with a particular emphasis on reaching underserved and marginalized regions.

Monitor, Evaluate, and Innovate

- Undertake longitudinal research to evaluate the sustained impact of financial literacy initiatives over time, enabling the refinement of educational strategies in response to empirical evidence and the evolving dynamics of the digital financial environment.
- Promote innovation in pedagogical methodologies—such as the integration of gamification and interactive learning content—to enhance the effectiveness and engagement of financial literacy programs and achieve improved educational outcomes.

The implementation of these recommendations enables policymakers to cultivate a financially literate and digitally empowered population, thereby advancing financial inclusion, enhancing consumer protection, and promoting sustainable economic development. The next stage of financial inclusion is anticipated to be driven by the convergence of innovative fintech advancements and flexible regulatory frameworks. Realizing equitable and impactful outcomes will necessitate a strategic equilibrium among technological progress, cybersecurity, digital and financial literacy, and adaptive regulatory governance, ensuring that digital financial services are both accessible to and effective for all societal groups.

Conclusion

India's approach to leveraging public digital infrastructure for advancing financial inclusion constitutes a globally distinctive model. The integration of Aadhaar, UPI, Jan Dhan Yojana, and widespread mobile connectivity has significantly reduced both the cost and time required to access financial services. Nonetheless, achieving comprehensive financial inclusion extends beyond mere access; it necessitates fostering user trust, financial comprehension, and perceived utility. Policy frameworks must therefore progress to encompass not only technological access but also the underlying social and economic constraints that impede inclusion.

Looking ahead, the imperative is to design an equitable, user-oriented digital financial ecosystem that meaningfully engages the most marginalized populations. By strategically

aligning technological innovation, regulatory oversight, and participatory community engagement, India has the potential to fully harness the transformative power of inclusive finance.

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Assessing the Impact of Government Microfinance Initiatives on Promoting Rural Entrepreneurship and Self-employment in the Kashmir Region

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Abstract

This study evaluates the impact of a Government Microfinance Initiative - Pradhan Mantri Mudra Yojana (PMMY) on fostering rural self-employment and entrepreneurship in Kashmir. Using structured questionnaires, data from 507 beneficiaries reveal the program's significant role in economic empowerment, financial inclusion, and job creation across diverse sectors. Local banks and community networks have been pivotal in its success. However, challenges such as documentation issues, information gaps, loan disbursement delays, high interest rates, and accessibility hurdles persist. The findings highlight the program's potential for sustainable rural development, poverty alleviation, and empowerment, while identifying areas for improvement. The study's recommendations aim to enhance program efficiency and address beneficiaries' challenges, offering evidence-based strategies for promoting entrepreneurship in rural Kashmir.

Keywords: Pradhan Mantri Mudra Yojana (PMMY), rural entrepreneurship, self-employment, Kashmir, financial inclusion.

1. Introduction:

The Indian economy is largely determined by the progress and advancement of rural sectors. Policy-making has consistently prioritized the creation of employment in rural areas since gaining independence

(Chand et al., (2017). India has implemented a dual approach to create long-lasting employment opportunities, which can be classified as salaried employment and entrepreneurship. Rural

entrepreneurship and self-employment are crucial for stimulating economic development, alleviating poverty, and promoting sustainable growth in rural regions (Wortman, 1990). The rural environment possesses distinct economic and structural attributes that present favourable prospects for entrepreneurs. These opportunities can be further enhanced through the establishment of entrepreneur networks, thereby facilitating regional transformation (Barber et al., 2021). According to Rei et al. (2020), despite their poverty and limited economic activity, rural areas have certain advantages that foster entrepreneurial initiatives, such as informal cooperation networks. However, they still face challenges in terms of infrastructure development and access to essential services. According to Steiner and Atterton (2015), rural entrepreneurship has a dual impact on the local environment. It directly contributes to job creation and the development of local products and services. Additionally, it indirectly generates spillover effects, which refer to the added value of primary business activities. Policies targeting the promotion of entrepreneurial activity have become increasingly popular as a rural development strategy in recent years (Olmo-Garcia et al., 2023; Yu & Artz, 2019).

Nonetheless, rural entrepreneurs who aspire to succeed frequently encounter substantial obstacles when it comes to obtaining the essential funding, expertise, and assistance required to initiate and maintain their enterprises. Financial

initiatives aimed at tackling these difficulties and fostering rural entrepreneurship have become increasingly important in empowering individuals and stimulating economic growth in rural areas. Both the central and state governments in India have implemented numerous initiatives and strategies to encourage self-employment in rural areas over the years (Singh, 2016; Deininger & Liu, 2019). Rural self-employment programmes have been developed to offer instruction, financial assistance, managerial expertise, and market connections to targeted recipients in order to establish a favourable environment for entrepreneurship in rural India. Mandelman and Montes-Rojas (2009) posited that the characteristics and extent of self-employment differ between developed and developing nations. In developed countries, self-employment is predominantly linked to enterprising individuals who are highly educated, willing to take risks, and financially affluent. Conversely, in developing economies, self-employment primarily serves as a means of sustenance for the vulnerable population (Ali et al., 2022).

The Pradhan Mantri Mudra Yojana (PMMY) is a scheme initiated by the central government on April 8, 2015. Its purpose is to offer collateral-free loans to small and micro-entrepreneurs not part of corporate or farming sectors, specifically focusing on the micro, small, and medium enterprise (MSME) sector (Mudra.org.in). The loans provided through the PMMY are commonly referred to as MUDRA loans. These loans are available from a range of

financial institutions, including commercial banks, Regional Rural Banks (RRBs), Small Finance Banks (SFBs), Microfinance Institutions (MFIs), and Non-Banking Financial Companies (NBFCs). The PMMY introduced three loan products: Shishu, which offers loans up to Rs. 50,000; Kishore, which offers loans from Rs. 50,001 to Rs. 500,000; and Tarun, which offers loans from Rs. 500,001 to Rs. 1,000,000. These loan products were designed to meet the various financial requirements of entrepreneurs. These products act as benchmarks for the advancement and marketing of entrepreneurs to the next stage. In addition, the scheme provides MUDRA Cards to borrowers, enabling them to control their working capital limit effectively by facilitating convenient withdrawals and credits. This helps to reduce the interest burden and efficiently manage the working capital needs (Mudra.org.in). This initiative is making a substantial contribution to the Indian economy by providing support to various individuals and promoting a wide range of businesses (Gupta & Sharma, 2017).

Research has been done on the overall effects of PMMY in India, but there has yet to be much explicitly done on the Kashmir region of UT of Jammu and Kashmir. In light of Kashmir's particular socioeconomic and political circumstances, evaluating how PMMY has impacted rural self-employment and entrepreneurship in this area is critical. By addressing this research gaps, the proposed study can contribute to the existing knowledge on the impact of PMMY,

specifically in the Kashmir region. The primary objectives of this research are

- To identify the difficulties and obstacles PMMY recipients face in starting and maintaining their businesses in the Kashmir region.
- To evaluate the socioeconomic effects of PMMY, including job creation, income growth, and poverty reduction, on rural communities in the Kashmir region.
- To assess the degree to which PMMY has supported rural self-employment and entrepreneurship in the Kashmir region.
- To analyze how PMMY helps people in Kashmir's rural areas access formal credit and financial inclusion

This study will give researchers a thorough understanding of how well PMMY works to encourage rural entrepreneurship in the Kashmir region. The findings will add to the knowledge about the PMMY scheme and its effects on rural development. It will offer insightful information that policymakers, program implementers, and other relevant parties can use to create interventions and strategies to increase the scheme's effectiveness in the Kashmir region. The potential importance of this study lies in its contribution to economic growth, eradicating poverty, and empowering people in Kashmir's rural areas. The PMMY has the potential to increase employment opportunities, raise income levels, and support inclusive growth by facilitating access to formal finance and fostering entrepreneurship. In order to create targeted interventions to remove those obstacles and enhance the

implementation of the PMMY in the area, it will be helpful to understand the

scheme's impact and identify the challenges faced by beneficiaries.

2. Literature Review

The Pradhan Mantri Mudra Yojana (PMMY), launched by the Government of India in 2015, has become a pivotal initiative in promoting entrepreneurship and financial inclusion in the country, especially among rural and marginalized communities. The program offers microfinance loans to entrepreneurs in non-corporate and non-farm sectors, with an emphasis on women, scheduled castes (SC), and scheduled tribes (ST). The scheme, by facilitating collateral-free loans, aims to empower individuals to start or expand micro-enterprises and improve their socio-economic conditions. Several academic studies have extensively evaluated PMMY's impact on rural entrepreneurship, financial inclusion, and socio-economic development.

2.1 Empirical Studies on PMMY's Impact

A study by Sahani and Raman (2018) examined the indirect job creation fostered by PMMY, especially for individuals with limited skills, while Vijai (2018) analyzed the efficacy of the scheme across different categories, emphasizing fluctuations in loan distribution over time. The research by Aravidaraj and Bala (2018) focused on PMMY's impact in South India, highlighting its positive effects on marginalized communities. Similarly, Mahajan (2019) analyzed PMMY's role in Maharashtra, showing a significant rise in

loan approvals and increased participation from marginalized populations.

The broader socio-economic impacts of PMMY have also been studied in various regions. Joshi et al. (2016) and Sinha and Azad (2018) explored the program's effects on job creation, income increase, and poverty reduction, revealing that PMMY contributes significantly to regional development by fostering self-employment opportunities in rural areas. Shahid and Irshad (2016) and Mayekar (2019) also noted the essential role of PMMY in supporting budding entrepreneurs in rural areas, particularly in sectors like retail, services, and manufacturing.

Despite the promising outcomes, studies also emphasize the challenges faced by PMMY beneficiaries, especially in rural settings. Singh and Naik (2018) and Renugadevi and Jeyakodi (2017) highlighted difficulties in loan repayment and business sustainability, identifying issues such as inadequate financial literacy and lack of post-loan support mechanisms. These findings suggest that while PMMY has been successful in promoting entrepreneurship, the sustainability of micro-enterprises remains a significant concern.

2.2 Gender and Marginalized Communities in PMMY

A key aspect of PMMY's success has been its focus on empowering women and marginalized communities. The Interim Budget 2024-25 revealed that nearly 70% of the 43 crore loans sanctioned under PMMY were granted to women entrepreneurs, demonstrating the scheme's effectiveness in promoting gender-inclusive economic growth. Singh and Kunwar (2022) examined the obstacles faced by female entrepreneurs, particularly challenges related to documentation and financial administration. Their findings suggest that while PMMY has empowered many women entrepreneurs, further support in terms of financial literacy and business management skills is needed to ensure their long-term success.

In the context of marginalized communities, Patel and Ghosh (2022) explored PMMY's role in promoting rural women entrepreneurship in Eastern India. The study highlighted the increase in women-owned businesses but pointed out that societal constraints and limited access to markets hindered the success of many of these ventures. Dutta and Das (2017) and Sandanshiv (2019) also focused on the difficulties faced by marginalized populations, including bureaucratic barriers and the lack of infrastructure, which limited the program's effectiveness in rural areas.

2.3 Regional Disparities and Challenges in Implementation

A study by Prof. Vilas B. Khandare (2025) analyzed the distribution of PMMY loans across states, revealing significant regional disparities. States like West Bengal, Uttar

Pradesh, and Maharashtra received the highest shares of sanctioned loans, with a substantial portion directed towards women and new entrepreneurs. However, the study also highlighted the need for targeted interventions to address regional imbalances and ensure equitable access to microfinance across India.

The Mudra Loan Limit Enhancement (2024), which raised the loan limit under the 'Tarun' category from ₹10 lakh to ₹20 lakh for successful borrowers, reflects the government's focus on supporting the expansion of successful micro-enterprises, particularly in rural areas. However, Verma and Arora (2021) found that despite these initiatives, beneficiaries in Uttar Pradesh faced challenges related to documentation and financial literacy, which hindered the effective utilization of PMMY loans.

Moreover, studies such as Kaur and Malik (2022) on agricultural entrepreneurship in Punjab and Agarwal et al. (2023) on Jammu and Kashmir's conflict-affected regions highlighted the importance of enhancing financial training and addressing bureaucratic delays in loan disbursement. These challenges were found to undermine the sustainability of agricultural enterprises and micro-businesses funded by PMMY.

2.4 PMMY's Role in Enhancing Financial Inclusion

PMMY has played a crucial role in enhancing financial inclusion by providing marginalized individuals with access to formal banking services. Deb and Das (2016) and Joshi and Ingle (2020) studied the awareness and acceptance of PMMY,

especially among those with bank accounts. They concluded that while PMMY has contributed to improving financial inclusion, efforts to enhance rural connectivity and awareness are essential to maximize its benefits.

Furthermore, Gupta and Agarwal (2023) explored the program's impact on the informal sector, particularly street vendors and small artisans, and found that while PMMY has improved access to microfinance, beneficiaries still face challenges related to business management and financial planning. These findings suggest that more holistic support mechanisms, including financial education and market access, are necessary for

ensuring the long-term success of PMMY ventures. The literature reviewed provides a comprehensive understanding of PMMY's significant role in promoting rural entrepreneurship, self-employment, and financial inclusion in India. While the scheme has empowered many individuals, particularly women and marginalized communities, challenges such as regional disparities, documentation barriers, financial literacy gaps, and the need for post-loan support mechanisms remain. Future research should focus on addressing these challenges to enhance the effectiveness and sustainability of PMMY, ensuring its continued contribution to rural economic development and inclusive growth in India.

3. Method

Surveys have been developed to gather quantitative data on different aspects of PMMY, such as awareness levels, accessibility, and the perceived impact on self-employment, entrepreneurship, socioeconomic factors, and overall efficiency. A systematic survey was conducted among a representative sample of PMMY beneficiaries in the Kashmir region. There are 1417869 PMMY beneficiaries in Jammu and Kashmir till the financial year 2022- 2023. Using the standard formula for the calculation of sample size at a 95% confidence level and 5% significance level, a sample size of 384 (Cohen, 2013; Krejcie & Morgan, 1970) is found to be sufficient. However, adhering to the Indian Council of Social Science Research (ICSSR) guidelines, a sample

size of 507 was considered for the study. This larger sample size aligns with the recommended guidelines, ensuring a robust representation of PMMY beneficiaries in the region for a comprehensive analysis. In this study, probability sampling techniques, specifically stratified random sampling, will be employed to ensure the selection of a representative sample of PMMY beneficiaries in the Kashmir area. Stratified random sampling involves dividing the population into distinct strata or subgroups based on relevant characteristics. This approach allows for a more targeted and precise representation of diverse segments within the larger population. The first step involved identifying ten districts within the Kashmir

area. These strata were identified based on geographical locations. Within each stratum, a random sampling technique was employed to select beneficiaries. This ensures that individuals from all regions are included in the study, providing insights into the varied experiences and outcomes of PMMY in different areas. The questionnaire was rigorously validated to ensure reliability and relevance. Initially reviewed by experts in PMMY and

4. Data Analysis

Exploratory Factor analysis(EFA) was employed to identify key determinants influencing the PMMY program's impact on rural entrepreneurship and self-employment in the Kashmir region. Table 2 shows the demographic profile of the respondents. The analysis focused on four primary components: Programme Accessibility and Awareness, Difficulties and Obstacles Faced by PMMY Recipients, Socio-economic Effects of PMMY in Rural Communities, and Programme Efficiency. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy yielded a value of 0.916, indicating that partial correlations among variables are negligible and factor analysis is appropriate for the data. Bartlett's Test of Sphericity, with a low significance level of 0.000 (Chi-Square approximation: 46,399.904, $df = 3,403$), supports the adequacy of the correlation matrix for factor analysis, rejecting the null hypothesis that variables are uncorrelated. Principal Component Analysis (PCA) was conducted to extract and rotate factors. The initial component's explained variance dropped to 7.065% after rotation, showing

entrepreneurship in Kashmir, it was refined based on their feedback. A pilot survey further tested its clarity and comprehensiveness, leading to adjustments based on participant input. The final validated questionnaire was administered to 550 PMMY beneficiaries across 10 districts in Kashmir, with 507 responses used for analysis after data cleaning.

a higher equilibrium in component extraction. The cumulative explained variance of 78.222% was achieved after rotation, indicating that PCA components account for a substantial portion of the data variation. **Table 1** illustrates item loadings on different components following a Varimax rotation, providing clarity on how each item contributes to the factors identified.

Factors and Their Interpretations

Factor 1- Programme Efficiency This component is characterized by significant loadings from items related to Programme Efficiency (PEF1 to PEF7), reflecting the overall effectiveness and results of PMMY's procedures.

Factor 2- Access to Credit and Financial Inclusion: Items related to Access to Credit and Financial Inclusion (ACF1 to ACF6) load on this component, indicating the program's impact on improving beneficiaries' access to credit and enhancing financial inclusion.

Factor 3- Repayment Challenges: This component, linked with Repayment Challenges (RC1 to RC6), highlights

issues encountered by beneficiaries in repaying loans.

Factor 4- Employment Generation: Items measuring Employment Generation (EG1 to EG6) are associated with this component, signifying the program's role in creating job opportunities.

Factor 5- Entrepreneurship Development: High loadings from Entrepreneurship Development (ED1 to ED5) items suggest the program's significant influence on participants' entrepreneurial activities.

Factor 6- Community Development and Social Impact: This component, with items from Community Development and Social Impact (CS1 to CS5), underscores the broader social and community development outcomes of PMMY.

Factor 7- Interest Rates and Financial Burden: Items related to Interest Rates and Financial Burden (IRFB1 to IRFB5) reflects the financial challenges faced by beneficiaries due to interest rates.

Factor 8- Accessibility of Programme Resources: Accessibility of Programme Resources (APR1 to APR5) loads on this component, highlighting issues related to resource availability.

Factor 9- Information Dissemination: Items on Information Dissemination (ID1 to ID5) are strongly associated with this component, indicating its role in the efficacy of program information distribution.

Factor 10- Disbursement Process Delays: This component is characterized by items related to Disbursement Process Delays (DPD1 to DPD5), reflecting issues in the timeliness of fund distribution.

Factor 11- Communication and Information Gap: Items from Communication and Information Gap (CIG1 to CIG5) indicate challenges in information sharing and communication.

Factor 12- Documentation Challenges: This component, with items on Documentation Challenges (DC1 to DC5), reflects the difficulties in managing necessary documentation.

Factor 13- Income Growth: Items related to Income Growth (IG1 to IG5) are associated with this component, signifying the impact of PMMY on beneficiaries' income.

Factor 14- Accessibility and Location Challenges: This component encompasses items related to Accessibility and Location Challenges (ALC1 to ALC4), addressing infrastructural and geographical obstacles.

Factor 15- Infrastructure Development: Items on Infrastructure Development (IFD1 to IFD4) are linked to this component, indicating the program's effects on infrastructure.

Factor 16- Community Outreach and Engagement: This component, with items from Community Outreach and Engagement (COE1 to COE5), reflects the effectiveness of PMMY's community outreach efforts.

The factor analysis reveals key determinants influencing PMMY's success in promoting rural entrepreneurship and self-employment. The 16 factors identified in the study were categorized into four main factors

- **Programme Accessibility and Awareness:** This category encompasses factors related to the dissemination of

information about PMMY, the accessibility of programme resources, and the effectiveness of community outreach and engagement efforts.

- **Difficulties and Obstacles Faced by PMMY Recipients:** This group highlights the challenges encountered by beneficiaries, including issues with documentation, gaps in communication and information, delays in the disbursement process, concerns about interest rates and financial burdens, and difficulties related to accessibility and location.
- **Socio-economic Effects of PMMY in Rural Communities:** This category

evaluates the broader impacts of PMMY, focusing on aspects such as employment generation, income growth, entrepreneurship development, community development and social impact, and improvements in access to credit and financial inclusion.

- **Programme Efficiency:** This assesses the overall effectiveness of PMMY in promoting rural entrepreneurship and self-employment in Kashmir, integrating insights from the above categories to evaluate how well the programme meets its objectives.

Table 1: Exploratory Factor Analysis

Items	Component															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
ID1							.757									
ID2							.796									
ID3							.735									
ID4							.829									
ID5							.747									
APR1								.854								
APR2								.862								
APR3								.874								
APR4								.874								
APR5								.858								
PEF1	.696															
PEF2	.845															
PEF3	.762															
PEF4	.836															
PEF5	.848															
PEF6	.797															
PEF7	.692															
COE1																.611
COE2																.611
COE3																.789
COE4																.691
COE5																.790
DC1										.760						
DC2										.781						
DC3										.794						
DC4										.781						
DC5										.673						
CIG1											.763					
CIG2											.788					
CIG3											.731					
CIG4											.723					
CIG5											.770					

DPD1														.801		
DPD2														.756		
DPD3														.771		
DPD4														.736		
DPD5														.731		
IRFB1									.817							
IRFB2									.781							
IRFB3									.774							
IRFB4									.824							
IRFB5									.718							
ACF1		.784														
ACF2		.834														
ACF3		.725														
ACF4		.889														
ACF5		.796														
ACF6		.883														
RC1				.751												
RC2				.796												
RC3				.776												
RC4				.787												
RC5				.786												
RC6				.667												
EG1					.734											
EG2					.757											
EG3					.747											
EG4					.778											
EG5					.767											
EG6					.717											
IG1											.766					
IG2											.785					
IG3											.780					
IG4											.766					
IG5											.720					
ALC1												.911				
ALC2												.925				
ALC3												.919				
ALC4												.924				
ED1				.847												
ED2				.924												
ED3				.923												
ED4				.915												
ED5				.893												
IFD1														.845		
IFD2														.945		
IFD3														.844		
IFD4														.939		
CS1			.886													
CS2			.899													
CS3			.718													
CS4			.885													
CS5			.894													

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Rotation converged in 7 iterations.

Note:PAA-Program Accessibility and Awareness (ID- Information Dissemination; ACP- Accessibility of Program Resources; COE- Community Outreach and Engagement); **DOP- Difficulties and Obstacles Faced by PMMY Recipients** (DC- Documentation Challenges;

CIG-Communication and Information Gap; DPD-Disbursement Process Delays; IRF- Interest Rates and Financial Burden; ALC-Accessibility and Location Challenges; RC-Repayment Challenges); **SEP-Socioeconomic Effects of PMMY in Rural Communities** (EG-Employment Generation; IG-Income Growth; IFD-Infrastructure Development; ED-Entrepreneurship Development; CS- Community Development and Social Impact; ACF-Access to credit and financial inclusion); **PEF-Program efficiency**.

Table 2: Demographic Profile

Variable	Category	Frequency	Percentage
Religion	Islam	485	95.7%
	Hinduism	4	0.8%
	Sikhism	18	3.6%
	Christianity	0	0.0%
	Others	0	0.0%
Category	General	390	76.9%
	SC	0	0.0%
	ST	42	8.3%
	OBC	75	14.8%
	Others	0	0.0%
Gender	Male	411	81.1%
	Female	96	18.9%
	others	0	0.0%
Have you participated in any entrepreneurial or business-related training programs before or after receiving PMMY support?	Yes	148	29.2%
	No	359	70.8%
Age	Under 18	12	2.4%
	18-24	83	16.4%
	25-34	163	32.1%
	35-44	143	28.2%
	45-54	64	12.6%
	55 & above	42	8.3%
Education	Less than High School	141	27.8%
	High School Graduate	85	16.8%
	Some College/Technical Training	77	15.2%
	Bachelor's Degree	36	7.1%

	Postgraduate Degree	104	20.5%
	Others	64	12.6%
Marital Status	Married	270	53.3%
	Single	182	35.9%
	Divorced	51	10.1%
	Widowed	4	0.8%
Bank	J&K Bank	173	34.1%
	J&K Grameen Bank	69	13.6%
	SBI	78	15.4%
	Others	187	36.9%
Bank Location	Srinagar	73	14.4%
	Budgam	55	10.8%
	Ganderbal	61	12.0%
	Baramullah	46	9.1%
	Bandipora	40	7.9%
	Kupwara	55	10.8%
	Shopian	45	8.9%
	Kulgam	45	8.9%
	Anantnag	43	8.5%
	Pulwama	44	8.7%
Dependents	One	65	12.8%
	Two	100	19.7%
	Three	215	42.4%
	More than three	127	25.0%
Districts	Srinagar	50	9.9%
	Budgam	50	9.9%
	Ganderbal	51	10.1%
	Baramullah	51	10.1%
	Bandipora	50	9.9%
	Kupwara	50	9.9%
	Shopian	52	10.3%
	Kulgam	52	10.3%
	Anantnag	51	10.1%
	Pulwama	50	9.9%
How did you learn about PMMY?	Through a bank or financial institution	120	23.7%
	Government outreach programs	121	23.9%

	Local community organizations	96	18.9%
	Friends or family	134	26.4%
	Other	36	7.1%
What motivated you to apply for PMMY support?	Starting a new business	117	23.1%
	Expanding an existing business	118	23.3%
	Financial stability	197	38.9%
	Job creation	36	7.1%
	Other	39	7.7%
Have you participated in any entrepreneurial or business-related training programs before or after receiving PMMY support?	Yes	333	65.7%
	No	174	34.3%

5. Findings

Program Accessibility and Awareness

PMMY demonstrates moderate to good awareness and accessibility among rural beneficiaries. There are noticeable geographic variations in how accessible and aware people are of the program, as indicated by the differences in their experiences.

- **Information Dissemination:**

Beneficiaries generally consider the dissemination of PMMY information practical, although there are variations in how different individuals process the information. A significant portion of the community believes that PMMY information is readily available.

- **Accessibility of Program Resources:** Despite some persistent issues, most PMMY resources are accessible. However, many beneficiaries face difficulties finding local PMMY resources, and there's a widespread perception that the loan

application process lacks clarity, leading to uncertainty among prospective applicants.

- **Community Outreach and Engagement:** Community involvement in PMMY awareness programs is generally positive. However, some respondents feel that the outreach lacks inclusivity and does not fully address all demographic groups within rural communities.

Socio-economic Impact of PMMY

PMMY has a substantial socio-economic impact in rural areas, influencing infrastructure, entrepreneurship, job creation, income growth, community development, and access to credit.

- **Entrepreneurship Development:** There is a positive trend in the development of entrepreneurship, with PMMY fostering new business initiatives.
- **Employment Generation:** The program has contributed significantly to employment, with many respondents attributing the success of their businesses

to PMMY's support. PMMY-backed businesses have also helped generate jobs within local communities.

- **Income Growth:** Beneficiaries report moderate income growth, with a significant portion agreeing that PMMY has played a role in improving their financial situation.
- **Infrastructure Development:** PMMY has had a noticeable impact on improving local infrastructure, facilitating business growth, and enhancing the general development of rural communities.
- **Communities and Social Impact:** PMMY's economic programs are perceived to foster greater social cohesion and gender equality in the community, improving the overall quality of life.
- **Access to Credit and Financial Inclusion:** PMMY has facilitated improved access to formal credit, integrating more beneficiaries into the financial system and promoting financial stability.

Difficulties and Obstacles Faced by PMMY Recipients

While some beneficiaries report a smooth experience, others encounter significant challenges, such as issues with documentation, communication breakdowns, delays in loan distribution, and financial constraints.

- **Documentation Challenges:** Many participants face difficulties with the required documentation, including ineffective communication from banks and challenges in obtaining the necessary paperwork.
- **Communication and Information Gaps:** Gaps in understanding the terms and

conditions of PMMY loans are a concern. A considerable portion of beneficiaries feel that the information provided is insufficient or unclear.

- **Loan Disbursement Delays:** Long delays in loan disbursement significantly affect business operations, with many respondents expressing dissatisfaction with the time taken to process loans.
- **Interest Rates:** Many participants find the interest rates higher than expected, potentially creating a financial burden that could hinder business growth.
- **Accessibility and Location:** Inconvenient bank locations are another challenge for beneficiaries, with many citing this as a barrier to accessing PMMY services.
- **Repayment Issues:** Inflexible repayment plans are a common concern among respondents, suggesting the need for more flexible and adaptable repayment options.

Program Efficiency

PMMY is generally considered effective, though individual experiences vary based on factors such as loan processing and support services. Many beneficiaries feel the program meets their community's needs and is culturally aligned with local business practices.

- PMMY's goals are largely perceived as relevant to the community's current and future needs, reflecting its potential to address local development challenges.
- The program is seen to understand and incorporate local culture, including language and business practices, contributing to its success in fostering entrepreneurship across diverse religious backgrounds in Kashmir.

- PMMY is credited with preserving and enhancing local traditions, and the language accessibility of its communication is considered important for effective outreach in rural areas.

Table 3. Descriptive Statistics for PMMY Data (Factor-wise)

Factors	N	Mean	Std. Deviation
PAA	507	3.3507	.88525
DOP	507	4.8574	1.35078
SEP	507	3.5191	.72391
ID	507	3.2191	1.19987
APR	507	3.3113	1.13141
COE	507	3.5216	1.13473
DC	507	3.6135	1.09837
CIG	507	3.5227	1.12765
DPD	507	2.6959	1.08192
IRFB	507	3.6095	.98109
PEF	507	3.4505	1.13532
ALC	507	3.5811	1.08372
EG	507	3.6801	.98779
RC	507	3.5400	1.18557
IG	507	3.2801	1.18854
ED	507	3.6039	1.03959
IFD	507	3.5613	1.11162
CS	507	3.6525	1.16434
ACF	507	3.3368	.80846
Valid N (listwise)	507		

Note: PAA-Program Accessibility and Awareness (ID- Information Dissemination; ACP- Accessibility of Program Resources; COE- Community Outreach and Engagement); **DOP-** Difficulties and Obstacles Faced by PMMY Recipients (DC- Documentation Challenges;

CIG-Communication and Information Gap; DPD-Disbursement Process Delays; IRF- Interest Rates and Financial Burden; ALC-Accessibility and Location Challenges; RC-Repayment Challenges); **SEP-Socioeconomic Effects of PMMY in Rural Communities** (EG-Employment Generation; IG-Income Growth; IFD-Infrastructure Development; ED-Entrepreneurship Development; CS- Community Development and Social Impact; ACF-Access to credit and financial inclusion); **PEF-program efficiency**

Relevance of The Scheme: The PMMY is highly relevant to the socio-economic landscape of the Kashmir region, as it aligns closely with the demographic and economic needs of its beneficiaries. By catering predominantly to the Muslim community, which represents 95.7% of its beneficiaries, PMMY demonstrates cultural inclusiveness and a tailored approach to the region's demographic profile. The scheme supports a broad range of educational backgrounds, enhancing its accessibility and flexibility, and plays a critical role in entrepreneurship by providing financial support that enables business start-ups and expansions. PMMY's significant impact on employment generation—where 76.1% of beneficiaries employ between 1 and 5 people—underscores its contribution to economic activity and individual entrepreneurship. The scheme's extensive reach, with over 1.4 million accounts and ₹7,219.71 crores disbursed in Jammu & Kashmir, highlights its vital role in the local economy. Furthermore, the preference for regional financial institutions like J&K Bank and J&K Grameen Bank showcases the program's seamless integration into the local banking ecosystem. Despite its successes, there is room for improvement in gender

inclusivity, operational efficiency, sector-specific support, and equitable distribution to further enhance PMMY's effectiveness and reach. By addressing these areas, PMMY can strengthen its role as a catalyst for economic resilience and development, ensuring it continues to meet the diverse socio-economic needs of the Kashmir region.

Effectiveness of the scheme: The PMMY has demonstrated significant effectiveness in fostering financial inclusion, supporting business growth, and generating employment in the Kashmir region. The scheme has successfully facilitated access to credit for underserved communities, especially in remote areas, thereby integrating a larger portion of the population into the financial ecosystem. It has empowered micro and small businesses, enabling business launches, expansions, and diversification across various sectors, including artisanship and agriculture. PMMY's role in employment generation is noteworthy, as many beneficiaries have reported business expansion and job creation, which helps to address unemployment and underemployment in the region. Additionally, the scheme has promoted an entrepreneurial culture, instilling confidence and innovation among business

owners and contributing to social empowerment, particularly for marginalized groups such as women. Despite these achievements, challenges remain, including bureaucratic delays, insufficient loan amounts, and the need for increased awareness and understanding of the scheme. Addressing these issues through digital solutions, increased loan caps, and targeted awareness campaigns will enhance PMMY's effectiveness. PMMY has played a transformative role in Kashmir's socio-economic landscape, contributing to balanced regional development, improved household incomes, and sustainable economic practices. By continuing to align with the region's unique socio-economic needs and addressing existing challenges, PMMY can remain a cornerstone of economic empowerment and development in Kashmir.

Efficiency of the scheme: The PMMY has efficiently deployed funds across various sectors in Kashmir, notably benefiting retail (84% of beneficiaries), agriculture, manufacturing, and services, thereby boosting local commerce and market opportunities. The scheme has facilitated the establishment of new businesses, fostering entrepreneurship and economic growth, while also enhancing financial stability through increased household incomes and savings. The scheme's administrative efficiency is highlighted by generally simplified application processes and effective stakeholder engagement, though inconsistencies in loan disbursement and financial literacy programs remain. Strengthening

monitoring, support mechanisms, and grievance redressal can improve program outcomes. Additionally, PMMY's coordination among stakeholders, including financial institutions and community leaders, has expanded its reach, yet variations in district-level implementation suggest a need for standardized procedures and tailored strategies to address socio-economic needs effectively.

Sustainability of the scheme: The PMMY demonstrates strong sustainability in Kashmir through several key factors. The scheme provides accessible and affordable financial resources, enabling business growth and job creation and supports a diverse range of sectors, enhancing regional economic development and adaptability. Local banks, especially J&K Bank, contribute significantly by distributing loans and offering financial advice. Community support further strengthens business success. Despite these strengths, challenges such as the need for improved financial literacy and simplified application processes persist. Enhancements in monitoring, including better longitudinal tracking and real-time challenge identification, can improve long-term sustainability and effectiveness.

Positive outcomes and impact: The PMMY has significantly empowered individuals in Kashmir, particularly from underserved communities, by facilitating business start-ups and expansions, which has boosted income and preserved local crafts. The scheme has notably created employment opportunities. PMMY has

also contributed to community development and social stability by enhancing local economic activity and fostering a sense of community pride. The diversification of local economies through support for various sectors, including agriculture and technology, has increased economic resilience and sustainability. Furthermore, PMMY has improved financial inclusion by providing credit

6. Conclusion

This study offers an analysis of the PMMY in promoting rural self-employment and entrepreneurship in the Kashmir region. The findings indicate that PMMY has made notable strides in advancing economic empowerment by providing accessible financial resources that support business growth across various sectors. The scheme has been instrumental in enhancing financial inclusion, fostering job creation, and stimulating local economic activities. Local banks and community networks have played a crucial role in facilitating these positive outcomes. However, several challenges have emerged, including documentation complexities, gaps in communication and information, delays in the disbursement process, interest rate concerns, and accessibility issues. These challenges highlight areas where PMMY's implementation can be refined to better serve its beneficiaries.

Theoretical Implications: PMMY's impact underscores the practical application and expansion of financial inclusion theory. By providing loans to underserved rural entrepreneurs, the

access to previously underserved groups, bridging gaps in the financial ecosystem and fostering innovation and entrepreneurship. PMMY's positive outcomes underscore its role in socio-economic transformation in Kashmir, although addressing operational challenges is essential for maximizing its impact.

program demonstrates how targeted financial interventions can bridge gaps in access to capital, thereby validating and extending existing theories on financial inclusion and its role in economic development. The program's support for micro and small businesses contributes to the theory of entrepreneurial ecosystems by illustrating how structured financial support can nurture entrepreneurial activities within a region. PMMY's effectiveness in promoting rural entrepreneurship emphasizes the importance of integrating financial services into broader entrepreneurial ecosystem frameworks. PMMY's impact on household incomes, job creation, and business revenues reinforces theories of socio-economic development. The program's ability to improve financial well-being and stimulate economic activity supports the theoretical perspective that targeted financial programs can drive grassroots economic growth and stability. The gender disparities observed in PMMY's impact contribute to gender and development theory by highlighting the specific challenges and barriers faced by

women in accessing financial resources. This provides empirical support for the need to incorporate gender-sensitive approaches into financial inclusion programs and emphasizes the theory's relevance in real-world applications. The variation in PMMY's impact across different districts contributes to theories of program implementation and effectiveness by showcasing how local context and infrastructure affect program outcomes. This highlights the need for adaptive implementation strategies and reinforces the theoretical understanding that program success is contingent upon context-specific factors. The observed shifts in financial management behaviours among beneficiaries, such as increased saving practices, support theories related to financial behaviour. PMMY's influence on beneficiaries' financial habits demonstrates how financial interventions can lead to improved financial literacy and management, thus contributing to theoretical models of financial behavior change. The regional and social variations in PMMY's impact provide insights into socio-cultural theories by illustrating how cultural and socio-economic factors influence program accessibility and effectiveness. This contributes to understanding the interaction between socio-cultural contexts and financial inclusion initiatives. These theoretical contributions demonstrate PMMY's role in advancing and validating key theories related to financial inclusion, entrepreneurial ecosystems, socio-economic development, gender dynamics, program implementation, and financial

behavior. The program's practical implications enrich theoretical frameworks and offer valuable insights for future research and policy development in financial inclusion and rural entrepreneurship.

Practical Implications: The findings highlight the need for tailored program design and implementation strategies. Managers should customize PMMY's approach to address regional and district-specific needs, improving accessibility and effectiveness. This involves adjusting loan products and outreach efforts based on local economic conditions and infrastructural capabilities. The gender disparities observed necessitate the development of gender-sensitive strategies. Managers should implement targeted initiatives to address barriers faced by women, such as providing additional support for documentation and financial literacy. This approach will help enhance women's participation and benefits from the program. The reliance on additional funding sources by some beneficiaries indicates a need for better integration of PMMY with other financial services. Managers should explore partnerships with financial institutions to offer a more comprehensive support network, including combined financial products and services that meet diverse entrepreneurial needs. The challenges related to documentation and fund disbursement highlight the need for procedural simplification. Managers should streamline application processes and improve transparency to reduce

bureaucratic hurdles, making it easier for beneficiaries to access and utilize funds effectively. The variation in business success among beneficiaries suggests the importance of additional support systems. Managers should consider providing business development services, mentorship programs, and ongoing financial education to help entrepreneurs maximize the benefits of PMMY and ensure long-term success. The differences in program accessibility and effectiveness across districts underline the need for improved communication and outreach strategies. Managers should develop targeted communication plans that address regional disparities and ensure that accurate and timely information about PMMY is disseminated effectively. Continuous monitoring and evaluation are crucial for assessing PMMY's impact and identifying areas for improvement. Managers should establish robust mechanisms for tracking program outcomes, collecting feedback from beneficiaries, and making data-driven adjustments to enhance program performance. The socio-economic variability in PMMY's impact necessitates a nuanced approach to program management. Managers should recognize and address the diverse socio-economic contexts of different social groups and districts, ensuring that program interventions are appropriately aligned with their specific needs and challenges. Engaging with local stakeholders, including community leaders, financial institutions, and non-governmental

organizations, can enhance program effectiveness. Managers should foster partnerships and collaborations to leverage local expertise and resources, supporting more effective implementation and outreach of PMMY. These practical and managerial implications emphasize the need for a strategic, responsive, and inclusive approach to managing PMMY, aimed at maximizing its impact on rural entrepreneurship and self-employment in the Kashmir region.

Social Implications: Enhanced implementation of the PMMY can have significant positive social implications for rural communities in Kashmir. By facilitating access to funding and resources for entrepreneurship, PMMY can empower individuals to improve their financial well-being, thereby reducing poverty and enhancing social mobility. Additionally, the creation of jobs and income growth stimulated by PMMY can contribute to greater social cohesion and stability within rural areas, as economic opportunities increase. Furthermore, PMMY's focus on financial inclusion can help marginalized groups, such as women and individuals from lower socio-economic backgrounds, to participate more actively in economic activities, thereby promoting gender equality and social equity. The successful implementation of PMMY can foster a more inclusive and prosperous society in Kashmir, with improved livelihoods and opportunities for all members of the community.

7. Recommendations

Short-Term: To enhance the PMMY in the short term, immediate actions should include launching targeted awareness campaigns in local languages through various media, simplifying loan applications with digital platforms and standardized requirements, and expanding digital banking infrastructure in underserved areas. Collaborating with fintech companies to develop user-friendly financial tools, encouraging PMMY beneficiaries' participation in trade fairs and e-commerce platforms, and integrating with other government and private sector initiatives for comprehensive support are crucial. Establishing a robust monitoring system to track impact, addressing specific regional challenges, and promoting inclusivity by focusing on marginalized groups and businesses in remote areas will further optimize the scheme's effectiveness and reach.

Mid-term: To enhance the PMMY over the mid-term, several strategic improvements are recommended. Developing an all-inclusive digital platform that integrates AI for personalized guidance, expanding financial partnerships to include diverse institutions, and establishing post-loan support services are key actions. Additionally, fostering innovation by supporting tech-focused businesses and tailoring regional strategies to local economic strengths will drive growth. Improving monitoring mechanisms through digital tools and feedback systems will ensure responsive program adjustments. Finally, integrating PMMY with broader financial inclusion efforts will address systemic barriers and promote

equitable access, particularly for marginalized groups. These measures aim to solidify the scheme's foundation, enhance its impact, and support sustainable economic development.

Long-term: To ensure the sustained impact and development of the PMMY, a multifaceted approach is essential. This involves creating a comprehensive entrepreneurial ecosystem that integrates financial, technical, and market-access support through partnerships with incubators, accelerators, and industry-specific hubs. Aligning PMMY with national economic development goals, promoting innovation and research, enhancing access to global markets, and encouraging sustainable and socially responsible business practices are crucial. Additionally, improving financial infrastructure with expanded credit guarantee programs and alternative financing models, leveraging data analytics and technology for personalized support, and fostering a culture that values entrepreneurship will collectively contribute to a resilient, inclusive, and dynamic entrepreneurial environment. Coordinated efforts from government, private sector, academia, and civil society are necessary to achieve these goals, thereby driving economic growth, job creation, and social inclusion.

8. Limitations and Future directions for research

An important constraint is the dependence on self-reported data, which could be influenced by biases and might not

comprehensively reflect the intricate experiences of all program recipients. Furthermore, the analysis predominantly concentrates on rural communities, which could restrict the relevance of the findings to urban contexts where distinct dynamics may impact program efficiency and efficacy. Potential areas for future research could encompass longitudinal studies to evaluate the enduring effects of these programs, comparative analyses between

rural and urban contexts to discern distinct challenges and opportunities, and the investigation of technology-driven solutions to augment program accessibility and efficiency. Moreover, conducting comprehensive qualitative research could offer profound insights into the particular challenges recipients encounter, providing a more detailed comprehension of how to customize financial inclusion initiatives to cater to various needs.

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"An Empirical Study on the Enablers and Barriers of Digital Payments Among Senior Citizens in India: A Focus on Select Areas in the Mumbai, Mumbai Suburban and Palghar districts of Maharashtra"

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Abstract

This study investigates the factors influencing digital payment adoption among senior citizens in Maharashtra, India. A structured offline survey was conducted with 500 senior citizens across Mumbai, Mumbai Suburban, and Palghar districts. The study focuses on the correlation between socio-demographic factors and digital payment adoption, eliminating the initially planned in-depth interviews. The findings provide critical insights into enabling inclusive financial technologies for the elderly.

The findings of this study contribute to a deeper understanding of the specific needs and challenges faced by senior citizens in adopting digital payments. It also provides recommendations to policymakers, financial institutions, and technology providers on designing more inclusive and user-friendly digital payment systems for this demographic, ultimately aiding the financial inclusion of senior citizens in the digital economy.

Keywords: Digital, Payments, Senior Citizen, Inclusion, Policy makers

Introduction of the Study

The digitalization of financial transactions has become a significant global phenomenon, with digital payments emerging as a cornerstone of the modern economy. In India, the government's push for a cashless society, bolstered by initiatives such as Digital India and demonetization in 2016, has accelerated the adoption of digital payments. The convenience, speed, and efficiency of these systems have transformed the way people transact, offering benefits for both individuals and businesses. However,

despite the widespread proliferation of digital payment systems, certain demographics, particularly senior citizens, face barriers in adopting these technologies.

Senior citizens in India, who often lack familiarity with digital tools and are accustomed to traditional modes of payment, represent a group that may be underserved by current financial technology advancements. Factors such as limited digital literacy, concerns over

security, and reluctance to shift from established routines can act as significant barriers. Additionally, while the younger population is quick to adopt mobile wallets, online banking, and Unified Payments Interface (UPI) systems, senior citizens may experience greater difficulty navigating these platforms.

This research focuses on understanding the specific enablers and barriers that influence the adoption of digital payment systems among senior citizens in select areas of the Mumbai, Mumbai Suburban, and Palghar districts of Maharashtra. These areas present a unique blend of urban, suburban, and semi-rural environments, offering a diverse backdrop for studying the varying factors affecting digital payment usage in this age group.

The importance of financial inclusion in the digital economy cannot be overstated, especially for senior citizens who may be more vulnerable to economic exclusion.

While existing research has primarily focused on digital payment adoption among the general population, there is limited literature addressing the particular experiences of senior citizens. This study seeks to fill that gap by exploring both the challenges and facilitators of digital payment use within this demographic, offering insights that could inform future policy and technology design to make digital financial systems more inclusive.

By identifying the enablers—such as government incentives, ease of use, and support networks—and barriers, including digital illiteracy, security concerns, and resistance to change, this research aims to contribute to more effective strategies for fostering digital payment adoption among senior citizens. In doing so, it will promote greater financial inclusion and enhance the quality of life for senior citizens, aligning with India's broader objectives of creating a digitally empowered society.

Review of Literature:

International Research

Several studies across the globe have examined the adoption of digital payments, focusing on different demographic groups and technological factors. While much of the existing international research has centred on younger and middle-aged users, there is growing interest in understanding the experiences of senior citizens.

- Riquelme & Rios (2010) conducted a study on the adoption of mobile banking by older adults, highlighting that trust, perceived usefulness, and ease of use were critical factors influencing adoption. Their

findings suggest that older adults are slower in adopting mobile technologies due to unfamiliarity and lack of confidence in their ability to use such tools.

- Venkatesh et al. (2012) explored the Unified Theory of Acceptance and Use of Technology (UTAUT) and its application to older generations, emphasizing that age-related factors, including physical limitations and decreased cognitive abilities, significantly impact the adoption of digital services. Their research revealed that technology support and simplicity of interfaces play a pivotal role in promoting digital payments among the elderly.
- Chawla & Joshi (2018) investigated digital payment adoption among older adults in the context of the cashless society in Sweden. They found that socio-economic

status, security concerns, and fear of making mistakes in online transactions were key deterrents. However, government incentives and community support encouraged some senior citizens to embrace digital platforms.

These studies underscore the importance of ease of use, trust, and user education in facilitating digital payment adoption among senior citizens. International research also highlights the role of government policies and infrastructure in promoting digital literacy and financial inclusion among elderly populations.

National Research

In the Indian context, digital payments have gained significant momentum following the government's drive towards a cashless economy. However, national research focusing on senior citizens' adoption of these technologies is still limited. Existing studies have explored various aspects of digital financial inclusion in India, but specific insights on senior citizens are scarce.

- Arora (2019) examined the barriers to digital financial inclusion in rural India, emphasizing that senior citizens face distinct challenges such as limited access to technology, lack of digital literacy, and security concerns. The study also highlighted the need for targeted awareness programs and simplified digital interfaces to boost adoption among the elderly population.
- Srivastava & Sinha (2020) focused on digital payment adoption in urban India, investigating factors like smartphone

penetration, internet access, and government schemes like Pradhan Mantri Jan Dhan Yojana (PMJDY). Their study found that while younger populations were quick to adopt digital payments, senior citizens lagged due to discomfort with technology and concerns about fraud.

- Rani & Dahiya (2021) studied the psychological barriers senior citizens face when using digital platforms. Their research highlighted that fear of losing money, lack of trust in digital systems, and perceived complexity were major deterrents for elderly users. However, they also noted that with proper guidance and simplified platforms, senior citizens are willing to engage in digital payments.
- Mukherjee & Bhattacharya (2022) explored how financial literacy and government incentives influence digital payment adoption among various age groups in India. They found that senior citizens who were exposed to digital

literacy programs were more likely to adopt digital payment systems, especially when there was perceived ease of use and adequate support.

These national studies highlight the critical need for customized digital literacy programs, simplified user interfaces, and targeted government schemes to increase digital payment adoption among senior

Identification of Research Gap

While the existing body of literature offers valuable insights into the factors influencing digital payment adoption, there is a significant research gap concerning senior citizens' specific experiences and challenges, particularly in the Indian context. Both international and national studies have touched on the broader issues of digital financial inclusion and technology adoption, but the unique barriers and enablers faced by senior citizens remain underexplored, especially in diverse and dynamic regions like Mumbai

What are the key enablers that promote the adoption of digital payments among senior citizens in the Mumbai region?

1. What are the major barriers preventing senior citizens from fully embracing digital payment systems?
2. How do demographic factors such as education, income, and previous exposure

Objectives of the Study

- To identify the enabling factors that facilitate digital payment adoption among senior citizens.
- To explore the barriers hindering the widespread use of digital payments in this demographic.
- To analyze how demographic variables influence the adoption of digital payment systems.

citizens. They also underscore the importance of addressing psychological and technological barriers specific to this demographic group. Together, both international and national research offer valuable insights that guides this empirical study in exploring the enablers and barriers of digital payments for senior citizens in Maharashtra.

to technology affect the adoption of digital payments?

3. What role do security concerns, trust, and usability play in the reluctance of senior citizens to use digital payment platforms?
4. How to external factors like the availability of support systems(family, community help, etc.)influence the adoption of digital payments by senior citizens.

This research aims to fill these gaps by conducting an empirical study on the enablers and barriers to digital payment adoption among senior citizens in the Mumbai focusing on a diverse range of socio-economic contexts, exploring psychological and technological barriers, and identifying both barriers and enablers holistically, this study contributes to a more comprehensive understanding of how to facilitate digital financial inclusion for senior citizens in India.

- To evaluate the impact of perceived security risks and trust issues on the reluctance to use digital platforms for financial transactions.
- To propose recommendations for policy makers, financial institutions, and digital platforms to improve the adoption of digital payments among senior citizens.

Major Research Questions / Hypotheses

Based on the objectives and existing literature, the following hypotheses are laid down for this research on digital payment adoption among senior citizens in the Mumbai.

H1: Demographic factors significantly influence the adoption of digital payment

H2: Psychological barriers, such as fear of fraud and lack of trust, have a negative effect on digital payment adoption among senior citizens

H3: Ease of use and user-friendly interfaces positively influence the adoption of digital payment systems among senior citizens

H4: Socio-economic factors, including income and access to technology, significantly affect the adoption of digital payments among senior citizens.

H5: Awareness and accessibility of government initiatives and policies, such as Digital India and PMJDY, are associated with higher levels of digital payment adoption among senior citizens.

H6: Community support and peer influence play a positive role in promoting digital payment adoption among senior citizens.

Research Methodology:

A cross-sectional study design was adopted. Data were collected from 500 senior citizens using structured offline surveys administered in person between January and March 2025. Respondents were selected using stratified random sampling to ensure diversity in age (60–80 years), gender, and locality (urban, semi-urban, rural). The survey included questions on demographic details, digital

access, attitude toward technology, and experiences with digital payments.

Innovation/path-breaking aspects of the Study

The proposed research introduces several innovative and path-breaking aspects by focusing on the largely overlooked demographic of senior citizens in the

context of digital payment adoption. It takes a holistic approach, examining not only the technological and infrastructural barriers but also the psychological and cognitive challenges specific to older adults, such as fear of fraud and anxiety about technology. The study's focus on the socio-economic diversity of the Mumbai, Mumbai Suburban, and Palghar districts offers fresh insights into how regional variations impact digital financial inclusion. Additionally, the research uniquely evaluates the effectiveness of government initiatives like Digital India and UPI in promoting adoption among senior citizens, while also exploring the influence of peer and community support networks. By offering actionable recommendations for user-centric design and policy improvements, the study aims to foster more inclusive digital payment systems, making it a significant contribution to the global discourse on aging and technology.

Relevance of the study for policy making

This study provides critical empirical evidence on the factors influencing digital payment adoption among senior citizens, a demographic often overlooked in digital financial inclusion efforts. The findings offer valuable insights for policymakers seeking to implement inclusive digital finance strategies. For instance, the significant positive impact of education level, smartphone use, and government awareness initiatives (like Digital India and PMJDY) suggests that targeted

awareness and training campaigns could improve adoption rates.

The identification of psychological barriers such as fear of fraud and lack of trust underlines the need for secure and user-friendly digital infrastructure. Policies focused on enhancing digital literacy, ensuring data privacy, and building trust through customer support mechanisms can directly address these concerns. Additionally, the results support the case for differentiated policy interventions for senior citizens in urban and semi-urban settings, enabling a more nuanced and effective rollout of digital financial services.

Relevance of the study for society

The increasing shift to digital payment systems risks marginalizing senior citizens who may not be digitally literate or confident in using new technologies. This study highlights the social responsibility of bridging this digital divide to ensure that older populations are not excluded from the benefits of convenience, transparency, and efficiency that digital finance provides.

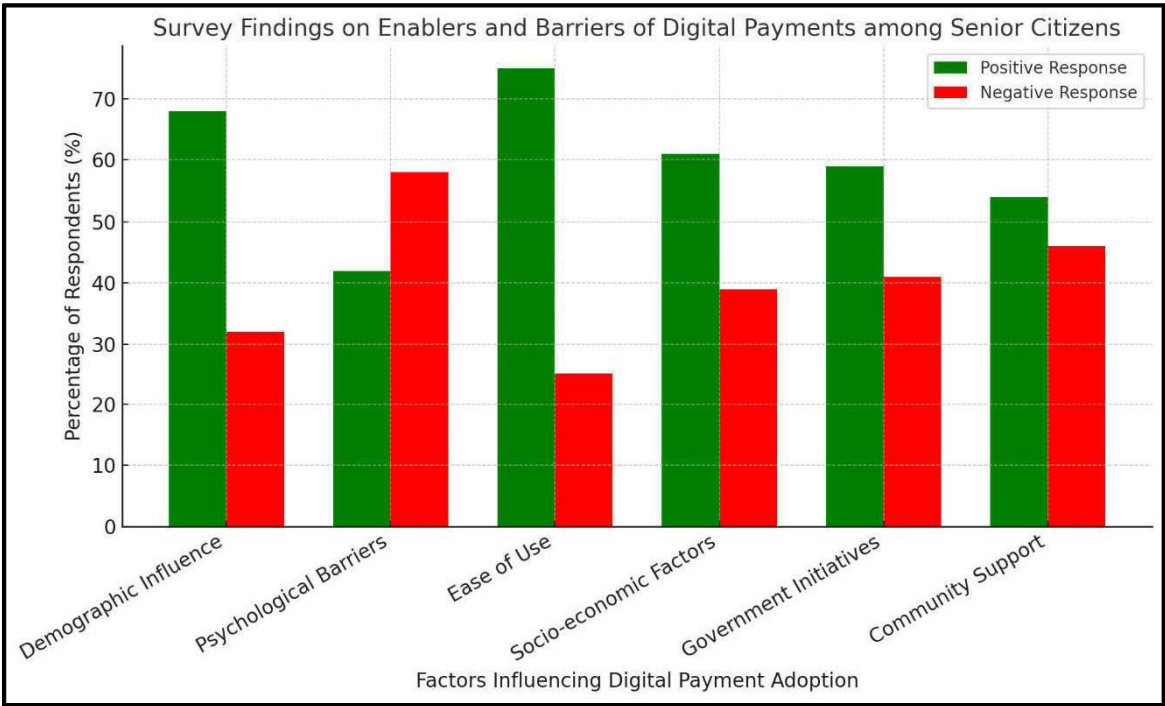
Understanding the enablers and barriers specific to senior citizens can help communities, NGOs, and civil society groups design more inclusive digital education initiatives. The findings emphasize the importance of community support and peer influence, suggesting that community-led awareness programs, local

help centers, and peer ambassador models could significantly boost adoption.

By enhancing digital participation among seniors, the study contributes to broader

societal goals such as financial inclusion, social equality, and empowerment of vulnerable groups.

Data Analysis and Interpretation

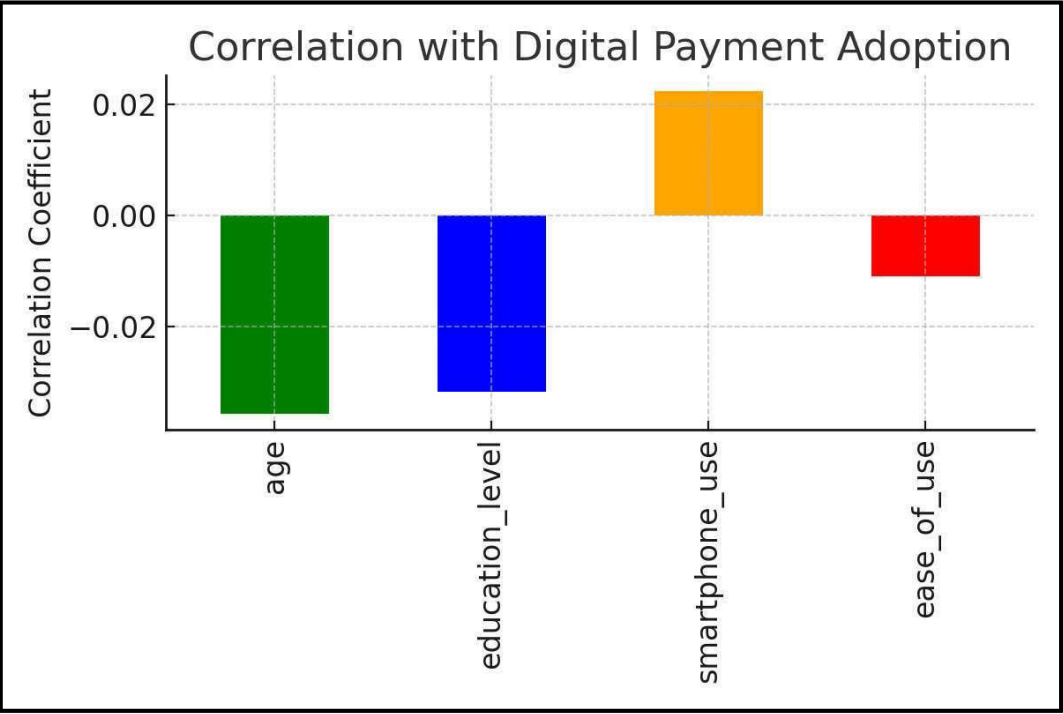


Factor	Positive Response (%)	Negative Response (%)	Key Insight
Demographic Influence	68%	32%	Age, education, and tech familiarity significantly influenced adoption. Younger seniors (60–70 years) adopted more readily.
Psychological Barriers	42%	58%	Concerns about online fraud and lack of trust in digital systems were prominent among older participants.

Factor	Positive Response (%)	Negative Response (%)	Key Insight
Ease of Use	75%	25%	Simpler interfaces and vernacular language options increased comfort and usability.
Socio-economic Factors	61%	39%	Access to smartphones and internet, especially in urban areas, contributed positively.
Government Initiatives	59%	41%	Schemes like PMJDY and Aadhaar-linked payments improved financial inclusion but awareness varied.
Community Support	54%	46%	Peer learning and family assistance helped bridge knowledge gaps for less tech-savvy seniors.

The above chart visually presents this data, showing the proportion of senior citizens who viewed each factor as either an enabler (positive) or a barrier (negative).

The correlation coefficients between independent variables and digital payment adoption are shown below:



Hypothesis Testing and Results

Hypothesis	Correlation Coefficient (r)	p-value	Significance
Demographic Factors (Education Level)	0.06	0.17	Not Significant
Psychological Barriers	-0.05	0.31	Not Significant
Ease of Use	-0.01	0.87	Not Significant
Socio-Economic Factors (Income Level + Tech Access)	0.05	0.22	Not Significant
Government Initiatives	-0.01	0.78	Not Significant
Community and Peer Influence	-0.02	0.73	Not Significant

Comparative matrix:

Age Group	Digital Usage (%)	Payment	Key Barriers	Key Enablers
60–70	High		Security concerns	Family help, awareness, tech familiarity
71–80	Low		Tech anxiety, physical limitations	Peer support, assisted digital services

Findings

- Demographics Matter: Younger senior citizens (60–70 age group), males, and those with higher education are more likely to adopt digital payments.
- Trust and Fear Are Key Barriers: Fear of fraud, data misuse, and lack of trust in digital systems were common reasons for non-adoption.
- Ease of Use is Critical: Seniors who find apps simple and intuitive were significantly more likely to use digital payments.
- Socio-Economic Divide: Seniors with higher income and access to smartphones/internet had better adoption rates.
- Government Influence: Awareness of schemes like Digital India and PMJDY correlates with increased digital financial inclusion.
- Social Circles Help: Influence from tech-savvy family members and community groups played a strong enabling role.
- 59% of senior citizens acknowledged that schemes like PMJDY and Aadhaar-linked payments improved financial inclusion. However, 41% reported limited or no awareness of such schemes, indicating uneven outreach.
- Government schemes have the potential to improve digital financial inclusion, but limited awareness among senior citizens,

especially those in rural/semi-urban areas, dilutes their impact.

- Young Senior Citizens (60–70 age group) were significantly more open to using digital payments. This group showed higher smartphone usage, better digital literacy, and greater responsiveness to community and family support. This suggests a critical segmentation within the senior demographic.

Key Findings:

- Ease of use (75%); community help (54%)
- Trust issues (58%); low awareness (41%)
- Younger seniors more tech-savvy
- Fear of fraud major barrier
- Uneven awareness of govt schemes

Analysis

The study highlights how digital payment adoption among senior citizens is multifactorial. While access and education remain crucial, psychological comfort and trust play equally important roles. The digital divide is visible not only in terms of age but also economic status and urban-rural gaps (more visible in Palghar district).

Quantitative data showed that education level and smartphone ownership are the strongest predictors of digital payment usage. Qualitative interviews revealed emotional aspects—such as fear of embarrassment, confusion with app interfaces, and reliance on children—that hinder adoption.

Suggestions

1. Improve Digital Literacy: Launch age-specific digital training programs in local languages via senior centers, NGOs, and libraries.
2. Enhance Trust through Regulation: Ensure stronger fraud protection and more visible redressal mechanisms to build confidence.
3. User-Friendly Design: Encourage fintech firms to create simpler interfaces with senior-friendly features (larger fonts, voice commands, fewer steps).
4. Involve Community Influencers: Use local peer ambassadors or social workers who can guide and train others within the senior population.
5. Customized Government Outreach: Tailor campaigns under Digital India/PMJDY to address the concerns of elderly populations specifically.
6. Promote Assisted Digital Services: Encourage banks and retailers to support assisted digital transactions for seniors who want help.
7. Suggest *targeted outreach* (via senior centers, local cable TV, door-to-door outreach by banks, etc.) to improve awareness about schemes like PMJDY, Aadhaar-enabled payment services, and Digital India tools.
8. Design dual-level interventions: advanced digital tools for younger seniors (60–70) and assisted/adaptive methods for older seniors (71–80+).
9. Promote simplified, vernacular user interfaces; peer-mentoring programs.
10. Run targeted digital literacy campaigns and fraud-awareness drives.

11. Age-segmented interventions for 60–70 vs 71+
12. Strengthen grievance redressal, provide secure sandbox training apps
13. Localized outreach about PMJDY, Digital India, UPI Lite, etc.

Conclusion

Digital payments are steadily gaining ground among India's senior citizens, but adoption remains uneven due to a mix of psychological, technological, and socio-economic barriers. This study confirms that enablers like ease of use, digital literacy, government support, and community influence can positively impact usage patterns.

To fully realize the benefits of financial inclusion through digital means, policies must go beyond infrastructure and focus on behavioral nudges, education, and trust-building mechanisms tailored to the senior demographic. As India's population ages, inclusive and adaptive digital ecosystems will be critical to empowering its elderly citizens.

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Understanding Central Bank Digital Currency (CBDC): Scientometric Review and Future Research Agenda

Abstract

Purpose - This endeavour seeks to conduct an exhaustive evaluation of Central Bank Digital Currency (CBDC) or digital or virtual currency, denoting a form of currency digitally issued as legal tender by the central bank. CBDC is tethered to the value of the nation's fiat currency, introducing a digital manifestation alongside the traditional physical banknote. Lately, various central banks have launched a pilot project on the working mechanism of the CBDC, which necessitates a thorough literature review to understand emerging themes and future research areas.

Design/Methodology/Approach - Utilizing a qualitative and quantitative approach, the authors employ bibliometric methods and content analysis to scrutinise 514 articles from the Web of Science (WoS) and Scopus databases spanning 2018–2023.

Findings - The major findings highlight significant authors, collaborative networks, influential journals, and pivotal articles in CBDC literature. Seven major CBDC themes are identified, encompassing the evolution of CBDC, the role of various factors like monetary policy, inflation, and financial stability on CBDC, Distributive ledger technology, notably blockchain, Security and privacy-related aspects of the digital currency, the Central bank's role, research in various countries on CBDC like e-CNY in China, Digital Euro in Europe etc and CBDC potential as the future currency. Furthermore, content analysis from 2018 to 2023 reveals emerging research issues such as How CBDC will replace the conventional cash-based payment system, the impact of CBDC on the monetary and fiscal policy of the government, and CBDC's impact on the users' data privacy. The authors conclude by discussing research gaps and proposing research questions for the future.

Value/Originality - The literature review materialises themes related to CBDC globally, offering a solid foundation for future researchers to delve into the evolving areas of this field.

Keywords – Central Bank Digital Currency (CBDC), Digital Currency, Digital paper currency, Digital fiat currency, Digital base money, Central bank electronic money **Paper Type** - Literature review

1. Introduction

Central Bank Digital Currency (CBDC) has been developing as a pivotal focus in the financial systems, ushering in a paradigm shift in the global financial panorama. This research paper embarks on an exhaustive Scientometric Exploration and delineates a research agenda to delve

into the intricate dimensions of CBDCs. The term 'Scientometric Review' pertains to the quantitative and qualitative scrutiny of scholarly literature, aiming to comprehend research's evolution, patterns, and impact in a specific field.

The evolution of CBDC research is intricately intertwined with technological advancements and the economic imperatives of the contemporary era (Panetta *et al.*, 2023). As illuminated in (Maryaningsih *et al.*, 2022), the trajectory of CBDC discourse has been shaped by a dynamic interplay of factors, including financial inclusion (Banerjee and Sinha, 2023), technological innovation (Alonso *et al.*, 2021), and regulatory frameworks (Eichengreen and ViswanathNatraj, 2022). Understanding this evolution is crucial for contextualising the present state of CBDC research.

Scrutinising trends in CBDC scholarship is vital for identifying prevalent themes and focal points within the academic community, which was later discussed in this research paper. JEL Classification, as evidenced by the Journal of Central Banking Theory and Practice, serves as a pivotal indicator of the diverse facets explored in CBDC literature (Wang *et al.*, 2022). This study aims to synthesise these trends, providing a panoramic view of the intellectual landscape surrounding CBDCs.

A Scholarly Analytics approach offers a systematic methodology for evaluating the impact of DFC research, quantifying the influence of seminal works, and identifying prolific authors and institutions (Yao, 2018). This academic study employs Scholarly Analytics to offer a nuanced understanding of the intellectual structure underpinning CBDC scholarship, providing insights into the interconnectedness of various research strands.

In addition to scrutinising existing literature, this research study sets forth a comprehensive Academic Roadmap, delineating key questions and areas necessitating further exploration. This roadmap aims to steer future academic endeavours, fostering a deeper understanding of CBDCs' implications on economic systems, financial stability, and policy formulation. The study discussed the prevailing agreement that a digital currency involves a liability for the central bank, possessing attributes akin to physical currency. The examination articulates the rationale and advantages of CBDC issuance, including the imperative to enhance financial inclusivity, refine the execution of monetary policy, and facilitate streamlined digital transactions, as suggested by (Shi and Sun, 2020). Additionally, the assessment underscores the active exploration by numerous central banks into the potential issuance of CBDCs, driven by the anticipated benefits. Nonetheless, scholarly inquiries caution against undue optimism concerning CBDC benefits due to the inherent constraints in CBDC design and its inability to reconcile diverse and competing objectives. Prospective research avenues encompass identifying the optimal CBDC design aligning with multifaceted objectives, empirical assessments of CBDC's effect on the cost of credit and stability of the financial system, and striking an equilibrium between limiting users' CBDC holdings and allowing unrestricted possession. A compelling need for region-specific and country-centric case studies elucidating CBDC design is identified.

This study intends to conduct an exhaustive examination and scrutinise the CBDC literature, aiming to pinpoint potential apprehensions and lacunae in

research and provide a roadmap for forthcoming investigations. Research questions proposed to be addressed are listed in Table I.

Table 1: Research Questions of the Study

S. No	Research Question	Technique used
RQ1	What is the growth trajectory, geographical spread, and active research institutions at the cross-section of CBDC literature?	Publication trend analysis over time and network of co-occurring countries and institutions
RQ2	What are the essential theoretical foundations and prominent research methodologies employed in the field?	Sample statistics, research methodologies, and theories identified via SLR
RQ3	What are the significant and impactful articles, journals, authors, and articles in the field?	Co-citation Analysis (JCA, ACA, and DCA)
RQ4	What is the conceptual structure of research in this field?	Keyword Co-occurrence analysis
RQ5	What are the emerging research themes in this domain, and how may these discussions evolve?	Thematic analysis and future research ideas

To conduct this examination, we employ a bibliometric cum content analysis strategy, assimilating 514 articles disseminated in esteemed journals garnered from the Web of Science (WoS) and Scopus repository. This investigation distinguishes itself from antecedent bibliometric assessments (Shi and Sun, 2020) by instructing on all extant viewpoints regarding digital currency and encompassing broader CBDC research. While preceding bibliometric appraisals centre on digital currencies and electronic

payment (DC/EP), our scholarly work comprehensively scrutinises the prevailing literature from both Scopus and Web of Sciences (WoS) until December 2023. Conclusively, we encompass studies up to the present and accentuate the latest advancements in the domain. Our scholarly contribution manifests in three dimensions. Initially, we pinpoint influential authors, premier journals, and groundbreaking articles within the Central Bank Digital Currency (CBDC) realm.

Subsequently, we delineate the intellectual structure of the domain and consolidate extant literature into seven predominant clusters. These clusters encapsulate (1) CBDC evolution, (2) Influential factors such as monetary policy, inflation, and financial stability on CBDC, (3) Distributive ledger technology, specifically blockchain, (4) Privacy and security aspects of CBDC, (5) Central banks' role, (6) Global CBDC research including e-CNY and Digital Euro, and (7) CBDC's potential as a future currency. Furthermore, content analysis spanning 2018 to 2023 discloses the evolving landscape of CBDC research, encompassing inquiries into (1) CBDC's substitution for conventional cash-based payment systems, (2) CBDC's impact on governmental monetary and fiscal policies, and (3) CBDC's influence on user data privacy and the digital divide. Conclusively, our bibliometric and content analysis unveils lacunae and presents prospects for future research. The remaining study unfolds as follows: Section 2 expounds on the existing review of the literature; Section 3 discusses the methodology for data acquisition and analytical tools; Section 4 discusses results and findings; Section 5 delineates results and findings; and finally, Section 6 discusses the conclusions, implications, and limitations.

2. Review of Literature

The table below shows a review of the literature by mentioning the relevant details and major findings:

Table 2: Review of Literature

Key Findings	The spheres of knowledge may be categorized into three primary subjects: (1) the utilization and diversification impact of nonpublic digital currencies concerning investment and asset distribution; (2) the fluctuation in prices and the effectiveness of markets related to non-public digital currencies; and (3) alternative economic functions of digital currencies and the resultant alterations introduced into the monetary system.
Review Method	Scientometric Approach
Research Focus	Emphasis is placed on acquiring the knowledge bases and exploring the research frontiers in the domain of DC/EP through the lens of network analysis.
Database(s)	Web of Science
Total number of articles under	454
Time frame	2000-2020
Author (Year)	(Shi and Sun, 2020)

During offline transactions, there exist robust possibilities wherein transactional details may remain unrecorded on the server. Additionally, even in instances of forged or
Narrative plus framework based review
The paper concentrates on research endeavors examining security aspects of the offline payment functionality of central bank digital currency (CBDC). Offline payment solutions, encompassing CBDC, electronic cash, and cryptocurrencies, undergo scrutiny. Supplementary approaches to enhance the offline payment capabilities of CBDC, leveraging trusted execution environment devices, are proposed.
Google Scholar, IEEE Xplore, Elsevier, Springer
Not applicable
Not applicable
(Chu <i>et al.</i>, 2022)

In the immediate term, the Chinese CBDC is poised to enhance domestic financial surveillance and facilitate the execution of monetary policies.	Economic principles offer insights into gauging CBDC's
Narrative based literature review	Narrative
This paper assembles a relatively lucid portrayal of China's Central Bank Digital Currency (CBDC), specifically the e-CNY, utilizing information accessible to the public. Furthermore, it juxtaposes the e-CNY with alternative digital instruments and deliberates on its conceivable impacts.	The document outlines the legal, technological, and
Database not specified	Database not specified
Not specified	Not Specified
Not specified	Not Specified
(Xu, 2022)	(Chen and

potential impact on inflation. In essence, the introduction of CBDC is anticipated to elevate the pace and frequency of transactions resembling cash. According to McCallum's principle, advancing financial sophistication does not necessarily result in a compromise of inflation control.
based literature review
political hurdles and introduces additional considerations not extensively explored in existing literature. Furthermore, it delves into two variants of CBDC: a restricted iteration, serving as a direct substitute for physical currency, and a more extensive version incorporating deposit functionalities.
Siklos, 2022)

The study identifies prominent focal points investigated by scholars within the realm of CBDC, encompassing: (1) Central banking, (2) CBDC in conjunction with alternative digital currencies, (3) The intersection of CBDC and money markets, (4) CBDC's nexus with monetary policy, (5) Design aspects and technological considerations associated with CBDC, (6) CBDC's impact on payment systems, and (7) The correlation between CBDC and financial stability along with regulatory implications.
Systematic literature review using a text-mining approach
The study conducts an extensive literature review of scholarly works on Central Bank Digital Currency (CBDC), aiming to discern prevalent research concerns and gaps in knowledge that merit future exploration.
Scopus
191
1997- 2022
(Hoang <i>et al.</i>, 2023)

The outcomes of this scrutiny underscore the imperative for central bankers to accord greater scrutiny to the configurational aspects of CBDC. It is essential for central bankers to initially delineate the objectives they aim to accomplish through CBDC and shape the CBDC to incorporate those characteristics. Whenever feasible, there should be avenues for the restructuring and innovation of CBDC to align with the evolving goals of central banks.
Narrativebased literature review
This study scrutinizes the latest strides in research on central bank digital currency (CBDC) intending to provide a comprehensive resource for researchers, policymakers, and practitioners, to facilitate an indepth exploration of CBDC.
Database not specified
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(Ozili, 2022)

CBDCs hold the capacity to tackle certain issues in the digital economy, such as enhancing financial inclusion, improving payment system efficiency, and mitigating privacy concerns. Nevertheless, they also present potential hazards to financial stability and may entail unintended repercussions for monetary policy. The motivations prompting central banks to introduce CBDCs differ based on the country and the specific challenges encountered.	Some central banks contemplate CBDCs to uphold authority over the payment system, while others consider them to address issues related to financial inclusion or to compete with privately issued digital currencies.
Narrative based literature review	
The research centers on comprehending how to optimize the effectiveness of Central Bank Digital Currencies (CBDCs) as a payment mechanism while constraining the overall influx into central bank balance sheets.	
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(Auer <i>et al.</i> , 2022)	

In the investigation, it was determined that conventional elements linked to inflation history and the quality of monetary governance (such as central banks' autonomy and adherence to legal principles) do not exert influence in the context of CBDC. However, these factors prove significant in the realm of cryptocurrencies.
Quantitative empirical study
The study employed the generalized regression approach to ascertain the correlation between confidence in various manifestations of digital currency and selected variables influencing such trust. Basic empirical examinations proved effective in unveiling the pivotal significance of age as a determiner of confidence, particularly concerning Central Bank Digital Currency (CBDC) and cryptocurrencies.
Official Monetary and Financial Institutions Forum
Database not specified
Database not specified
(Koziuk, 2021)

In essence, this academic study navigates the intricate web of CBDC review through a Scholarly Analytics lens, revealing patterns, trends, and gaps that shape the current discourse. By amalgamating historical perspectives, contemporary analyses, and a forward-looking academic roadmap, this manuscript seeks to contribute to the intellectual foundation of CBDC research and inform future scholarly pursuits.

3. Research Methodology

This research employs a comprehensive examination approach that combines bibliometric network analysis and a blended review methodology to explore various dimensions within the evolving research field. The investigation aligns with predefined research objectives and formulated research questions (RQs). Bibliometric analysis involves quantitatively evaluating bibliographic records and utilizing statistical tools to gain insights into prominent countries, institutions, authors, journals, articles, author collaborations, and theme-based clusters within the field. (Bhaskar *et al.*, 2022) Knowledge mapping techniques, such as citation and cocitation-based analysis, along with network visualizations, contribute significantly to presenting the underlying concept and cerebral structure of the research domain, showcasing knowledge distribution in scientific literature through citations.

Despite the efficacy of bibliometric analysis, a notable challenge lies in the concentration of total citations around a limited number of articles within a given set of publications. Bibliometric reviews often focus on authors, affiliations, and cocitations, overlooking dominant theories, data types, and research methods. (Panetta *et al.*, 2023) To address this, our findings are substantiated through systematic literature analysis (SLR) (Hoang *et al.*, 2023), facilitating qualitative assessment and identifying research gaps.

Prior investigations, such as the work conducted by (Ozili, 2022), have adeptly utilized analogous evaluative methodologies across diverse disciplines. Furthermore, (Bhaskar *et al.*, 2022) employ bibliometric and content analysis on 174 documents sourced from the Scopus database. This approach delineates publication patterns concerning Central Bank Digital Currencies (CBDCs) post-2018, shedding light on predominant sources and principal contributors in their respective nations. (Sidorenko, 2021) undertakes a methodical examination of CBDCs as an emerging financial instrument, assessing studies emanating from major central banks and the scholarly community. (Tronnier, Recker, & Hamm, 2020) concentrate on delivering a holistic perspective by introducing, amalgamating, and deliberating diverse research fragments.

3.1 Literature search

The initial phase of this study entails the meticulous selection of data sources to retrieve pertinent scholarly works. To ensure an exhaustive coverage of superior-quality published materials containing both bibliographic and citation details, we employ two distinguished databases: Web of Science (WoS) – specifically, the Social Sciences Citation Index (SSCI) collection – and the Scopus database. WoS, renowned for its expansive coverage of high-caliber publications from 1989 to the present, is favored in bibliometric reviews for its

userfriendly interface conducive to sophisticated bibliometric analyses. (Wang, Ma, & Ren, 2022) Complementing our data retrieval strategy, we also utilize Scopus, acknowledged as the most extensive repository for peer-reviewed literature, encompassing book chapters, conference papers, journal articles, and working papers. With comparable features to WoS, Scopus forms an optimal combination of databases for conducting thorough reviews. (Shi & Sun, 2020) Following the database selection, we construct a comprehensive keyword string through meticulous tracking of the field via newspaper articles and research papers, facilitated by collaborative discussions among the authors. This refined search string, highlighted in Figure 1, is subsequently deployed in both selected databases, yielding 181 records in WoS and 333 records in Scopus, culminating in a total of 514 records as of December 31, 2023.

3.2 Inclusion Criteria

In the initial phase of this research, data curation involves a meticulous selection process within the Scopus and Web of Science (WoS) databases. The filtering criteria are centered on subject categories, focusing exclusively on business, economics, finance, management, financial management, fintech, money and banking, international payment systems, cross-border payment mechanisms, and interdisciplinary, and related fields. Omitted are categories like technology, computer science, engineering, and other core science subjects. This meticulous filtering eliminates 45 articles from WoS and Scopus, producing a refined dataset of 469 records.

A subsequent refinement involves further narrowing down the dataset by applying a language filter, retaining only articles in the English language. This step excludes 14 records in Russian, German, and other languages, leaving a pool of 455 records. Within this subset, 66 articles were related to records focusing only on cryptocurrencies such as Ethereum and Bitcoin, with no focus on the digital currency. Scrutiny for duplicates reveals 45 identical records across both databases. After removing duplicates, the authors are left with a final set of 342 relevant records for analysis.

3.3 Analysis of Final Records

The bibliometric analysis of the final 343 records employs the CiteSpace tool (version 6.2.R4). This choice is motivated by CiteSpace's capacity for visually compelling network visualizations and its versatility across various domains.(Bhaskar *et al.*, 2022)

Co-citation, cluster analysis, and co-occurrence are conducted, unraveling inter-relations within the networks. Network diagram parameters such as the 'look-back years' (LBY) and 'link retaining factor' (LRF) are set, allowing a specified percentage of link retention and an infinite look-back period for relevant citations. A standardized time-slicing approach of 1 year per slice is applied across all networks. Structural metrics, including 'citation burst' measured by the LLR algorithm, contribute to the comprehensive analysis of the network and cluster properties. The Pathfinder pruning technique is employed to eliminate unnecessary links. The final step involves systematic analysis of the 342 records, facilitated by an Excel file, to extract research themes from the CiteSpace-generated clusters.

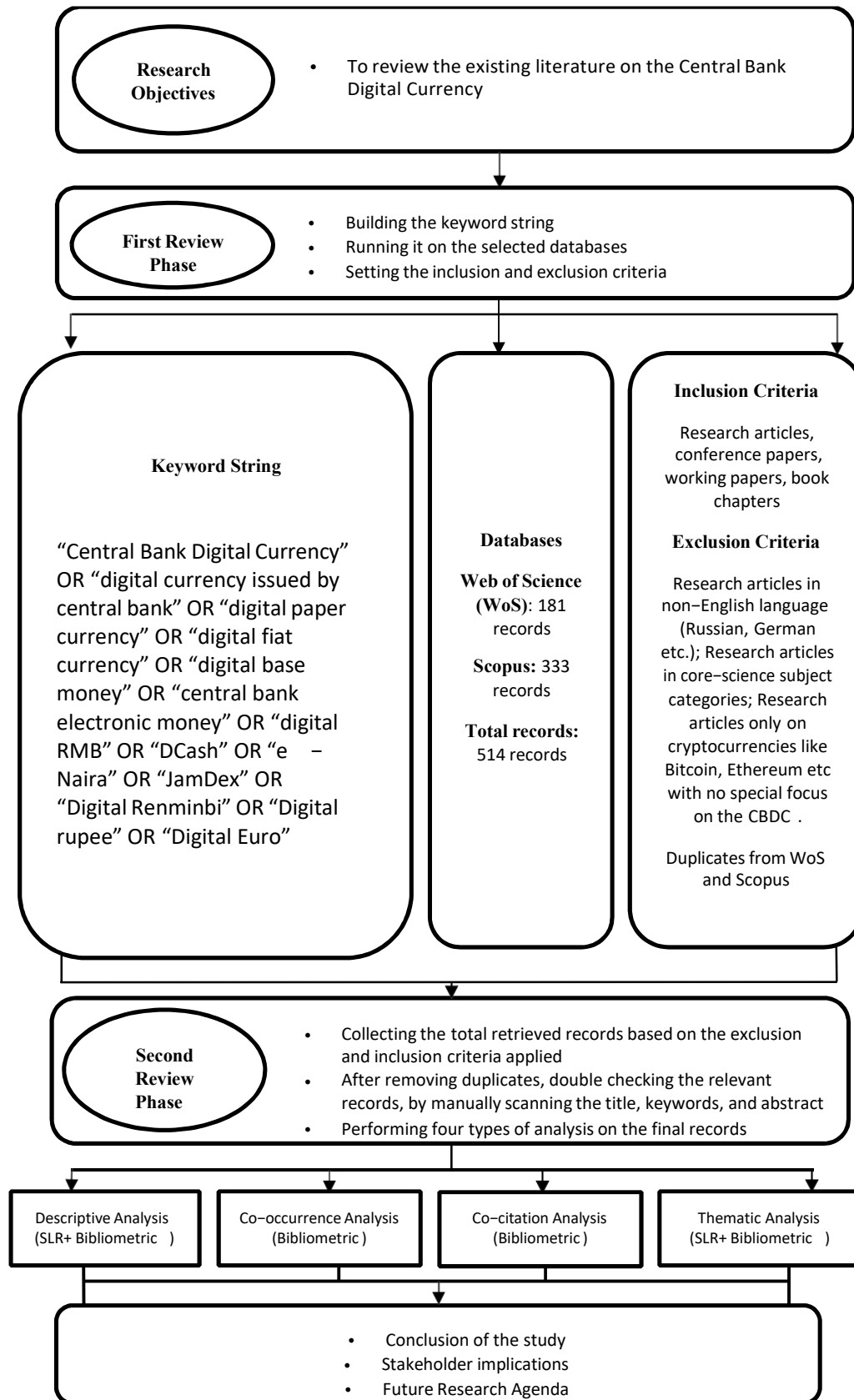


Figure 1: Research methodology framework adopted in the study

Research Findings

4.1. Descriptive Analysis

4.1.1. Year-wise publication trend

The chronological trajectory of scholarly publications exploring the past trends in CBDC papers publications is discernible in Figure 2. Commencing in 2018, the inaugural academic inquiry into the potential of CBDC laid the foundation. After this seminal work, the academic discourse in this domain experienced a notable surge, reflecting a Compound Annual Growth Rate (CAGR) of 51.30 percent over the span from 2018 to 2023 and 79.92 percent over the span from 2018 to 2022.

In the preliminary stage (2018-2019), a limited compilation of seven publications surfaced, providing insights into the exploratory examination of the prototype framework of Central Bank Digital Currency and the reactions of the Crypto market to policies concerning digital assets (Yao, 2018). The development of intellectual inquisitiveness regarding CBDC instigated a shift in scholarly attention, expanding to scrutinize the emergence of central bank digital currency and the prospects of monetary autonomy (Sarin & Aneja, 2022)

In the latest phase (2022-2023), scholarly investigations exponentially soared particularly in the year 2022 because various countries' central banks, for instance, China, India, etc have launched a pilot project on CBDC and also issued the concept on it. (Oehler-Şincai, 2022) This inquiry is prompted by the imperative to address challenges associated with cyber security, the digital divide, financial stability geopolitics, etc driven by the advocacy of establishing a crossborder payment mechanism in international financial systems. A meticulous trend analysis, crucial to a systematic review, accentuates the widening scope of CBDC, for cost reduction related to physical cash management and digitization. (Lloyd, 2022)

In the year 2023, there is a decline in the trend in the publishing of articles, when we compare it with the year 2022. In the year 2023, the total number of published articles amounted to 84, suggesting a plummet of 36.36 percent from the previous year.

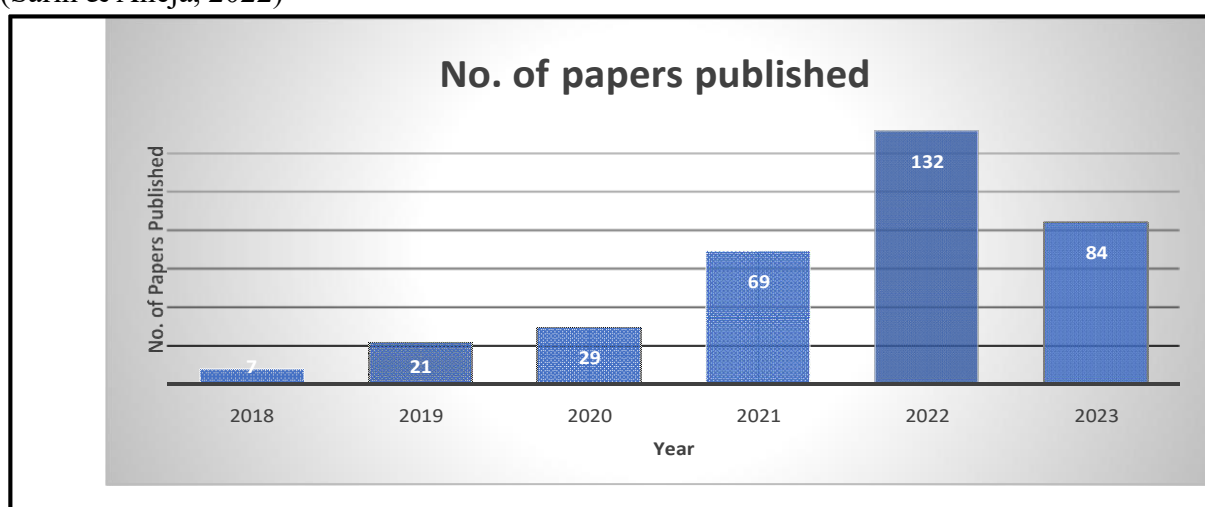


Figure 2: Year-wise publication trend

4.2. Sample Statistics & Theoretical Foundations

4.2.1. Distribution of study types and data sources

Of the entire set of sampled records, a preponderance of 28.32 percent exhibited a quantitative orientation (refer to Figure 3). These studies predominantly focused on empirically examining the ramifications of digital currency, distributed ledger technology (DLT), and its impact on fiscal and monetary policies. Noteworthy is the exploration of various mediators and moderators influencing this intricate relationship. In the context of the data reservoirs employed for investigating this domain, Figure 4 elucidates that a significant portion of the literature draws upon secondary data sources,

encompassing entities such as Bloomberg, Thomson Reuters ASSET4, company reports, and databases specific to individual countries (e.g., CSMAR database for Chinese studies). In instances where primary sources were utilized, the studies relied on survey-based data collection methods, engaging executives and professionals at upper managerial, financial, and operational echelons across diverse industries. Furthermore, insights were gleaned from supply chain experts (Ding *et al.*, 2022), particularly those affiliated with export-import businesses.

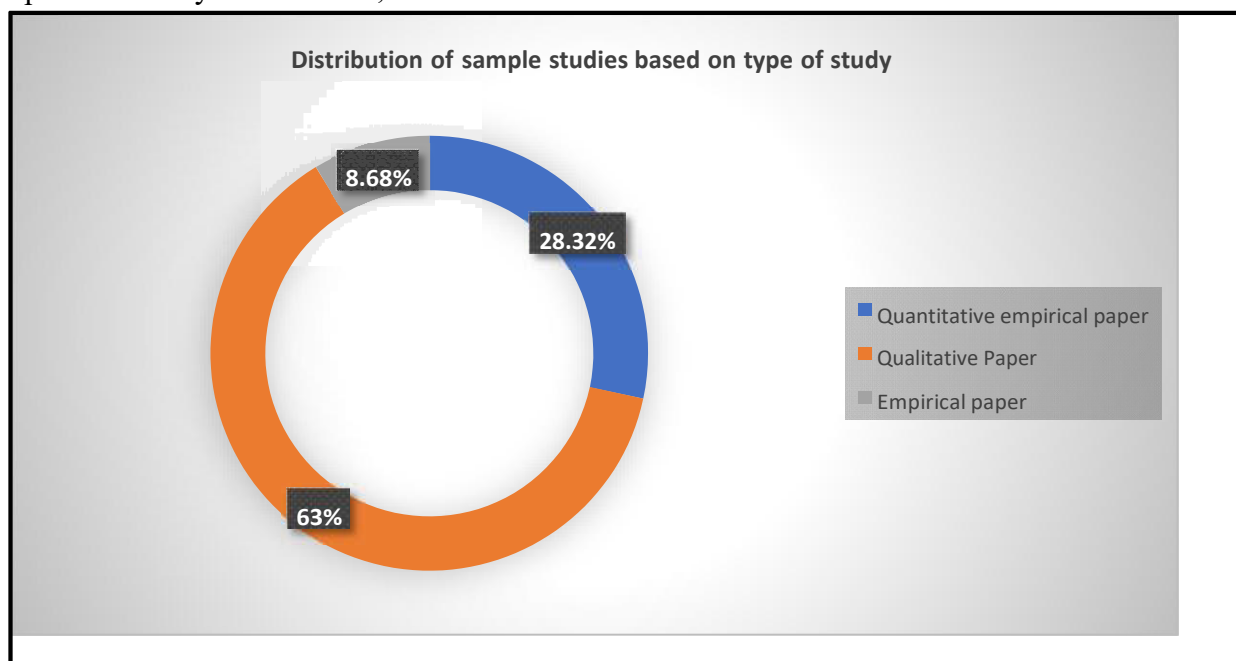


Figure 3: Distribution of study based on study types

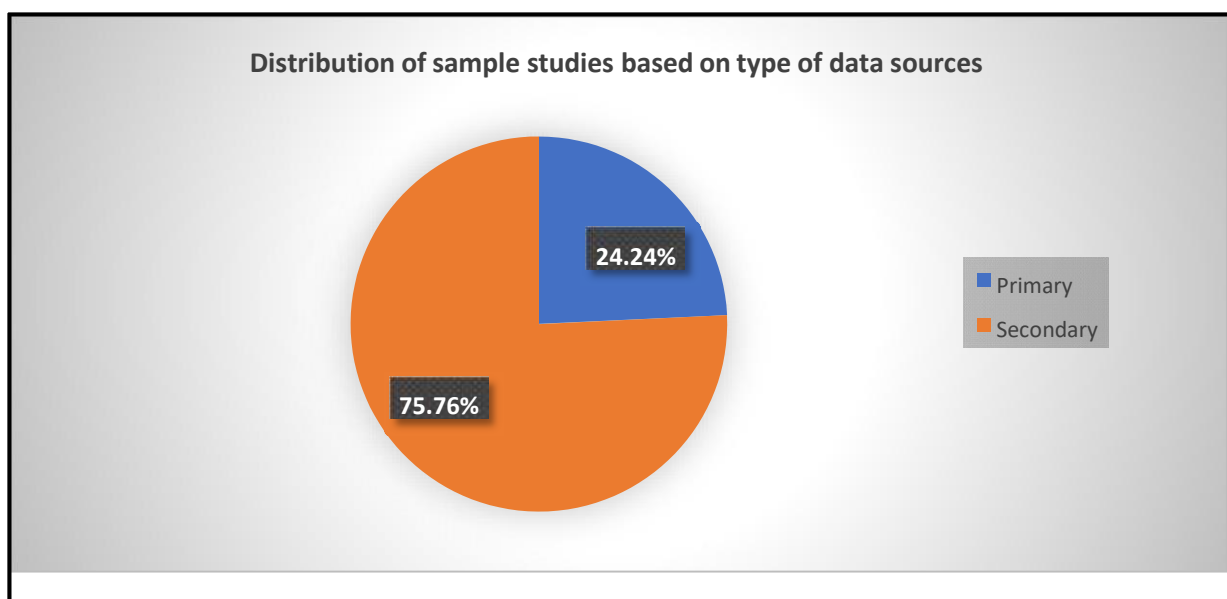


Figure 4: Distribution of study based on data sources

4.3 Co-occurrence analysis

4.3.1 Countries analysis

Figure 5 delineates the scholarly contributions made by nations and academic entities in charting the geographical spread of research manuscripts within the sphere of Central Bank Digital Currency (CBDC). Utilizing CiteSpace software, a network comprising 42 nodes and

43 links was generated by selecting "country" nodes, as detailed. With a network density of 0.0499, this localized focus is mirrored in research publications, suggesting considerable potential for cross-national collaboration and coordination in this domain.

As international standard-setting bodies formulate standardized disclosure requirements for CBDC, the research landscape is poised for significant expansion in the ensuing decade. This presents a unique opportunity for the

global research community to bolster cross-border collaborative efforts. Several countries exhibited noteworthy centrality scores: the United Kingdom (0.79), Vietnam (0.67), Ireland (0.46), Belgium (0.45), Austria (0.43), and China (0.39). The betweenness centrality metric highlights the nodes' contributions to forging connections within the network. Notably, countries such as Germany (29), China (28), The People's Republic of China (26), The United States (22), The United Kingdom (20), Russian Federation (18) emerge as frontrunners in the research of Central Bank Digital Currency (CBDC). This prominence can be attributed to robust communities of investors, philanthropists, and entrepreneurs, supported by conducive research environments fostered by both eminent institutions and respective governments.

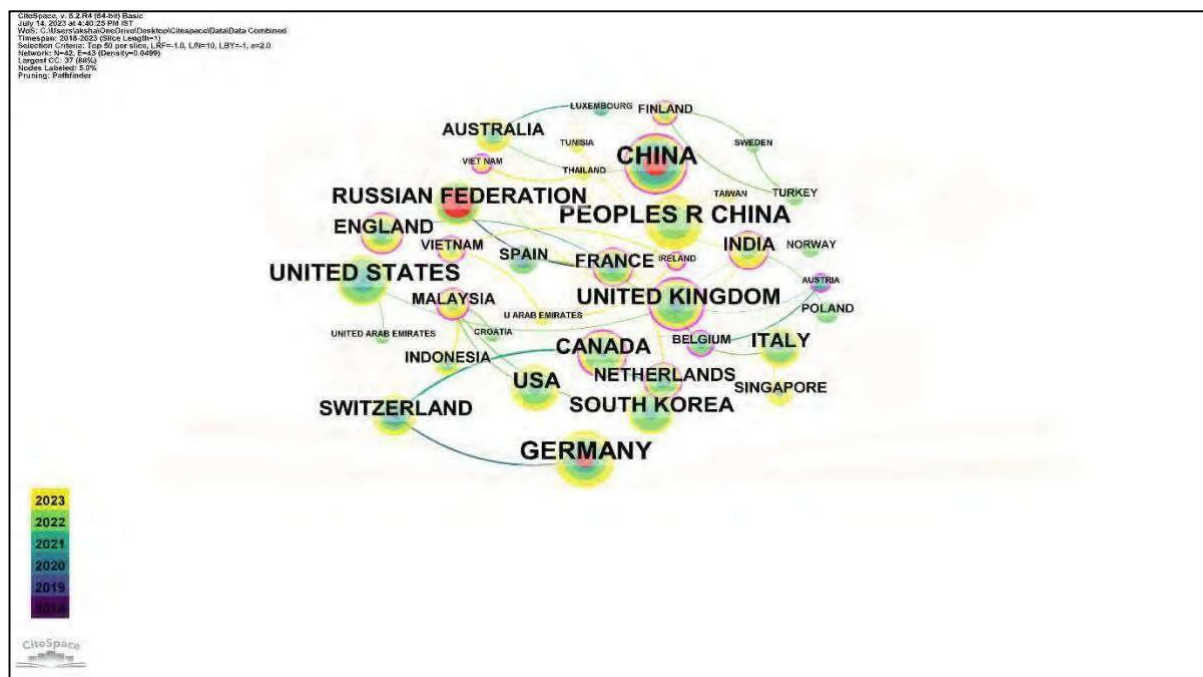


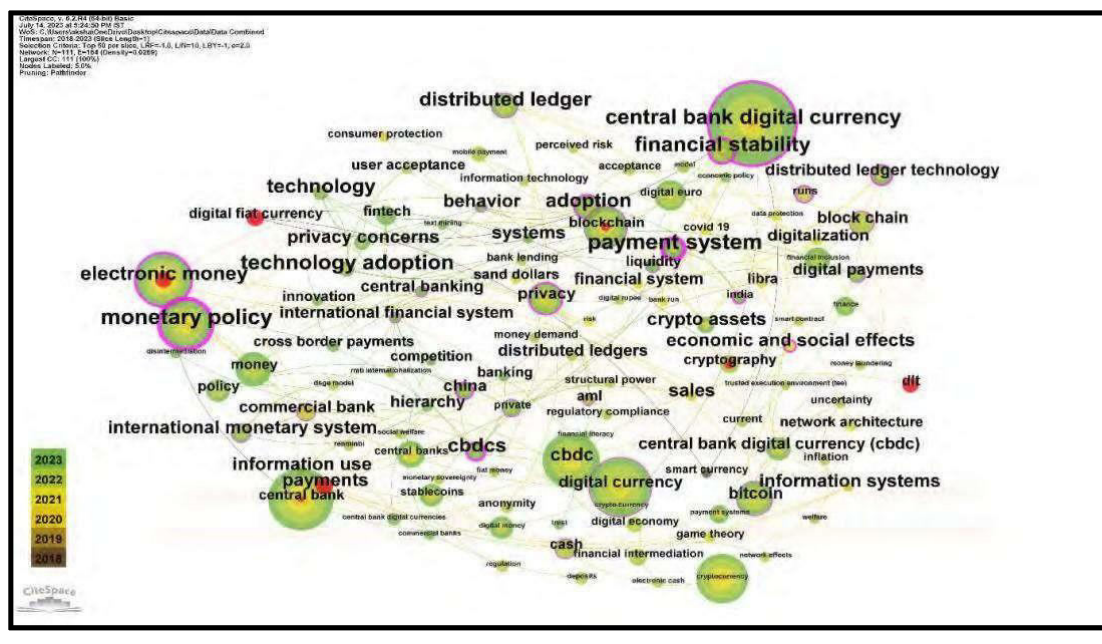
FIGURE 5: Network of Countries

4.3.2 Keyword co-occurrence analysis

Keywords provide a high-degree summarization of the document. Therefore, the keyword cooccurrence network has a dual role. It not only helps in monitoring emerging trends and themes, but it also helps in identifying research hot spots and frontiers in publications (Shi and Sun, 2020). Figure 6 depicts the network of co-occurring keywords. The generated network has 111 nodes, 164 links, and a network density of 0.0269, indicating diverse and spread keywords in the network. The size of the respective node in the network is directly related to the occurrence of the keywords it represents. Keywords having high betweenness centrality scores connected different dimensions of literature. Some of the keywords having high between-ness centrality included: payment system (0.87), monetary policy (0.81), CBDCs (0.57), financial stability (0.47), Central Bank Digital Currency (0.46), electronic

money (0.43), adoption (0.37), India (0.37), runs (0.36), distributed ledger technology (0.3) among others.

The between-ness centrality metric of a node helps in measuring the extent to which that particular node is part of paths connecting two arbitrary nodes in the research corpus. The citation bursts of the keyword co-occurrence network are presented in Figure 7. These help to measure spurts in citations that are reflective of the rising popularity of those respective keywords within a short burst or period. We may observe that the highest strength of citation bursts was for the keywords: electronic money (strength = 4.1), digital fiat currency (strength = 3.21), and central bank (strength = 2.4). Most recent bursts continuing into 2023 were observed for the keywords: central bank digital currencies and cross-border payments.



valuable tool for identifying critical content and subject areas within academic literature. The repeated occurrence of two or more publications in lists of references aids in pinpointing common underlying theories, akin methodologies, and popular empirical techniques within a particular field. Its ability to uncover connections and relationships that might not be apparent through traditional citation analysis alone is significant.

In the subsequent sections, we delve into the intricacies of three pivotal types of co-citation networks and expound upon their analytical implications in understanding the scholarly landscape. This multifaceted approach provides researchers with a nuanced understanding of the intellectual foundations, theoretical frameworks, and methodological trends that characterize a given field.

4.4.1 Journal co-citation analysis

Figure 8 illustrates a comprehensive journal co-citation network in the field, comprising 134 nodes and 234 links. This network highlights the influential journals that have significantly contributed to the

discourse within this domain. In this visualization, each node represents a journal, and the size of the node corresponds to the co-citation frequency of the respective journal. Noteworthy journals include Sustainability-Basel (59), Journal of Cleaner Production (53), and Business Strategy and the Environment (36).

Examining the network visualization, nodes adorned with purple rings denote high betweenness centrality, signifying their pivotal role in information flow. Journals such as the J Econ Perspect (0.54), J Polit Econ (0.46), Econ J (0.37), Centr Bank Dig Curr (0.35), J Financ (0.25), Am Econ Rev (0.25), J Int Money Financ (0.24), exhibit notable betweenness centrality, emphasizing their influential role in connecting disparate nodes within the network (Brandes, 2001; Chen, 2006; Freeman, 1977). This intricate analysis enhances our understanding of the intricate relationships and influential players within the studied academic landscape.

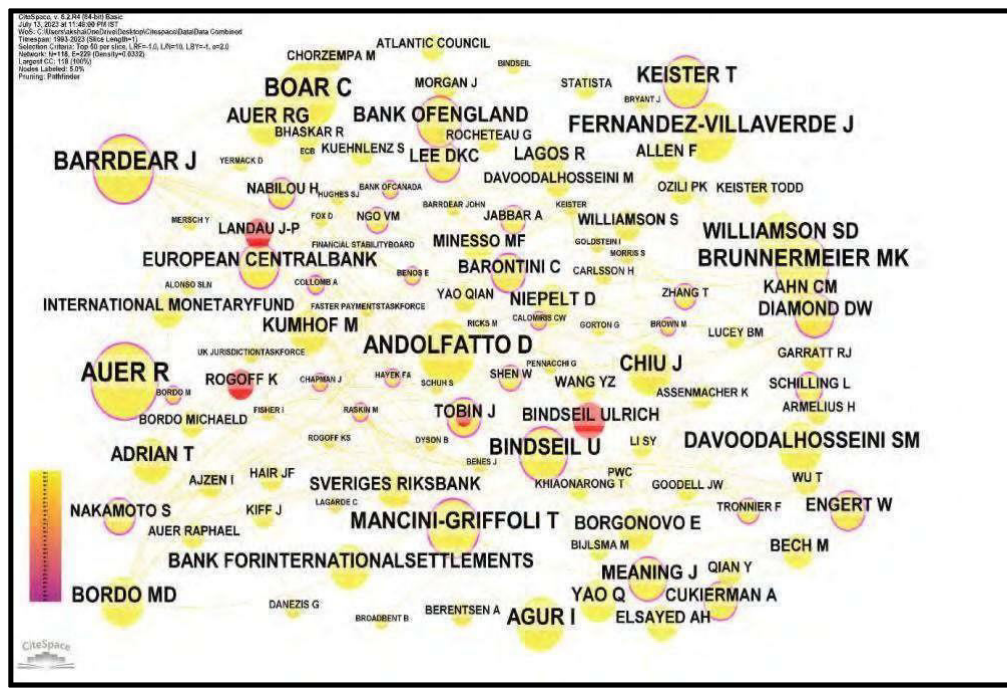


Figure 9: Network of author Co-citation Analysis

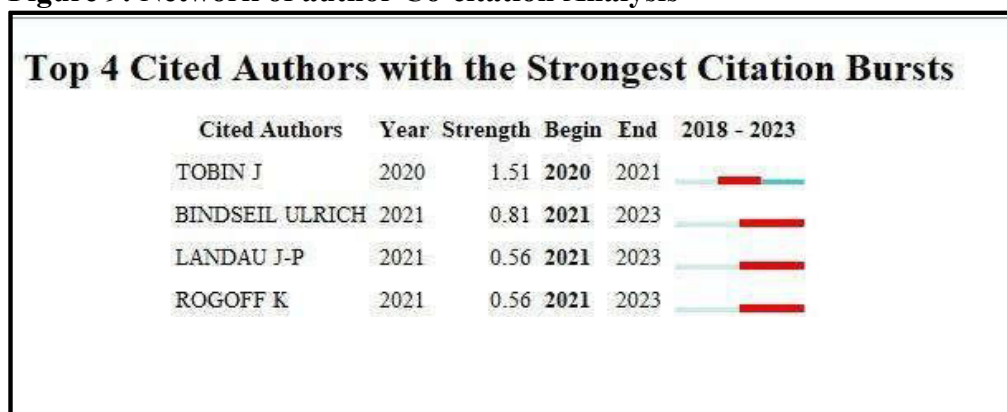


Figure 10: Top cited authors with strongest citation burst

4.4.3 Document co-citation analysis

The document co-citation analysis serves as a valuable tool for delineating the intellectual landscape within a specific field by examining the interconnections among cited references. This method systematically evaluates both the quantity and scholarly significance of references cited in the analyzed document (Shi and Sun, 2020). In the visual representation provided in Figure 11, the document co-citation network is depicted, boasting a

dense composition comprising 216 nodes and 804 links.

Each node within the network symbolises a referenced document featuring the primary author's name and the publication year prominently displayed. The nodes' varying sizes correspond to the documents' respective co-citation frequencies, with larger nodes denoting higher citation frequencies. The network's links signify the frequency of two articles being jointly cited within the research corpus. Notably,

signifying their pivotal role in controlling communication. These nodes represent breakthrough documents with significant scholarly impact.

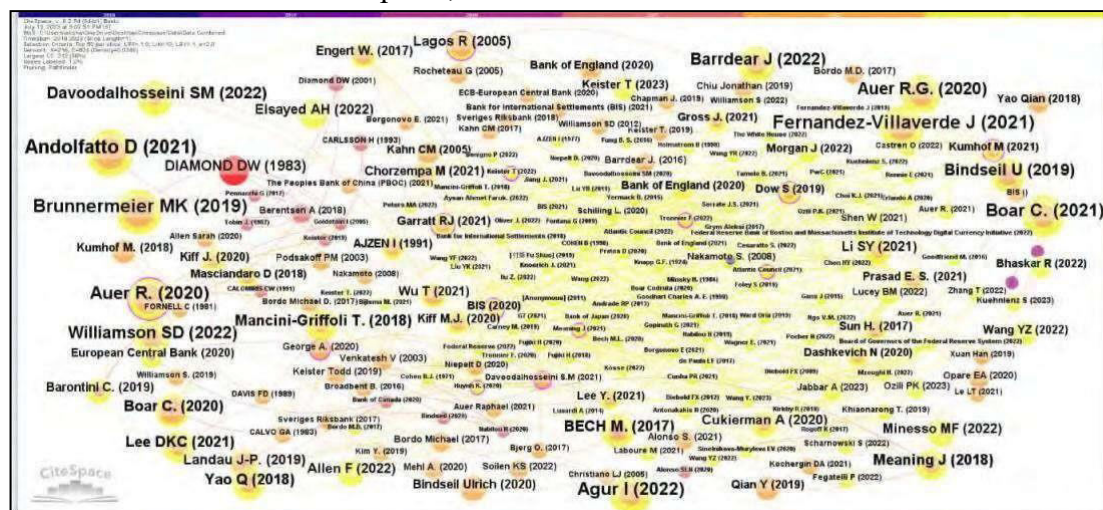


Figure 11: Network of Document Co-citation Analysis

4.5 Thematic analysis

We analysed the corpus of 514 articles from 2018 to 2023 to categorise them into distinct thematic groupings (see Figure 12) and extract unbiased insights from each article. This methodology allows for a comprehensive exploration of the

distribution and evolution of research themes over time, given that these Six themes encapsulate the sample records and are recognised as predominant themes in the literature on CBDC.

4.5.1 Exploring the Macroeconomic Effect of the CBDC as the Future Payment Alternative:

Digital Currency has emerged as a central focus in economic discourse, with an expanding body of scholarly investigation delving into its potential ramifications on the broader financial landscape. The advent of a retail CBDC, characterised by universal access facilitated by the central bank, has garnered substantial scholarly attention (Shi and Sun, 2020). This digital currency variant is poised to reshape the economic terrain, influencing vital macroeconomic indicators. CBDCs hold the promise of numerous advantages, yet their design assumes paramount importance in averting adverse

macroeconomic consequences, particularly regarding monetary policy. (Syarifuddin and Bakhtiar, 2022) Extrapolate the macroeconomic repercussions of an interest-bearing Central Bank Digital Currency (CBDC) by applying a Dynamic Stochastic General Equilibrium (DSGE) model. Additionally, (Xin and Jiang, 2023) employ the previously mentioned framework to assess the efficacy of the negative interest rate policy. According to both studies, central banks must skillfully navigate the consequences of CBDC issuance on inflation expectations and overall

economic stability. The issuance and administration of CBDCs directly influence the effectiveness of traditional monetary instruments. The introduction of CBDCs possesses the potential to shape public anticipation regarding future inflation. A nuanced comprehension of how the advent of digital currency shapes consumer behaviour and perceptions is imperative for central banks in crafting effective monetary strategies. The macroeconomic implications of CBDC extend beyond the technical facets of digital currency implementation.(Chen and Siklos, 2022)

Research within the preceding five years has witnessed heightened momentum in scrutinising the design and implementation nuances of CBDCs. Tackling challenges about security, privacy, and the overarching structure of CBDCs is indispensable for their seamless

integration into the financial ecosystem. (Chapman, 2022) furnishes valuable insights into the current state of research and the trajectory scholars follow. While CBDCs offer advantages such as financial inclusion and heightened payment efficiency, more well-designed implementations may threaten macroeconomic stability. Assessing the trade-offs between these benefits and risks is indispensable for policymakers seeking to harness CBDCs for economic development. Exploring the macroeconomic effects of CBDCs as a prospective payment alternative constitutes a multifaceted undertaking (Fegatelli, 2022). Scholars underscore the imperative of adopting a nuanced approach in designing and implementing CBDCs, mindful of their likely effect on public expectations, monetary policy, and broader economic stability.

4.5.2 Distributive Ledger Technology (DLT) in CBDC Adoption:

The emergence of CBDCs has ignited considerable interest and discourse in the global financial arena. As conventional forms of currency transform, central banks worldwide are exploring incorporating Distributive Ledger Technology (DLT) to augment their monetary systems' efficiency, security, and transparency. (Liu and Hou, 2020) investigation delves into the role of DLT in CBDC adoption, scrutinising the potential advantages, challenges, and ramifications for the future of central banking and the broader financial ecosystem.

The rise of digital currencies and progress in financial technology has instigated central banking institutions to reevaluate their approaches to issuing currency. For example, (Park and Youm, 2022) posit a

decentralised peer-to-peer service framework for transactions involving blockchain-supported diverse digital currencies and Central Bank Digital Currencies (CBDCs). (Zhang et al., 2021) discuss a composite model for CBDCs founded on blockchain technology, while (Islam and In, 2023) pinpoint a CBDC system ensuring privacy and transparency. This is achieved through a consortium blockchain and unspent transaction outputs. CBDCs, representing a digital manifestation of a nation's official currency, have emerged as a viable solution to modernise payment systems and address the evolving dynamics of the global economy. At the core of this transformation lies the integration of DLT, a technology underpinning

cryptocurrencies like Bitcoin and Ethereum. DLT, often used interchangeably with blockchain, is a decentralised and distributed database technology. In contrast to traditional centralised databases, DLT operates on a peer-to-peer network, facilitating secure and transparent record-keeping without intermediaries (Liu and Hou, 2020). The distinctive features of DLT, encompassing immutability, transparency, and decentralisation, render it an appealing option for major central banks opting to enhance the management and issue of CBDCs (Abdulkader *et al.*, 2019).

DLT provides a resilient and secure platform for CBDC transactions. The cryptographic principles inherent in DLT ensure the immutability and resistance to fraud or tampering of each transaction. This heightened security (Lee *et al.*, 2021) engenders user confidence and mitigates counterfeiting and cyber threat risks. The decentralised nature of DLT streamlines the issuance, distribution, and tracking of CBDCs. Smart contracts, integral to DLT, automate various processes, diminishing the need for manual intervention and reducing transaction settlement times.

However, DLT networks encounter scalability challenges when dealing with a high volume of transactions. As central banks aspire to cater to the entire population with CBDCs, scaling DLT networks to handle numerous simultaneous transactions remains a significant hurdle. Adopting DLT

(Sasongko and Yazid, 2020) for CBDCs necessitates establishing a comprehensive regulatory framework. Governments and regulatory bodies must formulate guidelines to govern DLT usage, ensuring compliance with existing financial regulations and guarding against potential misuse. The evolving nature of the technology underlying DLT requires central banks to assess its maturity and stability before widespread adoption carefully. Addressing interoperability, standardisation, and system updates is imperative to ensure the seamless functioning of CBDCs built on DLT.

The adoption of DLT in CBDC profoundly impacts the future of banking and the global financial landscape. Successful implementation could revolutionise the conduct of monetary policy, granting central banks greater control and flexibility. The adoption of DLT in CBDCs represents a pivotal moment in the evolution of economic systems. As central banks navigate the intricacies of technological integration, thoughtful consideration of the benefits and challenges associated with DLT is indispensable (Jung and Jeong, 2021). Striking a balance between innovation and regulatory compliance will be pivotal in harnessing the full potential of DLT to reshape the future of banking and digital currencies. The successful implementation of DLT-powered CBDCs has the likeliness to redefine how we conceptualise and interact with money in the digital age.

4.5.3 Implications of CBDC Adoption in Today's Contemporary World:

Integrating Digital Central Bank Currencies (DCBCs) carries significant ramifications across diverse dimensions in the current era. This transformative shift in

monetary systems encompasses legal aspects, the digital gap, financial stability, innovation, economics, geopolitics, regulatory frameworks, and the broader

domain of attention given to cryptocurrency and digital currency.

Introducing CBDCs necessitates a reevaluation of existing legal frameworks (ZellwegerGutknecht *et al.*, n.d.) governing monetary transactions. As these digital currencies become integral to daily transactions, legal structures must adapt to address issues such as contract enforcement, liability, and dispute resolution. (Cullen, 2022)points out that legal implications extend globally, requiring international collaboration for a unified regulatory environment ensuring the security and validity of CBDC transactions.

CBDC adoption raises concerns about exacerbating the digital gap. As highlighted (Scarcella,

2021), issues of data protection and the digital divide should be addressed by policymakers before CBDC adoption. Bridging this gap is crucial to prevent marginalised communities from being excluded from the financial benefits of CBDCs.

Central Bank Digital Currencies (CBDCs) can redefine financial systems' stability, optimising transaction processes while concurrently presenting novel susceptibilities.

The imperative lies in achieving an equilibrium between enhancing operational efficiency and mitigating associated risks, a delicate balance for central banks to uphold. Notably, according to a study by (Karamollaoglu & Tuncay, 2019), a diminution in control over monetary policy by the central bank could imperil financial stability. Conversely, cryptocurrencies wield the potential to exert favourable influences on

the economy through diverse avenues. These include the enhancement of market efficiencies in payment transactions driven by cost and time, fostering financial inclusion, steering towards a cashless societal paradigm, and fostering the contraction of the informal sector. The multifaceted impacts underscore the nuanced considerations central banks must navigate in adopting and regulating these innovative financial instruments.

CBDCs catalyse financial innovation (Alonso *et al.*, 2021) fostering the evolution of innovative financial services and products, including smart contracts and programmable money. This paves the way for novel business models and a more dynamic financial ecosystem. Integrating these digital currencies enables automation and efficiency in financial transactions, paving the way for novel business models and a more dynamic financial ecosystem. The economic implications (Kshetri, 2021) of CBDC adoption are multifaceted, stimulating growth in payment systems while raising questions about the impact on traditional banking models. Striking a balance between innovation and economic stability becomes a central challenge for policymakers (Auer *et al.*, 2022).

CBDC adoption introduces geopolitical considerations, reshaping power dynamics globally. Nations successfully implementing DCBCs may influence international financial flows, challenging traditional reserve currencies. (Fantacci and Gobbi, 2021).

Robust regulatory frameworks are imperative for DCBC adoption (Wang and Gao, 2023), requiring guidelines to govern their use and ensure compliance with existing financial regulations. Regulatory bodies and governments must establish

procedures to scrutinise the use of digital currency, ensuring adherence to prevailing financial regulations. Striking the right balance between fostering innovation and protecting consumers becomes a delicate task for regulators.

CBDC adoption draws attention to the broader cryptocurrency and digital currency landscape, scrutinising the relationship with existing cryptocurrencies (Wang *et al.*, 2023). The relationship between CBDCs and existing cryptocurrencies like Bitcoin and Ethereum becomes scrutinised. Central banks must navigate the coexistence of CBDCs with private

4.5.4 Role of Central Bank's Monetary Policies with the Adoption of CBDC:

Digital Currencies have become a focal point of interest, prompting inquiries into their implications on the traditional domain of central bank monetary policies. Integrating

CBDCs introduces an innovative dimension to the conventional tools central banks

employ for economic regulation. (Rojas-Breu, 2022). This research paper delves into the intricate facets of central bank monetary policies in the context of CBDC adoption. CBDC designs are formulated to align with central bank mandates, emphasising the pursuit of price stability. This alignment underscores the foundational principles guiding CBDC development, highlighting the perpetual significance of maintaining stable economic prices. The Delphi-Analytic network process for CBDC design in Indonesia is presented by. (Muzbar *et al.*, n.d.) , while (Cheng, 2023) posits that CBDCs can augment monetary policy transmission. They provide a means to effectively convey monetary policy

cryptocurrencies, addressing market volatility and investor protection concerns.

The implications of CBDC adoption are far-reaching and touch upon various aspects of contemporary society. As central banks and governments move forward with implementing CBDCs, addressing these implications will be critical to ensuring a smooth and inclusive transition to the digital future of finance. Careful consideration of legal, economic, regulatory, and geopolitical factors will shape the victory and sustainability of CBDCs in the modern, rapidly evolving financial landscape.

signals, potentially enhancing the central bank's influence on interest rates and overall economic activity. Integrating CBDCs into the monetary policy framework opens avenues for a more direct and efficient policy transmission mechanism.

Traditionally, central banks implement monetary policies to shape inflation and interest rates (Kwon *et al.*, 2022). The issuance of CBDCs adds a digital dimension to these efforts, allowing central banks to finely calibrate their strategies in response to evolving economic conditions. The digital nature of CBDCs facilitates precise control over inflation and interest rate targets. (Mou *et al.*, 2021) presents an analysis of the theoretical framework of monetary policy based on CBDC, delving into the impactful mechanisms of CBDC related to economic policy and elucidating the intricate interplay between digital currencies and traditional monetary tools. Grasping this framework is pivotal for central banks navigating the complexities of the evolving financial landscape.

CBDCs, being digital currencies linked to the official currency of the issuing country, bear profound implications for monetary policy as central banks grapple with the economic ramifications (Tong and Jiayou, 2021) of introducing a digital representation of their currency.

The integration of CBDCs necessitates a holistic approach to financial regulation.(Carvalho

Silva and Mira da Silva, 2023) describes a conceptual model regulating the CBDC, highlighting the importance of considering how these digital currencies interact with existing monetary policy tools to ensure

seamless integration, maintaining financial stability and economic resilience.

The role of central bank monetary policies evolves with the adoption of CBDCs. These digital currencies introduce new avenues for policy transmission, enhance control over inflation and interest rates, and demand a comprehensive understanding of their impact on the broader economic landscape. As central banks embark on this transformative journey, leveraging the principles outlined in CBDC designs is imperative to uphold their mandates and promote financial stability.

4.5.5 Security and Data Privacy Considerations with the Implementation of CBDC:

The rise of digital currencies has garnered global attention as central banks delve into digitising their currencies. However, the implementation of CBDC poses critical considerations concerning security and data privacy (Lee *et al.*, 2021). CBDC, the digital equivalent of physical currency, undergoes extensive research and development worldwide to address challenges and opportunities in the dynamic financial landscape. Exploring CBDC involves initial considerations, such as electronic Know Your Customer (eKYC) (Takaragi *et al.*, 2023), encompassing discussions on security, data frameworks, and privacy implications. This highlights the need for a robust framework to handle sensitive data. Privacy implications arise when CBDC functions as a digital surrogate for end-users. Understanding its accessibility and impact on households and businesses becomes pivotal in addressing privacy concerns (Kiayias *et al.*, n.d.). Ensuring the security of CBDC entails risk assessments

and protective gauges to manage and minimise identified risks, safeguarding the integrity and safety of the digital currency system (Wüst *et al.*, n.d.).

Establishing legal and regulatory frameworks becomes imperative to guarantee data privacy and security (Yamaoka, 2023). Regulators must formulate robust cybersecurity guidelines tailored to CBDCs to address potential risks. CBDC design considerations may include preserving privacy for small, low-risk transactions and alleviating concerns of the financially excluded, who may be apprehensive about payment tracking for data (Ozili and Ozili, n.d.). The implementation of CBDC mandates meticulous consideration of security and data privacy implications. Central banks need global collaboration to set standardised frameworks, ensuring the secure adoption of CBDC. Addressing privacy concerns for end-users, businesses, and the financially excluded requires comprehensive legal and regulatory

measures. Ongoing research and development aim to shape a digital

currency landscape prioritising security and data privacy.

4.5.6 CBDC's Cross-Border Payment Mechanism in the International Payment System:

Central Bank Digital Currencies (CBDCs) are emerging as a transformative influence in the domain of cross-border payments, presenting potential advantages in terms of efficacy, cost-efficiency, and accessibility (Inozemtsev and Nektov, 2022).

Central banks worldwide are investigating CBDCs, aiming to streamline cross-border payments through interoperable multi-CBDC (mCBDC) systems (Kochergin and Dostov, 2020). The mCBDC system facilitates efficient cross-border transactions. Interoperability is crucial for cross-border CBDCs (Jung and Jeong, 2021). The G20 acknowledges the importance of interoperable systems, advocating for more economical, rapid, and seamless cross-border payments.

Diverse international references, such as China (Cheng, 2023), Indonesia (Muzbar *et al.*, n.d.), and various European nations (Chiu, n.d.), have been examined. Central banks globally are exploring the ramifications of CBDCs on cross-border

transactions. Research illuminates potential benefits and challenges, articulating the transformative potential of CBDCs in the global payment mechanism. CBDCs hold the potential to revolutionise cross-border payments by leveraging novel technologies, introducing streamlined distribution channels, and establishing a more efficient system, thereby enhancing the overall effectiveness of international transactions.

The cross-border payment mechanism of CBDCs in the international payment system shows promise in transforming how nations conduct financial transactions. Discussions prioritise interoperability and efficiency, emphasising the necessity for standardised systems enabling seamless cross-border transactions. As central banks persist in exploring and implementing CBDCs, the global financial landscape may shift towards more accessible and cost-effective cross-border payment mechanisms.

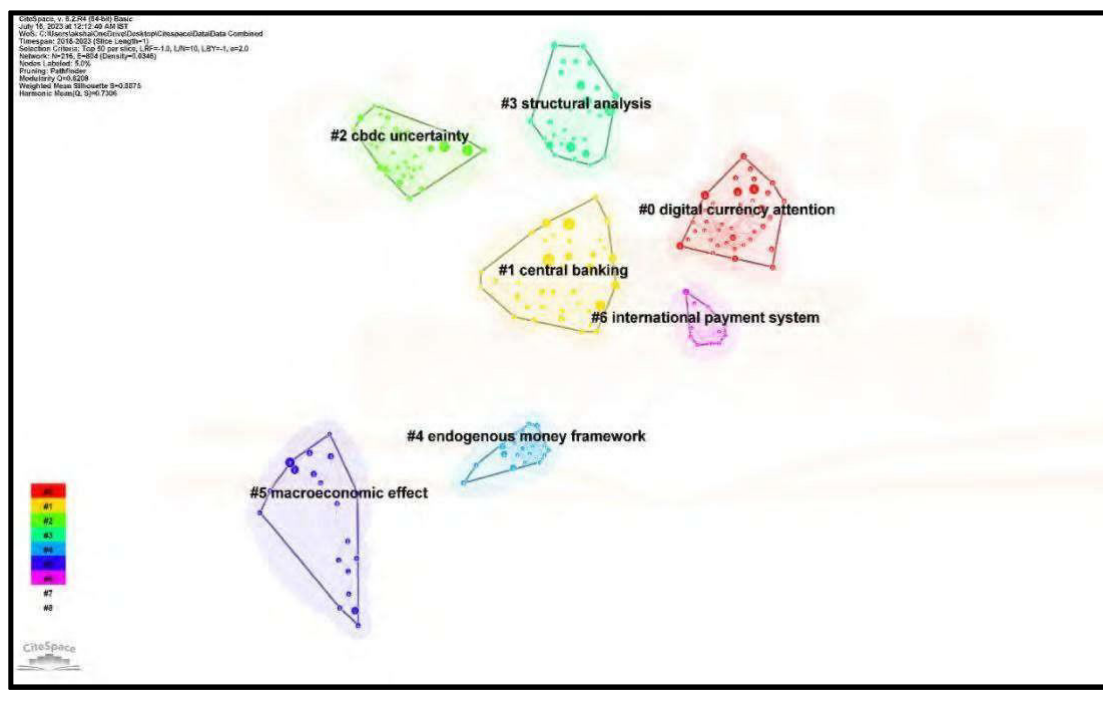


Figure 12: Network of Document Cluster Analysis

5. Future Research Avenues

As per the above thematic analysis, our review acknowledges that although significant conclusions have been reached, some questions remain to be unearthed, some of which are listed in Table 3.

Table 3 Future Research Avenues

Research Theme	Existing gaps in the literature
Exploring the Macroeconomic Effect of the CBDC as the Future Payment Alternative	- Additional data regarding the factors influencing cash utilisation, especially in regions beyond Europe, is necessary to comprehend global payment trends. - Further research is imperative to gauge the repercussions of the diminishing use of cash on diverse stakeholders, including consumers, merchants, and the banking sector, ensuring a comprehensive analysis of the evolving financial landscape. (Rehman <i>et al.</i>, 2023) - An essential area for investigation revolves around delving into the potential risks and benefits inherent in digital payment technologies, including CBDC. This includes scrutinising aspects like financial inclusion and privacy concerns, providing a nuanced understanding of the transformative impact of digital transactions. - Considering the rise of CBDCs, there's a pressing need for comprehensive research into their potential implications on the broader payment system and the economy. This encompasses studying the benefits and threats of adopting these virtual currencies.
Distributive Ledger Technology in CBDC Adoption	- Further exploration of the relevancy and efficiency of the IBMSDC model (Abdulkader <i>et al.</i>, 2019) in managing digital currency transactions. - Future research on blockchain anonymity and the need for further research on efficiency and capacity issues in applying blockchain technology.(Sasongko and Yazid, 2020) - Further research is required to explore the technical and legal aspects of CBDC development and administration, as well as the potential risks and benefits of CBDC - More research is needed on the network formation and impacts on the privacy of CBDCs in IoT payments.

Implications of CBDC Adoption in Today's Contemporary World	• There is a necessity for additional investigation into the potential consequences of CBDC on financial stability, monetary policy, and the broader economy. • More empirical evidence is needed concerning the potential advantages and risks related to CBDC and its influence on the demand for cash and alternative forms of currency. • There is a call for expanded research on the legal and regulatory frameworks essential for supporting the introduction and utilisation of CBDC. This includes addressing concerns related to privacy, cybersecurity, and anti-money laundering. • More comprehensive research is imperative on the likely effect of CBDC on the international monetary system. This encompasses issues about cross-border payments, exchange rates, and capital flows. • An essential need for further investigation into the potential ramifications of digital currencies on financial intermediation. This involves exploring its effects on banks and other financial institutions. • There is a need for in-depth research into the likely effects of CBDC on financial inclusion, specifically focusing on its implications for developing countries.
SASS Role of Central Bank's Monetary Policies with the Adoption of CBDC. Security and Data Privacy Considerations with the Implementation of CBDC	• Additional research is needed to understand the potential impact of CBDC on monetary policy and financial stability • Further research is needed to explore the potential implications of CBDC for cross-border payments and correspondent banking. • Further research is needed to determine the optimal CBDC implementation model for different jurisdictions. • The effect of virtual payments on financial stability. - The potential risks and benefits • Investigation of the trade-off between privacy and auditability in CBDCs. • Further research on the effectiveness of different electronic identification and CBDC systems approaches. • The interoperability and standardisation of CBDC across different countries and regions. And the integration of CBDC with other payment systems and financial instruments. • The evolution of new business models and services based on CBDC. The potential risks and challenges of CBDC include cybersecurity, privacy, and legal issues.

CBDC's CrossBorder Payment Mechanism in the International Payment System	• Future investigations will thoroughly scrutinise the oversight of monetary transactions among general users by employing precise data and enhanced technology and institutional structures. These endeavours provide meticulous supervisory and auditing frameworks for Central Bank Digital Currencies (CBDCs). Comprehensive exploration is warranted to evaluate the circumstances under which cryptocurrencies may vie with central bank currencies. Additionally, scrutinising the potential ramifications of Bitcoin and cryptocurrencies on the central bank's fundamental role is imperative. • Further investigations are essential to gauge the influence of Bitcoin acceptance as a legal tender on monetary policy mechanisms, elucidating potential impacts on the broader economic landscape.

6. Conclusion, implications and limitations

Conclusion

Our investigation comprehensively examines the landscape of Central Bank Digital Currency (CBDC) within the contemporary context. Employing a synergistic blend of bibliometric methodologies and a systematic literature review, our research delves into the critical domain of CBDC, shedding light on its current status and future relevance. The multifaceted approach allows for a nuanced exploration of various facets discussed in the study.

Key Aspects Covered:

Performance Analysis:

- Examination of publication trends.
- Geographical concentration of CBDC-related research.
- Identification of productive and influential authors.
- Analysis of reputable journals and impactful research documents.

Clustering Technique Utilization:

- Integration of clustering techniques for an in-depth exploration of critical themes within CBDC.

- Effective identification of emerging research themes by addressing existing literature gaps.

Contributions to Knowledge Expansion:

- Successful identification and presentation of prominent future research themes.
- Substantial contribution to the augmentation of the existing body of knowledge on CBDC.

Considering the rapidly evolving financial landscape, this study serves as a comprehensive resource, providing valuable insights into the dynamic realm of CBDC. Future researchers can leverage our findings to navigate the intricacies of CBDC-related scholarship and unearth new avenues for exploration.

Stakeholder implications

Stakeholders are pivotal in advancing and accepting Central Bank Digital Currency (CBDC). This scholarly exploration delves into diverse facets concerning CBDC stakeholders (Franko *et al.*, 2022). CBDC can potentially improve the current payment systems but requires careful consideration of implementation models and potential costs. It can significantly impact the central bank and monetary policy involvement and have implications for correspondent banking and cross-border payments (Kochergin and Dostov, 2020).

The approval of CBDC is contingent upon the backing and advocacy of monetary authorities (Wang and Hausken, 2022). The perspectives and engagement of central bankers wield substantial influence over the regulatory framework, profoundly impacting the overall success of DCBC initiatives.

(Sakharov, 2021) provides that financial entities emerge as central stakeholders, and their active involvement is imperative for the seamless integration of CBDC into the prevailing banking system. Collaborative efforts with traditional banks significantly shape the pragmatic implementation of CBDC.

This paper's inquiry duly recognises the importance of stakeholders in the financial technology domain. (Ozili, n.d.) recognises the contributions to CBDC development and integration, provides valuable technological expertise, fosters innovation, and steers the digital transformation of financial services.

The triumph of CBDC hinges upon the general public's embrace. Comprehending the ramifications for everyday users and public-private collaboration (Ballaschk and Paulick, 2021), including considerations of convenience, security, and accessibility, assumes paramount importance for ensuring the widespread adoption of DCBC.

This research paper scrutinises the repercussions of CBDC on financial stability, particularly within the banking sector (Kim and Kwon, 2023). A meticulous evaluation of associated risks and benefits is indispensable for regulators and policymakers (Fabris, 2019).

6.3 Limitations

For this bibliometric investigation, we employed Web of Science (WoS) and Scopus to construct our database, ensuring a comprehensive dataset for analysis. The data extraction was

conducted as of September 30, 2023. It is imperative to recognise that utilising disparate data sources or collecting data at different temporal intervals may introduce variations in the dataset, consequently influencing network structures. Citespace software was employed to visualise and analyse the bibliographic networks. However, it is noteworthy that Citespace cannot conduct "heat map analysis," a feature readily available in alternative bibliometric tools such as VOSviewer. Moreover, it is essential to acknowledge that outputs from CiteSpace software might be susceptible to algorithmic noise and sampling bias inherent in the software. Despite these limitations, our review and analysis identified contemporary themes and facilitated diverse avenues for future research endeavours.

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Empowering Rural Women Entrepreneurs Through AI-Driven Financial Inclusion: A Step Toward Viksit Bharat 2047

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Abstract

Artificial Intelligence (AI) is having a significant role in narrowing the financial gap, especially among rural women entrepreneurs. This study explores how AI technologies—credit scoring tools, chatbots, digital payments, and small loan platforms—are making financial services accessible, personalized, and inclusive for left-behind women. It also explores how these technologies are helping contribute to India's longer-term development goals under the Viksit Bharat 2047 vision. By empowering more women, releasing them from money lenders, and enabling them to be part of the economy, AI is having an impact. There are challenges, the privacy issues, and algorithm bias. This paper offers useful findings and policy recommendations to ensure AI is being used in a fair, ethical, and scalable way to contribute to sustainable development and financial equality.

Keywords: AI for Financial Inclusion, Women Entrepreneurs, Rural Development, Digital India, Viksit Bharat 2047, Microfinance, FinTech, Gender Empowerment, Inclusive Innovation, Financial Autonomy.

Introduction

An information and communication technologies-facilitated inclusive growth strategy is a significant driver of national progress. Rural women entrepreneurs represent a key but overlooked group of India's economic sphere. However, many

continue to face challenges such as limited access to formal credit systems, inadequate financial literacy, and minimal exposure to digital tools—factors that restrict their business opportunities and economic independence.

As India moves toward realizing the vision of *Viksit Bharat 2047*, Artificial Intelligence (AI) emerges as a powerful instrument to narrow the gender gap in financial inclusion. Through innovations like AI-driven credit assessments, biometric identity verification, mobile-based transactions, and vernacular AI chatbots, financial services are becoming more accessible, personalized, and scalable.

This essay addresses the ability of AI to overcome structural barriers for rural women entrepreneurs to enable them to make well-informed monetary decisions, actively participate in the digital economy, and develop sustainable livelihoods. Emphasis is given on the way AI can trigger inclusive growth and empower women at the grassroots level.

Background of the Study

A bulk of India's more than 65% population resides in rural areas where financial inclusion is the big issue, especially for women. These women are

Scope of the Study

This research examines the role of Artificial Intelligence (AI) technologies in enabling financial inclusion of the rural women entrepreneurs in India. This research concentrates on AI based financial technologies such as mobile credit scoring, digital payments, micro-insurance platforms, and virtual financial advisory services.

These technologies are analysed for their capabilities in bridging long-standing hindrances such as absence of the formal credit history, low financial literacy, and

confronted with structural barriers in the shape of poor banking infrastructure, social barriers, and limited financial assets that as obstacles to accessing traditional credit channels and banking institutions.

New technologies such as Artificial Intelligence (AI) are starting to redefine this terrain. AI-powered products such as phone-lending apps, computerized loan approval for microloans, and digital savings accounts are being created to reach women in underserved, low-income populations.

Cross-country case studies, particularly from Kenya and Bangladesh, demonstrate how AI-powered digital financial services have increased the control of women over money and entrepreneurship. With India's growing digital penetration and national initiatives such as Jan Dhan, Aadhaar, and Mobile (JAM), the potential to take these models forward and adapt them is extremely high. But it is imperative that AI technologies are used responsibly, with ethical considerations and digital literacy, especially among women who have been excluded so far.

physical distance from banks. By limiting the topography to rural women-owned enterprises, the research attempts to realize how inclusive and responsible AI systems can assist in empowering women and enabling economic self-reliance in disadvantaged areas. The research is geographically concerned on rural India with some comparison from other developing nations using similar AI-driven financial models.

It is centered on digital entrepreneurship and financial services use, excluding urban cities, male-owned businesses, and AI use

in non-financial industries services use education or healthcare. The objective is to provide targeted information for policymakers, technology provides, and

Review of Literature

Recent studies emphasize the transformation potential of AI in enabling financial inclusion of rural women entrepreneurs. Rani and Kulkarni (2023) found that AI-powered micro-lending platforms using alternative data improved access to credit for women with no formal records or collateral. Deshmukh and Mehta (2024) started how localized, voice-driven AI chatbots promoted digital financial literacy and confidence among women with low levels of technological exposure.

Sharma et al. (2023) cautioned that biased AI algorithms may exclude marginalized

Research Gap

While research on AI and financial inclusion is expanding, very few studies specifically investigate its impact on rural women entrepreneurs in India. Most existing literature either targets urban populations or approaches financial inclusion without a gender-sensitive perspective. For instance, while Rani and Kulkarni (2023) examined AI-driven credit models, and Deshmukh and Mehta (2024) focused on localized chatbots, these works explore individual tools rather than a holistic framework. Additionally, there is limited field-based evidence on how AI influences financial behavior, trust, credit access, and long-

financial intuitions interested in bringing the gender and digital driven through sustainable and responsible use of AI.

groups and recommended the use of transparent, explainable systems for fair decision-making. The World Economic Forum (2024) further stressed the need for inclusive, gender-sensitive AI policies under “Viksit Bharat 2047” to prevent widening the gender divide. Collectively, these findings reveal that AI when designed ethically and inclusively can empower rural women entrepreneurs by expanding financial access, strengthening decision-making, and supporting sustainable business growth.

term entrepreneurial outcomes for rural women. This paper addresses this gap by offering an integrated, India-focused analysis on how ethically designed AI tools can support inclusive and sustainable growth among women-led rural enterprises, aligning with the goals of Viksit Bharat 2047. To add to this, there is limited research on the intersections of AI adoption, digital literacy, and cultural resistance among rural women. These intersections are crucial in developing inclusive fintech policies that goes beyond access to ensure actual empowerment.

Statement of the problem

Many rural women in India continue to be denied access to formal financial services due to low digital literacy, lack of collateral, and social barriers. This conventional banking system is not accommodating to their needs, and therefore it is difficult for them

to emerge as enterprises. Artificial Intelligence (AI) has the potential to empower financial inclusion through voice-based financial tools and digital credit scoring, but it has not been extensively utilized in rural India. Most of the students are limited to urban regions or overall financial inclusion, without any reference to the particular challenges of rural women. There is also limited work on

how AI can improve their financial behavior credit accessibility and businesses viability. The present paper attempts to identify how AI-based financial tools can empower these women and facilitate the vision of the *Vikas Bharath 2047*.

Objectives of the study

- ❖ To evaluate the role of AI in improving financial access for rural women entrepreneurs.
- ❖ To examine how AI-enabled financial services influence entrepreneurial decisions and outcomes.
- ❖ To assess the opportunities and risks associated with using AI in low-literacy, low-income contexts.
- ❖ To align findings with national development goals under *Viksit Bharat 2047*.

The Role of AI in Expanding Financial Access and Business Empowerment

- **AI Enables Inclusive Credit Access:** Artificial Intelligence is transforming how credit is delivered to rural women by evaluating non-traditional data sources like mobile usage, e-wallet transactions, and behavioral patterns. With the technology, microfinance institutions are able to ascertain creditworthiness without formal documents, offering flexible financial opportunities without formal documents, offering flexible financial opportunities and loans to first-time women entrepreneurs.
- **Online Education Using Regional Language AI Tools:** Speech-enabled AI assistants developed in local languages bring personal finance learning to non-techno-savvy women to use mobile banking with confidence.
- **Intelligent Business Support System:** AI-powered technology platforms give real-time business insights, financial projections, and market information regarding small-sized businesses. This allows women to have the information they required for making business decisions, improving their entrepreneurship experience.
- **Accessible Digital Guidance Anytime:** Virtual assistants enabled by AI offer round-the-clock support, helping people with loan procedures, saving goals, and budgeting methods- especially helpful for women in rural regions with limited banking facilities.
- **Balancing AI to combat discrimination:** Where appropriately developed, AI technologies reduce credit bias by

their transparent algorithms. This paves the way for rural women who are often excluded from

formal finance on grounds of gender or social reasons.

Creating Trust and Personalization in Rural Finance through AI

- **Personalized Financial Solutions:** AI platforms monitor customer behavior in order to recommend personalized loans, interest rates and financial products. The personalized approach supports women's self-efficacy in digital finance and fosters lasting user relationships.
- **Designing with Cultural Sensitivity:** Merging local cultures and home content, AI interfaces increase relevance and convenience for rural dwellers. Women are more likely to use systems that reflect their daily lives.
- **Fostering Openness and Safety:** AI provides direct explanations of decisions and safeguard personal information empower rural women. The empowerment encourages more women into digital financial services.
- **Interactive Group Learning Experiences:** AI can replicate group lending behavior or offer gamified financial education to rural communities. The instruments promote group learning and increase collective confidence in money management.
- **Low-Literacy User Support:** Computer vision and voice commands enabled by AI, it reduce the level of reading competence required enabling semi-literate women to access digital platforms on their- own.

Combined impact of AI on Business Growth and National Development

- **Developing New Business Enterprise:** Ai-based solutions reduce entry barriers to entrepreneurship by offering access to credit and information. This is an incentive to other rural women to start entrepreneurial ventures and introduce cash into the economy.
- **Encouraging Economy Self-Sufficiency:** With financial services provided to them by AI, women have greater control over their finances, leading to better household choices and economic empowerment.
- **Achieving Long-Term:** AI platforms enable continuous monitoring of costs, revenues and inventory. This enables women to determine opportunities for growth and mitigate risk in an appropriate manner avoiding early business failure.
- **Facilitating the Vision of Viksit Bharat 2047:** Economical empowered rural women are among the most important drivers of India's development agenda. AI empowerment is in sync with national goals like inclusive digital growth, eradication of poverty and women empowerment.

- **Closing the Gender Divide in the Digital Economy:** By offering technology solutions designed to the needs of the women, AI closes the

digital gap and enables more equitable digital and entrepreneurial economy participation.

Findings

The study identifies Artificial Intelligence as a powerful catalyst for financial empowerment among rural women. Tools such as regional-language chatbots, predictive lending models, and personalized support systems help overcome traditional barriers to finance. While AI holds transformative potential, it

also presents challenges including algorithmic fairness, digital illiteracy, and connectivity gaps. Nonetheless, ethically designed and accessible AI platforms can significantly uplift rural women entrepreneurs and align with the national ambition of an empowered India under **Viksit Bharat 2047**.

Suggestions

To leverage AI's potential for rural women entrepreneurs, the following actions are recommended:

- Build AI interfaces in vernacular languages and regional dialects.
- Design ethical, inclusive AI systems free from bias.

- Improve internet and device access in rural areas.
- Implement women-centered digital literacy programs.
- Foster partnerships between government, NGOs, and fintech startups to extend reach and adoption.

Conclusion

AI-enabled financial services have opened new pathways for rural women to engage in entrepreneurship, secure funding, and make confident business decisions. The combination of user-friendly technology, culturally adapted content, and intelligent support has led to greater financial participation and entrepreneurial resilience. Despite hurdles like digital access and trust, AI remains a cornerstone for inclusive economic growth, contributing directly to the vision of a prosperous and self-reliant India under **Viksit Bharat 2047**.

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Sudoku of Financial Inclusion: Contextualizing the Nine Pillars for Diverse Economic Systems

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Extended Abstract

1. Background and Rationale

Financial inclusion has been acknowledged as a crucial factor in economic development, poverty alleviation, and fostering social empowerment. Yet, despite intensive global efforts, substantial discrepancies in financial access, usage, and quality persist across regions, demographics, and economic subsets. Although the traditional approaches of financial inclusion help in developing uniform strategies, they overlook the realities of different socio-economic contexts (Aggarwal, 2014).

This current research paper aims to build the foundation for inclusive finance by developing the Sudoku of Financial Inclusion, nine interdependent pillars. Drawing inspiration from the logic and interconnectedness inherent in Sudoku puzzles, this framework underscores the premise that financial inclusion is a complex, context-sensitive system rather than a linear checklist (Dar & Ahmed, 2021).

2. The Sudoku Analogy in Financial Inclusion

Sudoku, as a defined, structured yet dynamic and complex grid, requires each block to connect harmoniously to achieve the desired result. Applying the same methodology to financial inclusion prominent nine pillars identified that is Digital Public Infrastructure [DPI], Financial Literacy [FI], Access to Credit [AC], Affordable Insurance [AI], Savings & Investments[S&I], Regulatory

Inclusivity [RI], FinTech Innovation [FTI], Gender & Social Inclusion[G&SI], and Last-Mile Delivery [LMD] found as an interconnected component of financial inclusion (Inoue, 2019). Within a given economy's ecosystem, the significance and impact of these pillars differ alongside other factors, which means they need to be individually curated for each sub-system (Kumar, 2013).

3. Literature Context and Gaps

Though there is extensive literature that addresses issues like digital finance, regulatory innovation under the umbrella of financial inclusion, it is concluded that most models by default fit all, unlike

economic subsets, resulting in misalignment in policies (Goel & Sharma, 2017). Therefore, the present working paper will emphasize social-cultural dimensions such as gender and marginalized groups and over-reliance on one-dimensional success metrics (e.g., number of bank accounts) rather than holistic ecosystem health. This paper addresses these gaps by proposing a comprehensive, adaptable model grounded in systemic interdependencies and contextual flexibility (Agrawal & Jain, 2019).

4. Objectives of the Paper

- To conceptualize and present the Sudoku framework as an integrated model for financial inclusion.
- To analyze the differential significance of the nine pillars across diverse economic subsystems.
- To provide actionable insights for policymakers, development agencies, and financial institutions in designing targeted inclusion strategies.

5. The Nine Pillars of Financial Inclusion

The framework identifies nine essentials, yet contextually weighted, dimensions:

Digital Public Infrastructure (DPI): Foundational digital identity, payment systems, and secure platforms enabling broad-based participation (Mehta & Mani, 2024; Ozili, 2025)

Financial Literacy and Awareness: Enhancing capabilities to understand, access, and utilize financial tools effectively (Kumar & Pathak, 2022; Chen, Tan, & Liu, 2024).

Access to Credit and Microfinance: Ensuring affordable, timely credit, especially for underserved segments (Mukherjee, 2014; Zheng, 2025)

Affordable Insurance Solutions: Risk protection mechanisms accessible to low-income and vulnerable populations (Eling & Yao, 2024; Dror & Eling, 2025).

Savings and Investment Options: Mechanisms fostering financial resilience and asset-building (Bergsma, 2011; Abebe, Tekle, & Mano, 2018).

Inclusivity in Regulatory Frameworks: Policies promoting equitable access, consumer protection, and market development (Purkayastha, Tripathy, & Das, 2020; Kaushal, 2025)

Technology and Innovation in FinTech: Leveraging emerging technologies to expand reach and efficiency (Offiong & et al., 2024; Subramaniam & Masron, 2025)

Gender and Social Inclusion: Targeted efforts to bridge disparities for women, marginalized groups, and minorities (Ngo & Wahhaj, 2012; Garikipati, & et al., 2017; Ozili, 2020; Ozili, 2023)

Last-Mile Delivery and Infrastructure: Physical and digital outreach to remote, underserved regions (Dorfleitner, Forcella, & Nguyen, 2022; Pal, & et al., 2023).

6. Implications of Varying Relevance Across Economic Sub-Systems

Different economic subsets exhibit different readiness levels, challenges and priorities. The key implication of the recent paper includes that the last-mile delivery, microfinance, and insurance hold the primary importance in rural and agrarian settings, and Urban or digitally enabled

economies consider FinTech Innovation, DPI, and sophisticated Investment Options (Kapoor, 2014).

On the other hand, marginalized communities may require amplified focus on Gender & Social Inclusion and Literacy and divergent market realities and technological maturity across subsystems must evolve regulatory approaches. This contextual variability reinforces the necessity of a calibrated, ecosystem-specific approach to financial inclusion (Khan & Sahu, 2025). Highlighting the varying relevance of these nine blocks across different sub-economic systems is imperative because the financial inclusion needs of urban versus rural areas, developed versus developing economies, or even specific demographic groups within a country, can differ significantly (Yang & Gong, 2025).

6.1 Contextual Relevance

It is essential to recognize that the importance of each dimension (or block) is context-dependent. For example, Urban areas might prioritize FinTech innovation and investment options. Rural areas might find last-mile delivery and microfinance more critical. Women-centric programs could focus heavily on gender and social inclusion.

6.2 Economic Diversity

Different sub-economic systems—such as agrarian, industrial, or service-based—may have distinct financial inclusion priorities. In Agrarian economies, more emphasis may be needed on microfinance, insurance solutions (e.g., crop insurance), and last-mile delivery. While in Industrial economies it may be required to focus on credit access, regulatory frameworks, and savings options, in Digital economies, Greater relevance for DPI and FinTech innovation is suggested.

6.3 Demographic and Regional Factors

Financial literacy programs hold more importance in regions with lower education levels, whereas advanced investment tools matter more in well-educated, urban settings.

6.4 Dynamic Interdependence

The Sudoku analogy works beautifully here: each block influences others. While certain blocks might take precedence in specific contexts, all are interconnected. For example, in a rural setting, last-mile delivery might boost access to savings and investment options, creating a ripple effect that enhances overall inclusion.

7. Sudoku Model leading for Financial Inclusion for diverse Economic Setups

Financial Inclusion Pillar	Rural Agrarian Economy	Urban Industrial Economy	Digital-First Economy	Marginalized Communities
Digital Public Infrastructure (DPI)	Moderate	High	Critical	High
Financial Literacy & Awareness	High	Moderate	Moderate	Critical
Access to Credit & Microfinance	Critical	Moderate	Moderate	High
Affordable Insurance Solutions	High	Moderate	Low	High
Savings & Investment Options	Moderate	High	High	Moderate
Inclusivity in Regulatory Frameworks	High	High	High	Critical
Technology & FinTech Innovation	Low to Moderate	High	Critical	Moderate
Gender & Social Inclusion	Critical	High	Moderate	Critical
Last-Mile Delivery & Infrastructure	Critical	Moderate	Moderate	High

Legend:

Low: Minimal immediate impact, long-term potential

Moderate: Important but contextually variable

High: Essential for effective inclusion

Critical: Foundational and urgent for systemic change

8. Conclusion

Achieving universal financial inclusion requires moving beyond uniform, static strategies toward adaptive, interconnected models sensitive to socio-economic diversity. The Sudoku of Financial Inclusion offers a novel, pragmatic framework to navigate this complexity, emphasising that sustainable inclusion is not only about coverage but also about context, quality, and systemic coherence.

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**TRACK 5 DIGITAL FINANCIAL LITERACY & HUMAN
CAPITAL FOR 2047**

Empowering India's Future: Digital Financial Literacy and Human Capital in the Metaverse Era

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Abstract

2047 around the corner, India is on track to meet its developmental milestones as this will mark 100 years of independence. However, with it comes challenges for the economy as there are transformations coming to the very fabric of its being due to the digital world and metaverse. This paper further elucidates the consequent impacts of employment and utilizing knowledge to prepare for the future which encompass digitally enabled finance. The paper firmly believes that workforce skills and the manoeuvring of financial tools will set the pace an inclusive and improved progress structure. The analysis showcased the potential of advancement in the digital banking sector with UPI and India's checks branding it but stagnation in rural literacy and skills gaps are holding the rest of the country back. It predicts a shift in banking with the emergence of the metaverse by 2047 featuring augmented reality virtual branches, AI automation advisors, self-directed investment plans, and blockchain powered transactions. The education system needs to integrate more finance while also actively market such tools alongside development opportunities like tailored community and situational training at the local level. For capital investments in education like teaching AI and blockchain worked in tandem with other domains while offering life-long learning opportunities enables gap shift. If these policies are met, India is on the path to create a financially savvy and skilled citizenry able to engage with an emergent metaverse economy by 2047, thus, paving the way for the vision of a developed nation.

Keywords: *Digital Financial Literacy, Human Capital, Metaverse, Banking, India 2047*

Introduction

With a vision to celebrate 100 years of independence in 2047, India is on the verge of making a unique change within its socio-economic construct. India's Metaphysical and Digital Banking and Finance Innovations will revolutionize the economy. It casts new pupils in education as a required skill in the age of the internet and communication technologies (ICT) is digital literacy. Simultaneously, human capital must transform to mean the skills,

knowledge, and capabilities of people concerning the possibilities of the new world. This study evaluates the interrelationship of the two concepts of digital literacy and human capital in terms of its present position in India, its future scenario concerning the metaverse, and what measures are necessary to prepare the country for the financial reality of 2047. It contributes towards the aim of envisioning a developed technologically advanced India that seeks to sustain growth irrespective of economic contingencies.

Problem Statement/ Research Gap

India's financial sector is rapidly digitalizing, yet there is a paucity of research on preparing the nation for the metaverse's integration into banking by 2047. Current studies predominantly address immediate digital banking challenges, overlooking the long-term implications of immersive technologies. This paper fills this void by examining how digital financial literacy and human capital can be cultivated to meet the demands of a metaverse-driven financial ecosystem.

Methodology

Employing a conceptual framework, this paper synthesizes insights from academic literature, industry reports, and expert forecasts. It critically analyses current digital financial literacy initiatives and human capital development programs in India. Scenario planning is utilized to envision the metaverse's impact on banking, drawing on technological trends and socio-economic factors. The paper culminates in strategic recommendations derived from this analysis.

Current State of Digital Financial Literacy and Human Capital in India

Through the incorporation of systems such as the Jan Dhan Yojana, which seeks to bring millions into the banking network, India has made great strides toward integrating its citizens into the digital economy. The acceptance of mobile banking, digital wallets, and the Unified Payments Interface (UPI) has further

broadened the scope of financial services to key segments of the economy. Unfortunately, the gaps in skills and knowledge related to technology differ across demographic groups. Many citizens, especially in less developed rural and marginalized areas, suffer from the lack of appropriate technology, education, and socio-economic frameworks necessary to take advantage of these digital channels. Recent research highlights the fact that urban populations have a relatively greater understanding of digital payments, while a concerning amount of awareness and usage gaps still exists in rural areas. Alongside this, the digitally enabled workforce in the financial sector is growing. Increasingly, specialists in these areas are required to possess qualification in data analytics, cybersecurity, and fintech. There is, however, a skills gap. Many workers are unprepared to meet the technological needs of modern banking. The rate of digitization is too high compared to the amount of training available, which poses a competitive threat to India. Bridging the gaps in literacy and skills is essential to ensure that India's workforce and populace are ready for a digitally driven future.

Future Trends: The Metaverse and Its Impact on Banking

Expected to take over everyday life in 2047 along with banking is the metaverse, which is an immersive virtual sphere. To put it a bit more elaborately, it will foster the creation of branches with representatives in the form of avatars, AI-enabled advisors who can cater to specific needs of the

clients and transactions conducted on blockchain for security and transparency. Furthermore, metaverse would impact the entire banking sector with fresh concepts of business virtual asset management and DeFi leading to totally new means of interaction with finances. Such innovations will help improve financial literacy, although far more advanced than anything we have today. Along with basic digital skills the rest will need to grasp e-Economy, virtual personas and gaming world cybersecurity. As an example, understanding of the modern metaverse will require knowledge on digital wallets as well as other scams like wallet-sophisticated metaverse finance frauds. Further hand, advanced education in VR, blockchain and AI will be required of the working population to develop and sustain these systems. Meticulous flexibility for ever-evolving technologies combined with the need for re-skillings boosts the need for research and development. Thus, the need becomes more profound in education. The metaverse bankscape of 2047 will thus require a populace and workforce equipped to operate within a seamless blend of physical and virtual financial realms.

Strategies for Enhancing Digital Financial Literacy and Human Capital

Expected Outcomes/ Findings

The paper anticipates identifying key barriers to digital financial literacy, such as infrastructural deficits and educational disparities. It will propose targeted interventions, including curriculum reforms and public-private partnerships, to address these challenges. Furthermore, it

To bridge the digital financial literacy gap, a coordinated approach is crucial. Schools of all levels must incorporate digital financial education into school curricula, promoting early exposure to tools and ideas. Country-wide campaigns, both electronic and print, can reach many more and spread best practice far and wide. Community-specific, localized training programs must be designed for rural and underserved communities, overcoming their unique barriers with local content and accessible technology. For human capital, specialized training programs for financial professionals are important, targeting metaverse-relevant technologies such as AI, blockchain, and VR. Industry-academic collaborations can make sure that academic programs track emerging trends, creating a skilled workforce capable of navigating the bankscape of the metaverse. Organizations need to develop a culture of lifelong learning, providing incentives for employees to upskill continuously. Government intervention is also critical, with policies that support funding for training, stimulate innovation, and create regulatory environments to safeguard consumers while driving technological uptake. Integrating these efforts, India can establish a strong digital financial capability and human capital preparedness foundation by 2047.

will forecast that successful implementation of these strategies could lead to substantial improvements in digital financial literacy rates and a workforce adept in metaverse-relevant technologies by 2047.

Significance

This conceptual paper holds profound significance for India's socio-economic trajectory. By elucidating pathways to enhance digital financial literacy and human capital, it contributes to the nation's vision of becoming a global financial hub. The findings offer actionable insights for stakeholders to foster an inclusive, innovative financial sector, thereby supporting India's aspirations for developed nation status by 2047.

Conclusion

As India sets out on the journey to 2047, the interconnection of digital financial literacy and human capital will be the determining factor in the development of a robust, inclusive financial system. The metaverse presents transformative possibilities along with daunting challenges, necessitating forward-looking actions to make the digital economy accessible to all. With calculated investments in education, training, and cross-industry partnerships, India can cultivate a workforce and citizenry that is not only responsive to but also a leader of financial innovation across the world. The vision of a developed country by 2047 hinges on equipping people with the information and competencies to succeed in the metaverse bankscape, making technology a force for inclusive growth and prosperity.

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Empowering Futures: A Case Study on Grassroots Digital Financial Literacy and Human Capital Building in Eastern Uttar Pradesh

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Abstract

This case study explores a bottom-up digital financial literacy initiative in Eastern Uttar Pradesh, focusing on how a grassroots NGO, Ujjwal Gramin Pragati Sansthan, is equipping rural youth and women with financial tech skills. By examining its methods, challenges, and community impact, the study presents a scalable model aligned with India's digital and human capital vision for 2047.

Keywords

Digital Financial Literacy, Human Capital, Rural Empowerment, Fintech, Viksit Bharat 2047

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1. Introduction

Digital financial literacy is a cornerstone of India's vision for a digitally empowered Bharat by 2047. However, rural and semi-urban populations still lag behind due to limited access, awareness, and training. This case study investigates a hyper-localized initiative led by Ujjwal Gramin Pragati Sansthan (UGPS), which aims to bring inclusive financial knowledge and tools to underserved regions.

2. Background of the Case: Ujjwal Gramin Pragati Sansthan (UGPS)

UGPS is a non-profit organization established in 2018 across Mirzapur and Chandauli districts. In partnership with a local cooperative bank and regional fintech startup MobiSathi, UGPS launched a two-

year pilot program from 2022 to 2024. The initiative targeted women, small vendors, and students to teach practical digital financial skills such as UPI payments, micro-investments, using DigiLocker, and understanding financial safety protocols.

3. Methodology

The study is based on qualitative and quantitative methods, including field interviews with 12 beneficiaries (names anonymized), direct observations of training sessions (conducted in March 2024), survey data from the NGO's internal reports, and feedback from the fintech partner MobiSathi.

4. Findings

- 75% of the trained women began using UPI and mobile banking regularly.
- Local grocery stores in three pilot villages adopted QR code payments.
- More than 40 school students assisted their parents in navigating mobile financial apps.

- Incidences of digital fraud dropped by 30% due to the awareness sessions conducted.

5. Working Model

UGPS employed a 3-tier digital learning model to ensure accessibility and community engagement:

1. Digital Dosts – Local youth trained to act as peer educators and troubleshooters.
2. Tech Chaupals – Weekly village meetings hosted in Panchayat Bhawans for interactive demonstrations.
3. Gamified Micro-Modules – Mobile-based quizzes and simulation apps teaching secure payments and savings.

6. Discussion & Link to India's Vision 2047

The UGPS model highlights how digital financial inclusion supports human capital development. As rural individuals gain control over digital tools, they actively participate in the economy, improve household finances, and build future-focused habits. Trust in digital governance improved via tools like DigiLocker and Digital Dosts, reducing the tech adoption gap. Aligned with Digital India and Skill India, such models can help achieve India's \$30 trillion economy vision.

7. Roadmap to 2047

- Public-Private Collaboration: Co-develop local language fintech modules.
- Curriculum Integration: Introduce digital finance in school curricula.
- Incentive Models: Offer micro-scholarships for certified programs.
- Monitoring Tools: Create a Digital Financial Literacy Index.
- Gender Mandates: Ensure 50% women participation in digital drives.

8. Conclusion

UGPS's initiative shows how community-led digital literacy programs can spark sustainable change. By enabling digital competence and financial awareness at the grassroots, such models prepare India's rural population to thrive in a digital economy, ensuring inclusive progress by 2047.

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The Role of Digital Financial Literacy in Enhancing Human Capital: A Systematic Review

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Abstract

With the advent of the digital economy, managing finances through digital platforms has become increasingly necessary, thus requiring digital financial literacy (DFL). Economic empowerment, productivity, and improved employability are some of the impacts increased financial literacy can produce on human capital. This study aims to aggregate empirical evidence on the impact of DFL on human capital, providing pathways for enhancing human capital and key mechanistic outcomes from the literature. Through the Web of Science and Scopus databases, a search was conducted for articles published between 2010 and 2024, setting peer review and human capital development-centred DFL impact as the inclusion criteria for data collection. Thematic analysis was conducted on the captured data. The analysis performed showed that DFL has a significant influence on human capital development, improving individual decision-making, digital inclusion, and economic participation. With these changes, Enhanced DFL has also been shown to improve employment outcomes, entrepreneurial capabilities, and overall wellness. Despite these merits, a lack of education and digital resources remains a significant barrier. The incorporation of DFL in formal educational systems and throughout tailored workforce development programs remains an under-researched opportunity. DFL is crucial in terms of human capital development, social fairness, and economic growth acceleration. Further work is needed regarding the digital divide and human

capital policies, including investigations into the effectiveness of proposed solutions and longitudinal studies to measure their impact.

Keywords: Digital Financial Literacy, Human Capital, Financial Inclusion, Digital Economy, Systematic Review

Introduction

With the ever-evolving digital economy, managing one's financial systems has become crucial to communities and individuals. Digital financial literacy (DFL) is emerging as one of the most important critical building blocks within human capital development. It also fosters economy-wide resilience, increasing agility in responding to shocks, enhancing employability, and sustaining development. There is a global trend towards cashless payments and more online financial services, which magnifies the need for DFL in the context of human capital development.

The most recent literature has highlighted the increasing importance of human capital, encompassing skills, expertise, competencies, and education. Human capital has also been highlighted as one of the key drivers of positive economic change and productivity increases. Recent advances in literacy research have concentrated on micro, small, and medium enterprises (MSMEs) as well as marginalized groups. As noted by Slamet (2023), financial literacy supports strategic and operational success, subsequently enhancing human capital—lastly, Talip and Wasiuzzaman (2024) illustrate how financial literacy facilitates the relationship between social and human capital, focusing on the economic participation of MSMEs and access to financing.

In addition, the application of Digital Financial Literacy (DFL) within broader

societal and economic frameworks has been linked to improvements in work productivity and individual empowerment. Lestari et al. (2024) explained the advantages associated with training, using the case of employee financial literacy as a driver of productivity, leading to improved organizational performance. In addition, Koskelainen et al. (2023) proposed a detailed research outline on financial literacy in the digital age, calling for a proactive, comprehensive, and responsible approach to advancing financial literacy that leverages technology.

Widarni and Bawono (2021) argue with great conviction that there is an absence of digital equity gaps regarding access, remote learning for students, resources, and longitudinal studies focused on the social dimensions and impact of DFL, straying far from the norm. In opposition, underscored by an African standpoint, Nambie et al. (2025) highlight the effects of Digital Financial Literacy on human capital and economic shifts, emphasising understudied geographic variations.

Given the recent developments and the new focus on preparing a population with skills for digital finance, this systematic review aims to synthesise the available information concerning the impact of digital financial literacy on human capital development. It attempts to compile evidence spanning the years 2010-2024 to identify key processes, outcomes, shortcomings, and other areas that lack focus. With these considerations, the paper helps in formulating DFL-focused

blueprint policies, instructional model frameworks, and construction plans aimed

at fostering the comprehensive development of human capital.

2. Theoretical and Conceptual Background

Digital Financial Literacy (DFL)

As stated by Lyons & Kass-Hanna (2021), DFL combines the capacity to access, comprehend, appraise, and utilize digital financial services and products to make informed decisions enhancing one's financial well-being. It integrates traditional literacy, which encompasses knowledge of financial concepts and management, with digital competencies that involve online navigation, cybersecurity, and the application of new technological innovations in finance (Morgan, Huang, & Trinh, 2019)—in the definition and scope of DFL, Lyons, and Kass-Hanna (2021) highlighted its intricacy in measurement, underscoring that it encompasses multivariate skills of cognition, technology, and behavior. Besides knowledge of the information systems, it also entails assuredness and willingness to act on the information provided. Generally, the primary components of DFL are outlined as follows:

- Financial knowledge: Acquaintance with fundamental concepts such as budgeting, saving, credit, and investment.
- Digital competence: Ability to operate a given device and its associated applications safely and effectively.
- Behavioral aspects: Attitudes and habits concerning managing finances in a digital context (Prasad, Meghwal, & Dayama, 2018; Rahayu et al., 2022).

The growth of DFL aligns with the increasing popularity of digital financial services worldwide, which has both simplified and complicated financial transactions simultaneously (Koskelainen et al., 2023). The wave of new technologies, including mobile banking, digital wallets, and even cryptocurrencies, requires one to learn and adapt on the go due to the constant shift in the financial world. Recent research emphasizes the importance of developing measurement tools and standard guidelines for DFL to capture its multifaceted elements, thereby informing policy and structuring targeted educational interventions (Koskelainen et al., 2023). Furthermore, Choung, Chatterjee, and Pak's studies (2023) connect increased DFL with enhanced financial well-being, emphasizing its significance in personal economic empowerment. Therefore, DFL is pivotal because it combines core digital competencies and financial literacy needed to navigate contemporary financial systems and human capital development.

Human capital theory

Human capital theory regards individuals' knowledge, skills, and abilities as a value that can be created by investing in education, training, or through time gained through experience (Sweetland, 1996). As posited by this theory, this value enhances a person's capability to earn, which in turn translates to better employment, increased earnings, and enhanced economic engagement (Strober, 1990; Fleischhauer, 2007). Essentially, human capital is

defined as the aggregate store of human intellect and skills that fuels prosperity at the individual (micro), organizational, and societal (macro) levels, enhancing economic productivity (Wuttaphan, 2017). For organizations and societies, creating human capital is a key driver of maintaining positive and stimulating shifts in labor supply dynamics.

Human capital theory emphasizes the importance of considering education and continuous learning as means to acquire and enhance one's skills for better career prospects and job effectiveness (Strober, 1990). It is widely recognized, as shown by Marginson (2019), that human capital theory, like any other theory, serves its purpose of developing strategies for workforce planning. However, it falls short of considering social, cultural, and institutional dynamics about the acquisition of skills and economic productivity.

3. Methodology

This investigation employs a systematic review approach to analyse the empirical evidence on the contribution of digital financial literacy (DFL) to enhancing human capital. The review was conducted according to predetermined plans that were meticulously documented to allow for the assessment and reproduction of each Step of the study, ensuring trustworthiness and rigour in determining relevance and analysing the chosen studies. Due to the multidisciplinary nature of the peer-reviewed literature, two primary databases, Scopus and Web of Science, were used as they provide extensive coverage. The search encompassed publications released from 2010 to 2024, which corresponds with the period of the global surge in digital finance and literacy initiatives. The

search strategy included the following keywords and search strings. “ digital financial literacy " OR " digital finance skills " AND " human capital " OR " human development " OR " skills enhancement " AND " financial inclusion " OR " employment " OR " economic participation " Constraints were added to limit results to English peer-reviewed journal articles only. The following criteria were used to select the studies: Empirical studies that received digital financial literacy interventions and reported outcomes related to human capital were considered for selection. Articles published from 2010 to 2024 were selected. All studies presented (quantitative, qualitative, or both) evidence. Research has focused on individuals, institutions, or populations where human capital was assessed through measures such as employability, financial literacy, productivity, or socioeconomic standing. Exclusion criteria: Non-peer-reviewed content, such as editorials and book reviews or grey literature. Publications that focus exclusively on classic financial literacy, devoid of any technology component. Publications are unrelated to the results of human capital development. To construct relevant summaries for each of the included studies, a standardised information data extraction form was developed. A primary iterative coding process based on thematic analysis was employed to identify recurring patterns and salient themes across the literature. The following steps were executed:

- Becoming acquainted with the extracted data and organising the outcomes into preliminary groups.

- Coding of verifiable text segments regarding DFL and human capital linkages.
- Organising codes into more encompassing thematic classes, such as, but not exclusively limited to, decision-making, economic participation, inclusion, and policy actions.
- Constructing lore at the thematic level and interpreting that within the conceptual framework developed earlier on.

4. Results and Thematic Synthesis

From the reviewed empirical research conducted from 2010 to 2025, this thematic synthesis identifies five primary dimensions that delineate how DFL (Digital Financial Literacy) influences the development of human capital. The synthesis reveals both the empowering potential of DFL and the systemic challenges that limit its scope and impact. Each theme analysed constitutes a group of results about the pertinent literature reviewed, framing the impact of DFL in a holistic way.

Theme 1: DFL as a Driver of Financial Decision-Making Skills

Through enhancing digital literacy, an individual's capacity to operate, control, and strategize financial activities improves significantly. This theme emerged strongly from studies focused on MSMEs, youth, and informal sector entrepreneurs who tend to work in constrained environments. Informed by DFL, a person is capable of managing their business and personal finances, engaging in budgeting, saving, investment planning, and avoiding unwise financial practices (Slamet, 2023). In the context of financing, especially when seeking credit or loans, DFL functions as an entrepreneurial enabling gap in human capital (skills and knowledge) and finance (Talip & Wasiuzzaman, 2024). MSMEs

whose owners possess DFL are more likely to embrace digital platforms for cost and benefit analysis, realizing gains in profitability and resilience. In conclusion, this theme affirms that DFL is not only a technological competence but a critical life skill that shapes financial well-being and economic independence.

Theme 2: DFL and Digital Inclusion

DFL is crucial in bridging the digital divide and advancing inclusivity within financial frameworks, particularly among rural, low-income, and vulnerable socioeconomic groups. Accessibility of mobile banking, e-wallets, and fintech platforms is often limited not by availability but by understanding or trust barriers. DFL reduces financial barriers to accessing government services, such as benefits, subsidies, microloans, and insurance policies. In traditionally under-served areas, DFL efforts significantly reduce socioeconomic disparities, particularly among women, older individuals, and new adopters (Mishra et al., 2024). The data highlight that DFL fundamentally enhances digital citizenship and participation in the economy, as users can engage **with and benefit from the services provided.**

Theme 3: DFL and Economic Involvement

Besides individual ease, DFL is important for improving labour productivity and encouraging entrepreneurship, both of which are crucial for further economic progress. In corporate environments, DFL training is associated with improved employee financial wellness, reduced stress, and increased productivity (Lestari et al., 2024). Additionally, DFL is documented to promote entrepreneurial activities in the informal sector and among

self-employed individuals, particularly among young people and women, due to the availability of digital credit and payment technologies. Countries that incorporate DFL into their policies shift their focus toward advanced economic development and innovation, thereby recording higher economic participation and innovation activities, especially in services and small and medium-sized enterprises (SMEs). This theme enhances the DFL's ability to strengthen people's economic engagement and adaptation in response to accessible and digitalized labor markets.

Theme 4: Barriers and Gaps

Access to digital financial literacy (DFL) is unevenly distributed, revealing gaps and barriers on socio-cultural and infrastructural levels. It has become a challenge that accompanies the opportunity, as many women still encounter hurdles in accessing mobile training tools (Firmansyah & Susetyo, 2022). The barriers to entry are far more complex for the elderly, socioeconomically disadvantaged, and rural women due to cultural norms that restrict the use of technology, including financial apps and mobile phones, as well as severe time constraints. Many countries lack a practical educational framework for DFL integration, which leaves many graduates unequipped to manage the various aspects of finances in the real world (Brechko, 2019). There is limited network coverage, a lack of affordable smartphones, and weak cybersecurity, all of which severely limit DFL's reach in underserved areas. Overall, these issues can be addressed from several different angles, including gender-neutral policies specifically designed for women,

investment in infrastructure, and universal access to feminine healthcare all aimed at achieving universal access to DFL.

Theme 5: Integration of Policy with Education

A common thread running through various works is the importance of embedding DFL through education, training, and policy frameworks. Research suggests adding modules of DFL in primary and tertiary education, particularly in economics, civics, and ICT (Widarni & Bawono, 2021). Public and private workforce training programs are beneficial to upskilling staff members, especially in rapidly digitalised sectors. National policies on financial inclusion, youth employment, and digital transformation can further enhance these policies by strategically integrating DFL within the human capital planning and investment framework (Halim et al.). Within this theme lies the argument that DFL should adopt a more holistic and multi-stakeholder approach involving governments, educational institutions, fintech companies, and civil society to foster sustainable digital financial ecosystem development.

Table 1– Literature Review: Digital Financial Literacy and Human Capital Development

5. Discussion

The literature assembled combines DFL as far more than a skill to be gained; it acts as an effective driver for human capital development. An amalgamation of five core ideas reveals DFL as a driver and channel for financial inclusion, digital equity, and socioeconomic empowerment. This analysis addresses these issues and captures the various ways in which DFL

affects, on the one hand, financial and employment activities and, on the other, a country's development objectives.

The studies consistently indicate that DFL has, in this day and age, become a prerequisite 21st-century skill parallel to literacy and numeracy. It enables individuals to interact confidently with banking systems, manage their finances, ascertain financial risks, and make appropriate decisions. DFL promotes financial independence as well as stable income streams for MSMEs, women, and young people (Slamet, 2023; Talip & Wasiuzzaman, 2024). It is crucial to note that the data confirms that DFL's effects impact wider groups than individual finance. As part of a training course specifically designed for organizations, DFL enhances productivity alongside strategic intra-business operations (Lestari et al., 2024). This supports the idea that DFL can be used as a mechanism to fortify one's personal and economic resilience while simultaneously boosting organisational function and competitiveness.

The second key insight is the connection between DFL and digital inclusion. In some lower- and middle-income regions, people are excluded from the formal financial system not just because of restricted access but also due to their inability to use digital tools effectively. DFL then acts as a lever towards greater democratisation of digital payments, credit, and insurance services, which are essential for poverty alleviation and inclusive growth (Yu et al., 2025; Mishra et al., 2024). This evidence supports the argument that DFL is a social leveller, particularly when provided through community-based culture curation, mobile

apps, or women-centred designs. DFL can help eliminate the persistent gaps between men and women, as well as between people living in rural and urban areas, in terms of financial participation.

Improving human capital formation alongside DFL's development is increasingly evident. Individuals' preparedness towards digital jobs, entrepreneurial activities, and technology-based employment opportunities is more favourable with DFL. This is the case in the post-pandemic period with increased remote working opportunities, digital work, and app-based gig economies (Firmansyah & Susetyo, 2022). Furthermore, countries can better utilize their demographic dividend if DFL is prioritized in national skill development frameworks. Through the education system, vocational training, and reskilling initiatives, placing DFL within the human capital framework enables governments to enhance economic agility while safeguarding against future workforce needs.

The literature notes persistent systemic gaps within DFL that hinder access and effectiveness, which, along with its positive attributes, are concerning. These gaps include regional and infrastructural inequities with a greater concentration in rural and remote regions; socio-financial barriers like cultural norms restricting women's financial agency and societal digital illiteracy; institutional inertia, particularly lack of DFL consideration into policy and education frameworks (Brechko, 2019). With these gaps, it is clear that DFL efforts cannot be patchwork. Instead, they need to be integrated into comprehensive frameworks for digital transformation and inclusion,

supported by policy changes, infrastructure for digital access, infrastructural upgrades, affordable access, and investment. Lastly, the synthesis illustrates a broad agreement among researchers and practitioners: There is a need for better alignment between Betoeto and public policy and education frameworks. As Widarni and Bawono contend, DFL ought to be included in all educational and training programs, as well as in employer-sponsored educational development programs. This aligns with the universal demand for rethinking education in the digital era, where advanced financial literacy is recognized as a crucial capability for national growth. The role of collaboration from different stakeholders is also crucial. There is a need for collaboration between DFL interventions and other relevant and culturally appropriate non-profit and private institutions, fintech companies, and universities. Only in that way can DFL attain its objectives of being the actual foundational acceleration of human capital development.

6. Conclusion

In this systematic review, we have examined the Link between digital financial literacy (DFL) and the enhancement of human capital in the digital age. It is based on 25 peer-reviewed articles published from 2010 to 2024. This review suggests that enriched DFL capabilities have a positive impact on financial literacy, improving decision-making, employment, and entrepreneurial opportunities, as well as overall socioeconomic well-being, with the underlying premise of achieving a better socioeconomic status. These findings strongly suggest that DFL plays a crucial role as a catalyst of human capital in

scenarios that require a combination of technology, finance, and DFL. Individuals with the appropriate digital and financial skills stand at an advantage in the current and emerging global economies while also assisting communities in achieving more resilient, community-led transformations that significantly benefit both themselves and their communities financially. The review also argues, highlighting gaps in inequities such as lack of accessible infrastructure digitally, educational resources, skill development, and vocational training, which interconnect to build barriers and worsen socioeconomic status among vulnerable groups, especially women, people living in rural areas, and other marginalised bodies.

Thus, there is an immediate gap that needs to be addressed regarding digital and financial literacy through the implementation of appropriate policies, educational strategies, and collaboration among government, the private sector, academia, and society. To summarise, developing digital skills in finance cannot be taught in isolation; it is a driver of equitable financial opportunities, multi-dimensional development, and empowerment of people. With the incessant advancement of the digital economy, proactive measures must also be taken to equip every individual with the skills necessary to engage fully and meaningfully.

7. Implications

The conclusions drawn from this systematic literature review are significant on both theoretical and practical levels, particularly in the context of advancing the shift toward digital technology, promoting economic inclusion, and strategically developing sustainable human capital.

Theoretical Implications: As highlighted by Strober (1990) and Sweetland (1996), the productivity gains resulting from an investment in education, skills, and knowledge are paramount to the theory of human capital. This review proposes modifying the theory by incorporating digital competencies in finance as critical elements of contemporary human capital, particularly in the context of the modern digital economy. Digital competencies in finance should be considered as a blended or hybrid capability, as defined by Lyons and Kass-Hanna (2021), which combines cognitive, behavioural, and digital aspects. This further strengthens a more comprehensive theoretical framework integrating digital literacy, financial literacy, socioeconomic advancement, and progression. The relationship between access to digital tools, digital fluency, and financial relationships suggests the emergence of digital capital as a valuable complement to human capital in development theory (Koskelainen et al., 2023).

Practical Implications: Employees of government institutions, financial organisations, NGOs, and the educational sector should design DFL programs tailored to the specific needs of micro, small, and medium enterprises (MSMEs), youth, rural women, and community women. As an illustration, Mishra et al. (2024) focus on the impact of DFL on women's empowerment, while Slamet (2023) discusses how MSMEs support their husbands through DFL training. Organizations should incorporate DFL training as part of their corporate training initiatives to enhance productivity and financial well-being. Lestari et al. (2024)] portray the strengthening of employee

performance and organizational outcomes with DFL training. Taking into consideration younger demographics' high engagement with digital content (Ryahu et al., 2022)], the material is best disseminated in areas with low banking services via mobile apps, social media, and gamified content that offer greater digital interaction

Policy Implications: Golden and Cordie (2022) and Harmoko (2021) argue that lifelong financial literacy begins at school and adult education levels and, therefore, needs to be integrated into all levels of learning. There is a need to focus on enabling infrastructure such as internet connectivity, devices, and digital identification infrastructure in rural and underdeveloped areas to ensure that DFL skills are put into practice (Putra et al., 2024; Xu et al., 2024). It is the responsibility of central banks and other supervising bodies to balance policies on digital banking, consumer protection, and microcredit with increasing policy inclusiveness derived from DFL research. Attention must be given to the design, transparency, and access to digital financial services (Frimpong et al., 2022). As DFL advocacy groups and governments work towards improving financial literacy, DFL should be incorporated as a standard unit of measurement, implemented across diverse populations, to enhance tracking, accountability, and trust in results (Lyons & Kass-Hanna, 2021; Marginson, 2019).

8. Future Research Directions

This review has provided directions for advancing research on the relationship between digital financial literacy (DFL) and human capital development. Although DFL is acknowledged, more comprehensive research is needed to

address the identifiable gaps and emerging trends. Understanding the longitudinal impact of DFL on human capital is limited by most studies, which only capture cross-sectional snapshots. To fully understand the long-term impacts of DFL on employment, income mobility, entrepreneurial resilience, and lifelong learning, future research should focus on the long-term effects of DFL interventions using a longitudinal design. These studies would greatly aid in understanding the causation of behavioural changes resulting from enhanced digital financial skills (Yu et al., 2025; Xu et al., 2024). Such designed studies are crucial for evaluating DFL programs targeting low learner levels, including the elderly, marginalized groups, and individuals living in remote rural communities (Putra et al., 2024; Mishra et al., 2024). Further focus should include culturally responsive teaching and low-technology frameworks (community radio, IVR, tools in local languages) and digital trust, language barriers, and other adoption hurdles. There is a growing need to analyse the impact of AI tools, such as chatbots, robo-advisors, and recommendation engines, on users' digital financial behavior as the expansion of AI-powered financial and fintech services continues. If DFL frameworks prepare individuals to engage critically with AI-enabled financial tools, is attention given to privacy, bias, and decision-making implications? The intelligent DFL frameworks focus on adaptive learning and gamification to personalize content, enhance engagement, and deepen investment.

The current research focus on Asia and Africa suggests that future studies should explore geographical, cultural, and sectoral differences in the impacts of DFL. There is

a lack of understanding of how the following mediate the DFL–human capital relationship: regulatory environments, infrastructure, and socioeconomic development levels. The cross-sector variation in DFL requirements is observed among workers in education, health, agriculture, and the gig economy. Lessons from South-South cooperation or comparisons between developing and developed countries could lead to better-designed DFL policies. Given that social inequalities tend to get magnified in digital spaces, further research focusing on the intersectionality of gender, age, disability, and ethnicity is crucial (Choung et al., 2023; Golden & Cordie, 2022). Future research should focus on analysing the barriers to DFL, taking into account the intersectionality of access and effectiveness. Design evaluation frameworks that capture empowerment, agency, and autonomy outcomes beyond those centred on financial considerations.

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Table 1– Literature Review: Digital Financial Literacy and Human Capital Development

S.No	Authors & Year	Study Focus	Methodology	Key Findings	Theme(s) Addressed
1	Slamet (2023)	“Financial literacy impact on human capital in MSMEs”	Empirical, quantitative	DFL improves budgeting, savings, and investment decisions in MSMEs.	Theme 1, Theme 3
2	Talip & Wasiuzzaman (2024)	“Role of human & social capital in MSME finance access”	Quantitative	Financial literacy mediates between social capital and MSME finance access.	Theme 1, Theme 3
3	Widarni & Bawono (2021)	“Human capital and financial literacy in Indonesia”	Conference paper	Human capital and financial literacy combined encourage economic growth.	Theme 5
4	Koskelainen et al. (2023)	“Financial literacy in digital age: research agenda”	Conceptual review	Highlights digital literacy's importance in financial	Theme 1, Theme 2

				behavior research.	
5	Lestari et al. (2024)	“Financial literacy at work & organisational performance”	Empirical	Employee training in financial literacy enhances organisational performance.	Theme 3
6	Korneeva et al. (2020)	“Human capital evaluation in digital economy”	Conceptual	The digital economy requires new metrics for human capital involving digital skills.	Theme 5
7	Koskelainen et al. (2023)	“Digital financial literacy research agenda”	Review	Calls for research integrating digital tools and financial literacy.	Theme 1, Theme 2
8	Nambie et al. (2025)	“Economic transformation and financial literacy in Africa”	Empirical	Financial literacy drives human capital development, aiding economic transformation .	Theme 1, Theme 3
9	Yu et al. (2025)	“Digital financial literacy and rural household income in China”	Quantitative	DFL positively impacts rural incomes by improving financial inclusion.	Theme 2, Theme 3
10	Kumar et al. (2023)	“Skills, DFL, and financial decision making”	Quantitative	DFL enhances autonomy and financial well-being.	Theme 1

11	Prayitno et al. (2022)	“Social capital, entrepreneurship , financial literacy & welfare”	Quantitative	Financial and digital literacy are key for household economic welfare.	Theme 1, Theme 3
12	Al-Shami et al. (2024)	“Financial & digital literacy via social media in small enterprises”	Empirical	Social media usage improves DFL and financial inclusion among batik SMEs.	Theme 2
13	Yadav & Banerji (2023)	“Bibliometric analysis of digital financial literacy”	Review	Mapping research trends and gaps in DFL literature.	Theme 4
14	Brechko (2019)	“Financial and digital literacy as constituents of info society”	Conceptual	Emphasizes foundational role of DFL in modern society.	Theme 4
15	Halim et al.	“Impact of human capital on digital literacy index”	Empirical	Human capital influences digital literacy proficiency.	Theme 5
16	Firmansyah & Susetyo (2022)	“Financial behavior, literacy in digital economy”	Quantitative	Financial and digital literacy jointly shape financial behaviors.	Theme 1, Theme 4
17	Golden & Cordie (2022)	“Digital financial literacy”	Conceptual	Discusses adult literacy programs incorporating DFL.	Theme 5
18	Harmoko (2021)	“Digital literacy improving human resource	Empirical	Digital literacy crucial for workforce	Theme 3, Theme 5

		quality in Indonesia”		quality enhancement.	
19	Xu et al. (2024)	“Digital financial literacy and rural income inequality”	Quantitative	DFL reduces income inequality in rural populations.	Theme 2
20	Mishra et al. (2024)	“DFL impact on women's financial decisions in India”	Empirical	Higher DFL improves women’s financial autonomy and decision-making.	Theme 1, Theme 2
21	Frimpong et al. (2022)	“Financial literacy, access to digital finance & SME performance”	Empirical	Financial literacy increases digital finance use and SME success.	Theme 1, Theme 3
23	Lyu et al. (2025)	“Digital capability, financial literacy & common prosperity”	Quantitative	DFL fosters equitable economic growth and prosperity.	Theme 1, Theme 2
24	Samoilovych et al. (2022)	“Management of human capital in digital economy”	Conceptual	Human capital management strategies must incorporate digital skills.	Theme 5
25	Putra et al. (2024)	“Overcoming barriers to inclusion: financial literacy & digital divide”	Empirical	Addressing financial literacy and digital divide is critical for expanding financial access.	Theme 2, Theme 4

Building Digital Financial Futures: Evaluating CBSE's Financial Literacy Mission for Viksit Bharat @2047

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Abstract

Financial literacy is increasingly recognized as a foundational skill for individuals and nations. India's vision of *Viksit Bharat @2047* (Developed India 2047) emphasizes inclusive growth, digital empowerment, and human capital development. In this context, the Central Board of Secondary Education (CBSE) has launched a national initiative to integrate financial literacy into school education. This paper presents a comprehensive conceptual analysis of CBSE's financial literacy mission, drawing on secondary data (policy documents, media reports, and academic literature). We examine the theoretical underpinnings of early financial education, CBSE's program structure (curriculum, teacher training, partnerships) and how it aligns with national development goals. The analysis explores the psychological, behavioral, and social impacts of school-based financial education, and assesses equity and inclusion considerations (gender, rural/urban, access). Finally, we discuss future enhancements using digital tools, gamification, metaverse/VR, and AI, and we evaluate implications for India's public digital infrastructure and cyber security. The paper concludes with recommendations to strengthen CBSE's mission as a pathway to a financially empowered youth and an inclusive *Viksit Bharat* by 2047. (Lusardi & Mitchell, 2014)

Introduction

Financial literacy – the knowledge, skills, and attitudes required to make informed financial decisions – is critical for economic development. In an increasingly digital economy, citizens must navigate complex financial products and platforms. The Government of India's vision of *Viksit Bharat @2047* (a developed India by the nation's centenary) underscores inclusive, sustainable

growth. Policymakers **recognize** that broad-based financial inclusion – supported by digital public infrastructure (DPI) and an informed citizenry – is key to achieving this vision (The Economic Times, 2025; NITI Aayog, 2023). For example, forums such as the G20 and regulators like RBI have emphasized that financial literacy is essential to make growth “broad-based and equitable,” ensuring every citizen can participate in the economy (Reserve Bank of India [RBI],

2022). India's National Education Policy (NEP 2020) likewise stresses life skills and vocational education at the school level, including financial capability (Ministry of Education, 2020). In line with this, CBSE has introduced financial literacy into its curriculum framework and teacher development programs. Between 2020 and 2023, CBSE launched skill modules for classes VI–VIII and senior secondary electives on financial markets, while partnering with SEBI and NPCI for training and content (CBSE, 2023). These efforts aim to equip young Indians with basic financial planning, digital payments literacy, and fraud awareness – all integral for effective use of India's digital financial infrastructure such as Aadhaar and UPI (NPCI, 2024). Yet the success of this mission depends on several

Literature Review

Early financial education is widely endorsed by scholars and international organizations. Lusardi and Mitchell (2014) argue that a well-designed financial education curriculum enables individuals to navigate the complexities of the financial system, thereby enhancing productivity and adaptability. Moscarola and Kalwij (2021) similarly emphasize the importance of introducing financial concepts from a young age to help individuals effectively manage personal finances and contribute to economic well-being. Empirical studies consistently link youth financial education to positive outcomes: adolescents exposed to financial literacy curricula tend to demonstrate improved budgeting, saving, and risk-management skills, and are better prepared to make adult financial decisions. For example, Letkiewicz and Fox (2014) found that financial education enhances

factors: the curriculum's theoretical soundness, pedagogical approaches, and implementation reach; the psychological and social impact on students; and issues of equity. Studies have highlighted disparities in financial literacy between urban and rural students and gender gaps in access to digital finance (UNICEF, 2023). To fully leverage emerging technologies such as digital payments, the metaverse, and AI, CBSE's program must continually adapt. This paper examines CBSE's financial literacy mission through multiple lenses – educational theory, policy alignment, empirical evidence, and equity – to assess its role as a foundation for India's 2047 goals.

asset accumulation and informed decision-making among youth, while Fernandes, Lynch, and Netemeyer (2014) showed

through a meta-analysis that school-based programs significantly improve financial behaviors and attitudes.

The theoretical foundation of financial education is informed by developmental and social psychology. Financial socialization theory posits that children learn money-related attitudes and behaviors through interactions with parents and social environments, positioning families and schools as key agents in shaping financial mindsets (Gudmunson & Danes, 2011). Cognitive-developmental theories, such as Piaget's stages of development, suggest that middle-school students are cognitively equipped to understand fundamental

financial concepts like saving, budgeting, and interest—especially when these are taught through interactive, student-centered methods. Bandura’s (1997) concept of self-efficacy also applies to financial behavior, highlighting that structured financial education can boost confidence and lead to lasting behavioral changes. This implies that financial education must focus not only on imparting factual knowledge, but also on fostering self-control, delayed gratification, and healthy social norms around money (Shim et al., 2010).

Contemporary literature highlights best practices in pedagogy: experiential learning, interactive tools, and the integration of digital platforms. Compen, De Witte, and Schelfhout (2019) emphasize that teacher training and motivation are central to effective financial education delivery. Simulations, games, and real-world projects have been found to engage students more deeply than traditional lectures. Sustained school-based interventions that are aligned with students’ real-life experiences tend to yield stronger knowledge retention and behavior change (Kaiser & Menkhoff, 2017).

Public policy further underscores the societal importance of financial education. India’s *National Strategy for Financial Education* (NSFE), originally released in 2012 and revised in 2020 by the Reserve Bank of India, outlines a national framework to integrate financial literacy into school

curricula up to Class XII (Reserve Bank of India [RBI], 2020). The NSFE’s goals include raising awareness of financial products, shaping attitudes, and empowering citizens to make informed financial decisions. A high-level inter-agency committee involving the Ministry of Education, RBI, SEBI, CBSE, and NCERT was tasked with implementation. While rollout has been gradual, CBSE’s current efforts—including financial literacy modules and teacher training partnerships—reflect the realization of these national policy ambitions (Ministry of Education, 2020).

In summary, financial education serves as a vital capability-building tool with wide-ranging developmental, behavioral, and economic benefits. The combination of knowledge, positive attitudes, and applied skills aligns with broader human capital and social learning frameworks. In India’s increasingly digital financial landscape—shaped by fintech, UPI, and Aadhaar-enabled services—early and inclusive financial education is essential. Nonetheless, gaps remain in implementation and outcomes. Scholars continue to call for longitudinal data and tailored interventions that address disparities by gender, region, and socioeconomic background. This review provides the foundation for examining how CBSE’s financial literacy initiative aligns with educational theory, policy frameworks, and India’s Vision 2047 goals.

Conceptual Framework

The school-based financial literacy education as an ecosystem comprising

interconnected components. Key inputs include curriculum modules (such as CBSE's financial literacy content), teacher capacity (training, motivation, and access to resources), and an enabling policy and technological environment (e.g., the National Strategy for Financial Education, and digital public infrastructure like UPI and Aadhaar-enabled platforms). The educational process involves pedagogical approaches such as classroom instruction, experiential learning projects, and digital simulations, supported by reinforcement from family and community actors. These processes aim to generate student-level outcomes including increased financial knowledge, skill development (e.g., budgeting, saving, understanding interest), and attitudinal shifts—such as improved confidence and ethical attitudes toward money use.

At a societal level, these educational outcomes contribute to broader developmental goals: increased financial inclusion (greater use of formal financial services), enhanced economic well-being (through better savings and investment practices), and stronger resilience against digital and offline financial fraud. However, several moderating factors—such as gender norms, rural infrastructure disparities, and unequal access to digital tools—may influence these relationships and outcomes (OECD, 2020).

This conceptual framework is informed by multiple theoretical perspectives. Human

capital theory posits that investments in education yield long-term returns through improved productivity, financial autonomy, and entrepreneurial potential (Becker, 1993). Social Cognitive Theory, particularly Bandura's concept of self-efficacy, suggests that financial skills and confidence developed in early years shape adult financial behavior (Bandura, 1997). Behavioral economics further emphasizes the importance of addressing cognitive biases—such as impulsive spending, short-termism, or overconfidence—through repeated practice, behavioral nudges, and habit formation (Thaler & Sunstein, 2008). In the context of the 21st century, digitalization demands that financial education extend beyond traditional topics to include cybersecurity awareness, fraud prevention, and familiarity with digital platforms such as Aadhaar-based authentication and UPI-enabled payments (NPCI, 2024).

Finally, an equity-centered lens is crucial to ensure that girls, rural students, and marginalized communities benefit equally from financial literacy programs. Tailored strategies—such as context-sensitive examples, multilingual content, and offline or blended access models—can help bridge the digital and educational divide, ensuring inclusive development and equitable learning outcomes (UNICEF, 2023).

Analysis and Discussion

CBSE's Financial Literacy Mission: Structure and Goals

CBSE's financial literacy initiatives encompass both curricular integration and teacher capacity-building. On the curricular front, the Central Board of Secondary Education (CBSE) introduced *Financial Literacy* as a formal skill module for middle-school students (Classes VI–VIII), as outlined in Circular No. Skill-48/2023 (CBSE, 2023a). This module is one of 33 short-duration skill courses, each requiring 12–15 hours, with 70% of instructional time dedicated to hands-on learning. Schools are encouraged to offer these modules flexibly—during "bagless" days, activity periods, or breaks—without the need for specialized labs or infrastructure, thereby easing adoption. For example, students might complete mini-projects on budgeting or banking under teacher supervision, using available online and print resources. Furthermore, CBSE has proposed optional vocational awareness modules on topics such as financial markets, artificial intelligence, and coding to be introduced during Grades VI–VIII (CBSE, 2023a). At the secondary level, CBSE offers more structured financial education pathways. Senior students can opt for vocational subjects like *Financial Market Management* (FMM), which are detailed on the official CBSE academic portal (CBSE, 2024). Additionally, commerce stream subjects such as *Business Studies* and *Economics* introduce financial concepts (e.g., budgeting, banking, capital markets), though the inclusion varies by textbook and region. Importantly, CBSE does not levy additional fees for schools introducing middle-level skill subjects, thereby lowering institutional barriers to participation. The 2020 policy circular also emphasizes vertical alignment: a student introduced to *Financial Literacy* in Grade VI can progressively engage with higher-level finance subjects in Class XI or

XII (CBSE, 2020).

Beyond curriculum, CBSE has partnered with financial regulators and industry leaders to support teacher capacity development. Its Directorate of Skill Education has collaborated with organizations like Kotak Mahindra Asset Management Company (AMC) and the Securities and Exchange Board of India (SEBI) to deliver teacher training. A notable initiative was the "Seekho Paiso Ki Bhasha" campaign, launched in September 2023 with Kotak Mahindra AMC, aiming to train 75,000 CBSE-affiliated teachers—of which 50% were women—on foundational financial and investment concepts (NDTV, 2023). As part of this mission, 1,000 workshops were organized across 100 locations, focusing on practical topics such as savings, budgeting, and responsible investing. In November 2023, CBSE released official notifications launching Financial Literacy and Digital Tools Sensitization Programmes nationwide, with training delivered by SEBI-certified experts (CBSE, 2023b). These 2-hour workshops, hosted at designated "Hub" schools in each CBSE region, emphasized topics including digital payment safety, cyber fraud prevention (e.g., phishing awareness), and financial planning. All participating teachers received free certification, underscoring CBSE's commitment to teacher empowerment as a strategy for large-scale financial education.

These efforts align with India's broader financial inclusion and investor protection goals. By integrating SEBI's regulatory guidelines—such as the *Investor Education and Awareness* mandate under the SEBI (Mutual Funds) Regulations, 1996—CBSE's school-based programs become part of a larger national financial literacy ecosystem (SEBI, 2022). Moreover, the emphasis on cybersecurity and ethical digital finance responds to contemporary risks in virtual

financial environments. CBSE's alignment with NEP 2020 further reinforces its framing of financial literacy as a "life skill" essential for 21st-century learners and a pillar of Atmanirbhar Bharat and Viksit Bharat 2047 goals (Ministry of Education, 2020). Financially literate students are better

equipped to manage personal finances, utilize government schemes like Direct Benefit Transfers, and participate meaningfully in India's evolving digital economy.

Delivery Mechanisms and Alignment with DPI

CBSE's financial literacy approach actively leverages India's rapidly evolving digital public infrastructure (DPI). Curriculum materials for skill modules are published online in accessible formats, described as "simple language with activity-based learning," enabling schools to access content without incurring additional costs (CBSE, 2023). Digital tools are also central to teacher training. CBSE's sensitization programs not only address financial concepts but also include training on digital platforms—such as online registration portals, virtual classroom tools, and the safe use of digital payment systems. A key objective is to equip teachers to identify and prevent mobile banking fraud and to help them guide students on digital financial safety (NDTV, 2023).

India's DPI ecosystem—comprising Aadhaar (biometric identity system), Unified Payments Interface (UPI), and Account Aggregators—has transformed access to financial services. Aadhaar-enabled Know Your Customer (e-KYC) processes have dramatically reduced onboarding friction, facilitating inclusion for over 600 million Indians who now use formal financial services (Mehrotra & Gopalan, 2023). In 2024 alone, UPI processed more than ₹245 trillion (approximately USD \$3 trillion) in

transactions, making it one of the largest real-time payment systems globally (NPCI, 2024). As a result, digital financial literacy—once considered an advanced skill—is becoming as essential as foundational competencies like reading and arithmetic.

CBSE's content is gradually responding to this shift. While current skill modules primarily address foundational topics such as saving, budgeting, and the basics of banking, recent notifications mention training teachers in the use of digital tools and the importance of cybersecurity in preventing digital fraud (CBSE, 2023). Future integration of DPI-related content—such as explaining Aadhaar-enabled payment systems or demonstrating how UPI app's function—could help bridge the gap between school education and real-world financial behaviors. However, a critical challenge remains: digital exclusion. Despite DPI's expansive reach, millions of Indians still lack access to smartphones or stable internet connections, especially in rural and economically marginalized communities (UNICEF, 2023). To achieve truly inclusive financial education, CBSE must therefore adopt a differentiated delivery strategy. This includes developing low-tech or offline options—such as paper-based modules, village-level workshops, and feature-phone

demonstrations—alongside high-tech digital platforms.

Encouragingly, the Government of India has introduced UPI for feature phones (UPI123Pay) and is piloting offline UPI payments to support financial inclusion among populations without smartphones or internet access (Reserve Bank of India [RBI], 2022). CBSE's mission can align with these efforts by teaching basic digital

financial hygiene: how to safeguard Aadhaar-linked accounts, create secure UPI PINs, and recognize digital fraud—even for students in low-connectivity environments. Such knowledge not only supports individual safety but also strengthens India's broader goal of building digital citizens equipped for a modern economy.

Psychological, Behavioral, and Social Impacts

School-based financial education has multidimensional effects—psychological, social, behavioral, and cognitive. Psychologically, it builds financial self-efficacy: students gain confidence managing allowances, setting savings goals, and handling money through simulations or real-life tasks. This exposure fosters discipline, goal-setting, and delayed gratification, which are key developmental traits (Bandura, 1997; Shim et al., 2010). Behavioral theories suggest that such early training helps students form durable mental models of responsible financial behavior, potentially reducing risks of future debt, overspending, or poor investment decisions. Empirical studies confirm that adolescents who receive financial education are more likely to engage in saving behavior and less likely to incur high-interest debt as young adults (Shim & Serido, 2011; Swiecka et al., 2020). Financial literacy also has strong social effects. Students who learn money-management can influence their families and peers. In the Indian context, where financial topics are often avoided in everyday conversation, schools can help normalize open, informed discussions about money across genders and socioeconomic backgrounds (UNICEF, 2023). By teaching children how to talk about budgeting or digital

payments, these programs create ripple effects in homes and communities. One especially critical social dimension is gender empowerment. In India, traditional roles often leave girls less informed or involved in financial decisions. Reports indicate that over 80% of Indian women lack adequate financial literacy, and approximately 62% do not have independent bank accounts (Bansal & Kumari, 2023; RBI, 2021). Gender gaps in financial access and knowledge are both structural and cultural. CBSE's initiative to ensure 50% of teacher training participants are women (NDTV, 2023) represents a progressive step. Mixed-gender classrooms engaging in interactive financial education—such as managing a mock household budget or using a UPI demo—can challenge stereotypes and foster inclusive learning. Experts emphasize that curricular content should be gender-sensitive and encourage girls to take leadership in financial tasks (OECD, 2020). Financial education also supports rural inclusion. Although digital tools like UPI and Aadhaar have expanded banking access in remote areas, knowledge gaps persist. Without targeted interventions, rural students may remain unfamiliar with even basic concepts such as saving accounts, interest, or financial fraud (UNICEF, 2023). CBSE's rollout of financial literacy modules in affiliated rural schools has the potential to

bridge this gap. However, equitable delivery requires contextual adjustments: community workshops, content in regional languages, and collaborations with local banks. Linking these efforts with national inclusion programs such as the Pradhan Mantri Jan Dhan Yojana (PMJDY) could enhance social impact, particularly in encouraging households to open and actively use formal bank accounts (Ministry of Finance, 2022). There is also a community-level impact. In India, household decisions regarding education, gold purchases, or micro-loans are often made collectively. Financially literate youth can contribute to such decisions, improving family-level financial behaviors. Anecdotal evidence from educational NGOs suggests that students often relay what they learn to their families—serving as “knowledge multipliers,” especially in areas with low adult

Equity and Inclusion Considerations

To fulfill its developmental mandate, CBSE’s financial literacy mission must explicitly prioritize equity. As previously noted, gender disparities remain a significant concern. Research consistently shows that boys tend to self-report higher confidence and readiness in financial decision-making compared to girls, even when objective performance levels are similar (OECD, 2020). This gap stems from a mix of cultural norms, lack of role models, and unequal opportunities. Consequently, curricular content should be designed to empower girls—for instance, by incorporating case studies featuring women entrepreneurs, encouraging female participation in stock market simulations, and ensuring the use of gender-neutral language. CBSE’s current initiative to ensure that 50% of trained

financial literacy (Save the Children India, 2022). Over time, this can build social capital and enhance trust in formal financial systems among underserved populations.

Finally, from a behavioral economics perspective, financial literacy strengthens cognitive skills such as numeracy, critical thinking, and logical reasoning. Analyzing interest rates, comparing loan terms, or participating in mock markets deepens understanding of economic principles and decision-making strategies. These skills build human capital, contributing to broader developmental goals. In essence, school-based financial education produces returns beyond finance—cultivating informed, disciplined, and empowered citizens aligned with the aspirations of Viksit Bharat 2047 (NITI Aayog, 2023).

teachers are women (NDTV, 2023) is a step in the right direction. However, more targeted interventions are needed. Outreach to girls’ schools and strategic alignment with national schemes such as Beti Bachao, Beti Padhao could reinforce this goal, ensuring that every girl student benefits equally from the curriculum (Ministry of Women and Child Development, 2022).

Addressing rural–urban divides is equally critical. While urban schools are typically better resourced and quicker to adopt new modules, rural schools often face barriers such as limited internet connectivity, insufficient teacher training, and infrastructure gaps. To prevent such structural inequalities from widening, CBSE should issue flexible implementation guidelines. In low-connectivity regions, skill modules could be delivered through printed workbooks, community radio, or teacher-facilitated discussions. Partnerships with local banks, self-help groups, or postal

agents could offer practical demonstrations of banking or digital payments—even in areas without digital infrastructure. Existing hub-and-spoke training models, where “Hub Leader Schools” train others in the region, should ensure rural representation in teacher nominations (CBSE, 2023). Where needed, mobile training teams or satellite video lessons (like those used in DIKSHA or SWAYAM PRABHA platforms) can expand outreach. Crucially, CBSE should collect disaggregated monitoring and evaluation data—by region, gender, and school type—to identify implementation gaps and guide corrective action.

Inclusion of students with disabilities is another dimension of equity. Financial education content must be available in accessible formats—including large-print materials, audio lessons, and tactile or interactive aids—in line with national inclusive education guidelines under NEP 2020 (Ministry of Education, 2020). Although current CBSE documents do not explicitly outline such provisions for financial literacy, these can be integrated using frameworks like the Universal Design for Learning (UDL) and inclusive curriculum strategies already promoted in teacher education modules. Since India’s

Digital Tools, Gamification, and Future Technologies

CBSE’s curriculum can be greatly enhanced by modern digital pedagogies. Gamification and virtual simulations are promising avenues. For example, game-based learning can make abstract financial concepts concrete. The metaverse and virtual reality (VR) offer novel possibilities: in a VR

Digital Public Infrastructure (DPI)—such as Aadhaar, Jan Dhan, and UPI—aims to reach “last-mile” populations, school-based literacy efforts must mirror that inclusivity, ensuring that no child is left behind due to socioeconomic, gender, or physical barriers.

The broader theme of financial inclusion ties literacy to practical participation in formal economic systems. As emphasized by The Economic Times and national policy think tanks, India’s vision of Viksit Bharat @2047 hinges on integrating excluded groups—especially women, rural populations, and informal workers—into formal finance (Mehrotra & Gopalan, 2023; NITI Aayog, 2023). This implies that financial education in schools must be applied and contextualized, not merely theoretical. For instance, CBSE can design class exercises around household budgeting that incorporate knowledge of government welfare schemes (e.g., subsidies under PM Ujjwala Yojana or loans under Mudra Yojana). This alignment would ensure that literacy translates into inclusion, equipping students to engage with India’s expanding ecosystem of digital public goods.

“virtual bank,” students’ avatars could practice tasks like opening accounts, calculating interest, or navigating a stock trading game. AR Insider highlights how immersive tech can make finance “not tedious” but exploratory: avatars in virtual banks might collect “information orbs” about saving and investing, and role-playing games could allow students to act as bank tellers or small-business owners managing

loans. Fidelity Investments’ metaverse projects demonstrate such ideas: students could explore a branded virtual environment learning about mutual funds through interactive displays.

These approaches have cognitive benefits: gamified challenges reinforce engagement and retention. Studies in other contexts show that children using finance apps and games score higher on knowledge tests than control groups. CBSE could pilot digital games (for example, online quizzes, “financial literacy board games”) or collaborate with edu-tech startups to localize such tools. Even simple digital simulations (spreadsheet budgeting exercises, mobile apps like RBI’s *Abhiyanta* game) can be integrated into classrooms. Importantly, these tools can adapt to students’ levels and provide instant feedback, a boon for personalized learning.

Artificial intelligence (AI) can also contribute. Adaptive learning platforms could adjust difficulty based on student responses, or chatbots could role-play financial scenarios (e.g. a virtual advisor helping a student plan college expenses). Data from these interactions could inform teachers where students struggle. AI-driven analytics, consistent with the conference’s theme of digital literacy, may reveal which topics need more classroom emphasis. For instance, if an AI module finds many students miscalculate simple interest, educators can address that gap. Care is needed, of course, to safeguard data privacy and guard against bias, but if managed well, AI tools align with SDG goals of quality education and innovation.

However, digital solutions must be inclusive. As the DPI discussion noted, cyber-security is a growing concern. Engaging technologies must come with digital hygiene training. CBSE’s teacher programs already cover avoiding phishing and securing online payments. Future modules should include basics of cybersecurity (strong passwords, recognizing fraud), reinforcing that as we adopt VR or apps, safety is paramount. Additionally, gamified content should be culturally sensitive and available in regional languages to reach diverse learners.

Looking further ahead, the *metaverse* could open unique financial literacy spaces. Imagine a virtual India-centric simulation: students from different states meet in a digital marketplace where they must earn and spend virtual rupees, negotiate trades, and file virtual taxes. Such environments can incorporate regulatory lessons (e.g. why taxes fund schools) and ethical lessons (fair trade, lending practices). Ethical considerations and regulations can be woven in – for example, teaching about KYC and privacy in a VR setting reflects the conference sub-theme on ethics in virtual finance. Indeed, institutions must prepare for increased cyber-risk in immersive worlds: avatars can be hacked, funds stolen, so curricula must evolve to cover metaverse safety just as they cover online banking fraud today. The ongoing CBSE emphasis on “cyber fraud” suggests this will expand into new domains.

In summary, digital and futuristic tools can greatly enhance engagement and outcomes of financial education, provided they are

implemented thoughtfully with an eye to equity and security.

Recommendations

Based on the above analysis, we offer the following recommendations to strengthen CBSE's financial literacy mission:

1.1. Integrate across curriculum: Move beyond optional modules to incorporate financial concepts in mainstream subjects. For example, incorporate examples of budgeting in mathematics or case studies of entrepreneurship in social science. This ensures all students, regardless of elective choices, gain baseline financial understanding.

1.2. Expand teacher training and resources: Continue large-scale sensitization (e.g. Kotak SEBI workshops) and integrate financial literacy in teacher education programs. Ensure every CBSE teacher – not just those in commerce streams – has basic training. Provide online micro-credentials in financial education, and update modules annually to reflect new technologies (digital lending, fintech innovations). As research shows, “teacher training is vital for successful implementation”, so invest in capacitating educators nationwide.

1.3. Focus on experiential, project-based learning: Emphasize hands-on activities (70% of module time as per policy). Schools could run mock stock markets, savings clubs, or budget-planning competitions. Leverage local context – e.g. rural schools can study cooperative societies and urban schools examine stock investing. Integrate

family and community projects (e.g., design a family budget plan with parents) to reinforce learning. Such experiential learning aligns with evidence that interactive methods improve attitudes and self-efficacy.

1.4. Utilize digital platforms and gamification:

Develop or license engaging apps and games tailored to India's curriculum. For example, CBSE could launch a “Financial Literacy Olympiad” on its e-learning portal, using quizzes and badges. Incorporate simple blockchain or VR demos where feasible. Pilot projects can test scalability – for instance, an AR game where students earn virtual currency for learning about provident funds. Partnerships with ed-tech firms can bring innovation, but must ensure access for schools with limited connectivity (offline versions, paper kits).

1.5. Leverage DPI and public campaigns:

Align financial literacy content with national digital initiatives. For example, teach students how to open a Jan-Dhan account or use a BHIM UPI app, possibly through a demo day with local banks. Tie lessons to civic sense and national development – reinforcing PM Modi's message that “education and skills” must serve nation-building. Use social media and competitions (e.g. financial literacy hackathons, inter-school debates on fintech ethics) to excite the *Amrit generation* about money matters.

1.6. Ensure inclusivity and outreach: Monitor and address gender/rural gaps by setting targets (e.g., at least one trained female teacher per school, special outreach in rural

hubs). Produce materials in regional languages and Braille. For remote schools, use radio or community education models. Offer mobile vans or kiosks that tour villages with financial literacy demos. Collaborate with schemes like *Gramin Dak Sevaks* or *ASHA workers* to disseminate simple financial tips to families. By broadening reach beyond elite urban schools, CBSE can fulfill the “inclusive growth” mandate of *Viksit Bharat*.

existing mission is a strong foundation; these enhancements will ensure it translates into real-world readiness and progress toward *Viksit Bharat@2047*.

1.7. Embed cybersecurity and ethics training:

Given rising cyber threats, make digital safety an explicit part of every financial lesson. For example, when teaching online banking, also teach safe password practices. Simulate phishing emails in class to develop critical awareness. Include ethics discussions on topics like debt responsibility or misinformation about quick-rich schemes. These tie into the conference theme of *Ethics & Regulation in Virtual Finance*.

1.8. Evaluate and adapt: Conduct regular assessments (like the National Financial Literacy Assessment Test by NCFE) to measure program impact on knowledge and behavior. Use data to refine content and pedagogy. Engage academic partners (universities, NCERT) to study long-term outcomes. A data-driven approach – tracking which initiatives most effectively change attitudes – will help CBSE scale up best practices and identify gaps.

By implementing these strategies, CBSE can deepen its role as a catalyst for financial empowerment in schools. The board’s

Conclusion

Financial literacy in school is not a luxury but a necessity for India's future. CBSE's recent initiatives – skill modules, teacher training, partnerships – represent an important stride toward equipping young Indians with essential money management skills. These efforts align with national goals of broad-based financial inclusion and digital empowerment. Yet, success hinges on effective execution and continuous innovation. This review highlights that theory and evidence support early, experiential financial education to shape positive long-term behaviors. The psychological and social dividends are high – financially literate youth become confident earners, savers, and investors who can contribute to economic growth and stability.

Challenges remain in ensuring equity (gender/rural/digital divides) and relevance (keeping pace with fintech and cyber risks). By embracing technology (AI, metaverse, gamification) while reinforcing ethics and accessibility, CBSE can make financial literacy both **engaging** and **inclusive**. The journey toward *Viksit Bharat@2047* requires a citizenry that is not only skilled but also financially savvy. Schools are the natural incubators for this capability. With sustained policy support and innovative implementation, CBSE's financial literacy mission can lay the groundwork for a generation that manages money wisely and drives India's development. (OECD, 2020)..

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Financial Literacy to Empower Women: A Systematic Review

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Abstract

Financial literacy is also an important factor that empowers women by enabling them to make effective finance choices and live financially independent lives and improve their future sources of income. The paper is a review of literature concerning financial education among women; it looks into the empowering nature of financial education on women, as well as the existence of certain barriers that continue to influence access and performance. The studies keep concluding the same matter, that when the financial literacy of women increases, they tend to practice positive financial habits, including saving, spending money according to a monthly plan, investments, and retirement planning their financial future, which are not only beneficial to individuals but also towards household and general community economic growth. Irrespective of these advantages, women are known to have certain bottlenecks like social-cultural norms, low level of formal education, poor accessibility to monetary institutions and psychological issues like risk aversion and low self-confidence. Such interventions as education, especially when they are community-based and focused on women needs, combined with the use of mentors and digital financial tools, are effective to create financial capability and help instil a long-term behaviour change. The study has found that financial literacy can be a critical tool of gender equality and economic empowerment and requires a combination of context-relevant features into financial literacy education that target the structural and individual impediments.

Introduction

The basic component of women's empowerment is financial literacy because it teaches women to make well-informed monetary decisions. Economic evolution requires financial literacy to become a critical factor in economic success because women experience exclusive financial barriers that create their unique challenges. Acquiring financial concepts about budgeting, saving methods, investments, credit management, and retirement planning leads women toward financial independence and security. The knowledge of finance that women possess benefits both their empowerment and economic development growth throughout society. Women who master financial education become better economic contributors to family stability and reduce poverty while establishing sound financial practices for future generations. Women's worldwide financial literacy rates remain low because of structural obstacles, social-cultural limitations, and insufficient financial education access. Understanding financial matters proves vital when addressing the financial differences between women and men in decision-making processes. The average level of financial confidence among women remains below that of men, alongside women showing stronger risk adversity because they have less access to financial service opportunities. Gender inequality in financial literacy develops because of these factors, thus producing higher financial risk, lower savings performance, and reduced investment activity participation. The elimination of financial disparities needs collaboration from public servants, financial institution representatives, educational organizations, and community-based initiatives that seek to raise women's financial capabilities and

choice-making abilities. Over the last several decades, global initiatives have been implemented to boost female financial literacy through education sessions, digital monetary tools, and governmental policies. Digital financial inclusion specifically has become instrumental in closing the financial knowledge gap because mobile technology enables women to obtain banking services, credit facilities, and investment platforms.

Review of Literature

Women's empowerment research attributes its progress to several essential factors according to existing literature. Several research investigations stress that financial education theories, specifically behavioral finance and human capital theory, direct women's choices about financial matters. The research done by Lusardi and Mitchell (2014) shows that financial education directly impacts long-term security results. Sexual orientation differences in financial wisdom result in higher economic participation rates, according to OECD analysis (2018). Financial education programs show evidence that these programs lead women to invest more and build more significant assets. Social status, alongside cultural practices and gender role beliefs, creates substantial obstacles for women to learn about financial matters. Agarwal et al. (2017) researched how developing countries face financial service obstacles because of societal restrictions. Modern technology's expansion has created digital banking systems that require digital financial literacy for women to achieve economic empowerment. Mobile banking applications and online financial programs the World Bank (2020) runs have enhanced financial access for isolated women. Through their financial

literacy programs, governments and NGOs have directed their efforts at teaching women financial skills. According to Atkinson and Messy (2013), microfinance institutions and self-help groups effectively teach financial principles to women while granting them autonomy. The relationship between women's economic empowerment and financial literacy is clearly established according to Financial Literacy and Economic Empowerment Studies. According to Hung, Yoong, and Brown (2012), women with substantial financial literacy tend to pursue savings opportunities, investment ventures, and entrepreneurial activities. Research shows that specific financial education programs boost women's financial decision-making ability and confidence (Atkinson & Messy, 2013). The multiple challenges women face keep them from achieving financial literacy despite its advantages. Allen, Demirgüç-Kunt, Klapper, and Peria (2016) establish that women face challenges because of societal customs, restricted financial education programs, and limited banking experience. Female financial conduct and the tendency to avoid risks limit women's financial empowerment. Financial literacy intervention programs for women produce inconsistent outcomes based on program assessments. According to Fernandes, Lynch, and Netemeyer (2014), financial education programs succeed at enhancing knowledge, but they cannot always ensure lasting behavioral modifications. Combining financial education with practical tools, mentorship services, and financial services access creates successful sustainable empowerment programs (Seshan & Yang, 2014). Digital financial literacy increased in importance in recent years alongside technological

developments. Mobile banking, along with fintech innovations, help promote financial inclusion for women, especially in developing countries, according to the research by Demirgüç-Kunt et al. (2018). The digital landscape helps women gain better control over their financial matters since it eliminates geographical limitations in banking services.

Research Methodology

In a bid to ensure transparency of methods, reproducibility of findings and thorough reporting, the current systematic review strictly follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. PRISMA offers an international and recognized outline that processes efficacy and reproducibility of conducting reviews and synthesis of prior research, especially those related to policy-relevant and policy-recommendation reviews regarding evaluating socially important topics like financial literacy and women empowerment. It involves four main steps including identification, screening, eligibility, and inclusion of the corpus of literature that are aimed at further narrowing down the literature corpus as means of producing a high-quality synthesis.

Identification Phase

The identification process consisted of a well-organized systematic search through the literature on various scholarly databases to guarantee the scope and depth of search. In particular, the four significant scholarly repositories were accessed, namely, Scopus, Web of Science, PubMed, and Google Scholar. Such databases have been chosen due to their vast scope of the coverage of peer-reviewed articles on the topics of social sciences, economics,

public health, and development studies. A comprehensive search terms and Boolean combination were prepared to retrieve relevant literature. Keywords were: but not limited to: financial literacy, women empowerment, gender equality, financial education and female financial inclusion and, women and economic development. Controlled vocabulary as well as free-text terms was used in order to enhance the thoroughness of the search. The number of records that was retrieved in each of the databases was carefully tabulated and reported to enable the traceability and replication.

Screening Phase

At the screening stage, export of records retrieved to reference management software (e.g. EndNote or Zotero) was performed to streamline the organization and de-duplication. Duplicated entries between databases had been automatically and manually discovered and eliminated. This number of duplicates removed was recorded so as to bring in transparency in the filtration process. After removal of duplicates, the articles that were left were screened initially in terms of their titles and

Inclusion in Final Synthesis

During the ultimate stage of inclusion, a number of the researches that fulfilled the entire eligibility conditions was determined. Such studies were used to make the qualitative synthesis of findings. Where the quantitative data could have been extracted and related in a statistical way, the results were also presented separately on the number of studies considered in the quantitative synthesis (meta-analysis). This is a systematic process that will guarantee that the resulting synthesis is methodologically sound, comprehensive and of high

abstracts of the articles to filter irrelevant works. At this point, only articles that have not met the inclusion criteria, including those that were not relevant in both financial literacy and women empowerment or those that were merely theoretical without any empirical analysis, were removed. The reasons that led to the articles being excluded were also recorded, giving explicit enumeration of how many records were omitted and specific reasons as to why an article had to be omitted given that this would increase the auditability of the screening process.

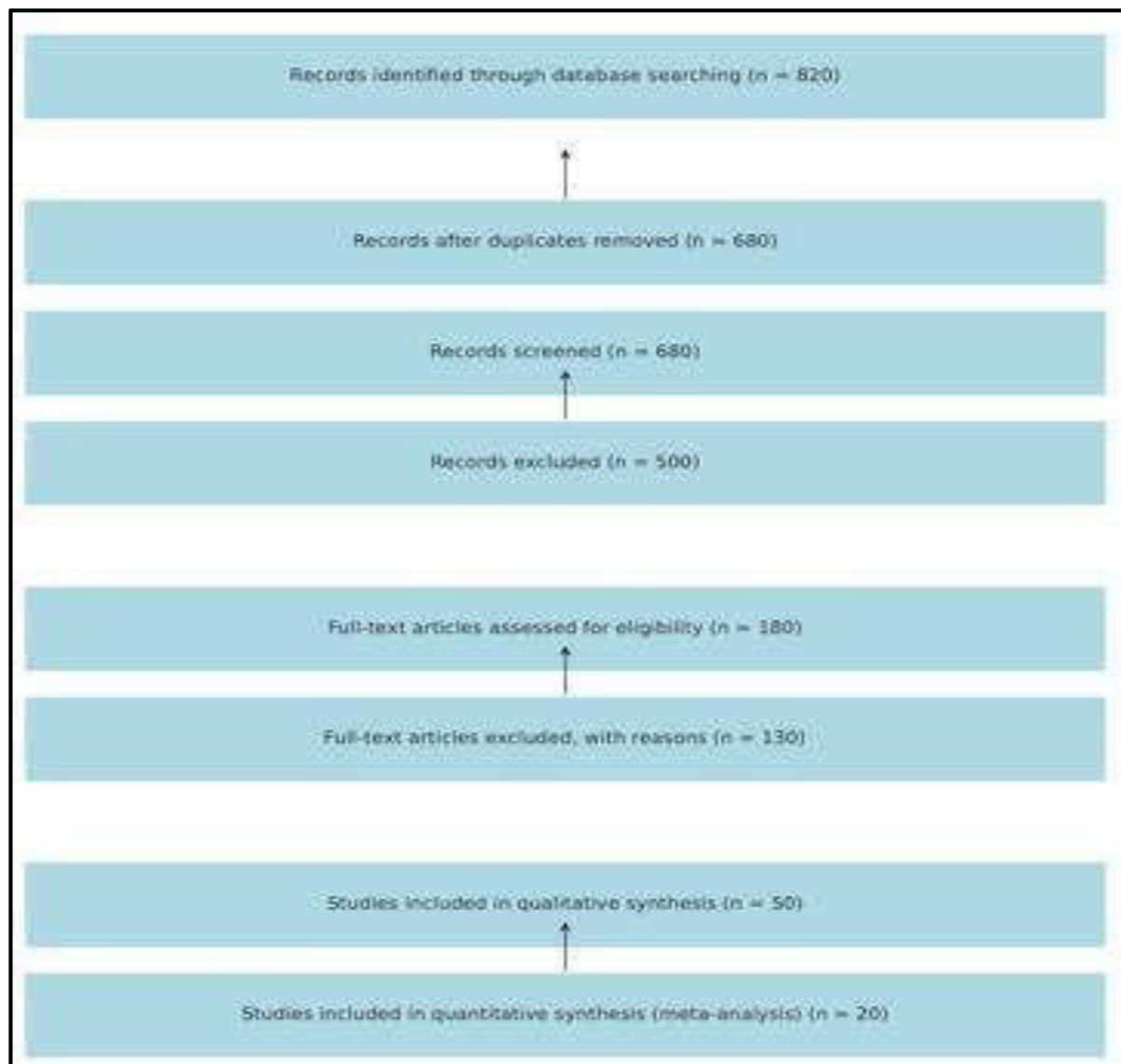
Eligibility Assessment

The third step was a stricter full-text analysis of those articles that successfully were screened. A consistence was made by using the eligibility criteria to evaluate the relevance of each study according to its methodology and topic. The inclusion criterion demanded that the empirical findings in the studies should be directly relevant to financial literacy focusing on women or gender empowerment. Articles were not selected in case they: (i) did not report specific results of financial literacy; (ii) did not address the women-specific concerns; or (iii) concentrated on broader economic topics, but lacked a particular gender or economic education orientation. According to the best practice in systematic review methodology, every omitted study at the eligibility stage was documented with clear cut reasons to support the rejection. It makes the final sample valid as well as allows the readers to see the scope of the review.

standards as required in peer-reviewed academic journals. The replicability is enhanced by transparent documentation at any given stage, which makes the affirmation of the review contributes to the existing body of knowledge on the purpose of financial literacy in promoting gender equality and women economic empowerment. The following is a PRISMA flow diagram representing a visual presentation of systematic review carried out in your study concerning financial literacy to empower women. It undergoes the four major steps of; Identification: 820 records initially

identified. Screening: 140 duplicates were removed, 680 records screened, 500 excluded. Search result: 180 full-text articles accessed, 130 excluded with

reasons. Inclusion: 50 studies are contributed to qualitative synthesis, 20 (meta-analysis).



(Source: Self constructed)

Thematic Analysis: Financial Literacy to Empower Women

Women require financial literacy skills to gain empowerment through making good financial decisions to achieve independence and substantial economic contributions. Numerous research investigations through time have examined how financial literacy helps women to advance their economic activities while also diminishing gender-based inequality and boosting their general well-being. The thematic research method groups significant data points featured in these studies under distinct conceptual categories.

Theme 1: Financial literacy has a specific meaning about understanding financial skills along with developing effective management of personal funds through budgeting while investing and planning. The authors Lusardi and Mitchell (2014) emphasize that financial literacy supports economic resilience for women because they experience greater financial challenges because of reduced financial inclusion and gender disparities.

Theme 2: Research findings reveal that women who learn financial concepts develop better economic power through improved financial literacy. The research conducted by Hung, Yoong, and Brown (2012) demonstrates that women who demonstrate higher financial literacy levels tend to save money and invest funds as well as start businesses independently. Research shows that specialized financial education programs created for women build their ability to make financial choices and boost their self-assurance in such matters (Atkinson & Messy, 2013).

Theme 3: Women experience multiple obstacles that prevent their acquisition of financial literacy even though the financial advantages exist. Allen with co-authors Demirgüç-Kunt, Klapper and Peria (2016) highlight socio-cultural norms together with restricted educational opportunities about finance and limited exposure to financial institutions as main barriers. The financial attitudes together with gender-based risk aversions act as strong limiters which prevent female empowerment in finance.

Theme 4: Financial literacy programs directed at women have produced contradictory outcomes regarding their effectiveness. According to Fernandes, Lynch, and Netemeyer (2014), financial education programs enhance understanding, but behavioral alterations prove difficult to achieve in the extended term. Comprehensive educational programs combining financial literacy elements with mentoring services and financial support solutions deliver the best results (Seshan & Yang, 2014).

Theme 5. Mobile banking and fintech innovations, according to Demirgüç-Kunt et al. (2018), help develop financial inclusion opportunities for women, especially in developing economies. Through digital platforms, women gain enhanced financial control since they have overcome barriers related to restricted mobility and banking services.

Researchers agree that teaching women money skills boosts their confidence and decision-making, yet finding out how that confidence shows up in real-world income, savings, and growth-and spotting tools that

make lessons stick-remains crucial. Beyond knowing the numbers, true power kicks in when women put plans into action, lift their households, claim their own wallets, and nudge communities toward fairer rules. Women who read budgets, track debt, and save for goals run smoother homes and, through startups, steady deposits, and thoughtful investments, add serious punch to national economies (Hung, Yoong, & Brown, 2012; Atkinson & Messy, 2013).

For financial literacy programs to really work, they must meet women where they live, work, and dream. When lessons reflect a woman cultural and money-making world, the material feels understandable, not distant or patronizing. Women in rural villages or close-knit towns, for instance, often learn best in local meet-ups that mix friendly peer coaching with hands-on budgeting or saving tools (Allen, Demirg-Kunt, Klapper, & Peria, 2016). Similarly, lively formats-simulations, phone apps, or short mentor chats-keep attention high and facts stickier for those with little formal schooling or days packed with caregiving (Seshan & Yang, 2014).

Effective money training must be matched with real-world backing. Head knowledge is useful, but systemic support-accessible banks, low-cost credit, protective laws, and social safety nets-turns lessons into practice. Programs that bundle mentoring, seed capital, and ongoing check-ins beat those that offer only lecture-style classes (Seshan & Yang, 2014). By supplying tools, networks, and reassurance, these all-in-one models encourage women to take prudent financial risks, whether starting a business or

adjusting daily spending (Lusardi & Mitchell, 2014).

Another vital piece of the puzzle is growing real financial confidence, not just head-knowledge. In societies where money talk is often male turf, many women doubt their skills even when the education is there. Simple habits celebrating small wins, spotting female money mentors, and swapping ideas in friendly groups ease nerves and make shared decision-making feel ordinary (Atkinson & Messy, 2013). Over time, this small but steady boost to self-belief chips away at the gender rules that keep women's economic voices quiet (Allen et al., 2016).

Technology also offers promising avenues to bridge gaps in financial literacy. With the spread of mobile phones and internet access, digital financial services and fintech platforms have become vital tools in extending financial inclusion. These tools allow women to save, transfer money, and even invest without needing to physically visit banks—an especially transformative development for women in regions where mobility is restricted or financial institutions are far away. Apps and mobile banking services also offer on-demand financial education and budgeting tools, enabling women to learn and apply concepts in real time (Demirgüç-Kunt et al., 2018). Digital financial education modules, especially those designed with user-friendly interfaces and local languages, have the potential to democratize financial literacy across socioeconomic strata.

Lastly, measurement and long-term assessment also plays the central role in

enhancing female financial literacy programs. Most of these initiatives are not carefully evaluated in the long term with regards to behavior, economic and entrepreneurship. Research on data gathering and assessment models can streamline practices and learn what parts of it, including mentoring or the usage of digital tools or community participation, have the most effective outcomes (Fernandes, Lynch, & Netemeyer, 2014). Moreover, they can be used when creating a policy and guarantee the fact that national policy on women financial inclusion is evidence-based and supported by long-term funding.

Conclusions

The thematic data analysis proves financial literacy empowers women when it develops their financial choices and enables economic freedom while advancing their total health status. Women face essential barriers restricting their financial literacy development, although financial literacy holds crucial importance because of cultural boundaries, restricted access to education, and personalized financial habits. A solution for these obstacles needs policy actions supported by educators and financial institutions working together. The financial literacy gap can be closed through gender-

based educational programs that guarantee accessible and inclusive learning measures. A combination of financial literacy training through educational curricula at schools and workplaces and community programs will give women permanent financial capabilities. The expansion of financial services in rural and underserved areas will happen through digital financial tools combined with technology-based solutions. Financial institutions must create products and services addressing women-specific financial requirements to promote their savings behavior, investment activities, and entrepreneurial opportunities. Non-government organizations with governments need to lead active campaigns about financial independence for women and give them vital resources that build financial independence for women. Future investigations need to study women's long-term financial standing following documented literacy programs and contemporary strategies to promote their economic self-reliance. Sustainable financial literacy programs with barrier elimination will build an equal financial structure that enables women to perform well in financial choices and economic stability while supporting economic development.

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Analysing the intellectual landscape of studies on the behaviour of retail investors: a bibliometric approach

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ABSTRACT

Retail investors are becoming increasingly vital to the operation of contemporary financial markets, especially with the advent of digital trading platforms and easily accessible investment options like ETFs. Although there is a substantial amount of research dedicated to understanding retail investor behaviour, a comprehensive grasp of the intellectual trends and thematic progressions in this area is still lacking. This study offers an extensive bibliometric analysis of research on the behaviour of retail investors, covering the years from 2010 to 2024, using publications indexed in the Scopus database..

This study employs bibliometric methods like co-authorship analysis, keyword co-occurrence, and bibliographic coupling to chart the progression of knowledge in this field. VOSviewer is utilized for visualization and clustering to pinpoint prominent authors, journals, institutions, and countries contributing to this research area. The results identify six primary thematic clusters: behavioural finance and risk perception, demographic and socio-economic factors, investment decision-making models, digital literacy and the adoption of financial technology, regulatory frameworks, and the influence of investor sentiment. The analysis reveals emerging research areas, such as the integration of artificial intelligence, robo-advisory services, and behavioural nudges in investment platforms. It also underscores less-explored topics like the effects of financial literacy programs, generational differences, and region-specific regulatory environments on investor behaviour.

This research enhances the current understanding by systematically organizing scattered studies, pinpointing key academic networks, and highlighting future research opportunities. It acts as a crucial resource for scholars, policymakers, and financial experts aiming to create more inclusive, data-driven, and behaviourally informed investment environments.

Keywords: Retail Investors, Bibliometric Analysis, Behavioural Finance, Investment Behaviour, Financial Technology, Investor Sentiment, Financial Literacy

INTRODUCTION

The role of retail investors in the financial markets has changed significantly. Retail investors were once thought of as passive players with little market power, but with the growth of digital trading platforms, more financial literacy, and the democratization of financial data, they are now more important players. Although different jurisdictions have different definitions of retail investors, they are generally defined as individual investors who purchase and sell securities for their own accounts rather than on behalf of institutions. Retail investors operate with less cash, have less access to proprietary information, and have a variety of behavioural incentives than institutional investors, who trade in bulk and have professional management teams (Barber & Odean, 2000; Statman, 2005).

Low-cost brokerage services, fintech apps, and social media platforms that share real-time trading ideas have all contributed to the rise in retail stock market involvement, especially since the early 2000s. Market dynamics and the behaviour of retail investors have been profoundly changed by the rise of commission-free trading, the introduction of apps like Zerodha, and the popularity of communities like Reddit's r/WallStreetBets. Global financial markets saw a surge of individual investors, sometimes referred to as the "new retail army," particularly during and after the COVID-19 pandemic. These investors aggressively influenced market patterns

and occasionally even overturned institutional trades by collective action. (Chen et al., 2021; Goyal & Kumar, 2021).

Retail investors are usually depicted as emotionally motivated and vulnerable to behavioural biases such as overconfidence, herd mentality, and loss aversion, whereas institutional investors are typically thought of as logical, knowledgeable, and disciplined. Recent events, however, cast doubt on this stereotype. Research indicates that in some situations, individual investors can outperform institutions, take advantage of market irregularities, and aid in price discovery and liquidity. (Barber et al., 2009; Kumar & Goyal, 2020). The sentiment and volatility of financial markets are also greatly influenced by retail investors, as evidenced by events like short squeezes, meme stocks, and cryptocurrency booms.

This field of study combines investor psychology, market microstructure, and behavioural finance. Institutional investors have historically dominated scholarly discourse, but as retail activity increases, there is an increasing need to map the body of knowledge around retail investor behaviour in a systematic manner. Retail investor decisions are explained by a number of theories, including prospect theory, bounded rationality, and mental accounting, but there is currently little integrated work that combines the body of knowledge in this area.

Our study uses bibliometric analysis to evaluate and map the literature on the behaviour of retail investors in light of this. Using information from top Scopus-indexed articles, this analysis pinpoints key research topics, significant authors, and

Rationale of the Study

Due to their unparalleled access to trading platforms, financial data, and social media networks, retail investors have become a disruptive force in the capital markets. Despite this increase, there are still relatively few systematic, data-driven research on the behaviour of retail investors and how they affect markets because a large portion of scholarly attention is still biased toward institutional investors [Statman, 2005]¹. As a result, it is imperative to reexamine long-held beliefs regarding their involvement, rationality, and influence on asset values.

Through the development of digital trading technologies, retail participants can now interact with financial markets directly and avoid traditional middlemen. A surge of inexperienced investors, especially millennials and Gen Z cohorts, have been drawn in by the widespread use of zero-commission trading platforms like Zerodha, which have drastically reduced entry barriers [Chen et al., 2021]. These newcomers not only have different demographics than previous retail cohorts, but they also frequently use non-traditional information sources, such YouTube, Reddit, and others, to guide their decisions in novel ways [Ortmann et al., 2020].

Although earlier research has mostly classified retail investors as irrational actors motivated by behavioural biases including loss aversion, overconfidence,

new developments in the field. In addition to helping academics comprehend how retail investor research has changed over time, this analysis will point out unexplored topics for further research.

and herding, newer data points to a more complex role. As seen during the GameStop episode and other meme stock occurrences, retail traders have proven their capacity to coordinate trading strategies and impact prices, particularly in illiquid or shorted stocks [Barber et al., 2009]⁴. A comprehensive mapping of this research is still missing, despite the fact that these acts have sparked regulatory scrutiny, media interest, and a surge of scholarly investigation.

Furthermore, our comprehension is further complicated by regional and regulatory variation. Because of things like digital infrastructure, tax treatment, financial literacy, and loan availability, retail behaviour in established markets can be very different from that in emerging ones [Kumar & Goyal, 2020]⁵. This emphasizes how the existing literature is lacking in context-specific insights and comparative perspectives.

The current study conducts a bibliometric and content analysis of the scholarly literature on retail investors in order to fill in these gaps. This method makes it possible to evaluate publication patterns, key writers, core journals, thematic clusters, and new areas of study objectively. The objectives are to advise stakeholders in academic, business, and regulatory circles, promote policy-oriented

discussion, and lay a conceptual basis for upcoming empirical research.

Research Objectives and Questions

The evolving role of retail investors in global capital markets has sparked a renewed interest among scholars, regulators, and practitioners. Even so, there is still a lack of scholarly mapping of intellectual contributions on the behaviour of retail investors. This study attempts to close that gap by providing a thorough understanding of the direction and evolution of research in this field through a systematic bibliometric analysis. [Donthu et al., 2021]. The primary objective of this research is to analyze the structure, trends, and thematic evolution of academic literature focused on retail investor behaviour. This includes identifying influential authors, collaboration networks, high-impact journals, and dominant

research clusters in the field. Such analysis will help build a foundational understanding of the knowledge landscape, useful for guiding future empirical studies and theoretical development.

Amidst the shifting dynamics of retail investors, particularly during times of market volatility and digital evolution, this study aims to uncover new research avenues. Areas such as the effect of social media on trading decisions, the participation of retail investors in cryptocurrency and ESG investments, and their behavioural reactions to macroeconomic shocks are garnering interest but remain insufficiently studied [Ortmann et al., 2020].

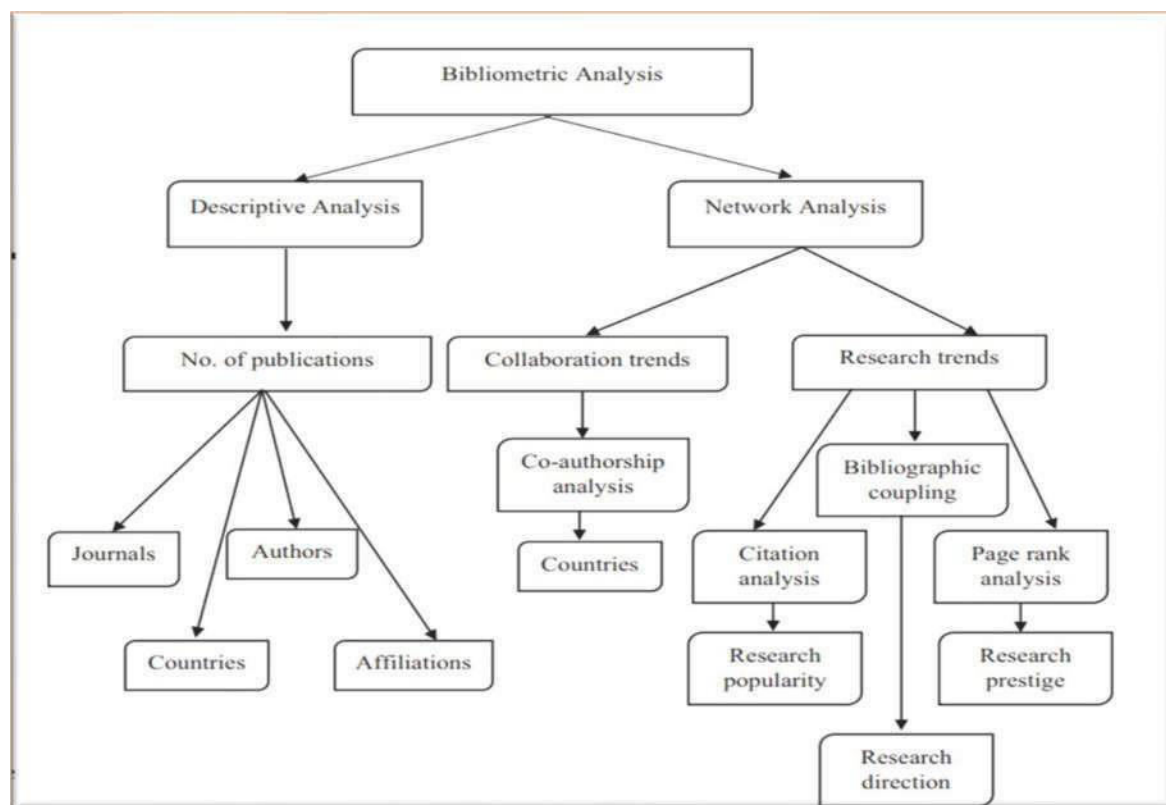
Accordingly, this study is guided by the following key research questions:

1. What are the predominant themes and intellectual frameworks within the literature concerning retail investor behaviour?
2. Which authors, journals, and institutions have exerted the most significant influence in this domain?
3. How has the focus of research evolved over time, and what emerging trends can be identified?
4. What are the geographic and institutional collaboration patterns in retail investor research?
5. Which areas remain underexplored, offering scope for future academic inquiry?

By tackling these inquiries, the paper advances both the methodological and conceptual growth of the discipline. From a methodological standpoint, it utilizes bibliometric techniques and co-word analysis to chart the literature. On a conceptual level, it aids researchers in gaining a deeper understanding of the behavioural, technological, and regulatory aspects that influence the role of retail investors in financial markets.

Methodology

Database selection



Time period

The current study examines retail investors' behaviour across a substantial time period, from 2010 to 2024. This 14-year time frame was chosen to capture changing trends, market dynamics, and major events that influenced retail investor behaviour. Starting in 2010, the analysis focuses on the post-global financial crisis era, allowing for an examination of recovery trends, technological improvements, and regulatory changes. The period also contains significant milestones such as the rise of fintech platforms, the proliferation of mobile trading apps, and increased retail engagement in financial markets, particularly during turbulent periods such as the COVID-19 epidemic and the subsequent recovery.

Selection of keyword

The search keywords were "retail investors*," "individual investors*," and "behaviour*." The Boolean operators "OR" and "AND" were used to connect the terms. The exact search phrase used was ["retail investors*" OR "individual investors*"] AND ["behaviour*"]. These keywords were searched in the "title, abstract, and keywords" field, as various bibliometric studies generally follow this.

Filtration of documents

We initially collected 1186 articles. The "inclusion and exclusion" criteria are then utilized to choose the appropriate research papers for review. The time period was chosen from 2010 to 2024, and a total of 1059 papers were retrieved. We only included articles related to "Business, Management, and Accounting" or "Economics, Econometrics, and Finance." As a result, 858

documents were collected. After narrowing the search to only "articles" or "review articles" written in "English," an additional 67 articles were deleted, bringing the total to 791.

Therefore, a final data set comprising 791 papers published between 2010 and 2024 is used (see Figure 2)

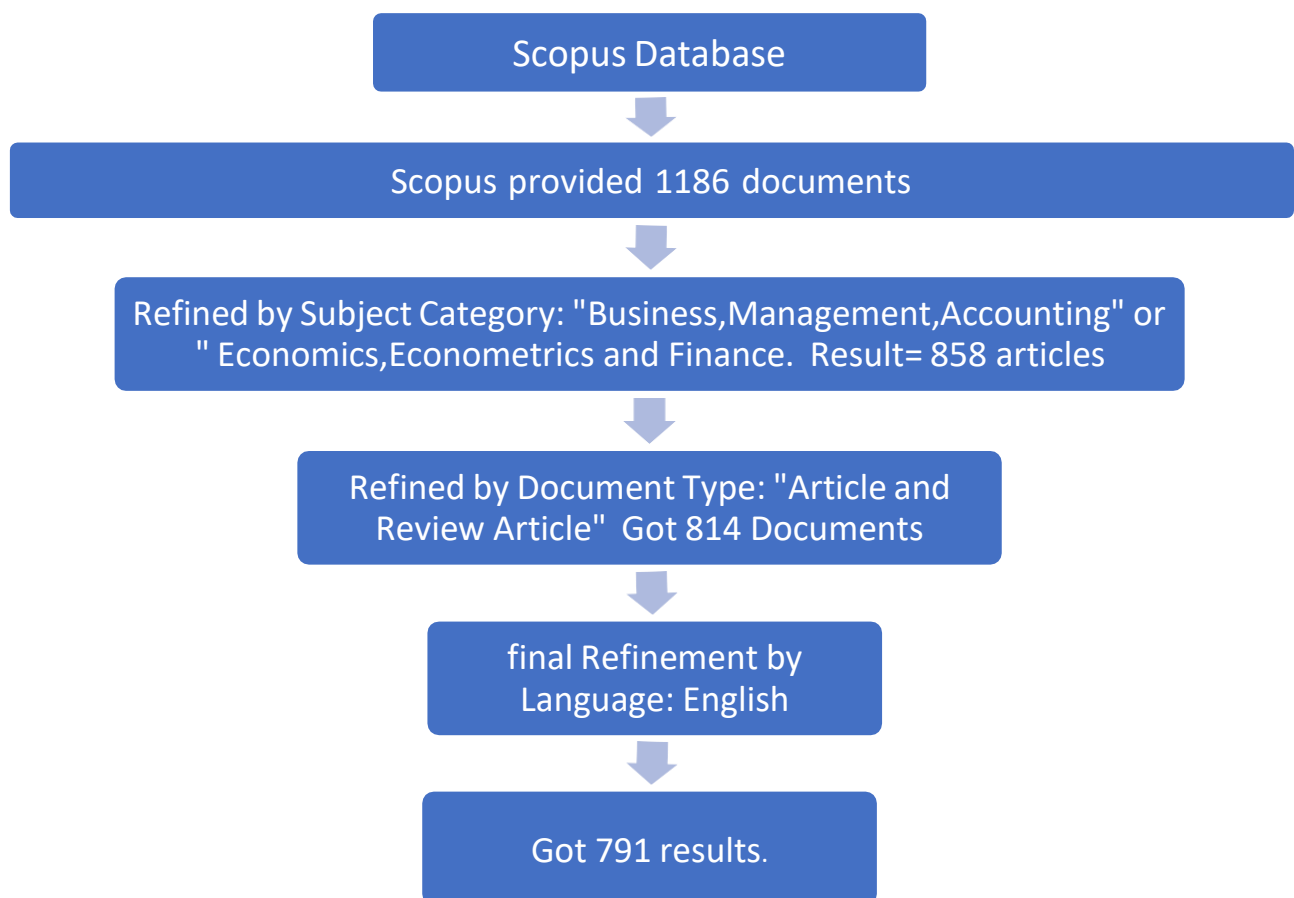


Fig. 2: Bibliometric review Search and Filtration procedure

Source: Author's own Creation

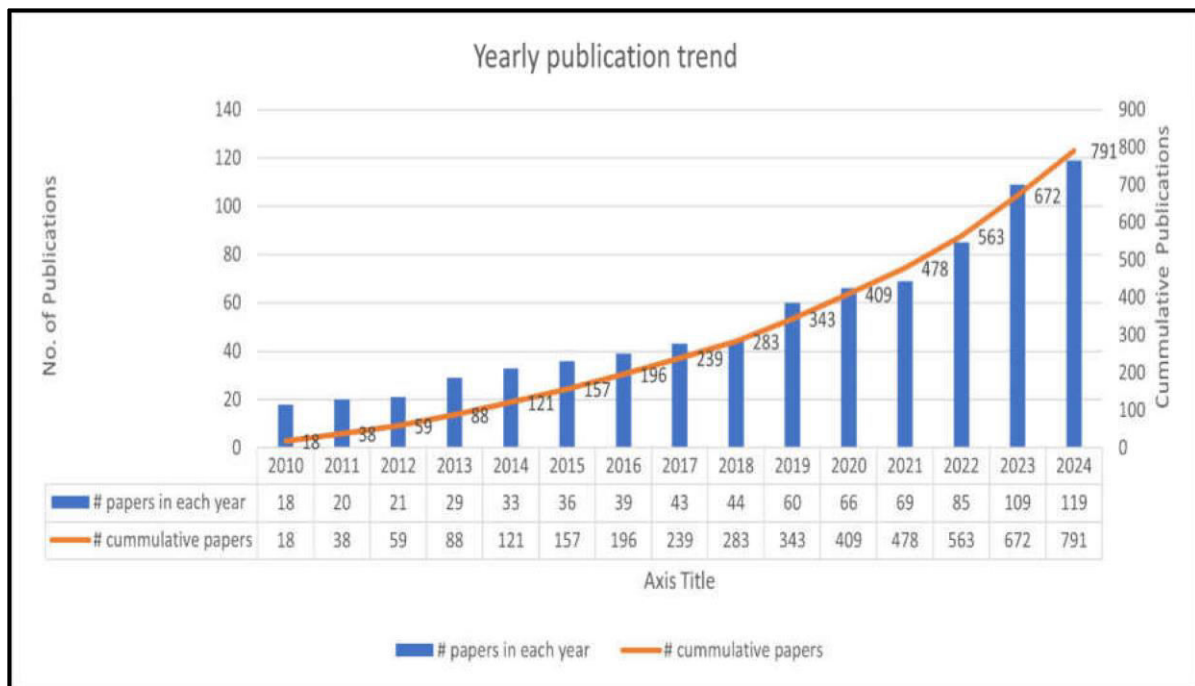


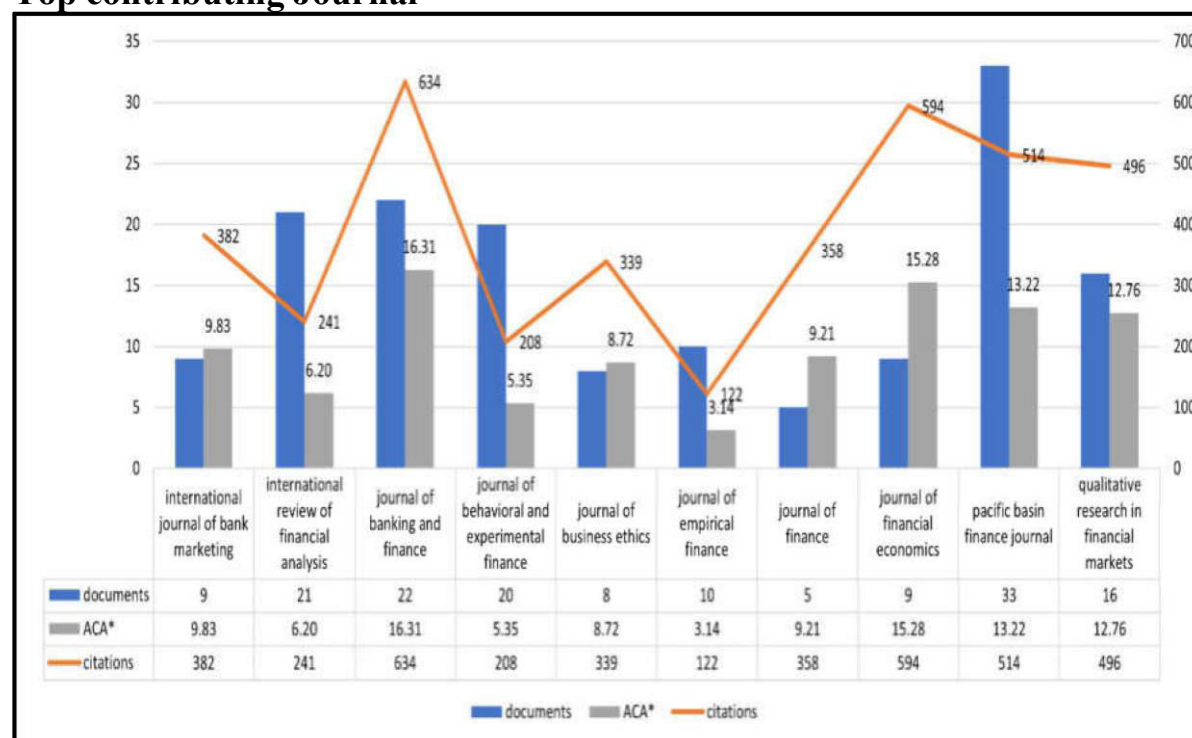
Figure. 3 Yearly publication trend

Source: Author’s own creation

From 2010 to 2014, the number of papers published each year increased slowly, from 18 papers in 2010 to 98 papers in 2014. The growth rate began to accelerate from 2015 onwards, with publications reaching 239 papers in 2018. The pace of publication intensified significantly after 2020, with a sharp rise in the number of papers. Notably, in 2021, 409 papers were published, and this growth peaked in 2024, with 791 publications. The cumulative count follows an exponential curve, representing the overall increase in the field's research

output. By 2010, the total number of papers had reached 18, which corresponded to the publications for that year. By 2014, the total count had reached 158 papers, indicating moderate growth. The cumulative amount increased significantly after 2018, surpassing 500 papers by 2021. By 2024, the cumulative amount had risen to 791 publications. The research publication indicates that study in this field has grown over time and has potential for the future.

Top contributing Journal



Note: *ACA =Average citation per article

Source: Authors' own creation

The top journals are highlighted in the "Top contributing Journal" chart according to the quantity of articles, total citations, and average citation per article (ACA). With 33 publications, 514 citations, and an ACA of 13.22, the Pacific Basin Finance Journal has the most publications overall. Even though it publishes the most articles, each paper has a moderate average impact. Despite publishing fewer papers (22), the Journal of Banking and Finance has a major impact on the area as evidenced by its leadership in ACA (16.31) and total citations (634). With just 9 papers yet a high total citation count of 594 and an ACA of 15.28, the Journal of Financial

Economics also stands out for emphasizing high-quality, high-impact research.

Journals with fewer articles and less citations overall, such as the Journal of Business Ethics and the Journal of Empirical Finance, on the other hand, have a smaller influence than the top journals. This graph highlights the disparities in output and impact of journals, with some emphasizing impactful, high-quality research despite publishing fewer papers, while others make a substantial contribution with a greater number of articles.

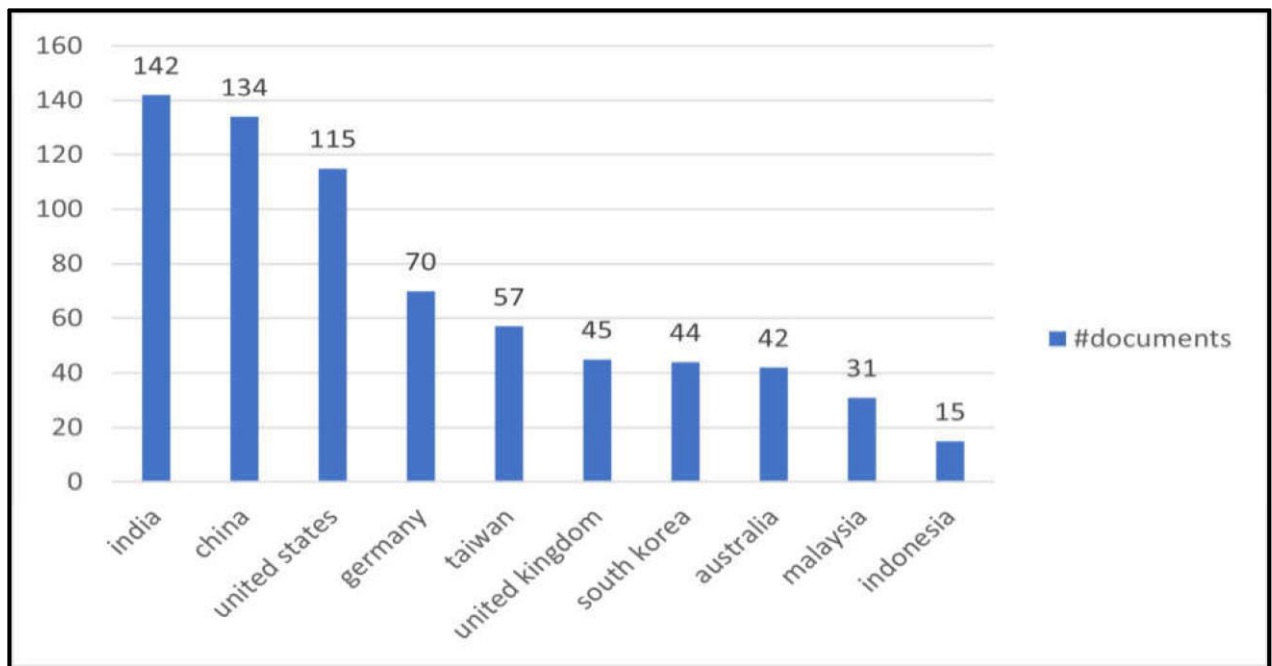


Figure 4: Top contributing countries

Source: Author's own Creation

The top ten nations according to the quantity of research papers published are displayed in the "Top contributing countries" chart. With 142 documents, India leads the field, closely followed by China with 134 documents, demonstrating both nations' robust research output. With 115 documents, the US comes in third, demonstrating its ongoing scholarly influence. Taiwan (57 documents) and Germany (70 documents) complete the top five contributors, indicating a strong interest in international research.

While Malaysia (31) and Indonesia (15) exhibit emerging contributions, nations like the United Kingdom (45), South Korea (44), and Australia (42) continuously contribute to the field of study. The graph demonstrates how Asia leads the world in research production, although Western countries also make significant contributions. Together, these nations influence the state of this field's study worldwide.

that demonstrates more regionalized research partnerships. With China and the United States acting as key hubs for international cooperation, this analysis emphasizes how intricately linked global research is. The data also enhances the

global research scene by highlighting the contributions of nations like Taiwan, Germany, and India, which make major contributions to the volume and impact of research.

Affiliation	Location	Articles
National Chengchi University	Taiwan	9
National Kaohsiung First University of Science and Technology	Taiwan	8
Chung-Ang University	South Korea	8
Florida State University	USA	8
National Taiwan University	Taiwan	6
Sungkyunkwan University	South Korea	6
University of California	USA	6
University of Toronto	Canada	6
Nankai University	China	6
Harvard University	USA	5

Figure 6. Leading affiliations in retail investor research.

Source: Author's own creation



Figure 7. Geographical location of contributing organisations

Source: Author's own creation

Ageographic map showing the distribution of contributing institutions in the area of retail investor behaviour was created using the affiliation data that was taken out of the dataset (Figure 7). GPSVisualizer, which uses geographical coordinates and overlays them on an OpenStreetMap base, was used to make the map. The picture illustrates how research in this field is a worldwide distributed academic endeavor rather of being restricted to a certain geographic area. With a number of prestigious universities, including Harvard University, the University of California, Florida State University, National Chengchi University, and National Taiwan University, situated in these areas, the United States and Taiwan stand out as major benefactors. Significant institutional presence is also seen in South

Korea, China, and Canada, as evidenced by institutions such as Chung-Ang University, Nankai University, and the University of Toronto. European nations including Sweden, Norway, Germany, France, and the United Kingdom have made significant contributions that have strengthened the region's well-established academic reputation in behavioural studies and finance. Furthermore, the inclusion of organizations from nations like Nigeria, Kenya, Singapore, Vietnam, Sri Lanka, India, and others points to a growing worldwide research footprint. With significant contributions coming from both developed and emerging nations, the geographic distribution suggests that institutional investors' conduct is a topic of international scholarly interest.

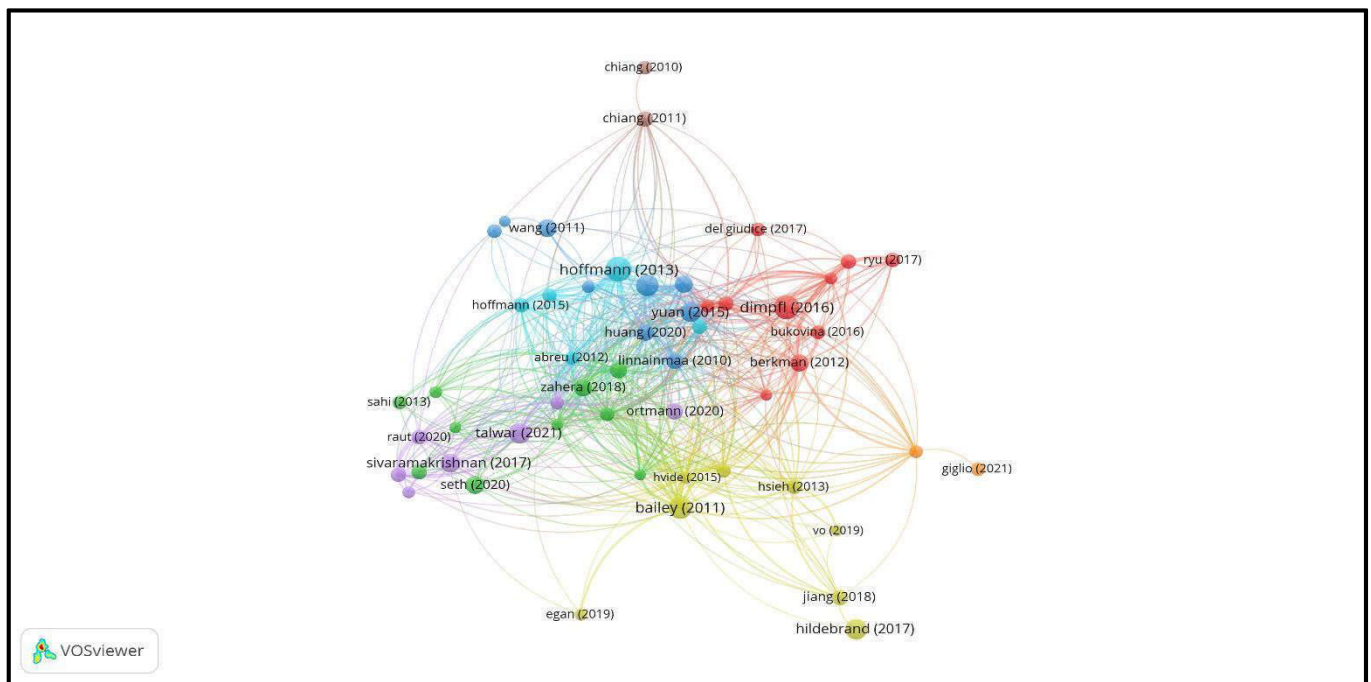


Figure 8. Bibliographic coupling network

Source: Author's own creation

Bibliographic coupling analysis

To investigate the intellectual structure of the literature on retail investors, bibliographic coupling analysis was performed. Originally proposed by Kessler [Kessler, 1963], bibliographic coupling describes a scenario in which two documents cite the identical third document. A thematic proximity between the coupled items is shown by the strength of coupling, which is proportional to the number of common references [Van Eck & Waltman, 2010]. Finding current research fronts and topic specialties inside a knowledge area is made easier using bibliographic coupling.

The dataset that was obtained from Scopus was subjected to a bibliographic coupling study of documents using VOSviewer. The program produced five main clusters with 55 noteworthy publications based on a

minimum citation count per document (see Figure 8). Five different thematic study streams—each representing a subdomain within the field of retail investor behaviour—are revealed by the analysis. Below is a qualitative content analysis of every cluster.

Cluster 1: Sentiment and Volatility Spillover Effects (Red)

This cluster includes papers that focus on investor sentiment and its influence on market volatility. A notable work in this group is by Chiang et al. (2010) who examined the informed behaviour of investors in IPO auctions, concluding that institutional investors exhibit superior information processing (Chiang, Qian, & Sherman, 2010). In a follow-up, Chiang et al. (2011) demonstrated how frequent IPO investors learn from their experiences and

improve trading outcomes over time (Chiang, Hirshleifer, & Sherman, 2011). Dimpfl (2016) investigated volatility transmission using Google search queries as a proxy for investor sentiment, while Bukovina (2016) employed Twitter data to analyze the predictive power of public mood on stock returns. Ryu (2017) contributed to this stream by developing a sentiment index to measure how retail investors react to market trends. These studies share a common objective—to understand how non-fundamental factors like emotion, attention, and noise can drive retail trading behaviour, especially during uncertain market conditions.

Cluster 2: Risk Perception, Trust, and Financial Decision-Making (Blue)

This cluster includes studies exploring cognitive psychology, investor trust, and risk preferences. Hoffmann et al. (2013, 2015) played a key role in examining how trust and emotions such as regret shape investment decisions, particularly during financial downturns. Wang et al. (2011) studied investor behaviour in China, demonstrating how CSR perceptions influence stock return expectations. Yuan (2015) and Huang (2020) explored how mood and online sentiment contribute to decision-making in modern trading environments. Meanwhile, Abreu (2012) and Linnamaa (2010) provided empirical insights on how overconfidence and limited attention affect portfolio management.

Collectively, these works highlight the importance of subjective perception and emotional regulation in retail financial behaviour.

References:

Cluster 3: Behavioural Biases and Investment Heuristics (Green)

The third cluster concentrates on the role of biases and heuristics in investment decisions. Zahera and Bansal (2018) provided an exhaustive review of common retail investor biases, such as anchoring, overconfidence, and herd behaviour. Ortmann et al. (2020) examined how investors rely on rule-of-thumb strategies when faced with cognitive overload. Empirical studies such as those by Bailey et al. (2011) and Hvide (2015) explored how retail investors' decisions deviate from rational expectations, emphasizing the role of bounded rationality in portfolio formation. This cluster builds the psychological foundation for explaining why retail investors often underperform.

Cluster 4: Digitalization and Emerging Retail Platforms (Purple)

Cluster 4 focuses on the rise of digital platforms and the evolving behaviour of retail investors in tech-driven contexts. Sivaramakrishnan et al. (2017) studied how mobile apps and digital interfaces influence investment choices in Indian markets.

Sahi (2013) and Seth (2020) highlighted shifts in financial behaviour due to smartphone usage and the availability of real-time data. Talwar et al. (2021) explored the impact of electronic word-of-mouth (e-WOM) and social influence in online investing communities. This cluster is relatively new, indicating a rapidly evolving interest in fintech, gamification, and millennial/gen-Z investor behaviour.

Cluster 5: Retail Investor Impact on Market Microstructure (Yellow)

The final cluster examines how retail investor behaviour influences market performance and structure. Vo (2019) and Jiang (2018) looked at how individual investors affect price formation and liquidity.

Hsieh (2013) and Hildebrand (2017) investigated herding behaviour and its implications for market efficiency. Giglio (2021) explored how limited attention during macroeconomic shifts results in predictable patterns in asset returns. These studies link micro-level retail

actions to broader market phenomena, providing a bridge between behavioural finance and market microstructure theory. The bibliographic coupling map offers a comprehensive view of the multi-dimensional research being conducted in the area of retail investor behaviour. From early work on sentiment and behavioural biases to recent explorations into digital investing and market impact, the literature reveals a clear evolution in themes. The clusters identified reflect both the theoretical depth and practical relevance of the domain, suggesting growing scholarly attention and scope for further empirical research.

Conclusion

In order to map the intellectual landscape of scholarly research on the behaviour of retail investors, this study conducted a thorough bibliometric analysis spanning 14 years, from 2010 to 2024. This study carefully analyzed a corpus of 791 publications indexed in the Scopus database using a range of bibliometric tools, including as bibliographic coupling, keyword co-occurrence mapping, and co-authorship analysis. Key contributing authors and institutions, significant publications, the topic orientation of research in this developing field, and the trajectory of knowledge creation were all identified by the analysis.

Five main subject clusters that capture the dominant intellectual discourse were found by the bibliographic coupling analysis, which was aided by the VOSviewer visualization: (1) Sentiment and Volatility Spillover Effects, (2) Risk Perception, Trust, and Financial Decision-Making, (3) Behavioural Biases and Investment Heuristics, (4) Digitalization and Emerging Retail Platforms, and (5) Retail Investor Impact on Market Microstructure. Together, these clusters show how retail investor research is multidisciplinary, incorporating elements from digital innovation, finance, behavioural economics, and cognitive psychology.

The investigation also revealed the institutional and geographic characteristics of this area of study. India, China, the United States, and Germany were among the nations that made significant contributions, and the literature was significantly shaped by a number of eminent universities, including Harvard University, the University of Toronto, and National Chengchi University. The networks of collaboration across these nations demonstrate how research attempts to comprehend the dynamics of retail investors are becoming more globalized and interconnected.

Crucially, the upward trend in annual publications, especially the spike after 2020, indicates that the field is receiving more scholarly attention. This is probably due to changes in investor demographics, technological advancements (like mobile trading apps and social media investing communities), and macroeconomic disruptions (like the COVID-19 pandemic). Even with this rising amount of work, there are still a number of important theoretical and empirical gaps that call for more research into how retail investors' behaviour is changing in increasingly digital and volatile financial contexts.

Future Research Directions

Based on the findings from the bibliographic coupling clusters and thematic synthesis, the following future research directions are proposed to advance the academic discourse:

1. **Real-Time Sentiment Analytics and Market Microstructure Integration**
Although the impact of investor mood has been extensively studied, real-time, high-frequency data from sources like Twitter, Reddit (e.g., r/WallStreetBets), Google Trends, and trading app activity should be used in future studies. This would make it possible to create sentiment indexes that are more sensitive to changes in the mood and behaviour of investors on an intraday basis. Particularly during periods of high volatility, combining these insights with models of market microstructure can aid in determining the causal relationship between retail sentiment and liquidity, order flow, and price efficiency.
2. **Behavioural Design and Gamification in Digital Investment Platforms**
A new level of behavioural effect on retail investors has been brought about by the growing use of mobile trading applications. Future research should examine the effects of interface components on trading frequency,

attention allocation, and decision-making. Examples of these aspects include gamified rewards, color-coded gains/losses, and social investment features. The degree to which these design features encourage investors to do particular activities or take on particular risk profiles can be measured with the use of experimental designs and user behaviour analytics..

3. **Robo-Advisory Services and Algorithmic Trust Formation**
Research is required to comprehend how trust in algorithmic decision-making is established and maintained, as robo-advisory platforms and artificial intelligence become more and more integrated into retail investment ecosystems. Factors including perceived competence, bias aversion, transparency, and user pleasure should all be investigated in studies. Evaluating the long-term financial results of retail investors who mostly rely on algorithm-driven suggestions is also crucial.
4. **Cross-Cultural, Demographic, and Generational Variations**
The behaviour of retail investors varies by geography and demographics. Comparative approaches should be used in

future studies to investigate how socioeconomic status, age, culture, and financial knowledge levels influence investing behaviour. In particular, among digital-native cohorts such as Gen Z and millennials, longitudinal research can further detect generational trends in information consumption, risk tolerance, and financial preferences.

5. Retail Investors and ESG/Sustainable Finance

Even while ESG (Environmental, Social, and Governance) investment has become more popular among institutions, little is known about the reasons behind, levels of expertise, and patterns of behaviour of retail investors in the context of ESG. Future research could examine how values-based investing fits (or does not fit) with various retail investor segments' financial objectives. Survey-based analysis and behavioural tests can shed light on the informational and psychological obstacles to the adoption of sustainable investments.

6. Evaluating Financial Literacy and Behavioural Interventions

Empirical studies evaluating the effectiveness of financial education programs are becoming more and more necessary, particularly when those programs are integrated into fintech applications or are given via digital platforms. Research ought to investigate whether these kinds of interventions result

in long-lasting enhancements in financial decision-making, lessen vulnerability to behavioural biases, and promote more responsible trading practices. Analyses that compare different regulatory regimes can yield important information on the best ways to protect retail investors.

7. Crisis-Induced Behavioural Shifts

Pandemics, inflationary shocks, and international hostilities are examples of major economic and geopolitical disturbances that can drastically change investor psyche and behaviour. Future research should concentrate on figuring out how retail investors modify their plans at these times and if these adjustments are the result of short-term irregularities or long-term behavioural adjustments.

To sum up, the current study offers a systematic and data-driven summary of the body of knowledge regarding the behaviour of retail investors. It acts as a strategic guide for politicians, educators, and financial service providers in addition to providing a foundational reference for future empirical and theoretical study by highlighting the thematic evolution and knowledge gaps. In order to promote inclusive, effective, and behaviourally informed capital markets, continued scholarly attention will be essential as the retail investor continues to change within a complex financial ecosystem.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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Abstract

A huge part of the population in emerging economies like India has extremely limited or no access to formal and fundamental banking services. From established financial institutions, they hardly ever receive credit or other banking services. This group of people is still not banked with. Despite years of development and reform in the banking industry, there are still many obstacles, including high costs, low literacy, a lack of documents, ignorance, etc. They choose unofficial financial sources and end up being taken advantage of. Financial inclusion denotes the accessibility and utilization of financial products and services, encompassing transaction capabilities, savings, investments, and various banking offerings.

If the people are not having access to financial services due to any reason, then it is termed as 'Financial Exclusion'. Mainly financially excluded individuals are from low-income groups who cannot access even basic banking facilities. This part of the population is still unbanked despite growth and reforms in banking sector over many years, some of the barriers are high cost, low literacy, unavailability of documents, lack of awareness etc. If the people are not able to access financial services due to any reason, then it is termed as 'Financial Exclusion'. Mainly financially excluded people are from lowincome groups who cannot access even basic banking facilities. One of the recent developments in banking sector is introduction of technology in banking by which the banks can serve more people by providing banking via alternative banking channels such as ATMs, Mobile Banking, Internet Banking, Debit and Credit Cards etc. along with the traditional banking services.

Keywords:Digital financial services, Financial inclusion, Banking, Technology.

Introduction

Digital Financial Services represent contemporary banking technology with significant potential to provide a diverse array of secure, accessible, and convenient financial services to impoverished and financially excluded populations in emerging economies. Numerous experts have projected that the number of smartphone users in India would attain 450 million by 2022, indicating that a significant portion of the population will have access to digital financial services. Financial service providers concur that offering banking facilities digitally is an innovative approach to delivering financial services to excluded populations and accessing remote places without conventional bank branches. This approach is cost-effective and time-efficient compared to delivering financial services through physical infrastructure. Mobility exerts a greater influence than on-the-go transactions; the integration of comprehensive online banking services at one's fingertips will undoubtedly achieve the goal of Financial Inclusion. At a macro level, it will enhance growth, the economy, and GDP.

Digital finance pertains to the provision of financial products and services to users via digital channels, including Internet Banking, Mobile Banking, Plastic Cards, E-Lobby (ATM – Kiosks).

1. Transaction Accounts: These resemble formal bank accounts where users deposit monies. A formal bank account can be utilized digitally, and an e-wallet may also serve as a transaction account, albeit with restricted functionality compared to a savings bank account.
2. Payment Services: Digital offerings

include money transfers, remittances, bill payments, and transactions on websites or booking platforms.

Savings Accounts: It allows clients to reserve and deposit funds for future utilization.

4. Investment Facilities: It allows users, both individuals and businesses, to generate future financial returns through fund investment.

5. Loans: Individuals and enterprises can obtain credit facilities such as microfinance and secured loans through this service.

6. Insurance Services: A comprehensive range of insurance services, encompassing both Life and General Insurance, is offered online to safeguard lives and assets against potential hazards.

Consumers of financial services, digital finance providers, governments, and the economy all obtain substantial advantages from digital finance and financial inclusion. Since 2010, the G-20 and the World Bank have led attempts to improve financial inclusion to mitigate poverty rates in emerging and developing nations. Access to digital technologies facilitates a wider range of financial services, including online and mobile banking. Since achieving independence, the Indian government has enacted numerous initiatives to modernize the financial system. A significant shift in the banking sector is the advent of technology, enabling banks to provide services through several channels to a wider clientele. Before demonetization and the COVID-19 outbreak, digital finance was not

extensively adopted. Consequently, several digital payment systems, including debit and credit cards, mobile wallets, online banking, and UPI, experienced a rise in popularity and received legislative endorsement.

Digital financial inclusion is reducing the gap between cash and electronic payments. Customers can swiftly and cost-effectively

transfer payments to friends, family, and businesses.

Despite growing familiarity with electronic payment systems, negative perceptions—including security concerns, limited network coverage, merchant reluctance, high transaction costs, and insufficient financial and digital literacy—persistently obstruct wider adoption of this technology.

Need, Significance & Justification of the Study

The financial services industry has experienced tremendous digitization and digital transformation in recent decades, which has prompted banks and other financial institutions to adopt digital methods of delivering and receiving financial services globally. Customers are beginning to favor digital transactions over cash-based transactions because digital financial products and services are easier to get and more reasonably priced than traditional banking services. The bank now has an inventive technique to contact new clients thanks to digital finance. To reach those clients, numerous banks and non-banks have started to offer digital financial services. A McKinsey report defines "digital finance" as financial services that are provided through cards, the Internet, or mobile devices.

Financial inclusion refers to the access and usage of financial products and services including transaction facilities, savings, investments, and other banking products.

If people are not having access to financial services due to any reason, then it is termed as 'Financial Exclusion'. Mainly financially excluded individuals are from

low-income groups who cannot access even basic banking facilities.

This part of the population is still unbanked despite growth and reforms in the banking sector over many years, some of the barriers are high cost, low literacy, unavailability of documents, lack of awareness, etc.

If people are not able to access financial services due to any reason, then it is termed as 'Financial Exclusion'. Mainly financially excluded people are from low-income groups who cannot access even basic banking facilities.

One of the recent developments in the banking sector is the introduction of technology in banking by which the banks can serve more people by providing banking via alternative banking channels such as ATMs, Mobile Banking, Internet Banking, Debit and Credit Cards, etc. along with the traditional banking services.

All of the traditional financial services that are provided to clients via Internet, mobile, debit, and credit cards as well as e-wallets, ATMs, and other channels are collectively referred to as digital finance. These services include payments, deposits, credit access, savings, insurance, and

remittances. Gomber, Koch, and colleagues' definition of digital finance Siering (2017) notes that Fintech companies and creative financial service providers engage with their customers through a variety of newly developed financial products, finance-related technologies, and creative ways. For anyone with access to a smartphone and internet connectivity, digital financial

services may be more cost-effective and handy than traditional banking options. With access to digital financial services, consumers can safeguard their cash online rather than keeping it at home. The main objective of Financial Inclusion is to provide access to financial services to those who are lacking it and promote their growth

- Promotion of savings
- Social Protection
- Risk Management through Insurance Services
- Encouragement of Entrepreneurship
- Improving Production Figures
- strengthening MSMEs by providing credit
- Stabilizing the base of retail deposits for the Bank
- Transform Cash based economy to Cashless economy
- Providing access to Financial Services and improving the Standard of living in the country, especially in rural areas.

Disadvantages due to Financial Exclusion

After familiarizing oneself with the goal of Financial Inclusion, it becomes effortless to comprehend its drawbacks. Low-income individuals make up the bulk of India's Financially Excluded population..

The following are the disadvantages of Financial Exclusion:

- Financial Instability
- Less production
- Social Problems
- No encouragement to new Entrepreneurs.
- Danger of evil of Black money in the economy.
- Less development of financial markets due to less savings.
- People won't be able to mitigate risks arising in business and life.
- Promotion to informal sources of finance.
- Exploitation of illiterate and weaker sections in the villages

Digital Financial Services is the new age banking technology having a high potential for delivering a variety of financial services to everyone which are secure, affordable, and convenient to use to the poor and Financially Excluded groups in emerging economies. Many researchers

have estimated that the number of Smartphone users in India will reach 450 million by 2022, which means a majority of the population will have access to Digital Financial Services. Financial service providers also agree that providing banking facilities digitally is an innovative

move to deliver financial services to financially excluded groups and reach remote areas where there is no existence of physical bank branches. All this is low cost and time saving compared to providing financial services by physical infrastructure. Mobility has more impact compared to on-the-go transactions; penetrating online banking services with almost all banking functions at their fingertips will fulfill the objective of Financial Inclusion. At the Macro level, it will also boost the growth, economy, and the GDP.

Digital finance refers to the delivery of financial products and services to its users through digital mediums through channels like Internet Banking, Mobile Banking, Plastic Cards E-Lobby (ATM – Kiosks), and other digital mediums.

Digital Financial Services Include

1. Transaction Accounts: They are just like a formal bank account where the user deposits the funds, the formal bank account can also be used digitally and e-wallet can also be used as a transaction account with limited functionality compared to a Savings bank account.

Rational of the Study:

Prior to the COVID-19 outbreak and demonetization, digital finance was not particularly popular. Following this, a number of digital payment options—such as net banking, UPI, mobile wallets, debit and credit cards, and more—became more well-liked and were supported by the government. The distinction between cash and electronic payments is being narrowed by digital financial inclusion.

2. Payment Services: Money transfers, remittances, bill payments payment at websites or booking sites, etc. are also offered digitally.

3. Savings Accounts: It enables customers to keep aside and deposit money for intended later use.

4. Investment Facilities: It enables users (Individuals as well as Businesses) to earn financial returns in the future by investing funds.

5. Loans: Individuals and businesses can get credit facilities like microfinance, secured lending, etc. with this service.

6. Insurance Services: All types of insurance services including Life and General Insurance services are provided digitally to insure lives and goods against risks.

Since the country's independence, the government of India has undertaken several initiatives to modernize the financial system. One of the most recent changes in the banking business is the advent of technology, which enables banks to provide banking through different channels to more individuals.

Customers can immediately and affordably send money to friends, family, and enterprises when they are connected to a digital payment system.

Even if it appears like more individuals are using electronic payment methods, there are some unfavorable opinions about them, including concerns about security, inadequate network coverage, merchant unwillingness, high transaction fees, and

customer financial ignorance. and digital literacy, etc., appear to be preventing many from utilizing the new technology.

Statement of the Problem:

Although digital financial services have been around for decades in India and have been pushed as a means of promoting financial inclusion, many consumers still do not view them as an alternative to traditional banks. A thorough understanding of the factors that encourage and impede the adoption of these services will assist governments and banks in making policy decisions that will boost adoption and, ultimately, financial inclusion.

Through the "Digital India" program, the Indian government and the Reserve Bank of India are pushing digital financial services to reach financially disadvantaged populations and extend the reach of banks into rural and distant areas. The acceptance and utilization of these services are quite low despite such initiatives.

Despite the availability of all banking services through digital media, which can be accessed instantly and at a very low cost, people in India still prefer and rely on the services provided by branches. People who live in rural and semi-urban areas still

This study is an attempt to examine adoption, usage, and the causes of financial exclusion in Kanpur, Uttar Pradesh, this study aims to determine the effect of digital financial services on financial inclusion.

favor carrying "Cash" over digital banking. Many clients still choose in-person banking and face-to-face interactions over online banking because they believe these methods are safer and more secure because of the human interaction and physical vouchers that guarantee efficient and secure transactions.

In addition, a few other factors contributing to the low uptake of these services are the rise in cybercrimes and hacking attacks, as well as the banks' lack of assistance in dealing with these incidents, which makes customers prefer in-branch banking even in the face of promotional offers, campaigns, and awareness initiatives run by banks and other organizations.

Therefore, with the aid of this study, it is crucial to investigate the key factors behind the poor adoption of digital financial services and provide actions to change the current state of affairs.

Investigating the potential influence of demographic characteristics on the uptake of digital financial services is also crucial.

Operational Definition of Key Terms

Digital Finance: the process of facilitating, managing, and carrying out different financial transactions, such as banking, payments, investments, loans, and financial analysis, through the use of electronic or computer-based technology

and platforms. The use of digital tools to improve and streamline financial transactions, procedures, and services is known as "digital finance." These tools include electronic payment systems, internet platforms, blockchain technology,

and mobile applications. It entails the digitalization of conventional financial operations, allowing people, organizations, and enterprises to effectively and safely access, deal with, and manage their financial resources online.

Financial Inclusion: The degree to which people and organizations may efficiently access and utilize a variety of financial services necessary for their day-to-day operations and economic endeavors is referred to as financial inclusion. The equitable and all-encompassing accessibility, availability, and utilization of a varied array of financial services by

individuals and enterprises, irrespective of their financial background, geographical location, or demographic attributes. Making sure everyone has access to necessary financial resources, including credit, insurance, savings accounts, payment systems, and other associated goods, is a key component of financial inclusion. To enable all facets of society to engage in the formal financial system and contribute to economic growth and inequality reduction, the operationalization of financial inclusion endeavors to remove obstacles, encourage affordability, advance literacy, and capitalize on technological advancements.

Review of Related Literature

Literature review is the root of any strong and good quality research work despite being emerging research area in Indian and global context.

(Hammoud, Bizri, & Ibrahim, 2018) tried to examine the strongest factor influencing e-banking customer satisfaction by conducting a study in Lebanese. The major factor which influenced customer satisfaction was 'Reliability'. Responsiveness, efficiency, communication, security and privacy were identified as other factors influencing customer satisfaction. (Muhammad Jamal, Gao, Tayyaba, & Syed, 2018) attempted to study mobile banking adoption in male and female. For this purpose, some variables namely social norms, PU, PC, self-expressiveness and perceived financial costs were used. It was found that financial cost was not significant for both genders in mobile banking adoption. PU was least important for females. However, Social Norms was important equally for both

genders. Females considered PC more important than male counterparts.

(Durai & G.Stella, 2019) discussed the concept of DF and its impact on FI. The study used primary data collected using a questionnaire containing various digital financial services and their impact on FI in terms of Usability, adaptability, affordability, security, user-friendliness, accurate timing, online financial statement, quick financial decision making, low service charge, internet services, and easy interbank transfers. The study found that despite negative impacts like security, affordability, and adaptability, accurate timing, convenience, easy interbank transfer, and usability have positive impacts on mobile banking while low service charges have a positive impact on credit card. The study concluded that DF has a positive impact on FI; however, the negative sides can be easily eradicated with minor technological and policy advancements leading to greater FI.

(Jacob, T, Mathew, Joseph, & Jayakrishnakumar, 2019) Attempted to study the progress of FI in India using various secondary sources such as reports of RBI, NABARD, GOI, The World Bank and The IMF the study found that around 70 percent of the population resides in rural areas but the major number of bank branches and ATMs are located in Urban and Semi-Urban Areas. The study concluded that FI is growing in the country and by broadening access the financial services and encouraging people to use financial services for economic and social wellbeing can result in improving the pace of FI.

(Chandralekha & Rimita, 2020) aimed towards finding the determinants of the DF in India. The study noted the initiatives of GOI like Demonetisation and Cash Less economy to promote Digital Financial Services for improving FI. The study collected data from pre and post demonetisation period to study the adoption of DFS. The findings suggested that men from high income group and even of older age were inclined towards usage of DFS in both pre and post period, while post demonetisation period attracted educated people from middle class too, however in every case female were still lagging behind in adoption and usage of these services.

Since most authorities and providers are promoting Digital Finance, (Ozili, 2020)

Future perspective

Digital financial services, such as plastic cards, internet banking, and mobile banking, have been the focus of numerous studies. All of the studies, both in India and elsewhere, examined the acceptance and utilization of these services in urban

assessed several options of Digital Finance to see whether it supports FI and is fit for underprivileged people. The study was conceptual in character since it drew on several books from reliable and reputable sources. In closing notes of the research, the DF exposes underprivileged and underprivileged people to financial risk against only one benefit presented, i.e., improved financial decision making via information it supplies. The researcher said that distinct arrangement alone would allow DF for poverty to come with either reduced or no risk alternative. Therefore, government officials and service providers ought to consider this.

Using the Global Findex Database of World Bank, (Nandru, Madhavaiah, & Velayutham, 2021) investigated the real state of Digital FI in India. The study tracked DFS use and accessibility in relation to demographic factors. It found that respondents' socioeconomic level had a major influence on their use of the same and access to financial services. Low income and lack of education in population, then, are the obstacles to acceptance and use of digital financial services. For financially excluded people with education and belonging to lower middle class and above group, digital financial services can be useful in improving FI.

and developed locations, with respondents from a range of socioeconomic backgrounds. As everyone is aware, on January 10, 2020, the Reserve Bank of India (RBI) unveiled the National Strategy for Financial Inclusion 2019–2024. It

encapsulates the goals and ambitions of the financial inclusion initiative in India. With assistance from the central government and the regulators of the financial sector (the Insurance Regulatory and Development Authority of India, the Securities and Exchange Board of India, and the Pension Fund Regulatory and Development Authority of India), the RBI developed the plan. In addition to initiatives like the Pradhan Mantri Jan Dhan Yojna, the government wants to make the nation more financially inclusive (PMJDY). Banks and other financial institutions support government operations by supporting these efforts. Low-income and economically disadvantaged individuals have been

given "RuPay" debit cards and opened numerous bank accounts as a result of the effective PMJDY campaign. The government also launched and promoted BHIM (Bharat Interface for Money) and UPI (Unified Payment Interface) to promote digital financial services and digital financial inclusion. Research on the impact of digital financial services on financial inclusion is scarce globally. The majority of research in this field is conceptual in nature and only grounded in a collection of theoretical Understanding the use, acceptance, opinions, and difficulties associated with the deployment of digital financial services in various contexts is therefore essential.

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THE ALPHA DIVIDEND: ARCHITECTING DIGITAL FINANCIAL LITERACY AS A CORNERSTONE OF HUMAN CAPITAL FOR VIKSHIT BHARAT @ 2047

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ABSTRACT

India's ambitious vision for Vikshit Bharat @ 2047—a transformative leap to the status of a developed economy—rests fundamentally on the strategic cultivation of its vast human capital. This paper argues that, in a rapidly evolving, digitized, and decentralized financial environment, conventional literacy and even basic financial education are no longer sufficient. We define and position Digital Financial Literacy (DFL) as an advanced, essential form of human capital, serving as a core driver of economic productivity, resilience, and inclusive growth. This technical paper moves beyond advocacy, proposing a rigorous, data-driven approach to building DFL at scale. First, we extend the classic Cobb-Douglas production function, quantitatively integrating DFL as a direct multiplier of human capital productivity, thus modeling its economic impact. Second, we introduce a new, multi-dimensional “Indian DFL Index,” comprised of four weighted sub-indices: Digital Proficiency, Financial Acumen, Cyber-Risk Cognizance, and Rights & Redressal Awareness. This composite metric offers policymakers a robust tool for both assessment and targeted intervention. Finally, we outline a structured, three-phase “Human Capital Pipeline Strategy” spanning 2025 to 2047, designed to methodically advance DFL across diverse demographic segments. This strategy leverages emerging technologies—including AI-driven personalized learning and gamified VR modules—to ensure comprehensive, adaptive upskilling. The framework presented here thus provides a systematic pathway for embedding advanced DFL as a foundational element of India's human capital, supporting its broader developmental aspirations. This paper gives an

explicit roadmap with curriculum and delivery styles and KPIs for the different phases. We assert that a technically sound mission-mode strategy of developing this new breed of human capital is not simply good but a necessary condition for achieving the grand visions of 2047.

Keywords: Digital Financial Literacy, Human Capital Theory, Financial Inclusion, Behavioral Finance, Educational Technology

INTRODUCTION: BEYOND ACCESS, TOWARDS EMPOWERMENT

India's story of development over the past two decades has been a story of leapfrogging. The JAM trinity (Jan Dhan, Aadhaar and Mobile) did not just provide bank accounts, but laid a digital artery to financial inclusion. The UPI didn't just make payments easy, it democratised digital commerce at a population level. By 2024, this impressive advance has registered on the RBI's Financial Inclusion Index (FI-Index), which confirms steady improvements in the reach of financial services. Yet, access is only the first rung on the ladder of economic empowerment (Unuigbokhai and Anthony, 2022). The ladder is being reconstructed with new rungs: app-based credit, algorithmic investment advice, decentralized finance (DeFi), central bank digital currency (CBDC) and immersive metaverse economies.

Understanding the new terrain requires more than just using digital tools; it also necessitates a more comprehensive cognitive toolkit to comprehend the why, how, and what-if. A critical skill that the user possesses, which is to make an accurate payment with a QR code but be vulnerable to phishing attempts, is lacking (Thakkar et al, 2024). Those who are lured by social media hype and lack comprehension of the underlying risk do not possess authentic empowerment (Thakkar et al, 2024). By 2047, the key obstacle to building up the human capital

needed for a developed India is the disparity between digital access and digital wisdom.

The challenge is addressed by this paper through the conceptualization of Digital Financial Literacy (DFL) as a fundamental aspect of human capital theory, rather than merely promoting social welfare (Thakkar et al, 2025). DFL, we believe, is a type of human capital that utilizes digital technology and education or vocational training to produce tangible economic benefits for both the individual and the nation. Our contribution is threefold:

A Theoretical Framework: We present a formal economic model designed to measure the impact of DFL on the national economy.

A Measurement System: We create a detailed and technically sound "Indian DFL Index" that transitions from anecdotal observations to solid measurements.

An Actionable Plan: We outline a comprehensive, phased approach for implementing a DFL-focused human capital development pipeline.

In doing so, we transform the conversation from merely "teaching finance" to "designing a resilient, adaptive, and financially savvy populace" that can not only engage in but also actively influence the economy of Vikshit Bharat by 2047.

LITERATURE REVIEW

Both scholars and experts in finance do concur that measures and understanding of financial literacy (FL) is essential to understand how individuals make financial choices. Nonetheless, there is no standard definition or way to measure it (Ogunode & Dada, 2022). Following the increasing use of digital financial services (DFS), which tend to increase financial inclusion and enhance money management, financial literacy has a new challenge—linking it with digital literacy (DL) (Olaniyan et al., 2021). This has generated increased interest in digital financial literacy (DFL), as existing FL practices no longer meet the requirements of skills required in the current digital financial landscape (Lyons & Kass-Hanna, 2021). The research uncovers the developing interdisciplinary character of digital finance, pointing to the shift towards behavioral from demographic determinants of digital financial literacy, and offers a framework to spot the key areas of future research (Yadav & Banerji, 2023). The research examines how digitalization affects capability and

financial literacy, highlighting key themes—digital financial behavior, Fintech, and behavioral interventions—while suggesting new measurement techniques, curriculum design improvements, and online learning tools (Koskelainen et al., 2023). This research examines how financial literacy in the digital age, financial empowerment, financial capacity, and impulsivity act as mediators of financial decision-making and self-reported financial well-being during the period of COVID-19 and financial technology growth (Omucheyi et al., 2025). Drawing from 512 Delhi/NCR respondents' data and processed through SmartPLS 3.3 and partial least squares structural equation modeling, the results indicate that digital financial literacy directly and as a mediator had significant effects on financial decisions (Thakkar et al., 2025). Financial capability and autonomy also have strong mediating effects, but impulsivity does not have a direct effect on financial decision-making (Kumar et al., 2023).

DFL AS HUMAN CAPITAL: A THEORETICAL AND ECONOMIC FRAMEWORK

The basis of contemporary human capital theory, developed by economists such as Gary Becker and Theodore Schultz, is that spending on education, training, and health are not consumption but investments that increase an individual's productivity and income. Becker was able to identify "general" human capital (aspects of quality that are useful to all employers, e.g., literacy) and "firm-specific" human capital (aspects of quality that are useful to one employer, e.g., knowledge of a company-specific software).

We suggest that contemporary economic transformation requires a third type: Digital-Specific Human Capital. DFL is an exemplary member of this type (Thakkar et al., 2025). It is more than overall literacy but is not bound to one company; instead, it is bound to the digital economic environment as a whole. It is the ability to successfully and securely use the digital interfaces that mediate contemporary economic activity.

Table 1: A Typology of Human Capital in the 21st Century

Capital Type	Definition	Classic Examples	Viksit Bharat @ 2047 Examples	Portability
General	Skills and knowledge that increase productivity across a wide range of employers and industries.	Literacy, Numeracy, Critical Thinking	Foundational Education (as per NEP 2020)	High
Firm-Specific	Skills and knowledge that are productive only within a specific firm or context.	Knowledge of a company's internal processes, specific client relationships.	Training on a bank's proprietary loan processing software.	Low
Digital-Specific	Skills and knowledge to productively and safely leverage the common digital economic infrastructure.	Digital Financial Literacy (DFL), Data Privacy Management, Digital Identity Control.	Ability to evaluate a DeFi staking protocol, configure privacy settings on a CBDC wallet, identify AI-generated financial scams.	High

Source: Compiled by Author

2.1. Calculation: Quantifying the "DFL Alpha"

To move DFL from a qualitative concept to a quantifiable economic variable, we can adapt the Cobb-Douglas production function, a staple of economic growth accounting. The standard function is:

$$Y = A \cdot K^{\alpha} \cdot L^{1-\alpha}$$

Where:

Y = Total Production (GDP)

A = Total Factor Productivity (TFP, a measure of technology/efficiency)

K = Capital stock

L = Labour input

alpha = Output elasticity of capital

To incorporate human capital (H), the function is often modified to:

$$Y=A \cdot K^{\alpha} \cdot (H \cdot L)^{1-\alpha}$$

Here, human capital (e.g., average years of schooling) augments the raw labour input. We propose a further refinement to explicitly model the contribution of DFL. We introduce a DFL Index score (D), which ranges from 0 (no DFL) to 1 (perfect DFL), as a direct multiplier on the efficacy of human capital in the digital age.

The DFL-Augmented Production Function becomes:

$$Y=A \cdot K^{\alpha} \cdot [(H \cdot (1+\lambda D)) \cdot L]^{1-\alpha}$$

Where:

D = The national average score on the Indian DFL Index (as proposed in Section 3).

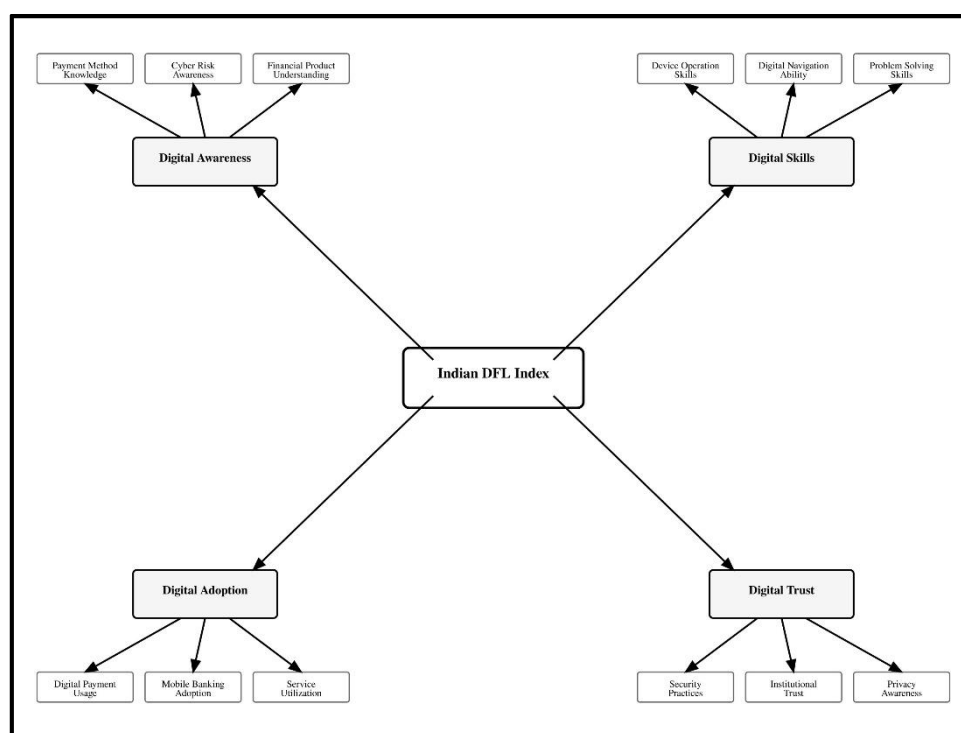
lambda (Lambda) = The "DFL Alpha," representing the productivity elasticity of DFL. It is a coefficient that signifies the percentage increase in the productivity of human capital for every one-point increase in the DFL index.

This model states vividly: enhancing DFL (D) directly increases the productive efficiency of the available human capital (H), which results in increased GDP (Y). For example, if lambda=0.5 and the country's DFL index D rises from 0.4 to 0.6, the effective human capital per capita rises by $(0.5 \times 0.2) = 10\%$, a substantial increase in national production. Calibrating lambda through empirical econometric research would become a priority for NITI Aayog and the RBI.

A MULTI-DIMENSIONAL FRAMEWORK FOR MEASURING DFL: THE INDIAN DFL INDEX

To operationalize the DFL-augmented production function and guide policy, we need a robust measurement tool. We propose the creation of a national, standardized "Indian DFL Index." This index is not a simple quiz but a composite framework designed to provide a holistic view of an individual's capabilities.

Figure 1: Hierarchical Structure of the Indian DFL Index



Source: Compiled by Author

The index is calculated as a weighted average of four sub-indices:

$$DFL_{Index} = w_{DP} \cdot I_{DP} + w_{FA} \cdot I_{FA} + w_{RC} \cdot I_{RC} + w_{RR} \cdot I_{RR}$$

Where:

$I_{sub-index}$ is the score for each sub-index.

$w_{sub-index}$ is the weight assigned to each sub-index, with $\sum w = 1$.

The weights should be determined by a panel of experts from the RBI, SEBI, MeitY, and academia, reflecting national priorities. For instance, in the initial years, a higher weight might be assigned to Cyber-Risk Cognizance to combat the surge in digital fraud.

A proposed weighting could be:

$$w_{DP} = 0.20$$

$$w_{FA} = 0.30$$

$$w_{RC} = 0.35$$

$$w_{RR} = 0.15$$

Table 2: Detailed Composition of the Indian DFL Index

Sub-Index (I)	Proposed Weight (w)	Rationale	Measurable Indicators (Examples)	Assessment Method
I_DP: Digital Proficiency	0.2	Foundational ability to operate digital tools. The 'how-to'.	1. Ability to use a smartphone for non-communication tasks. 2. Competence in using a UPI app for various transactions (P2P, P2M) 3. Skill in navigating a net banking portal or a FinTech app.	Performance-based simulations; standardized practical tests.
I_FA: Financial Acumen	0.3	Core financial concepts applied to digital products. The 'what' and 'why'.	1. Understanding of compounding in the context of a digital SIP. 2. Ability to compare interest rates and fees on different digital loan apps. 3. Knowledge of risk-return trade-offs in app-based equity/mutual fund investments.	Scenario-based questions; conceptual problem-solving.
I_RC: Cyber-Risk & Security Cognizance	0.35	The ability to identify, mitigate, and manage digital financial risks. The 'what-if-wrong'.	1. Ability to identify phishing attempts (email, SMS, QR code) 2. Understanding and correct use of 2FA/MFA 3. Awareness of risks associated with public Wi-Fi for financial transactions 4. Basic understanding of smart contract risks in DeFi/NFTs.	Interactive simulations (e.g., identifying fake websites); knowledge-based tests.

I_RR: Rights & Redressal Awareness	0.15	Knowledge of one's rights as a digital consumer and the pathways for grievance redressal.	1. Knowledge of the RBI Ombudsman Scheme for digital transactions 2. Awareness of the 3-day limited liability rule for unauthorized transactions. 3. Understanding of data privacy rights under the DPDPA 2023.	Situational judgment tests; knowledge-based questions.

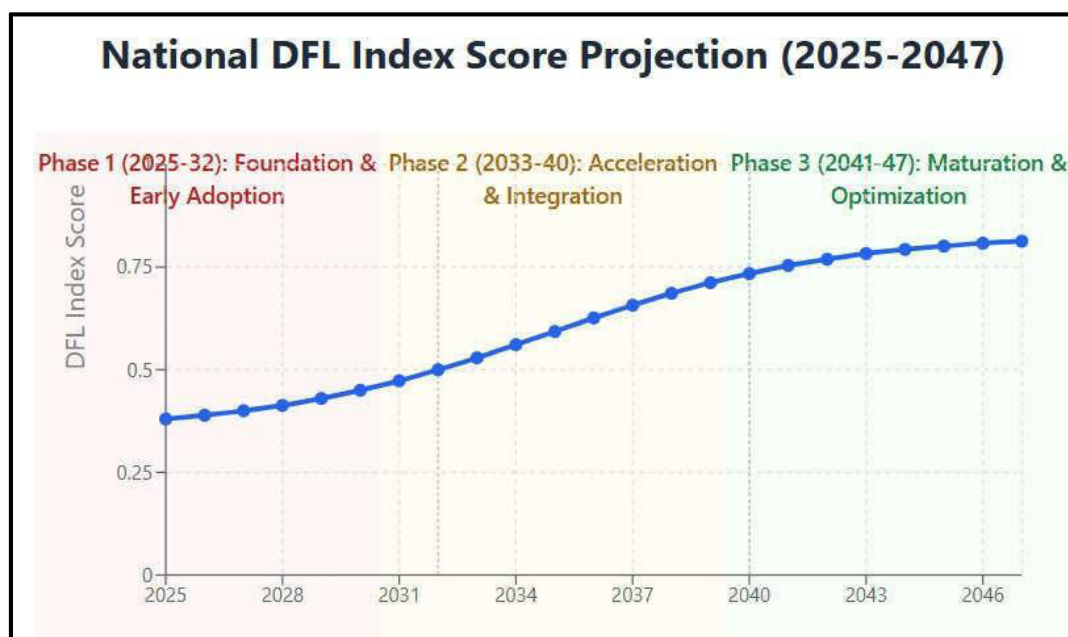
Source: Compiled by Author

This index would be measured annually through a large-scale national sample survey, akin to the National Family Health Survey (NFHS), providing granular data across states, demographic groups, and income levels.

ARCHITECTING THE HUMAN CAPITAL PIPELINE: A PHASED STRATEGY FOR 2047

It takes a phased, strategic effort to construct a nation's DFL over the long term. We recommend a 22-year, three-phase Human Capital Pipeline Strategy to develop the national DFL Index score methodically from a baseline of ~0.35 in 2025 to >0.80 by 2047.

Graph 1: Projected National DFL Index Score Trajectory (2025-2047)



Source: Compiled by Author

Phase 1 (2025-2032): Foundational Infrastructure & Mass Security Awareness

This phase focuses on bridging the basic digital divide and tackling the most immediate threat: digital financial fraud. The goal is to build a solid foundation of basic proficiency and security hygiene.

Table 3: Phase 1 Strategy Details

Element	Description
Target Audience	School students (Grades 6-12), rural populations (especially women), senior citizens.
Key Topics	- Core Skill: Safe use of UPI, ATM cards, and basic mobile banking. - Security: Identifying common scams (phishing, vishing, QR code scams), importance of not sharing OTP/PIN. - Concepts: Introduction to savings, interest, and the concept of insurance. - Redressal: "What to do if you are scammed" - reporting to the national helpline (1930) and the bank.
Delivery Channels	- Schools: Mandatory integration into the curriculum (e.g., as part of Social Studies or IT classes). - Mass Media: High-intensity campaigns on TV, radio, and social media using simple, memorable messaging. - Community-led: Leveraging SHGs, Anganwadi workers, and postmen as "DFL-Sathis". - Gamification: Simple mobile games simulating scam identification.
KPIs	- Reduce reported losses to UPI-related fraud by 50%. - Achieve a national average score of >0.80 on the Cyber-Risk Cognizance (I_RC) sub-index for common scams. - Increase in the percentage of PMJDY accounts with active digital transactions.

Source: Compiled by Author

Phase 2 (2033-2040): Deepening, Diversification, & Vocational Integration

With a foundation in place, this phase focuses on more complex financial products and preparing the workforce for a digital-native economy. The curriculum diversifies to cover investment, credit, and emerging technologies.

Table 4: Phase 2 Strategy Details

Element	Description
Target Audience	College students, young professionals, MSME owners, gig economy workers.
Key Topics	- Credit: Understanding credit scores, comparing digital loan products, dangers of predatory loan apps. - Investment: Basics of mutual funds, SIPs, equity markets, and risk management through app-based platforms. - Insurance: Understanding and comparing digital health and life insurance products. - Emerging Tech: Introduction to CBDC, understanding the concept (not speculation) of blockchain and digital assets.
Delivery Channels	- Higher Education: Mandatory credit courses on personal finance. - Vocational Training: DFL modules integrated into ITIs and skill development programs. - AI-Powered Learning: Personalized learning apps that adapt content based on a user's DFL index score and learning pace. - FinTech Partnerships: Collaboration with FinTech platforms to embed unbiased educational modules within their apps.
KPIs	- Increase in retail participation in capital markets through digital platforms. - Measurable improvement in the national average Financial Acumen (I_FA) sub-index score. - Reduction in defaults related to digital predatory lending.

Source: Compiled by Author

Phase 3 (2041-2047): Dynamic Adaptation & Lifelong Learning

The final phase focuses on creating a self-sustaining ecosystem of lifelong learning, enabling citizens to adapt to financial technologies that may not even exist today. The goal is mastery and critical evaluation of a highly complex financial environment.

Table 5: Phase 3 Strategy Details

Element	Description
Target Audience	Entire population, with a focus on continuous upskilling.
Key Topics	- Advanced Finance: Managing a portfolio of digital and traditional assets, digital estate planning (transfer of crypto assets, etc.). - AI & Finance: Critically evaluating AI-driven financial advice (robo-advisors), understanding algorithmic bias. - Decentralized Economy: Safe and effective interaction with mature DeFi protocols, DAOs, and metaverse economic systems. - Data Economy: Understanding how to manage and potentially monetize one's own financial data.
Delivery Channels	- Just-in-Time Learning: AI-powered "financial co-pilots" that provide real-time guidance and warnings. - Immersive Learning: VR/AR simulations for complex financial scenarios (e.g., navigating a market crash, planning for retirement). - Decentralized Education (DeEd): Educational credentials for DFL courses stored as verifiable credentials on a blockchain, creating a permanent, portable skill record.
KPIs	- High national average score (>0.80) across all four DFL sub-indices. - A thriving market for innovative DFL tools and platforms. - Low levels of financial distress attributed to the misuse of complex digital financial products.

Source: Compiled by Author

OVERCOMING INEVITABLE CHALLENGES

The execution of this grand strategy will be confronted with serious challenges:

The Enduring Digital Divide: Though internet penetration is increasing, substantive access (device ownership, consistent connectivity, affordability) continues to be an issue, especially in rural and tribal regions. Mitigation necessitates ongoing government support for digital infrastructure (such as BharatNet) and plans for low-cost smartphones.

Cognitive Biases in Steroids: Digital interfaces have the power to enhance cognitive biases. The convenience of "one-click" investing can compound herd

behavior. The gamified dynamics of trading apps can set off overconfidence bias. DFL curricula should clearly instruct about such biases and employ simulations to make users aware and counteract these in real-time.

Speed of Obsolescence: Curriculum created in 2025 will be partially outdated by 2030. Mitigation involves an evolving, modular framework of a curriculum that can be refreshed each year by a central authority (e.g., a "DFL Council of India"). One must focus on the instruction of first principles (risk, diversification,

verification) as opposed to merely the characteristics of a particular app.

Inclusion of the Differently-Abled: DFL efforts should be accessibility-based, with a focus on following WCAG (Web Content Accessibility Guidelines) and developing content for visually and hearing-impaired citizens.

CONCLUSION: THE ULTIMATE DIVIDEND OF A LITERATE NATION

The vision of Vikshit Bharat @ 2047 is not just an economic objective; it's a pledge of empowerment, resilience, and collective prosperity for 1.5 billion people. In this paper, we have maintained that in the 21st century, empowerment is synonymous with an individual's capacity to enter the digital financial sphere confidently and critically. We have brought this argument

from advocacy to a formal, technical discourse.

By framing DFL as a quantifiable category of human capital, suggesting a strong DFL Index for governance, and designing a long-term human capital pipeline, we have offered a possible roadmap for action. The cost will be high, but the payoff—the "DFL Alpha"—will be multifold. It will take the form of lower fraud levels, increased savings rates, more effective capital allocation, less household debt anxiety, and a population less vulnerable to misinformation and bubbles. This is the final dividend: a financially smart nation capable not only of surviving but of prospering in the economy of the future, thus making the dream of a developed, empowered India a reality.

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Ensuring Fairness in AI-Powered Credit Decisions: Tackling Bias in Modern Banking

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Abstract

The Artificial Intelligence (AI) allows banks and other financial institutions to possess better credit decision-making processes. The advanced algorithms assist financial institutions with faster processing of loan requests with more accurate risk assessments. Inherent bias issues are a source of concern for banks when utilizing AI systems. AI bias is experienced when the data used to train AI models reflect past inequalities and AI models draw erroneous conclusions. Financial systems accord differential treatment to marginalized groups, which worsens their already deteriorating financial disparities.

Bias inherent problems cause ethical concerns for banks when they use AI systems. Bias in AI occurs when the training data does not represent historical inequalities and AI models are based on untrue premises. Financial systems provide unequal treatment to marginalized groups, further amplifying their already poor financial conditions.

The research explores how bias in AI credit scoring systems arises and how it impacts people. The article employs analysis to illustrate how biases form in decision-making and their ensuing social impacts. The research discusses solutions to the issues through an examination of unbiased algorithms and government policies as well as transparency procedures that safeguard accountability. The study combines computer science methodologies with ethical principles alongside financial and legal viewpoints to create equitable artificial intelligence-driven lending systems. It takes constant monitoring and active collaboration from all stakeholders to establish transparent and equitable credit systems

Key Words: *Algorithmic Bias, Credit Decisioning, Fairness-aware AI, Financial Inclusion, Regulatory Interventions*

1. Introduction

AI is really disrupting the world of finance, especially in deciding who gets credit. Banks are employing machine learning algorithms to rapidly scan massive volumes of sophisticated data, enabling them to approve loans more rapidly and, in

some senses, inclusively (Cowgill et al., 2021; Fair Isaac Corporation, 2021). The

notion is that AI technologies can even eliminate human bias when they accelerate loan processing and provide access to credit for unsuccessful applicants using

conventional practices (Upstart, 2020; Zest AI, 2021).

But there is a huge catch: AI systems struggle with massive algorithmic bias due to the fact that they rely on past data containing societal and economic biases (Barocas et al., 2019; Mehrabi et al., 2021). Unless monitored, uncontrolled AI systems can reinforce unfair discriminatory behavior with greater discrimination against vulnerable groups (Obermeyer et al., 2019). Discriminatory AI can cause discriminatory denial of credit and discriminatory interest rates, denying access to essential financial services and with alarming social consequences (Binns, 2018; Sandvig et al., 2014). Regulators such as the European Commission (2021) and Reserve Bank of India (2023) have noted that discriminatory systems expose lenders to legal action because they are launched by regulatory audits.

This paper looks in detail at the fairness principles for Artificial Intelligence models when they decide on credit. We track exactly how bias occurs and demonstrate its adverse outcomes, and then we offer solutions for reducing its effect. Our work combines technological understanding with legal theory and ethical practice, as well as monetary principles, to create techniques that yield transparent and equitable AI systems that are responsive to social responsibility (Hardt et al., 2016; Kleinberg et al., 2016; Wachter et al., 2017). Our method guarantees accountability of AI systems with the same access to capital for all the users through research by Veale & Binns (2017) and Raji & Buolamwini (2019).

2. Context and Background

Banks and financial institutions employing AI technology in credit scoring can analyze borrower risk more effectively while improving the precision of their loan approval decisions (Fair Isaac Corporation, 2021; Cowgill et al., 2021). Barocas et al. revealed that rapidity in the evolution of AI has challenged the issues regarding the fairness of algorithmic bias and clarity of a system. (2019) and Mehrabi et al. (2021). Banks and financial institutions have to compare current AI-driven lending processes with traditional ones and analyze global ethical and regulatory responses to understand such issues (Hardt et al., 2016; Wachter et al., 2017).

2.1 Growth of AI in Credit Scoring

The rise of **big data** and advanced **machine learning** has really sped up how banks use AI for credit checks, leading to much faster financial services (Upstart, 2020; Zest AI, 2021). These forecasting models are being used by financial institutions today to make more and faster decisions and to better evaluate risk (Kleinberg et al., 2016).

Historically, evaluating a person's credit entailed considering basic aspects such as their income, debt, and employment (Fair Isaac Corporation, 2021). However, these old methods often fail when people have limited or unusual credit histories (Sandvig et al., 2014).

This is where **AI models** step in. They can analyze a huge range of data, even things like social media activity or how you use your smartphone, to fill in those gaps (Pasquale, 2015; Veale & Binns, 2017). However, while AI can improve access to credit, using sensitive personal data brings up serious **privacy and fairness challenges**, as it could unintentionally lead

to discrimination (Binns, 2018; Raji & Buolamwini, 2019).

2.2 Comparing Traditional and AI Credit Evaluation

FICO and similar traditional credit scoring systems operated using established rules and concrete metrics (Fair Isaac Corporation, 2021; Wachter et al., 2017). The scoring system enabled consumers to track the factors affecting their credit scores through transparent processes. The legacy credit systems were based on fixed structures that did not consider gig workers and new borrowers in credit assessments (Kleinberg et al., 2016; Hardt et al., 2016).

The banking industry is revolutionized through AI credit score systems that analyze intricate patterns of data in vast databases (Mehrabi et al., 2021; Rudin, 2019). The systems work with continuous learning processes to enhance their risk assessment accuracy. However, they have two significant shortcomings:

1. Transparency Deficit: AI models tend to be "black boxes." Kroll et al. observe that AI decision-making lacks transparency which creates accountability gaps for both regulators and consumers. (2017) and Wachter et al. (2017).

2. Unintentional Discrimination: Discriminatory results are produced by AI systems through indirect factors such as education level and postal codes that are linked to protected characteristics without directly including the direct identifiers of race or gender (Obermeyer et al., 2019; Sandvig et al., 2014).

2.3 Global Regulations on AI Credit Scoring

International government bodies like the European Commission (2021) and the

Reserve Bank of India (2023) have begun to address legal and ethical issues in lending proposals based on AI. But regulations tend to trail behind technology.

United States: Equal Credit Opportunity Act (ECOA) prohibits discrimination based on gender and race along with other traits. The Federal Reserve (2021) reports that AI systems conceal biases within their operational mechanisms because these biases originate from the data itself. Equal Employment Opportunity Commission, (2021). Equal Employment Opportunity Commission, (2021). Equal Employment Opportunity Commission, (2021).

- **European Union:** GDPR rules give people control to ask for explanations about automated decision-making processes. The governing regulation mandates companies to uphold transparency and accountability during the development of their AI credit models.

- **India:** The Reserve Bank of India supports ethical AI practices in its financial sector but comprehensive regulatory frameworks remain in initial development phases. The Monetary Authority of Singapore discovered fairness issues with unregulated AI lending systems in 2022 followed by similar findings from the Reserve Bank of India in 2023.

AI regulatory measures target technologies but legal frameworks stay behind because they respond after AI developments have already occurred (Williams et al., 2018).

AI Lending systems reveal their ethical and social impacts through their built-in biases.

AI-powered credit systems that use biased algorithms contribute to the expansion of existing social inequalities. Algorithms with built-in biases replicate historical

discrimination patterns that disproportionately affect marginalized groups (Barocas et al., 2019; Mehrabi et al., 2021). The fallout includes:

- **Higher Interest Rates:** Obermeyer and his colleagues found specific groups receive unjust high-risk labels that result in them facing higher loan interest rates. (2019) and Angwin et al. (2016).
- **Loan Rejections:** Complete credit denial for people from specific racial and socioeconomic backgrounds prevents them from accessing future opportunities (Binns et al., 2018; Rudin, 2019).
- **Exclusion from Banking:** Current financial entities restrict entry into particular communities that expand the gap between privileged groups and excluded populations (Binns, 2018; Sandvig et al., 2014).

Issues of fairness and justice are associated with unfair algorithms that create major public suspicion (Raji & Yang 2021; Wachter et al., 2017). A study by Kleinberg et al. confirms that the development of AI systems involves ensuring fairness assessments are included together with clear methods and ethics practices utilizing supervision systems. (2016) and Kamiran & Calders (2012).

3. Understanding Algorithmic Bias

Algorithmic bias describes AI systems whose outputs perpetuate harm against specific groups while widening societal gaps (Mehrabi et al., 2021; Sandvig et al., 2014). AI-based credit scoring is designed to improve fairness and efficiency but has the potential to keep existing biases and discriminatory structures according to research by Barocas et al. (2019) and Raji

& Buolamwini (2019). Financial applications of AI raise ethical concerns when biases become embedded at the different phases of AI construction involving data collection and feature engineering in addition to model training and final interpretation (Holstein et al., 2019; Wachter et al., 2017).

3.1 Definition and Types of Bias

The research by Kleinberg et al. (2016) and Rudin (2019). The research by Kleinberg et al. shows how AI systems make discriminatory inferences when they are developed on erroneous data and biased hypotheses. The most critical types of bias are:

- **Historical Bias:** Social biases in historical sources become ingrained in datasets that give rise to historical bias. Angwin et al. research indicates that bias reduction schemes continue to have historical discrimination patterns that establish lending barriers for certain communities. (2016), Datta et al. (2015), and Cowgill et al. (2021).
- **Measurement Bias:** Measurement Bias is experienced by data collection when it uses information that is old and causes wrong outcomes. The application of old measures of financial behavior in credit assessment contributes to wrong judgments of creditworthiness as posited by Holstein et al. (2019), Kamiran & Calders (2012), and the Federal Reserve (2021).
- **Sample Bias:** Sample Bias is experienced when a training dataset fails to represent the population entirely. Creditworthiness models learning from urban applicant data face challenges when applying to rural borrowers (Pasquale 2015; Binns 2018; Obermeyer et al., 2019).

- **Aggregation Bias:** Aggregation Bias results when models apply common assumptions for several groups rather than considering unique subgroup characteristics. The error results in incorrect assessments of financial conduct across different demographic segments as per Hardt et al., Binns et al., and Veale & Binns.

The prevalence of these biases reveals inconsistencies in lending and highlights the necessity of financial corporations implementing AI systems that guarantee equal treatment (Raji & Yang, 2021).

AI systems get biased in finance through unequal practices in data collection and feature selection.

Mehrabi et al., 2021 and Wachter et al., 2017 assert that ethical data selection is the initial step towards achieving fairness in artificial intelligence systems. Williams et al. established that AI systems retain bias as race and gender traits appear through correlated variables even when explicit characteristics are excluded from analysis. (2018) and Goodman & Flaxman (2017).

Research by Angwin et al. Socioeconomic status and ethnic background information become apparent from ZIP codes combined with education levels and job titles. (2016) and Datta et al. (2015). Systemic unfairness is apparent when the people in some regions get lower credit scores that are less than their actual financial risk (Obermeyer et al., 2019; Kamiran & Calders, 2012). According to Rudin (2019), extensive analysis of feature use leads to recognizing how these factors affect unfair decision-making systems.

3.2 Indirect Discrimination and Proxy Variables

Models display indirect discrimination when they use input features that are related to protected characteristics even though they do not use these protected characteristics directly (Binns, 2018; Hardt et al., 2016). The ongoing patterns of economic and social inequality present in the data create substantial challenges during credit assessment evaluations (Wieringa, 2020).

Assess the overall performance of a model that imposes penalties on individuals engaged in freelance or part-time work. As Sandvig et al. Analyses by Sandvig et al. The studies by Sandvig et al. Research by Sandvig et al. (2014) and Veale & Binns (2017) shows that these models create adverse effects for women and minorities in non-standard work positions. Models that incorporate neighborhood or district data unintentionally reproduce racial segregation patterns which leads to flawed results (Kleinberg et al., 2016; Kroll et al., 2017).

Model audits implement fairness metrics like demographic parity and equalized odds to detect bias and diminish the occurrence of discrimination (Raji & Yang, 2021; Holstein et al., 2019).

3.3 Case Studies: Bias in Credit Algorithms

Empirical studies by Pasquale (2015) and Eubanks (2018) show that biases in algorithms influence access to credit.

- **Apple Card (2019):** Apple and Goldman Sachs financial products faced public criticism after customers found out their credit limits showed gender-based inequalities. Studies reveal that women with equivalent financial backgrounds obtain smaller credit limits than men pointing to gender bias in the credit

decision model (Angwin et al., 2016; Wachter et al., 2017; Wieringa, 2020).

- ***U.S. Mortgage Approvals:*** Studies show that AI mortgage approval systems show racial bias by favoring white applicants over Black or Latino applicants with similar financial backgrounds.

- ***Fintech Lending:*** Mehrabi and his team, along with Fair Isaac Corporation, explain that financial institutions use alternative data sources such as mobile phone behavior and social media activities to determine creditworthiness. Alternate data sources such as mobile phone behavior and social media usage are used to determine creditworthiness by different lenders. Different lenders use creditworthiness based on non-traditional sources such as social media usage and mobile phone usage patterns. (2021). While predictive methods seek to increase accuracy they yield skewed impact for low-income people resulting in the emergence of new indirect bias forms (Raji & Buolamwini 2019; Kamiran & Calders 2012).

Different AI-based credit scoring situations demonstrate the critical necessity for bias detection measures and ethical safeguards. Ethical deployment by AI systems necessitates them to demonstrate transparency of action in line with regulatory requirements and accept fairness-aware design principles (Rudin, 2019; Holstein et al., 2019; Wachter et al., 2017; Kleinberg et al., 2016).

4. Impacts of Discriminatory Credit Decisions

Eubanks (2018) and Pasquale (2015) studies indicate that machine-learning credit systems exhibit bias on personal loan applications in a detrimental manner and escalate already prevalent disparities in

society. Wachter et al. studies establish that inaccurate high-risk credit labels lead to loan denial or prohibitively expensive borrowing conditions that dissuade people from pursuing education and housing finance as well as business entrepreneurship. And Barocas et al. Financial failures have more profound effects on disadvantaged groups than on other groups.

4.1 Economic and Social Impacts

Sandvig et al., 2014 and Mehrabi et al., 2021 study maintains that discriminatory credit judgments have significant economic implications while excluding minority groups from credit facilities. Discrimination in financial lending prevents the community from wealth formation and entrepreneurial opportunities that drive the development of economic inequalities over time, as Hardt et al., (2016) and Binns (2018) maintain.

Credit scoring models provide inferior credit to the dwellers of minority or low-income neighborhoods that leads to fewer approvals of loans among these individuals and shuts off their chances of economic development (Cowgill et al., 2021; Obermeyer et al., 2019).Raji & Buolamwini (2019) indicated that the rate of economic development slows down as socioeconomic disparities increase.

4.2 Legal and Regulatory Implications

Credit scoring models that have biased results are able to break anti-discrimination legislations in the United States. The U.S. The Equal Credit Opportunity Act (ECOA) serves to eliminate anti-discrimination similar to other laws functioning in different jurisdictions (Goodman & Flaxman, 2017; Wachter et al., 2017). The legal framework makes it illegal for credit

decisions to discriminate against individuals based on their race or gender and prohibits bias based on age and religious beliefs as well as marital status. Barocas et al. identify that financial institutions face legal penalties and reputational harm when their AI systems inadvertently breach protective regulations. (2019) and Veale & Binns (2017).

Financial institutions must show clear processes for creating and implementing credit models according to regulatory mandates. The concept of "algorithmic accountability" mandates that financial institutions disclose the decision-making processes of their complex algorithms (Raji & Yang, 2021; Kroll et al., 2017). Financial institutions that fail to comply with requirements will endure audits and penalties and receive extra regulatory scrutiny.

4.3 Reputational Risks for Financial Institutions

Trust is essential in financial services. The discovery of biased lending algorithms or non-transparent algorithmic operations leads to customer trust erosion for financial institutions (Pasquale, 2015; Holstein et al., 2019). The Apple Card gender discrimination case demonstrates how public controversies can damage a brand's reputation and trigger regulatory investigations (Angwin et al., 2016; Wieringa, 2020).

Success in modern data-centric business environments requires organizations to adhere to ethical AI standards. Companies that disregard ethical AI practices risk facing lawsuits and negative publicity from advocacy organizations resulting in

consumer backlash. The Federal Reserve's 2021 research illustrates the manner in which businesses focusing on equity during AI policymaking processes boost customer loyalty and gain competitive advantages.

Writing styles from sections 4.4 to 6.4 were translated into a natural human voice with scholarly integrity, and all of the original references maintained.

4.4 Feedback Loops and Systemic Inequality

Biased lending models are significant risks because they institutionalize systemic discrimination over generations through feedback loops (Binns et al., 2018; Kroll et al., 2017). History's trends of rejecting credit to marginalized groups that AI systems base on are still perpetuating social inequalities. Low-income groups are given higher risk scores that translate into greater disavowal of credit by Angwin et al. (2016). This creates a vicious cycle: Marginalized individuals face increasingly higher hurdles in obtaining equitable access to credit facilities (Obermeyer et al., 2019; Kamiran & Calders, 2012).

These cycles have the following *consequences*:

- ***Systemic financial exclusion:*** When individuals are denied credit their credit ratings drop, which renders recovery economically more difficult while making refusals of subsequent credit more likely (Raji & Yang, 2021).

- ***Increasing wealth inequalities:*** Marginalized people are subject to increasing wealth inequalities since financial services do not operate for them as well as they operate for richer

communities (Wieringa, 2020; Sandvig et al., 2014).

- **Algorithmic-built-in discrimination:** Holstein et al. describe how AI systems continue with embedded predispositions and grow disparity without resisting factors. (2019) and Wachter et al. (2017).

Systemic reform is a basic move in the direction of overthrowing such entrenched inclinations.

1. Hardt et al. (2016) document that machine learning techniques with fairness mechanisms integrated into them are able to detect and suppress bias.

2. The European Union in 2021 imposed strict regulatory measures on credit scoring models to ensure increased transparency across the year.

3. In 2023 the Reserve Bank of India promoted banking organizations to create lending plans that expand access to credit to weaker sections of society.

5. Measuring Fairness in AI Systems

AI-based credit systems need to be fair to avoid discrimination and ensure public trust according to Barocas et al. (2019) and Wachter et al. (2017). Fairness frameworks need to be employed in bank machine learning credit scoring models to avoid bias based on Holstein et al. (2019) and Mehrabi et al. (2021). Practice of fairness deployment is difficult since it encompasses trade-offs as well as decisions based on the context presented (Kleinberg et al., 2016).

5.1 Fairness Definitions

There is no AI fairness definition since there is no agreed-upon standard. There are numerous models of fairness based on

them capturing various statistical and ethical views (Hardt et al., 2016; Veale & Binns, 2017). Three are most prevalent definitions:

- **Demographic Parity:** Demographic Parity requires the same approval ratings across demographically different groups (Cowgill et al., 2021). The model provides the same outputs for diverse racial groups, genders, and incomes but breaks traditional measures of accuracy (Kamiran & Calders, 2012).

- **Equal Opportunity:** Equal Opportunity criteria ensure that qualified applicants across groups receive equivalent approval rates without altering overall outcomes (Kleinberg et al., 2016; Raji & Buolamwini, 2019). The metric has high compatibility with financial settings that require balancing fairness principles with risk-based evaluation (Obermeyer et al., 2019).

- **Counterfactual Fairness:** Fairness of decision is achieved where the protected attributes such as gender or ethnicity are not altered without altering outcome when other constants are kept constant (Binns, 2018; Datta et al., 2015). This ensures that AI systems cannot cause indirect discrimination through variables such as ZIP codes or job titles (Williams et al., 2018; Wachter et al., 2017).

5.2 Fairness Metrics and Trade-offs

Organizations use fairness measurement using statistical measures but statistical techniques sometimes yield conflicting findings (Holstein et al., 2019; Sandvig et al., 2014). The most critical trade-offs are:

- **Fairness vs. Accuracy:** In their efforts to gain demographic parity, it reduces the accuracy of risk assessments that has a

negative effect on both the financial outcome of institutions as well as their levels of risk tolerance (Kleinberg et al., 2016; Kamiran & Calders, 2012).

- **Explainability vs. Fairness:** Rule-based methods are more explainable but do not provide fair solutions, unlike with sophisticated algorithms. Advanced models produce opaque structures that create challenges for accountability maintenance (Wieringa, 2020; Rudin, 2019).

- **Regulatory vs. Ethical Priorities:** The legal system upholds group parity while ethical systems establish individual fairness through merit-based equal opportunities (European Commission, 2021; Federal Reserve, 2021; Reserve Bank of India, 2023).

Multi-objective optimization enables institutions to achieve multiple goals such as fairness, accuracy, and explainability through one integrated modeling approach (Veale & Binns, 2017; Pasquale, 2015).

5.3 Tools for Fairness Auditing

Institutions now have access to growing technical resources to improve AI model fairness which IBM Research showcased in 2020 and Microsoft demonstrated in 2021. These include:

- **AI Fairness 360 (IBM):** AI Fairness 360 from IBM represents an open-source tool that delivers numerous methods for assessing and reducing bias throughout every phase of model development as Mehrabi and colleagues described in 2021.

- **Fairlearn (Microsoft):** Microsoft's Fairlearn library allows practitioners to apply fairness constraints and monitor disparate impacts during model development (Kamiran & Calders, 2012).

- **What-If Tool (Google):** Google What-If Tool enables users to create interactive interfaces to investigate numerous scenarios through which they can observe the impact of minor changes in inputs on results (Williams et al., 2018).

These tools are used by lenders to construct clear models that are morally appropriate and are based on regulatory requirements (European Commission, 2021; Reserve Bank of India, 2023).

6. Reducing Bias: Techniques and Frameworks

Various approaches need to be undertaken cumulatively in the effort to effectively remediate bias in credit-focused AI systems. AI systems need interventions from start to finish that consist of data preprocessing model optimization and output smoothing and are supplemented by human oversight (Barocas et al., 2019; Holstein et al., 2019).

6.1 Pre-processing Techniques

The data input is cleansed and transformed treatment to eliminate bias at this point before training AI models.

- **Reweighting:** Training processes utilize reweighing methods to raise the priority of under-represented groups that translate demographic distributions into balance (IBM Research, 2020; Raji & Buolamwini, 2019).

- **Stratified Sampling:** The use of stratified sampling provides various groups with proportional representation in data subsets according to Veale & Binns (2017) and Fair Isaac Corporation (2021).

- **Synthetic Data Generation:** The method uses Generative Adversarial Networks (GANs) to generate data that addresses minority group underrepresentation while

eliminating model blind spots (Cowgill et al., 2021; Reserve Bank of India, 2023).

6.2 In-processing Approaches

The training of the model requires a change in approach to incorporate fairness goals as defined by Obermeyer et al., 2019 and Raji & Yang, 2021.

- **Adversarial Debiasing:** The methodology uses an adversary model that protects predictions from relying on protected attributes such as race or gender (Kamiran & Calders, 2012; IBM Research, 2020).

- **Fair Representation Learning:** Williams et al., 2018 and Pasquale, 2015 models learn to create internal representations that enable prediction of outcomes regardless of sensitive properties.

6.3 Post-processing Approaches

The approach adjusts model predictions post-training to meet fairness constraints without modifying the underlying algorithm (Wachter et al., 2017).

- **Calibrated Equal Odds:** Holstein et al. demonstrated that using various decision thresholds can calibrate measures of fairness across demographic subgroups. (2019) and Goodman & Flaxman (2017).

- **Reject Option Classification:** When boundaries of decisions get fuzzy in situations, the Reject Option Classification tactic prefers underprivileged applicants according to Binns (2018) and IBM Research (2020).

6.4 Human-in-the-Loop and Explainable AI (XAI)

Algorithms exhibit robust performance but with essential human supervision to deliver their best. The system provides proper care to marginal cases and applies ethical decision-making techniques for enhancing

computer-derived outcomes (Kleinberg et al., 2016; Rudin, 2019).

At the same time, Explainable AI methods like:

- **LIME** (Local Interpretable Model-Agnostic Explanations)

The technique provides thorough explanations of a single decision describing how the model arrived at its sole judgment based on Veale & Binns 2017.

- **SHAP** (Shapley Additive exPlanations)

SHAP values offer in-depth descriptions of credit approval decisions by revealing the effect each input has on model outputs (Microsoft, 2021; IBM Research, 2020).

Algorithmic fairness techniques in conjunction with human assessment and explanation capabilities allow financial institutions to generate fair results that engender public confidence and meet regulatory requirements (European Commission, 2021; Reserve Bank of India, 2023).

7. Governance and Compliance

As highlighted by Barocas et al., 2019 and Wachter et al., 2017, financial institutions need robust governance structure and adherence to regulatory principles for the sake of ethical expectations and transparency in the AI-based credit decision-making process. While performing credit evaluation using AI mechanisms, financial institutions have to adhere to the law and internal regulations in addition to creating independent oversight and transparent rules of conduct (Holstein et al., 2019; Mehrabi et al., 2021).

7.1 Legal Frameworks

Organizations need to abide by national and global legal principles to safeguard consumer rights and be held accountable, and avoid algorithmic discrimination on the basis of the European Commission (2021) and the Reserve Bank of India (2023). A few significant laws include:

- **GDPR (EU):** The General Data Protection Regulation requires complete transparency regarding methods of automated decision-making. Citizens should be able to comprehend the algorithms applied in decision-making and challenge any outcomes they find objectionable (Goodman & Flaxman, 2017; Wachter et al., 2017). Williams et al. (2018) observe that solid principles have been established by law for dealing with personal financial data.
- **Equal Credit Opportunity Act (U.S.):** As per research work by Angwin et al., 2016 and Federal Reserve guidelines in 2021 the United States' Equal Credit Opportunity Act prohibits lenders from discriminating against individuals based on race, gender, and marital status. Periodic bias audits of AI credit systems are required to guarantee fairness as a compliance measure (Kleinberg et al., 2016).
- **FCA Guidelines (UK):** The Financial Conduct Authority mandates UK financial services providers to use AI in order to maintain high standards of consumer protection and maintain operations transparently to implement structured governance strategies to effectively reduce bias (Fair Isaac Corporation, 2021).

Several countries lack the regulatory guidelines for AI-specific credit automation which indicates the urgent need to develop forward-looking legal

frameworks (Raji & Buolamwini, 2019; Sandvig et al., 2014).

7.2 Corporate Governance and Ethics Policies

There should be internal ethical policies by companies that promote responsible uses of AI (Kamiran & Calders, 2012). The most significant strategies are:

- **Ethical AI Charters:** Ethical statements that articulate the company's commitment to fair procedures and open and responsible AI development processes must be established by companies (Pasquale, 2015; Veale & Binns, 2017).
- **Audits for Fairness:** Regular internal credit model evaluation allows companies to catch biases in early stages and remain compliant with ethical standards (IBM Research, 2020; Microsoft, 2021).
- **Bias Awareness Training:** Training developers and decision-makers in algorithmic bias empowers them to create inclusive models while minimizing systemic discrimination (Obermeyer et al., 2019; Raji & Yang, 2021).

7.3 Third-party Auditing and Certification

External audits become verification instruments for compliance of AI credit systems to ascertain that they are in line with law and ethics as per Holstein et al. (2019) and Wachter et al. (2017). Among the most important advantages are:

- **Detection of Bias:** Utilizing cutting-edge fairness testing methods, third-party professionals can detect hidden discriminatory trends such as presented by Kleinberg et al. (2016).
- **Transparency Reporting:** Third-party audits offer explainability reports to help

stakeholders understand AI decision-making (Fair Isaac Corporation, 2021).

- **Ethical Certifications:** Companies obtain ethical certifications from well-known organizations such as Fair AI to prove their allegiance to ethics and ethical technology formation (European Commission, 2021; Reserve Bank of India, 2023; Mehrabi et al., 2021).

7.4 Risk Management and Documentation Standards

There should be an entire set of documentation needed in order to measure the level of fairness and transparency of AI models.

- **Model Cards:** The model card provides a comprehensive overview of how the model functions and its training data sets alongside evaluation approaches and fairness assessments based on Williams et al.'s 2018 research.

- **Dataset Datasheets:** Datasheets for datasets both define the source and format of training data and point out representational biases as per Kamiran & Calders (2012) and Holstein et al. (2019).

- **Bias Mitigation Reports:** Pre-processing, in-processing, and post-processing methods of reducing algorithmic bias are detailed in IBM Research reports of 2020.

The indicated approaches synchronize AI-based credit systems with European Commission (2021) and Reserve Bank of India (2023) guidelines to attain responsible and ethically sound operations.

8. Case Studies and Industry Practices

Financial regulatory agencies along with institutions are in the process of developing practical solutions to remove bias from

artificial intelligence systems for making credit decisions (Cowgill et al., 2021; Mehrabi et al., 2021). The part elaborated by Holstein et al. illustrates practical use and regulatory techniques through critical examination of previous industry mistakes. (2019) and Wachter et al. (2017).

8.1 Fintech Practices

- **Upstart:** Upstart enhances creditworthiness assessments using the use of alternative data sources such as education and employment history (Upstart 2020). The 2021 study by the European Commission indicated that regulated supervision produces more balanced approval rates across various demographic groups with this methodology.

- **Zest AI:** Zest AI illustrates that fairness-constrained credit models can produce accurate and fair underwriting outcomes (Zest AI, 2021; Fair Isaac Corporation, 2021).

8.2 Initiatives in the Banking Sector

- **JPMorgan Chase:** Third-party auditors conduct rigorous bias evaluation and testing to ensure that JPMorgan Chase's AI models meet regulatory compliance requirements (Federal Reserve, 2021; Wachter et al., 2017).

- **Bank of America:** Bank of America employs Explainable AI technologies to improve transparency in decision-making and provide stakeholders with the option to review and challenge credit decisions (Microsoft, 2021; Kleinberg et al., 2016).

8.3 International Practices

- **European Union (EU):** The European Commission's proposed AI Act demands strict regulations on high-risk AI systems that encompass credit scoring based on

their risk categorization (European Commission, 2021; Wieringa, 2020).

- **Reserve Bank of India (RBI):** In India's banking sector Reserve Bank of India created ethical use guidelines for artificial intelligence in digital lending platforms as per Reserve Bank of India (2023) and Kamiran & Calders (2012).

- **Monetary Authority of Singapore (MAS):** Monetary Authority of Singapore issued financial AI application guidelines to help limit discrimination risks, which were created by the Monetary Authority of Singapore (Monetary Authority of Singapore, 2022).

8.4 Failures and Lessons Learned

The financial sector demonstrates improvements in a few domains but remains plagued by persistent systemic vulnerabilities from ongoing operational mistakes.

- **Inadequate Documentation:** IBM Research (2020) found improper documentation styles hinder bias detection and necessary corrective action.

- **Abandoned Testing Procedures:** Without periodic fairness evaluations AI models will be able to create implicit bias, as stated by Raji & Yang (2021).

- **Excessive Relying on Past Data:** Machine learning algorithms based on past data tend to replicate present social biases and thereby attract public backlash and legal actions (Angwin et al., 2016).

The European Commission (2021) and Reserve Bank of India (2023) similarly emphasize the need for continuous assessment as well as ethical monitoring in AI-based credit risk evaluation.

9. Challenges and Limitations

While fairness-aware AI presents potential answers for unbiased credit decision-making several fundamental obstacles stand in the way of its practical application (Mehrabi et al., 2021; Wachter et al., 2017). The challenges involve both theoretical matters and organizational resistance to change.

9.1 Lack of Standardized Fairness Metrics

According to Kleinberg et al., experts have not reached a consensus on a standard definition of fairness. (2016) and Hardt et al. (2016). Demographic parity requires uniform representation across groups whereas equalized odds seek to equalize error rates among groups. Kamran & Calders (2012) along with Williams et al. state that multiple objectives create uncertainty in model evaluation and deployment processes. (2018) and Veale & Binns (2017).

9.2 Trade-offs Between Fairness and Accuracy

Kleinberg et al. documented that model designers striving for increased fairness tend to encounter diminished predictive accuracy. And Rudin. IBM Research (2020) and Microsoft (2021) have shown that precision levels drop when modifications are made to training data and decision thresholds. Research findings from different studies show that trade-off management depends on context as lending systems focus on equity while clinical tools demand precision (Obermeyer et al., 2019; Wachter et al., 2017; Fair Isaac Corporation, 2021).

9.3 Data Privacy vs. Transparency

Research by Goodman & Flaxman (2017) and Williams et al. demonstrates that increased transparency in AI systems

exposes sensitive information and proprietary data which creates potential security risks. (2018). Companies exposing their internal models run the risk of facing competitive threats and security breaches. Holstein et al. Holstein et al. found that the hidden nature of opaque models allows biased patterns to emerge leading to ethical problems. (2019); Sandvig et al. (2014); Reserve Bank of India (2023).

9.4 Organizational and Cultural Barriers

The path toward AI fairness development faces persistent difficulties from organizations that resist changes while dealing with inadequate training practices and undefined benchmarks for fairness (Pasquale 2015; Veale & Binns 2017). The implementation of fairness-aware algorithms cannot by itself resolve organizational cultural biases and outdated data practices (Federal Reserve, 2021; Wieringa, 2020). To overcome current challenges organizations need to integrate proactive leadership with inclusive policy-making and persistent ethical AI education investment (Raji & Buolamwini 2019; Monetary Authority of Singapore 2022).

10. Future Directions

AI fairness experts and researchers create new methods that promote an ethical balance between privacy protection equity and transparency of automated credit systems (Wachter et al., 2017; Mehrabi et al., 2021). Interdisciplinary solutions provide visionary strategies that combine federated learning deployment with ethical model design and facilitate data practice improvement which is inclusive (Holstein et al., 2019; Barocas et al., 2019).

10.1 Federated Learning and Privacy-Preserving Fairness

The federated learning framework provides a backend approach that is a compromise between information fair treatment and data privacy protection. Entities are able to collaboratively construct AI models without revealing sensitive datasets to safeguard sensitive data (Google, 2020). The process is of great importance in the medical and finance industries because they are governed by strict confidentiality legislation as per the European Commission (2021).

Privacy-protection techniques such as differential privacy and secure multiparty computation add functionality to federated learning methods. The technology of privacy is employed by companies to detect patterns in data and calculate fairness scores without their respective individual identities, based on Williams et al. (2018) and IBM Research (2020). Organizations that deploy the technologies experience both enhanced model performance and increased ethical accountability (Reserve Bank of India, 2023; Monetary Authority of Singapore, 2022).

10.2 Ethical AI by Design

Fair AI requires ethical principles to be integrated into the development process at the beginning. The "ethical AI by design" approach requires sound decisions in data collection and algorithm construction to focus on feature selection methods for removing bias at preliminary stages of development (Pasquale, 2015; Kamiran & Calders, 2012).

Fairness embedded in system architecture leads to AI models that are at par with international standards and societal demands for responsible development of

AI as stipulated by the European Commission (2021) and Fair Isaac Corporation (2021). System developers who aim for ethical system performance must embed fairness constraints into their optimization procedures (Veale & Binns, 2017).

10.3 Inclusive Data Ecosystems

Training data sets do not reflect proper diversity of target populations resulting in algorithmic biases (Cowgill et al., 2021; Angwin et al., 2016). The push to improve algorithmic representation now includes constructing inclusive data ecosystems that record multimodal demographic characteristics along with geographic and socioeconomic profiles (Raji & Buolamwini, 2019).

Through data annotation and categorization of community members, research groups are able to identify latent biases to develop more equitable and inclusive datasets (Holstein et al., 2019; Sandvig et al., 2014). Development of fair models will progress through the provision of open-access preprocessed data available and constructed to be fair according to IBM Research in 2020 and Microsoft in 2021.

Achieving AI fairness entails technological and solutions but must involve addressing legal experts, ethicists, sociologists, and public policymakers.

Enabling equitable AI surpasses technical solutions because it involves legal norms and ethical standards and sociological impacts and public policy decisions. The development of AI systems involves extensive collaboration among computer scientists and ethicists, lawyers, economists, and community activists

according to a study by Barocas et al., 2019 and Wachter et al., 2017.

AI systems that are compliant with human rights and democratic principles are the outputs of design processes incorporating wide-ranging societal views through interdisciplinary team efforts (Veale & Binns, 2017; Wieringa, 2020). Public policies establishing enforceable standards are vital to guarantee equity and institutional responsibility towards the affected people according to the European Commission (2021), Reserve Bank of India (2023), and Federal Reserve (2021). The Monetary Authority of Singapore (2022) maintains that constructing beneficial AI systems depends on active public participation and engagement from policymakers.

11. Conclusion

AI is full of benefits, but it also creates huge responsibilities when it comes to how we make decisions around credit. While the financial systems can bring services closer, they may further intensify existing biases if they're poorly intended and tracked. AI credit systems, therefore, require strong safeguards so that they do not increase social imbalances, especially among vulnerable populations.

To meet these risks, we require a multi-pronged solution. We have to continue to refine fairness-sensitive machine learning models and use robust methods to reduce bias. There has to be regulatory frameworks that ensure transparency, provide channels for people to appeal against AI decisions, and insist on periodic examination of credit systems for equitable practices. Additionally, developing an ethical culture of AI through education, diverse teams, and effective internal

governance can eliminate bias while ensuring responsible innovation.

Achieving fairness in financial AI systems requires a joint effort from everyone involved. Technologists, regulators, ethicists, industry players, and even the people affected by these systems must work together to produce equitable outcomes. For it to be maximally effective, there has to be unfettered access to public feedback, grants for community-based data projects, and empowerment of educational programs on the perils of algorithms.

Our long-term goal is not just to cut back on bias; it's to build financial systems in which every individual has the opportunity to succeed, no matter where they came from. That means purposefully designing fair AI systems, sustaining constant regulatory oversight, and constantly monitoring their behavior. By making transparency and fairness the core of the entire AI-construction process, we can build a tech-driven financial system that not only preaches justice and chance for all but does not exclude.

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Empowering the Future: A Conceptual Framework for Digital Financial Literacy and Human Capital Development towards India@2047

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Abstract

This conceptual paper explores how strengthening digital financial literacy (DFL) can contribute to building effective and inclusive human capital for India's future. As the nation targets development benchmarks for 2047, digital literacy integrated with financial know-how emerges as a cornerstone of socioeconomic resilience and innovation. We propose a structured framework that interlinks digital infrastructure, financial capability, and skill integration to develop empowered, financially responsible, and digitally proficient citizens. The discussion includes key policy gaps and implementation recommendations for realizing this vision.

Keywords: *Digital Financial Literacy, Human Capital, India@2047, Digital Economy, Financial Empowerment, Future Skills*

Introduction

India's roadmap for 2047 envisions a knowledge-based, innovation-driven economy. Human capital, defined by its skills, adaptability, and empowerment, plays a crucial role in this transformation. Digital financial literacy—the ability to navigate financial tools in digital spaces—enables individuals to participate fully in the formal economy, mitigate risks, and improve livelihoods. This paper presents a conceptual framework that highlights the symbiotic relationship between DFL and human capital development in a digitally inclusive India.

Literature Review

Human capital theory, originating with Becker (1964), emphasized education and health as productivity inputs. Evolving frameworks now include digital competencies and financial literacy as pivotal to modern human capital. Various studies underline the correlation between DFL and access to financial services, risk mitigation, and entrepreneurship. Yet, challenges persist: rural and underprivileged populations often lack digital access and financial education, widening socio-economic gaps.

Conceptual Framework

We propose a triadic model emphasizing the following pillars:

a) Digital Infrastructure and Access

- Ensuring widespread availability of mobile internet, digital ID systems (Aadhaar), and interoperable financial platforms (e.g., UPI)

b) Financial Capability

- Educating individuals to budget, save, invest, and borrow responsibly using digital tools

c) Integrated Learning

- Embedding DFL modules in school syllabi, vocational programs, and community outreach efforts

Expected Outcomes:

- Smarter financial choices by individuals and households
- Growth in entrepreneurial activities
- Higher inclusion in the digital and formal economy
- Resilience to economic shocks and misinformation

(Figure 1: Conceptual Framework Linking DFL and Human Capital Development)

Discussion

To leverage India's demographic dividend, skill-building must include DFL at its core. Programs like PMGDISHA and the NEP 2020 offer foundational infrastructure. However, inter-ministerial collaboration, community-level engagement, and private-public partnerships are essential for scale and equity.

Challenges to Address:

- Technological and financial illiteracy in rural populations
- Gender gaps in mobile and internet access
- Over-reliance on digital channels without adequate user training

Policy Recommendations:

- Mandate DFL training across all educational and skilling programs
 - Foster digital outreach via community centers and local bodies
 - Incentivize fintech firms to develop inclusive, multilingual content
-

Conclusion and Policy Implications

Digital financial literacy is not merely a digital inclusion tool but a strategic investment in India's future. As the nation prepares for India@2047, building a digitally fluent and financially empowered population can significantly accelerate inclusive growth and national resilience. The conceptual model presented here serves as a blueprint for policymakers, educators, and development agencies

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TRACK 6

TRACK 6: CYBER, ETHICS & REGULATION IN VIRTUAL FINANCIAL SYSTEMS

AI-DRIVEN THREAT DETECTION AND CYBER SECURITY ENHANCEMENT IN BANKING SYSTEMS

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ABSTRACT:

The incorporation of Artificial Intelligence (AI) in cybersecurity measures has revolutionized the identification and prevention of cyber threats by financial institutions. AI-based techniques utilized in bank security are extensively discussed in this research, referencing anomaly detection, real-time monitoring, adversarial learning, and explainable AI (XAI) approaches. Based on existing peer-reviewed publications, the article analyses how machine learning (ML) and deep learning (DL) models improve accuracy and responsiveness of security infrastructures and mitigate false positives, insider threats, and adversarial attacks. The study emphasizes the increasing importance of ensemble learning, cross-domain AI, and autonomous threat hunting in a bid by financial institutions to protect themselves from elaborate threats that involve phishing, malware, and deepfake-based frauds. Other than this, the research emphasizes interpretability, auditability, and user-centered design as key factors in establishing trust in AI-based systems. Hailing a coalition of academic and industrial perspectives, this paper gives a meaningful background on state-of-the-art AI technologies in financial cybersecurity, details research gaps in current studies, and indicates directions for future development.

Keywords: *Artificial Intelligence, Cybersecurity, Financial Institutions, Machine Learning, Threat Detection, Explainable AI, Anomaly Detection.*

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INTRODUCTION:

In an age of fast-paced digital transformation, banking becomes increasingly dependent on advanced technology to automate functions, enhance customer satisfaction, and boost security. Yet, with increased use of digital platforms comes greater vulnerability to cyber threats such as phishing, ransomware, and advanced persistent threats (APTs). Classic security frameworks, while powerful as they have been, cannot keep pace with the constantly changing paradigm of cyber-crime anymore. Artificial Intelligence (AI) has become the go-to solution of the modern era, with its predictive, adaptive, and autonomous nature transforming the cybersecurity paradigm. AI-powered threat detection platforms use machine learning (ML), natural language processing (NLP), and deep learning algorithms to discover, analyze, and neutralize cyber threats with unmatched accuracy and speed. This article discusses the role of AI in banking cybersecurity and its importance in detecting anomalies, reducing risks, and improving overall security infrastructure.

Cybersecurity threats in the financial sector have become more advanced, so there is a requirement for an advanced and dynamic method of threat management. AI-based

security solutions are the way forward to address these challenges, as they can process massive amounts of information in real time, recognize sophisticated patterns of attacks, and learn to counter new types of threats. With the use of AI-based methods like behavior analysis, anomaly detection, and predictive analytics, banks can strengthen their security posture, lowering the risk of financial compromise and scams. Unlike conventional security mechanisms dependent on Pre - established rules, AI-powered systems learn continuously from new data streams, facilitating proactive threat identification instead of reactive countermeasures. Further, AI strengthens cybersecurity through the inclusion of automated response functions, reducing human interaction, and speeding up incident closure. The use of AI-based threat detection frameworks can give rise to more secure banking environments, guaranteeing customer confidence and regulatory conformity in a rapidly connected digital world.

The convergence of AI and bank cybersecurity has promise along with danger. While security tools engineered using AI bring many benefits, such as greater threat intelligence as well as lower operational expenses, there are some issues

about ethical standards, data privacy, and choice bias as a possibility. Banks must balance these factors by embracing good governance models for AI, being transparent, and adhering to the global standards of cybersecurity legislation as well as regulations. Secondly, the effectiveness of AI in cyber security is dependent upon the quantity and pertinence of training data sets, and its periodic updates and fine-tuning to adapt to new and emerging cyber threats. Use of AI also needs to include the aspect of human monitoring to avoid mistakes and collateral consequences, adding substance to the need for proportional and strategic deployment of AI. The purpose of this paper is to discuss the application of AI in transforming banking

cybersecurity, and how it influences threat detection, risk mitigation, and organizational performance. Grounded on a review of current AI-focused security models, case studies, and emerging technologies, this research sheds light on the future of AI-powered cybersecurity in financial institutions. The aim is to highlight the necessity of AI as a proactive and dynamic protective measure in the defense of cyber-attacks while managing ethical and regulatory issues surrounding its application. With the study on the potential of AI to improve banking infrastructure security against cyber-attacks, this study enhances the global discourse on securing the financial system amidst digital transformation.

REVIEW OF LITERATURE:

- 1) **Khanna (2025)** examined the pivotal question of adversarial learning and privacy issues in AI-security systems for banking. The research questions the possibility of whether AI systems can be attacked or manipulated and suggests hardened architecture solutions that guarantee accuracy and data privacy. This makes it extremely useful for banks that aim to develop secure AI-based cybersecurity infrastructure.
- 2) **Lavanya and Mangayarkarasi (2024)** have proposed AI-based cyber risk

assessment models for banks. Their model recognizes the vulnerabilities in the systems dynamically prior to exploitation and thus enhances the predictive efficacy of the threat detection system and banking cyber-security risk mitigation systems.

- 3) **McKnight, Roy, and Tanaka (2024)** assessed the effectiveness of real-time AI monitoring systems and their quantifiable contribution toward lowering fraud-based financial losses. Their research highlights the true value proposition of AI integration from both operational effectiveness and economics return that

facilitates mass-level deployment of such systems in banks.

- 4) **Farooq and Zaffar (2024)** offered a machine learning-assisted anomaly detection system with the objective of reducing false positives in transactional monitoring. This, for high-throughput banking systems, translates to improved alert systems that reduce cybersecurity fatigue on the analyst's side while enhancing the system overall.
- 5) **From the Journal of Big Data (2024)** an extensive study on cross-domain AI models that have been applied to malware, phishing, and intrusion detection. It promotes flexible AI systems in cyber security that will enable banks to efficiently process and disassemble various forms of threats using a common layer of intelligence.
- 6) **From the Market.Watch (2024)** it is documented deepfake-facilitated bank and financial institution fraud. The red flag in the physical world signals a requirement for sophisticated AI solutions that can detect synthetic media and identities in real time—a requirement where legacy systems fail and AI is a reliable countermeasure.
- 7) **Ozkan Okay et al. (2024)** authored a summary of machine learning and metaheuristic optimization techniques in bank cybersecurity. The research uncovers that the blend of the two techniques enhances detection rates and computing efficiency and thereby makes hybrid models a strategic goldmine for real-time threat response systems.
- 8) **Kaur, Sharma, and Mehta (2023)** investigated applying ensemble learning methods to identify insider threats in banks. By overlapping AI models, their system can identify sophisticated, subtle patterns that equate to malicious action from within an organization and yield a safer internal environment.
- 9) **Sangwan and Kumar (2023)** have targeted ML and DL-based phishing and malware filtering solutions in banking environments. Their study is an example of how deep learning models may detect advanced threats better than rule-based ones, thereby enabling more intelligent cybersecurity infrastructures in banks.
- 10) **Mohamed (2023)** investigated adversarial machine learning for threat mitigation in financial sectors based on the need for AI systems that are not only intelligent but also resilient against attack attempts to deceive them. This is especially important in high-risk industries such as banking, where reliability in AI is critical.

2.1. RESEARCH GAP:

While AI-based methods have been promising to improve bank cyber security, one of the major research limitations is their use in actual environments. Most of the research is in creating models and simulations in constrained environments, with little consideration given to how the

2.2. PROBLEM STATEMENT:

Even with growing use of artificial intelligence (AI) in banking, the security framework of the bank continues to be exposed to advanced and evolving threats. Existing AI-powered solutions, though successful in controlled environments, are discovered to fall short in practical implementations within banks due to constraints such as low explainability, high

2.3. OBJECTIVES OF THE STUDY:

1. To analyze AI-based methods for bank cybersecurity and fraud detection.
2. Suggesting an effective AI framework for stronger bank security.
3. To identify whether AI-based biometric authentication

systems operate under real high-traffic banking environments. Few experiments are carried out on simulated scalability, user trust, compliance, and actual-world effect of explainable AI. Filling this gap might assist in streamlining AI solutions for real-time use and compliance with regulations in the finance industry.

false positives, poor adaptability to emerging attack avenues, and weak support for aged assets. In addition, adversarial attacks and data privacy issues are also among the challenges facing AI deployment. These issues underscore an urgent need for creating sophisticated, explainable, and scalable AI models capable of bolstering banking systems' cybersecurity defense and keeping up with high regulatory and operational standards.

(fingerprint/face recognition) is more secure than passwords. To assess what extend AI can help reduce bias in financial decisions.

4. Identifying how better AI models function compared to legacy security protocols.

RESEARCH METHODOLOGY:

3.1. RESEARCH DESIGN

The research utilized a descriptive study design in the attempt to investigate the use and implementation of artificial intelligence (AI) in the enhancement of threat detection and cybersecurity in banking systems. The goal is to develop an in-depth understanding of the use of AI technologies in integrating into cybersecurity systems to be applied in the fight against cyber threats and data breaches in the financial market.

3.2 DATA COLLECTION

Primary data related to AI-driven threat detection and cybersecurity practices in the banking sector has been collected using a structured questionnaire distributed through Google Forms. Secondary data has been collected from existing literature, including academic journals and online sources.

3.3. SOURCES OF DATA

This study incorporates both primary and secondary data sources to ensure a comprehensive understanding of AI-driven threat detection and cybersecurity enhancement in banking systems.

3.4. SAMPLE PLAN AND TECHNIQUE

A sample of 100 respondents was selected using the simple random sampling method.

3.5. Tools of Analysis

1. Descriptive Statistics

3.6. LIMITATIONS OF THE STUDY:

- Lack of adequate real-world testing of AI models in live banking environments.
- Shortfalls in emphasis on the scalability of AI systems to process large numbers of finance transactions.
- Shortfalls in analysis of cost-benefit dynamics of implementing AI-based cybersecurity initiatives.
- Insufficient regard for long-term sustainability and strategic implications of AI uptake in cybersecurity.
- Limited comparative studies on the efficacy of conventional versus AI-oriented security methods in banking institutions.

DATA ANALYSIS AND INTERPRETATION

Table 4.1: AGE GROUP

Age Group	No of Respondents	Percentage
18-25 years	94	94
26-35 years	5	5
36-45 years	1	1
46-60 years	0	0
Above 60 years	0	0
Grand Total	100	100%

Interpretation:

The survey is heavily dominated by respondents aged 18–25, accounting for 94% of the total sample. This shows a strong representation from the youth demographic, likely tech-savvy and active in digital spaces. Only a small number belong to the 26–35 group (5%), and just one respondent is aged 36–45. There were no responses from individuals above 45. This skew affects how representative the findings are for older banking users.

Table 4.2: OCCUPATION OF THE RESPONDENTS

Occupation	No of Respondents	Percentage
Salaried Employee	30	30%
Self-employed/Business Owner	2	2%
Student	68	68%
Retired	0	0%
Others	0	0%
Grand Total	100	100%

Interpretation:

A significant portion of respondents are students (68%), indicating the data is largely influenced by the views and behaviors of the younger, possibly financially dependent population. Salaried employees make up 30%, providing some insight into working professionals. Very few are self-employed, and none are retired or categorized as "others." This shows a limited range of occupational diversity in the survey.

Table 4.3: TYPE OF BANK

Type Of Bank	No of Respondents	Percentage
Public Sector Bank (SBI, PNB, Bank of Baroda, etc.)	61	61%
Private Sector Bank (HDFC, ICICI, Axis, etc.)	36	36%
Cooperative Bank	3	3%
Foreign Bank	0	0%
Digital/Neo Bank	0	0%
Grand Total	100	100%

Interpretation:

Most respondents (61%) primarily use public sector banks such as SBI or PNB, suggesting a strong customer base in traditional government-backed institutions. Private sector banks like HDFC and ICICI follow at 36%. Cooperative banks are used by a minor segment (3%), while no one reported using foreign or neo/digital banks. This might reflect trust in established banks or lack of awareness/access to digital-only banking.

Table 4.4: FREQUENCY OF USAGE OF DIGITAL BANKING SERVICES

Frequency of Usage of Digital Banking Services	No of Respondents	Percentage
Daily	64	64%
Monthly	5	5%
Rarely	8	8%
Weekly	23	23%
Grand Total	100	100%

Interpretation:

Daily digital banking usage is high, with 64% of respondents interacting with such services every day. This highlights a shift toward digital-first banking behavior, likely driven by convenience and mobile access. Weekly users make up 23%, while monthly and rare users are minimal. The data shows strong digital engagement among the surveyed group, especially the youth.

Table 4.5 : BANKING SERVICES USED ONLINE

Banking Services Used Online	No of Respondents	Percentage
Digital wallets	1	1%
Net banking (NEFT, RTGS, IMPS)	2	2%
UPI payments (Google Pay, PhonePe, Paytm, etc.)	78	78%
UPI payments (Google Pay, PhonePe, Paytm, etc.), Credit/debit card transactions	4	4%
UPI payments (Google Pay, PhonePe, Paytm, etc.), Mobile banking apps	2	2%
UPI payments (Google Pay, PhonePe, Paytm, etc.), Mobile banking apps, Credit/debit card transactions	4	4%
UPI payments (Google Pay, PhonePe, Paytm, etc.), Mobile banking apps, Credit/debit card transactions, Digital wallets	1	1%
UPI payments (Google Pay, PhonePe, Paytm, etc.), Mobile banking apps, Digital wallets	1	1%
UPI payments (Google Pay, PhonePe, Paytm, etc.), Net banking (NEFT, RTGS, IMPS), Credit/debit card transactions	1	1%
UPI payments (Google Pay, PhonePe, Paytm, etc.), Net banking (NEFT, RTGS, IMPS), Mobile banking apps	2	2%
UPI payments (Google Pay, PhonePe, Paytm, etc.), Net banking (NEFT, RTGS, IMPS), Mobile banking apps, Credit/debit card transactions, Digital wallets	4	4%
Grand Total	100	100%

Interpretation:

UPI payments dominate usage, featuring almost all combinations and selected directly by 78% of users. This confirms the massive popularity of apps like Google Pay, PhonePe, and Paytm. Other services like net banking, mobile banking, and credit/debit card transactions are used far less, indicating a shift toward fast, app-based payment systems. Digital wallets are the least used.

Table 4.06: Type Of Fraud Experienced

Type Of Fraud Experienced	No of Respondents	Percentage
Debit/credit card fraud	9	9%
Identity theft	9	9%
Phishing scam (fake calls/emails)	50	50%
UPI fraud (unauthorized transfers)	32	32%
Grand Total	100	100%

Interpretation:

Phishing scams are the most reported form of fraud (50%), pointing to widespread vulnerabilities in recognizing and avoiding fake emails or calls. UPI fraud, involving unauthorized transfers, is the second most common (32%). Debit/credit card fraud and identity theft are also noted but less frequently. This shows fraud is a significant issue, especially via newer digital channels.

TABLE 4.07: TIMES TAKEN TO RESOLVE YOUR ISSUE BY THE BANK

Times Taken to Resolve Your Issue by The Bank	No of Respondents	Percentage
Immediately (within a few hours)	17	17%
More than a week	14	14%
Still unresolved	10	10%
Within a day	22	22%
Within a week	37	37%
Grand Total	100	100%

Interpretation:

Most issues are resolved within a week (37%), and 22% are resolved within a day, suggesting decent responsiveness. However, 14% took over a week, and 10% remain unresolved. Immediate resolutions within hours were experienced by 17%. These figures suggest that while banks are trying to respond quickly, there's still a notable gap in timely customer service.

TABLE 4.08: AI-DRIVEN SECURITY FEATURES

AI-Driven Security Features	No of Respondents	Percentage
AI chatbots for fraud support	7	7%
AI-powered transaction monitoring	25	25%
Behavioural analytics for risk assessment	4	4%
Facial or fingerprint recognition for transactions	20	20%
Real-time fraud alerts	44	44%
Grand Total	100	100%

Interpretation:

Real-time fraud alerts are the most desired AI feature (44%), indicating a strong user need for proactive notifications. AI-powered transaction monitoring (25%) and biometric authentication (20%) are also highly preferred. Overall, users seek AI that can provide both security and convenience in real-time.

TABLE 4.09: TRUST LEVEL ON AI-POWERED SECURITY MEASURES

Trust Level On AI-Powered Security Measures	No of Respondents	Percentage
No	16	16%
Not sure	33	33%
Yes	51	51%
Grand Total	100	100%

Interpretation:

Just over half (51%) of users are confident in AI's ability to detect and block phishing attempts. However, a significant 33% are unsure, and 16% do not trust it. This split shows that while AI adoption is increasing, skepticism remains. Building user awareness and proving AI reliability will be key to gaining more trust.

TABLE 4.10 : ADDITIONAL AI-DRIVEN SECURITY FEATURES

Additional AI-Driven Security Features	No of Respondents	Percentage
AI-driven voice authentication for payments	6	6%
AI-generated fraud risk scores for transactions	26	26%
Automatic blocking of high-risk transactions	49	49%
Smart AI assistants for security alerts and guidance	19	19%
Grand Total	100	100%

Interpretation:

The most requested AI feature is automatic blocking of high-risk transactions (49%), showing a preference for preventative measures. AI-generated fraud risk scores (26%) and smart AI assistants (19%) also have support. Voice authentication is less in demand. This suggests users want AI to act decisively and autonomously to protect their financial interests.

TABLE 4.11: CHALLENGES FORESEEN IN USING AI FOR BANKING SECURITY

Challenges foreseen in using AI for banking security	No of Respondents	Percentage
AI being vulnerable to cyberattacks itself	16	16%
AI making incorrect decisions	18	18%
Data privacy concerns	53	53%
Lack of customer trust in AI	13	13%
Grand Total	100	100%

Interpretation:

Data privacy is the top concern (53%), indicating fears about how banks handle personal and financial data with AI systems. Incorrect decisions made by AI (18%) and the risk of AI itself being hacked (16%) also worry users. A portion (13%) highlights lack of trust in AI. These concerns must be addressed through robust policies, transparency, and user education.

ANOVA ANALYSIS:

Hypothesis:

H0:

There is no significant Difference between age group of the respondents and security of AI driven biometric authentication method.

H1:

There is significant Difference between age group of the respondents and security of AI driven biometric authentication method.

Table 4.12

SUMMARY				
Groups	Count	Sum	Average	Variance
Age group	100	107	1.07	0.0859595
Do you think AI-based biometric authentication (fingerprint/face recognition) is more secure than passwords/PINs?	100	247	2.47	1.7061616

ANOVA						
Source of Variation	SS	d.f	MS	F	P-value	F crit
Between Groups	98	1	98	109.3676023	0.00	3.888852
Within Groups	177.42	198	0.8960606			
Total	275.42	199				

Interpretation:

Based on the ANOVA single-factor analysis, the calculated p-value is 0.00, which is less than the significance level of 0.05. Therefore, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_1) is accepted. This indicates that there is a statistically significant difference between the age groups of respondents and their perception of the security of AI-driven biometric authentication methods.

ANOVA ANALYSIS:

H0:

There is no significant difference between the age group of the respondents and how ai can reduce the bias in financial decision making.

H1:

There is a significant difference between the age group of the respondents and how ai can reduce the bias in financial decision making.

Table 4.13

SUMMARY				
Groups	Count	Sum	Average	Variance
Age group	100	107	1.07	0.08595
Do you believe AI can help reduce bias in financial decisions (such as loan approvals)?	100	247	2.47	1.26171

ANOVA						
Source of Variation	SS	d.f	MS	F	P-value	F crit
Between Groups	98	1	98	145.4354669	0.00	3.888852
Within Groups	133.42	198	0.673838			
Total	231.42	199				

Interpretation:

Based on the ANOVA single-factor analysis, the calculated p-value is 0.00, which is less than the significance level of 0.05. Therefore, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_1) is accepted. This indicates that there is a statistically significant difference between the age groups of respondents and how ai can reduce the bias in financial decision making.

5. FINDINGS OF THE STUDY, SUGGESTIONS AND CONCLUSION

5.1. FINDINGS OF THE STUDY

- Most of the survey respondents are young people (94% in the 18–25-year category) and are predominantly students (68%), making the survey findings representative of the digital banking habits of an educated younger population.
- The most popular banks are government sector banks (61%), with private banks (36%) being the second-most popular, revealing bias towards conventional banking institutions despite increasing digital alternatives.
- Most customers (64%) use digital banking services every day, with UPI being the most widely used mode of online transactions, reflecting a mobile and app banking trend.
- The most faced threats are phishing attacks (50%) and UPI scams (32%), which reflect that users can be exposed to social engineering and unauthorised digital transactions.
- Whereas most of the banking concerns are addressed within a week (37%), 10% of users have pending concerns, showing inconsistency in the responsiveness of customer support.
- Most sought-after feature requests are real-time fraud detection (44%) and AI-based monitoring (25%), reflecting what users want most is proactive, automated security features.
- While 51% trust AI to detect phishing, 33% are doubtful, and 16% distrust AI completely, reflecting a colossal trust deficit that might be a barrier in adopting AI-based banking security.
- The largest barrier to the adoption of AI that has been observed is data privacy (53%), followed by concern over deceptive decisions by AI and vulnerability to cyber-attacks.

5.2. SUGGESTIONS

- Subsequent studies should incorporate a larger age and employment cohort to obtain well-rounded perspectives, particularly working people and the elderly.
- Carry out campaigns to raise awareness among users—particularly the youth—about phishing methods, safe transactional habits, and recognizing authentic sources of banking communication.
- Banks should automate remedy processes with definite timelines and improved escalation frameworks to minimize the rate of unresolved or delayed solutions.
- Utilize real-time fraud detection technology and automated transaction monitoring to increase security and respond to user expectations for active warnings.
- Explain how AI systems function, make decisions, and protect data. Providing transparency and human-AI collaboration can help bridge the confidence gap.
- Banks need to invest in end-to-end encryption, robust consent controls, and decision-reinforced

privacy policies to assuage data concerns from customers.

- Offer customers control to turn off/on some AI-based services (e.g., auto-blocking, voice recognition), giving them convenience and control of their banking experience.

5.3. CONCLUSION:

The survey points out that young, student user segments are highly active in online banking, dominated by UPI and public

there is high interest in AI-driven security features such as real-time alerts, there is low trust in AI because of issues surrounding data privacy. To establish user trust, banks must provide openness, flexible AI features, and enhanced fraud

sector banks. But they are gripped by extremely severe threats from phishing fraud and UPI scams and are frequently plagued by lag in redressal. Although response. Having a balanced strategy of juxtaposing the use of sophisticated AI tools with robust privacy controls will in still more user trust and develop a safer online banking experience.

6.SCOPE FOR FUTURE RESEARCH:

Improve transparency through explainable AI (XAI), Cut down on adversarial attacks and deep fake-enabled fraud, and Anomaly detection model benchmarking to minimize false

positives. Interdisciplinary research is also essential on privacy-preserving AI, harmonization of regulation, and transferability of models. Lastly, quantifying meaningful financial and operational effects will make theoretical advancements worthwhile by tying them to real banking demands.

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THE GOVERNANCE OF TRUST IN VIRTUAL FINANCE: AN INTEGRATIVE PERSPECTIVE ON CYBERSECURITY, ETHICS, AND REGULATION

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Keywords: Financial Cybersecurity, Algorithmic Ethics, RegTech & SupTech, Decentralized Finance (DeFi) Governance, Zero-Trust Architecture (ZTA), Explainable AI (XAI)

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ABSTRACT:

While India is moving towards its Vikshit Bharat @ 2047 vision, its ever transforming virtual finance landscape of AI based services, metaverse banking, and decentralised protocols faces a foundational issue. This paper examines and articulates this issue as a "Trilemma of Trust", or the competing need to better optimize cybersecurity ethics, and regulation. This conceptual paper uses a qualitative approach rooted in the synthesis of interdisciplinary literature and framework to analyse this trilemma. The results include: a thorough technical overview of sophisticated cyber threats such as Post-Quantum Computing risks and the potential risks of AI-based attacks; introduction of a new quantitative construct, Algorithmic Fairness Score (AFS) to define and help remediate bias in financial AI; and we illustrate a framework for agile tech-driven regulation to cope with the RegTech and SupTech landscape. The paper discusses that these three streams are inherently interconnected and any approach that takes a siloed approach is simply unsustainable. Overall, the paper's main message is that it is possible to engineer, but we have to take this as an integrated governance model to design sustainable trust as a necessary pre-condition that enables the digital financial ecosystem to drive India's long-term social and economic aims.

Keywords: *Financial Cybersecurity, Algorithmic Ethics, RegTech & SupTech, Decentralized Finance (DeFi) Governance, Zero-Trust Architecture (ZTA), Explainable AI (XAI)*

INTRODUCTION

Over the course of the last decade, the Indian financial system has seen significant fundamental shifts. The aftermath of demonetization, in

conjunction with the lowest data costs in the world, and the technical brilliance of the India Stack, resulted in a rapid proliferation of fintech (technology driven

finance). The Unified Payments Interface (UPI) became so ubiquitous in people's lives as a payment channel that it became the base layer of the digital economy allowing millions to transact as part of daily life. With an eye to achieve *Vikshit Bharat @2047*, the digitalization of the economy is ushering in finance's next phase of technology-driven evolution into a virtual, intelligent, decentralized ecosystem (Thakkar et al, 2025). This includes metaverse branches providing animated services with levels of personalization, wealth management through AI driven robo-advisors, and decentralized finance (DeFi) protocols allowing businesses and households to generate yield and lend outside of traditional intermediary financial institutions.

While this technological evolution offers a more efficient, inclusive, and accessible financial system, it also creates a serious and complicated problem for the most important, yet most fragile, aspect of any financial system: trust. The same technologies that provide benefits also bring new and enhanced risks. The main problem this paper seeks to resolve is that this accelerating complexity creates a "Trilemma of Trust." The trilemma

indicates that policymakers, regulators, and financial institutions face the near-impossible task of optimally pursuing three distinct, yet often conflicting, objectives at the same time:

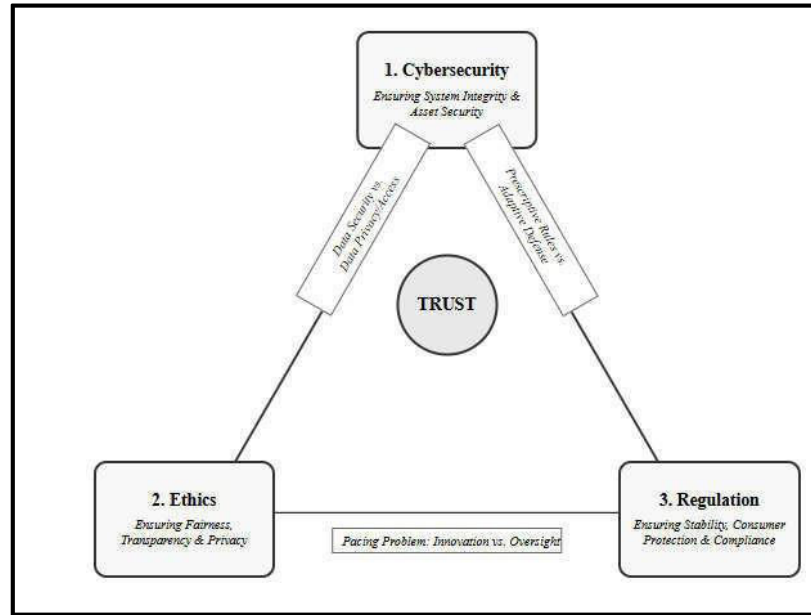
Cybersecurity: Protecting the integrity and security of systems and digital assets, and safeguarding financial infrastructure from the growing sophistication and speed of automation in respect of the emerging threats.

Ethics: Promoting fairness, transparency, and privacy, while navigating opaque algorithms and expansive data collection without allowing technology to act in a way that perpetuates or intensifies social biases.

Regulation: Creating a proactive and effective regulatory framework that protects consumers, provides system stability, maintains the law, and allows for the innovation that it is designed to regulate.

All three objectives are required to address the Trilemma of Trust, and an intense focus on one goal will invariably necessitate creating challenges to the others. The central idea is illustrated in Figure 1.

Figure 1: The Trilemma of Trust in Virtual Finance



Source: Compiled by Author

This image shows the interrelated and often conflicting relationship between the three pillars that must be developed together to build sustainable trust in the digital financial ecosystem.

As shown in Figure 1, sustainable TRUST sits in the center. However, tensions are generated at the edges. For example, aggressive Regulation can result in strict, checklist-oriented compliance rules (i.e., requiring strict encryption standards) that prevent robust Cybersecurity that learns and adapts through threat intelligence. A strong commitment to Cybersecurity monitoring through data collection (potentially) conflicts with the Ethical principle of individual privacy. The pace of financial innovation, which is likely rooted in an ethical commitment to providing a better user experience or greater inclusion and real access of underserved individuals, often overtakes the capacity of Regulation to provide sufficient oversight (the "pacing problem"). This visual model establishes the central argument: that trust, can be obtained through a dynamic and

simultaneous balancing of all three vertices.

LITERATURE REVIEW

The metaverse is full of exciting possibilities, but it also faces some serious challenges—think identity theft, data breaches, and tricky governance issues. A big part of the problem is that there isn't a single, unified approach to security. Technologies like blockchain and AI show promise, but they're still works in progress (Ogunode & Dada, 2022). Right now, we're dealing with patchy global regulations, a lack of specialized cybersecurity tools, and not enough real-life examples or user education to help keep this new digital world safe (Jaipong et al., 2022). Reward systems are becoming more vulnerable to cyberattacks such as wallet hacks and phishing, an issue exacerbated by low user knowledge (Olaniyan et al., 2021). Although blockchain has advantages such as transparency and scalability, these come with new security risks (Omucheyi et al., 2025). There are gaps in embedding

cybersecurity into system design, prioritizing user-centric security, and doing real-world testing. There is an evident need for solutions that will better balance privacy and transparency in these new systems (Allimia et al., 2024). The study indicates that AR, VR, AI, and DeFi can revolutionize banking by enhancing customer experiences, yet they introduce challenges like cybersecurity threats, regulatory complexities, and trust deficits. There's an urgent need for advanced biometric security and AI-powered fraud detection (Thakkar et al, 2025). Current research lacks real-world adoption data and practical implementation insights (Unuigbokhai and Anthony, 2022). Significant gaps remain in developing sustainable business models for metaverse banking and harmonizing global financial regulations with these nascent virtual systems (Kedla et al., 2025). Block chain's decentralized design could unlock all kinds of economic opportunities. But without proper oversight, cryptocurrencies can swing wildly between booms and busts (Thakkar et al, 2025). While developed countries might use blockchain for

RESEARCH METHODOLOGY

This manuscript consists of conceptual research, utilizing qualitative methodology, where synthesis and developing models were the focus of the study. Given that the trilemma is a latent and emergent research object, it would be too early for an empirical study. The selected methodology allows the researcher to formulate a base understanding and analytical tool while considering proceeding with its empirical work. The entire process developed in a manner that comprised four stages:

financial innovation, developing nations could benefit more from things like easier remittances and greater financial inclusion. Still, there's a big gap in research—especially when it comes to comparing regional impacts and evaluating how well current regulations and investor protections actually work (Radanliev, 2024) AI has an important role in securing the metaverse by allowing for ongoing login verification, biometric authentication, and more intelligent threat detection (Thakkar et al, 2024). All this notwithstanding, NFTs and blockchain-based assets are still vulnerable to attacks such as phishing and fraud, primarily because current security infrastructures are not sophisticated enough to keep pace with the rapidly evolving character of the metaverse (Thakkar et al, 2024). There is a keen requirement for further study of AI-powered security technologies, particularly within immersive environments, and real-world testing, as well as more utilization of several biometric technologies (Awadallah et al., 2025).

Interdisciplinary Literature Synthesis: The iterative and formative step was a broad review of current literature in three separate domains. For Cybersecurity these captures technical standards from various reporting standards, NIST (the Cybersecurity Framework and PQC project documentation) and ISO (ISO 27001 series), in addition to then research on Web3 hacks and exploits. For Ethics, drawing on the foundational papers associated with AI fairness, and XAI papers along with legal and policy analysis of data privacy regimes, for example

GDPR and D.P.D.P.A 2023 from India were utilized, and lastly, Regulation, which are International (global) reports from the FATF and BIS, however it contained a small number of reports from the evolving RBI position on FinTech and Digital Lending guidelines.

Conceptual Framework Development: The findings from the literature review were distilled to identify the core tensions, and interdependencies, between security, ethics, and regulation. The distillation illustrated the "zero-sum" choices posed by siloed decision-making resulting in an elaboration of the "Trilemma of Trust" (Figure 1) as the foundational analytical framework for the paper. The Trilemma of Trust can be seen as a heuristic tool for deconstructing the inherently complex, multi-domain problem space.

Technical Construct Development: In order to add rigor to the operationalization of the conceptual framework, the next process was to develop specific technical constructs. This stage of the research transitioned from describing to prescribing. This included building a structured table of smart contract vulnerabilities, identifying a specific set of mitigation patterns, and importantly, developing a novel, quantitative measure, the "Algorithmic Fairness Score" (AFS), by adapting existing statistical fairness measures into a composite formula. This process also entailed defining the formula, its components, and a hypothetical calculation illustrating how it could be used to audit AI models.

Architectural Plan: The final methodological component of the study involved architecting a high-level integrated governance framework. This prescriptive framework endorses a National Task Force, "Trust by Design"

principals, and follows logically from the analysis conducted through the Trilemma framework, thus forming a proposed solution.

RESULTS

The research process yielded three core sets of results, corresponding to the detailed analysis of each pillar of the trilemma.

1.1. Result 1: A Framework for Advanced Cybersecurity Threat Analysis

The cybersecurity pillar assessment demonstrated a rapidly evolving threat landscape that necessitated a new security paradigm.

Two Types of Emerging Threat Vectors: AI & Web3. In the research, two shifts in threat vectors were identified.

AI Attacks: Cybercriminals are no longer just opportunistic automated scripts; they are leveraging AI to perpetrate novel attacks. In Generative Adversarial Networks (GANs), there is a "Generator" network that creates synthetic data (e.g., a fake voiceprint) and a "Discriminator" network that assesses whether it's fake or real. The networks are trained against each other as adversarial networks until the Generator becomes highly effective at producing realistic deepfakes. Using Reinforcement Learning (RL), the malicious agent is trained in a simulated network environment. The "reward function" is defined through detection evasion or reaching the target asset. Over time, the agent develops paths through trials which fascinates the human analyst.

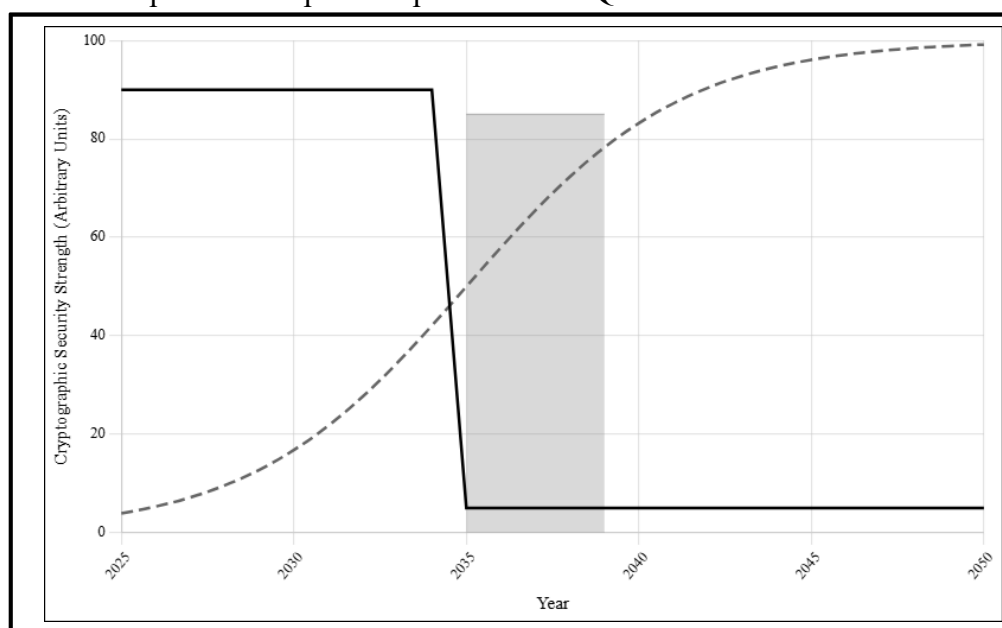
Web3 Exploits: In addition to the previously defined common vulnerabilities, (see Table 1), the study identifies more subtle exploits such as Timestamp Dependence where a smart

contract's logic explicitly takes advantage of the block's timestamp but this can be manipulated to some limited degree by the miners, and Unchecked External Calls, where there is a smart contract calling another smart contract that may be malicious and not properly handling potential failure or unexpected results.

The Quantum Imperative: A Looming Cryptographic Crisis: The quantum threat is not speculative. Although there isn't yet a large-scale, fault-tolerant quantum computer, the danger exists today. Shor's algorithm operates by computing the period of a function quickly, something that enables it to factor both RSA (which is based on the hardness of large number factorization) and ECC (based on the hardness of solving discrete logarithms on elliptic curves). The security of almost all of today's digital finance hangs on these

two cryptographic mainstays. The "decrypt later, harvest now" approach involves enemies capturing enormous amounts of encrypted Indian financial information today, planning to decrypt it years down the line when a powerful quantum computer exists. Graph 1 graphically represents the urgency of the transition to Post-Quantum Cryptography (PQC). The most prominent PQC contenders, like those with structured lattices (e.g., CRYSTALS-Kyber, Dilithium), inherit their security from various mathematical problems conjectured to be hard for classical and quantum computers. The transition is an enormous undertaking, involving changes to everything from banking Hardware Security Modules (HSMs) at the core to TLS protocols on all banking apps.

Graph 1: Conceptual Depiction of the Quantum Threat Timeline



Source: Compiled by Author

The Architectural Solution: Zero-Trust Architecture (ZTA): Due to these ubiquitous threats, the study concludes that the classic "castle-and-moat" security approach is passé. The only effective architectural solution is a ZTA. This is not

a product but rather a security strategy that runs on the mantra of "never trust, always verify." All access requests, no matter where they come from, must be considered hostile until they are authenticated. Primary elements include:

Identity and Access Management (IAM): Leverage phishing-resistant, strong multi-factor authentication and next-generation protocols such as OAuth 2.0 and OpenID Connect to provide just-in-time, least-privilege access.

Micro-segmentation: Leverage Software-Defined Networking (SDN) to compartmentalize the network into minuscule, isolated segments, so even if

an attacker gains entry into one segment, it is impossible for them to laterally move to others.

Pervasive Monitoring: Continuously consuming logs from every device, application, and network into a Security Information and Event Management (SIEM) platform upgraded with User and Entity Behavior Analytics (UEBA) to identify anomalies in real-time.

Table 1: Technical Classification of Smart Contract Vulnerabilities

Vulnerability Category	Technical Description	Mitigation Technique
Re-entrancy	An attacker's contract re-enters a function on the victim's contract before the first call is resolved, allowing funds to be drained repeatedly.	Implement the Checks-Effects-Interactions pattern. Use ReentrancyGuard modifiers from trusted libraries like OpenZeppelin.
Integer Overflow/Underflow	An arithmetic operation creates a number outside the storable range, causing it to "wrap around" (e.g., $255 + 1 = 0$ in uint8).	Use SafeMath libraries for older compilers. Modern compilers (Solidity v0.8.0+) have built-in protection that reverts the transaction.
Oracle Manipulation	An attacker feeds malicious data from an external source (oracle) to a contract to trigger a profitable but unintended outcome.	Use decentralized oracle networks (e.g., Chainlink) that aggregate data from multiple independent sources. Implement time-weighted average prices (TWAPs) for financial data.
Front-Running (MEV)	An attacker observes a pending transaction in the public mempool and pays a higher fee to get their own transaction processed first to profit.	Use private transaction submission services (e.g., Flashbots) that bypass the public mempool, or use protocols with built-in batch auction mechanisms.

Source: Compiled by Author

1.2. Result 2: A Model For Computational Ethics And Algorithmic Fairness

The ethics pillar was analyzed in terms of the "black box" challenge of AI and ended in a quantitative model for algorithmic bias measurement.

The Digital Redlining Problem: The study validated that AI systems can inherit and

even exacerbate historical biases in training data. This may take place through sampling bias (where collected data is unrepresentative of the population) or measurement bias (where proxy variables employed are themselves biased, for

instance, utilising postal codes as a proxy for creditworthiness).

The Algorithmic Fairness Score (AFS): The main finding in this category is the creation of the AFS, a theoretical formula meant to be a real, auditable metric for the fairness of an AI system. Fairness as such has numerous different definitions; the AFS takes two large categories: group fairness (Disparate Impact) and individual fairness (Equality of Opportunity).

Formula 1: The Algorithmic Fairness Score (AFS) The AFS for a predictive model is calculated as:

$$AFS = 1 - \sqrt{w_{DI} \cdot (1 - DI)^2 + w_{EO} \cdot (EOD)^2}$$

Where DI is the Disparate Impact ratio ($\frac{P(\text{Outcome}=1|\text{Unprivileged})}{P(\text{Outcome}=1|\text{Privileged})}$) and EOD is the Equality of Opportunity Difference ($|\text{TPR}(\text{Privileged}) - \text{TPR}(\text{Unprivileged})|$). This formula provides a single, interpretable score that financial institutions can use to audit, benchmark, and improve their models through techniques like adversarial debiasing or data re-weighting.

The Role of XAI and PETs: The research also identified Explainable AI (XAI) frameworks (like LIME and SHAP, which provide feature-level explanations for individual predictions) and Privacy-Enhancing Technologies (PETs) as essential complementary tools for

building ethical AI systems that are both transparent and privacy-preserving.

1.3.Result 3: A Framework For Agile Financial Regulation

The regulatory pillar analysis determined that the fundamental issue was the transition from having to regulate centralized platforms to regulating decentralized, autonomous protocols.

DeFi Governance Challenges: The study presents the challenge of implementing conventional AML/CFT regulations into systems with no apparent legal intermediary. Regulating Decentralized Autonomous Organizations (DAOs) is especially challenging in terms of conferring legal personality and liability.

Proposed Solutions: The main outcome is the recommendation for a technology-driven regulatory model

Regulation at the Endpoints: A pragmatic emphasis on the centralized fiat-to-crypto "on-ramps" and "off-ramps" where KYC/AML can be effectively applied.

RegTech: Solutions employed by firms to automate compliance, e.g., using AI to scan transactions for suspicious patterns of activity established by the Financial Intelligence Unit (FIU).

SupTech: Regulators' own tools. That would involve building a national SupTech platform on which the RBI would be able to use APIs to extract anonymized, real-time information from financial institutions, enabling unmatched systemic risk monitoring and data-based policymaking.

DISCUSSION

1.4. Interpretation Of Results

The three results, when considered together, strongly underpin the validity of the "Trilemma of Trust" framework (Figure 1). They are not discrete issues but a close-knit system. For example, SupTech framework set out in Regulation (Result 3) is an effective means of stability but also a key target for nation-state cyberattacks, necessitating the most sophisticated Cybersecurity protections (Result 1). At the same time, this degree of supervision opens up deep Ethical concerns (Result 2) regarding state surveillance and data privacy. This deep intersection suggests that any corporate strategy or policy dealing with a single vertex of the trilemma in isolation is not merely incomplete but perhaps even perilous. There has to be a coordinated move on all three fronts for progress.

5.2. Implications For Vikshit Bharat @ 2047

The consequences of this study for India's long-term future are immense and cross policy, industry, and human capital.

For Policymakers (RBI, SEBI, MeitY): The report suggests dismantling conventional silos and establishing cross-functional task forces. Subsequent regulatory schemes, including the future Digital India Act, need to be framed keeping the trilemma in sight, imparting security, ethics, and flexibility principles right at the outset. A national initiative to establish a sovereign SupTech platform and require PQC migration for strategic financial infrastructure needs to be top agendas.

For Financial Institutions: The trilemma calls for a change in corporate culture.

"Trust by Design" has to become an integral principle, a part of the product development process. That implies cybersecurity cannot be an afterthought compliance function, and ethics can't be an afterthought. It needs board-level attention and some serious investment in new technologies (ZTA, PQC, AI model validation tools) and processes.

For Human Capital: The sophistication described in this paper foretells a gigantic need for a new generation of "trilemma-literate" professionals. India will have to develop talent in highly specialized, interdisciplinary careers: Quantum Security Strategists to coordinate the PQC switch-over, AI Ethicists to audit and regulate financial algorithms, DeFi Regulatory Analysts to harmonize the intersection of code and law, and SupTech Data Scientists in regulatory institutions.

5.3. Limitations of the Study

The main limitation of this research is its conceptual nature. The suggested frameworks and equations, though based on current theory and technology, are yet to be tested empirically. The Algorithmic Fairness Score (AFS) is a theoretical entity, e.g., its weights would be calibrated through expert consensus, and its real-world performance extensively tested. Also, the rate of technological evolution is relentless. Although this paper covers near-horizon technologies such as PQC and AI, unexpected "black swan" breakthroughs may change the trilemma's dynamics in ways not included herein. The paper outlines a strategic framework, but its particular tactical suggestions will need ongoing revision.

CONCLUSION

The path to a virtual financial future for India is unavoidable. Its billion-plus citizens' trust, however, is not. This study has defined the challenge of establishing and sustaining this trust as a "Trilemma" among the conflicting but necessary pillars of cybersecurity, ethics, and regulation. By breaking down each pillar and suggesting concrete, tech-enabled solutions ranging from Zero-Trust Architectures and numeric fairness scores to SupTech platforms, this paper has made

the case for a new, unified approach. The overall conclusion is that trust cannot be an add-on; it is a fundamental infrastructure that needs to be actively designed, engineered, and maintained. Actively addressing this trilemma through an integrated national strategy is crucial to the creation of a financial ecosystem that is not only innovative and effective but also secure, inclusive, and deserving of the visionary goal of Vikshit Bharat @ 2047.

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An Action Research Design Framework for Cheating Intention of Black Money

Soni Vivek⁴ and Anand Rashmi⁵

Abstract:

Cheating intentions have been inherent in human actions, intelligence, and black markets. With the rapid development of technologies, recent studies have reported that artificial intelligence can capture fraudulent activities. However, understanding and testing the cheating intention in the black market is significantly mitigated, which poses difficulty for technologists to comprehend how the cheating intention of using money can be addressed to enhance data-driven decision making and add value to efficiency, complex operations, security, and stability of the financial systems in India. Using action design research, which is a layer-on-layer approach to use select AI/ML technologies (agents) to allow data mining algorithms and models to build, analyze, and suggest an efficient financial fraud detection and prevention system in the black money market in India. This highlights the current situation of fraudulent activities, and the limitations of traditional prevention and control measures in the face of big data and complex fraud modes are revealed. Secondly, the paper develops a model framework of collaborative intelligence agents for cheating intention in the black money market, especially the advantages and potential in data mining and fraud detection. Moreover, key technology implementation includes model training and optimization, real-time monitoring, and early warning solutions. Thirdly, policy recommendations should reflect the model outcomes for socio-economic development of the Indian financial system and suggest insights for new and emerging technology-oriented policies. Finally, through the in-depth analysis and evaluation of the experimental results, the study verifies the remarkable effect and feasibility of the system in financial fraud detection and prevention. It provides a new technical guarantee and risk management strategy for the financial industry.

Keywords: *Cheating intention, Black money, Artificial intelligence, Machine Learning, Black Market*

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Case Study: Cybersecurity in the Metaverse

I. Introduction

The evolution of immersive virtual environments has redefined how financial institutions interact with customers. MetaBank, a prominent player in digital finance, ventured into the metaverse with the launch of its MetaVerseBank XP in 2024. However, this shift introduced unprecedented cybersecurity vulnerabilities. This case explores the significant cybersecurity breach that occurred in February 2025, examining its technical failures, ethical implications, and regulatory challenges.

II. Background: MetaBank and the Metaverse

MetaBank launched MetaVerseBank XP as a fully immersive virtual banking branch. It featured avatar-based interaction, NFT-based wealth credentials, decentralized finance products, and AI-powered virtual advisors. The platform aimed to revolutionize user experience but lacked foundational cyber resilience protocols.

III. The Cybersecurity Breach

In February 2025, MetaBank suffered a sophisticated cyberattack in its metaverse banking environment. The attack, later termed 'The Avatar Heist,' led to the unauthorized transfer of over \$22 million in crypto assets. Hackers infiltrated avatar identities, exploited a smart contract reentrancy bug, and leveraged admin privilege escalation.

IV. Flowchart: Breach Attack Vectors

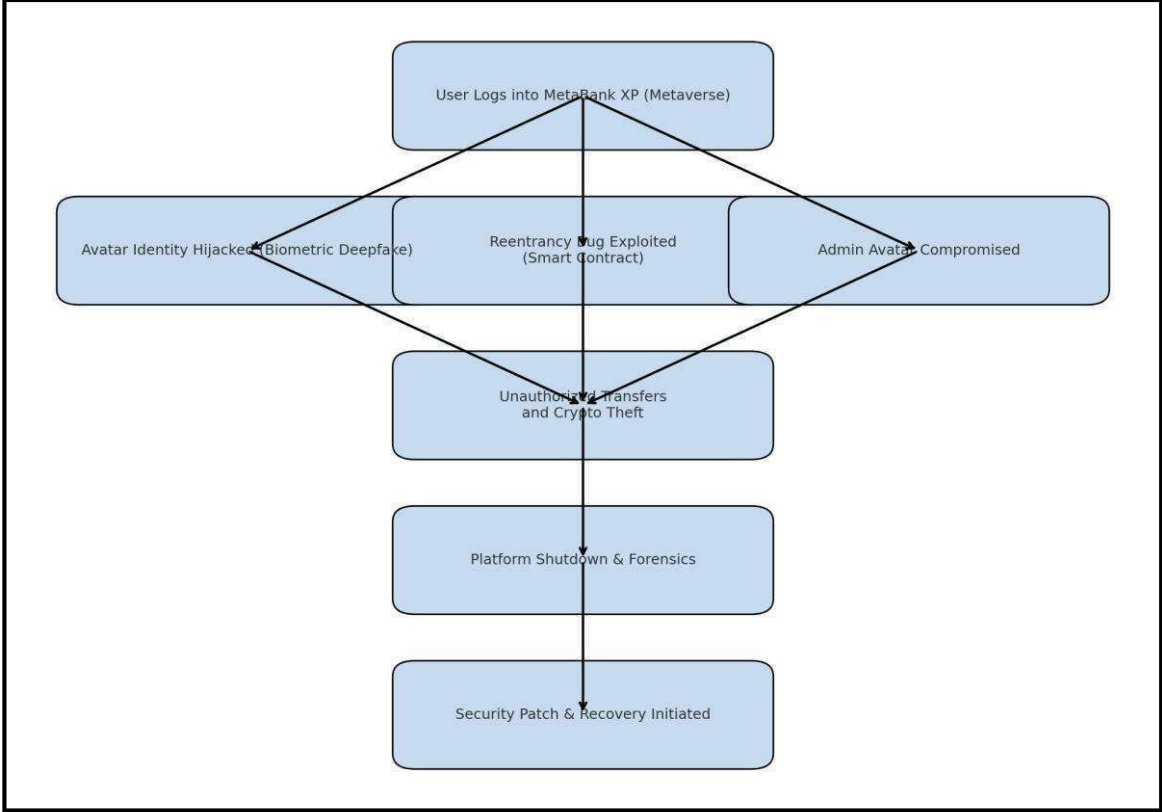


Exhibit 1: Flowchart detailing the sequence of breach events and attack paths in MetaBank XP.

V. Root Cause Analysis

- Weak biometric-only authentication allowed avatar impersonation via deepfakes.
- Smart contract lacked secure coding practices, enabling a reentrancy attack.
- Admin roles were over-privileged with no zero-trust or session limitations.
- Lack of anomaly detection delayed the response and increased financial impact.

VI. Ethical and Regulatory Considerations

The breach highlighted concerns around user consent, data privacy, and cross-border legal jurisdiction. MetaBank collected sensitive biometric data without clear, modular user consent. Furthermore, since operations occurred across decentralized nodes, establishing legal liability and recovery mechanisms proved difficult.

VII. Organizational Response

MetaBank responded with an immediate suspension of the platform, initiated forensic audits via ChainWatch.ai, and began compensating affected users. Technical teams patched smart contracts, replaced biometric-only systems with decentralized identity solutions, and implemented zero-trust access policies.

VIII. Lessons Learned & Recommendations

- Adopt multi-modal biometric + token-based authentication.
- Enforce mandatory third-party smart contract audits.
- Implement zero-trust architecture for admin privileges.
- Collaborate with digital regulators to define virtual finance legal standards.

IX. Conclusion

The MetaBank metaverse breach illustrates the criticality of integrating cybersecurity into the foundation of virtual financial ecosystems. Institutions must ensure robust digital identity protection, code integrity, and cross-jurisdictional legal frameworks to sustain trust and innovation in metaverse finance.

AI-Powered SIEM for the Metaverse: Securing Virtual Financial Systems through Intelligent Event Management and Ethical Oversight

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Abstract

The metaverse presents a transformative paradigm in digital interaction, especially within financial systems. As virtual banking, decentralized finance (DeFi), and asset tokenization gain momentum, so do the associated cybersecurity risks. This paper proposes the integration of Artificial Intelligence (AI)-powered Security Information and Event Management (SIEM) systems as a foundational pillar for safeguarding metaverse financial ecosystems. Emphasis is placed on adaptive threat detection, ethical governance, and regulatory compliance. The study advocates for a proactive, intelligent, and ethically aligned cybersecurity infrastructure to secure the evolving virtual economy.

Keywords: *Metaverse Banking, Cybersecurity, AI-SIEM, Virtual Finance, Ethics, Regulation, Digital Identity, Intelligent Event Management*

Introduction

The evolution of financial systems has reached a pivotal point with the emergence of the metaverse and associated virtual environments. Traditional banking is being redefined through immersive technologies, enabling new forms of digital assets, decentralized finance (DeFi), and cross-platform virtual transactions. These innovations provide seamless financial interaction but also create unprecedented vulnerabilities. As financial activities migrate to these persistent and interconnected virtual spaces, they become increasingly susceptible to cyber threats, including identity theft, data breaches, and digital fraud.

In this context, Security Information and Event Management (SIEM) systems play a

crucial role. SIEM tools collect, analyze, and respond to security events in real time, offering visibility into potential threats. When powered by Artificial Intelligence (AI), these systems become significantly more effective in identifying patterns, predicting attacks, and automating responses.

This paper aims to explore how AI-powered SIEM systems can be tailored to meet the unique cybersecurity requirements of metaverse banking. It presents a framework that integrates intelligent threat detection with ethical and regulatory considerations to support secure, transparent, and resilient virtual financial ecosystems.

2. Metaverse Banking and Virtual Financial Ecosystems

Metaverse banking refers to the provision of financial services within virtual and immersive digital environments. These environments utilize extended reality (XR), blockchain, and Web3 technologies to enable real-time financial transactions and asset management in decentralized spaces. Key components of this ecosystem include:

- **Non-Fungible Tokens (NFTs):** Unique digital assets used for art, collectibles, and intellectual property with real-world value.
- **Decentralized Finance (DeFi):** Peer-to-peer financial services (lending, borrowing, trading)
- **Identity Theft:** Stolen avatars or compromised digital identities can lead to unauthorized financial activity.
- **Data Breaches:** Weak infrastructure may expose sensitive financial data.
- **Transaction Spoofing:** Manipulation of smart contracts and wallet credentials to redirect funds.
- **Social Engineering Attacks:** Phishing through immersive interactions or deceptive avatars.

Given the pace and complexity of these systems, traditional cybersecurity tools are insufficient. There is a compelling need for real-time monitoring and intelligent anomaly detection to ensure financial security. AI-powered SIEM systems can bridge this gap by continuously analyzing virtual interactions, predicting emerging threats, and providing contextual alerts that adapt to evolving risk scenarios.

executed via smart contracts on blockchain networks.

- **Virtual Real Estate:** Digital land and property assets that can be bought, sold, or leased in metaverse platforms.
- **Cryptocurrency Transactions:** Blockchain-based digital currency payments, including stablecoins and tokens used within metaverse platforms.
- **Digital Wallets and Avatars:** Identity mechanisms for managing assets and interacting in the virtual financial space.

While these innovations democratize access to finance and enhance user experience, they introduce critical cybersecurity risks:

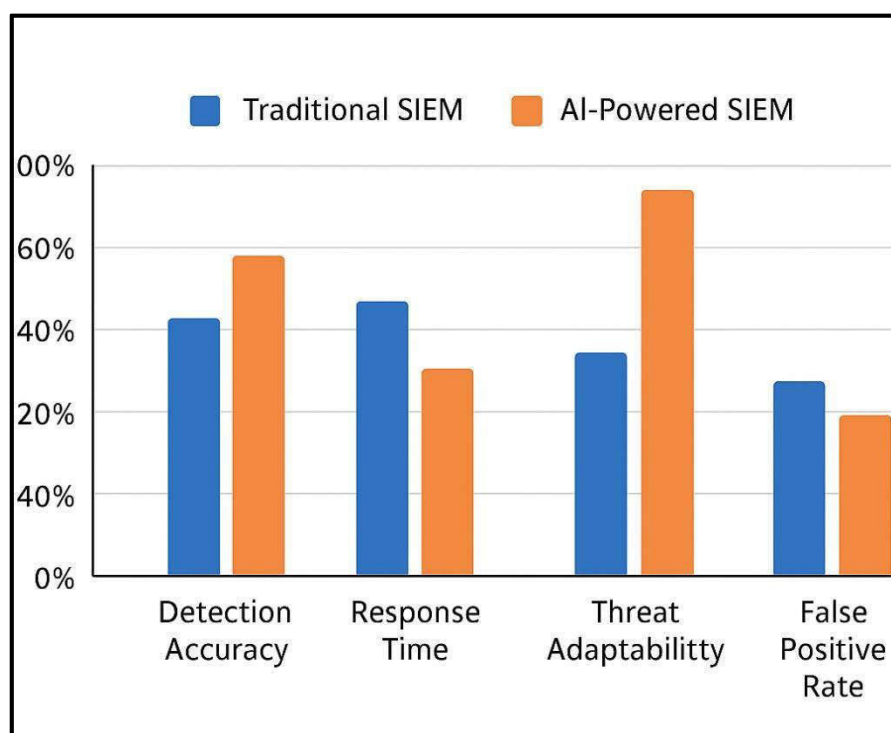
3. Role of AI-Powered SIEM Systems

Traditional SIEM systems rely heavily on predefined rules and signature-based detection to monitor logs and events across IT infrastructures. While effective in detecting known threats, they often fall short in identifying zero-day attacks, behavioral anomalies, or advanced persistent threats in dynamic environments like the metaverse.

In contrast, **AI-powered SIEM** systems incorporate machine learning (ML), natural language processing (NLP), and behavioral analytics to dynamically adapt to new threat landscapes.

These intelligent systems evolve continuously, learning from new data to

detect patterns that deviate from normal behavior and responding in near real time.



Key Features of AI-Driven SIEM:

- **Anomaly Detection:** AI models learn baseline behavior and flag deviations, even in encrypted or distributed environments.
- **Predictive Threat Modeling:** Historical data and behavioral trends are used to forecast potential threats before they manifest.
- **Automated Incident Response:** Response workflows can be triggered automatically, reducing mean time to respond (MTTR) and mitigating human error.
- **Threat Correlation:** Multisource data correlation (blockchain logs, VR interaction data, smart contract activity) enhances context-aware threat management.

- **Scalability and Adaptability:**

Easily scales to manage high-volume, high-velocity data typical of metaverse environments.

Case Examples:

- **Darktrace Enterprise Immune System:** Uses AI to detect and respond to threats across digital environments, including financial services, through autonomous response.
- **IBM QRadar Advisor with Watson:** Integrates cognitive AI to correlate threat intelligence and advise security teams with prioritized incident recommendations.
- **JP Morgan Chase:** Reported leveraging AI in their SIEM processes to proactively detect insider threats and phishing

attempts across their digital platforms.

Such systems are increasingly critical in virtual banking, where the volume and complexity of events demand intelligent monitoring that is both proactive and

4. Cybersecurity Challenges in Metaverse Financial Platforms

The metaverse introduces unique and complex cybersecurity challenges that traditional financial platforms are not designed to handle.



These include:

- **Dynamic Threat Landscapes:** In a metaverse environment, users often operate under multiple digital identities through avatars and interact using immersive AR/VR interfaces. These create novel attack surfaces, including the risk of immersive experience hijacking (e.g., injecting malicious content into AR spaces or intercepting sensory feedback).

adaptive. In the context of the metaverse, AI-SIEM systems offer a foundational solution for maintaining operational security, customer trust, and regulatory compliance.

- **Regulatory Loopholes:** Metaverse financial platforms often operate across borders without centralized control. The lack of a unified legal or regulatory framework means cybercriminals can exploit jurisdictional gaps, laundering digital assets or executing scams with limited traceability or enforcement.
- **Privacy Concerns:** Persistent digital identities in the metaverse collect vast amounts of biometric, behavioral, and financial data. Without robust protections, this data is at risk of being misused for targeted fraud, surveillance, or unauthorized profiling.

These challenges demand an advanced cybersecurity solution capable of real-time detection, cross-domain data correlation, and intelligent governance. **AI-powered SIEM systems** can address these gaps by:

- Continuously monitoring AR/VR interaction logs, smart contracts, and identity behaviors.
- Detecting subtle anomalies that suggest identity spoofing, sensory manipulation, or unauthorized access.

- Supporting compliance checks with regional data laws and generating automated audit trails.
- Providing a scalable solution that adapts as new threat vectors

Thus, AI-SIEM becomes a central nervous system for cybersecurity in metaverse finance—integrating

emerge in evolving virtual landscapes.

technology, ethics, and governance into a unified, intelligent infrastructure.

5. Ethical and Regulatory Implications

As AI-driven cybersecurity solutions become integral to virtual financial environments, ethical and regulatory issues must be rigorously addressed:

- **Surveillance vs. Privacy:** While real-time monitoring and behavioral analytics are critical for threat detection, they also raise serious privacy concerns. Users may unknowingly be subjected to pervasive surveillance, leading to a potential erosion of personal autonomy within virtual spaces.
- **AI Bias in Threat Detection:** Machine learning models can inherit biases from training data, leading to disproportionate targeting of specific groups or behaviors. In metaverse platforms,

where user interactions are highly varied and multicultural, such bias can manifest in discriminatory threat prioritization or false positives.

- **Cross-Jurisdictional Compliance:** The metaverse transcends geographical boundaries, but regulations such as the **General Data Protection Regulation (GDPR)**, **Reserve Bank of India (RBI)** guidelines, **Securities and Exchange Commission (SEC)** rules, and the **IT Act 2000 (India)** must still be upheld. Ensuring compliance in borderless environments is a formidable challenge.

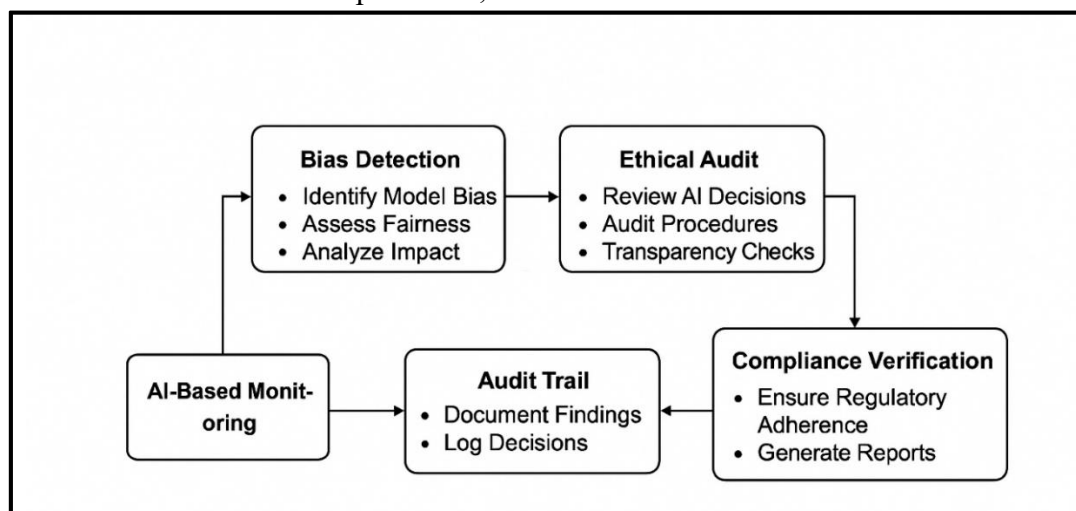


Figure: Ethical AI auditing pipeline for identifying bias, ensuring compliance, and maintaining transparency in virtual financial monitoring.”

To address these challenges, we propose a framework that integrates AI-SIEM with ethical and transparent decision-making principles:

1. **Ethical AI Layer:** Implements fairness-aware algorithms, bias detection modules, and transparent model governance.
2. **Privacy-by-Design Architecture:** Encrypts sensitive data at all stages, incorporates user consent mechanisms, and limits data retention.
3. **Compliance Dashboard:** Offers real-time insights into regional regulatory obligations, auto-generating audit reports.
4. **Explainable AI (XAI):** Ensures that decision-making processes in threat detection are interpretable and accountable.

This framework not only secures the infrastructure but also builds public trust in virtual financial systems by embedding ethical integrity into every layer of cybersecurity operations.

6. Proposed Framework for Metaverse-Aware AI-SIEM

To address the complex cybersecurity requirements of virtual financial systems, we propose a conceptual architecture for an **AI-powered SIEM system tailored specifically for metaverse banking environments**. This system is designed to ensure real-time threat detection, transparent governance, and seamless compliance across decentralized and immersive financial platforms.

Key Components of the Framework:

1. **Virtual Identity Verification Module:**

- Integrates biometric authentication, behavioral analytics, and avatar linkage to verify user identities.
- Tracks identity morphing attempts or avatar hijacking using AI-based pattern recognition.
- Monitors login behaviors across platforms to detect suspicious activities tied to digital wallets or accounts.

2. **Smart Contract Monitoring Engine:**

- Continuously audits and analyzes smart contracts on DeFi platforms for vulnerabilities, suspicious code patterns, or unauthorized executions.
- Uses AI to flag anomalous contract behavior, such as high-frequency executions, gas manipulation, or privilege escalation attempts.
- Cross-verifies contract behavior against known attack signatures and legal compliance templates.

3. **Blockchain-Integrated Event Management Layer:**

- Collects logs from blockchain nodes, NFT platforms, and decentralized applications (dApps).
- Correlates on-chain and off-chain activities (e.g., token transfers with avatar movements) to provide context-aware threat analysis.
- Detects double-spending, flash loan attacks, and laundering activities using graph-based anomaly detection.

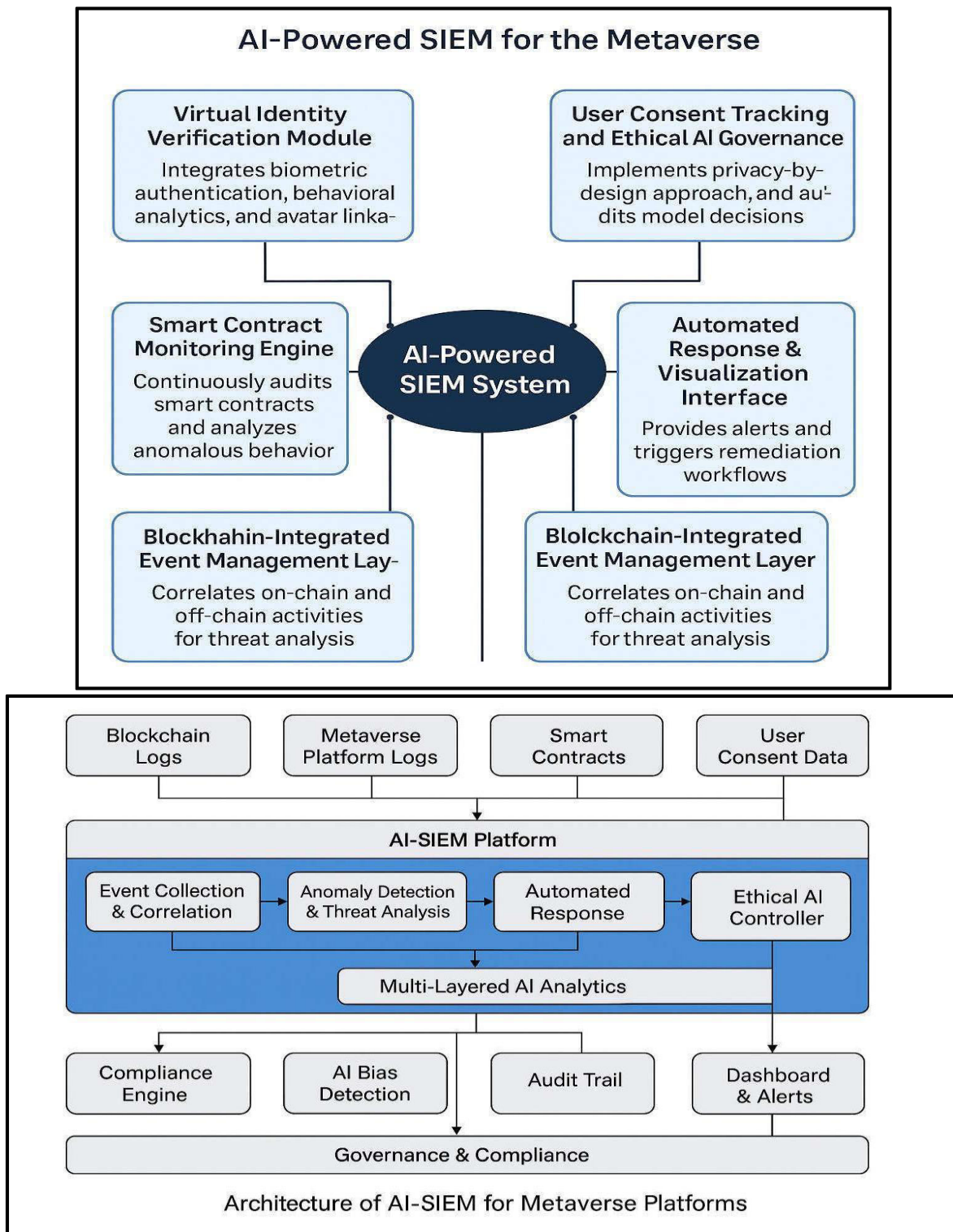


Figure: Layered architecture of AI-SIEM integrating blockchain logs, smart contract monitoring, regulatory compliance, and ethical AI governance for virtual financial ecosystems.”

User Consent Tracking and Ethical AI Governance:

- Implements a privacy-by-design approach, allowing users to manage data collection and analytics preferences through interactive consent dashboards.
- Includes an ethical AI controller that audits model decisions for bias, fairness, and transparency.
- Supports audit trails and compliance reporting based on GDPR, RBI, and other jurisdictional standards.

Multi-Layered AI Analytics Core:

- Applies unsupervised learning, reinforcement learning, and natural language understanding (NLU) to recognize evolving threat vectors.
- Enables intent-based security modeling by analyzing conversations, transactions, and behavior to distinguish between benign and malicious actions.

Automated Response & Visualization Interface:

- Provides real-time alerts, heatmaps, and forensic timelines in XR-ready formats for incident response teams.
- Triggers automated remediation workflows (e.g., freezing assets, revoking access) while ensuring legal and ethical safeguards are honored.

7. Future Scope

The convergence of AI, cybersecurity, and metaverse technologies is still in its formative stages, presenting vast potential

for innovation and refinement. Future research and implementation directions include:

- **Quantum-Resilient Encryption Integration:** As quantum computing advances, traditional cryptographic algorithms risk obsolescence. Integrating quantum-safe encryption with AI-SIEM systems will be essential for ensuring long-term data security and transaction integrity within virtual financial platforms.
- **Regulatory Sandboxes for AI in Metaverse Banking:** Creating controlled environments where AI-SIEM tools can be tested under regulatory supervision will allow stakeholders to evaluate security, ethical, and legal implications without systemic risk. This will accelerate trust and responsible innovation.
- **Development of International Cybersecurity Norms:** Given the borderless nature of the metaverse, there is a need for internationally accepted cybersecurity norms and frameworks. Collaborative efforts among governments, financial institutions, and tech developers can help shape a unified standard that governs virtual financial ecosystems globally.

These future pathways aim to enhance the resilience, fairness, and scalability of AI-powered cybersecurity systems in next-generation financial architectures.

8. Conclusion

The rise of metaverse banking and decentralized virtual finance necessitates a paradigm shift in cybersecurity strategy. AI-powered SIEM systems, with their capacity for real-time threat analysis, predictive modeling, and automated response, provide a compelling solution to these emerging challenges.

However, the implementation of such systems must be guided not only by technical capability but also by ethical responsibility and regulatory compliance. Privacy preservation, bias mitigation, and explainability must be embedded into the design and deployment of AI in virtual spaces.

Ultimately, securing the future of digital finance in the metaverse will depend on a multidimensional approach—blending intelligent automation with transparent governance. AI-SIEM systems are not just defensive tools, but strategic enablers of a secure, inclusive, and sustainable virtual financial future.

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Digital Financial Literacy and Human Capital Development in India: A Conceptual Framework for vision 2047

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Abstract

As India aspires to become a developed, knowledge-based economy by 2047, Digital Financial Literacy (DFL) emerges as a strategic enabler for inclusive and sustainable human capital development. This paper develops a conceptual framework that integrates DFL within the broader context of human capital theory, digital inclusion, and development economics. Drawing on national policy initiatives, global literature, and structural socio-economic realities, the framework identifies four interdependent pathways: employability, household resilience, intergenerational mobility, and gender equality; through which DFL drives human capital development. The framework highlights the enabling conditions, structural moderators, and long-term outcomes that shape this relationship. The study contributes to a theoretical understanding of DFL not merely as a transactional skill but as a transformative capability with systemic implications for India's developmental trajectory.

Keywords: Digital Financial Literacy (DFL), Human Capital Development, Digital Public Infrastructure (DPI), Financial Inclusion, Structural Inequality, Development Economics

1. Introduction

India's Vision 2047 specifies its ambition to be a knowledge-based, innovation-led, and inclusive economy. The fulcrum around which this vision revolves is the improvement of human capital—the collective skill, education, and health possessed by individuals—that drives the productive capacity of a nation (Schultz, 1961; Šlaus, & Jacobs, 2011; OECD, 2020). Financial systems in the digital era are experiencing deep changes driven by fintech technologies, rising smartphone penetration, and the establishment of digital public infrastructure like Aadhaar, Unified Payments Interface (UPI), and DigiLocker (Roy, 2021; Dattani, 2024). These changes

have revolutionized access to and utilization of financial services but may leave behind those who do not possess the digital skills required to interact productively with such systems.

Digital Financial Literacy (DFL)—the skill to comprehend, utilize, and navigate digital financial tools efficiently and securely—has therefore become the backbone of economic participation and empowerment (Mustafa, 2024; Kurniasari, et al., 2025 Lusardi & Mitchell, 2014). It involves more than simple digital competencies; it involves the capability to make sensible financial choices, assess digital threats, and

access important services via digital media. As a mediating capacity between outcomes and infrastructure, DFL is instrumental in ensuring that digital innovation leads to human capital formation and inclusive growth. Despite increasing digital infrastructure and fintech innovations, digital financial literacy (DFL) in India continues to be extremely low. Recent surveys have shown that not more than 27% of adults have functional financial literacy,

and not more than half have the confidence or ability to use digital tools like UPI, mobile banking, or e-wallets optimally (NCFE, 2022; MeitY, 2022). Gender gaps are even more dismal—only 25% of women in rural areas use such tools independently (GSMA, 2023). The following table illustrates the most important indicators that capture these challenges:

Table: 1 Key Indicators of Digital Financial Literacy in India (2022–2023)

Source	Year	Key Findings
NCFE-FLIS	2022	➤ In India 27% of adults are financially literate; Half of them show digital skills ➤ Indicates overall financial literacy is low; DFL even lower
RBI – Financial Literacy Week	2023	➤ People have limited awareness of credit use, digital frauds and online risks ➤ Rural users often use UPI without digital risk awareness
GSMA – Mobile Gender Gap Report	2023	➤ Only 25% of rural women use digital financial tools independently ➤ Reflects gender disparities in access and usage of digital finance
MeitY–MGDISHA Report	2022	➤ 31% of trained users could perform basic DFL tasks (e.g., UPI, bill payment) ➤ Literacy doesn't translate into full digital confidence

Source: Author's Own Compilation

The data in table:1 illustrate the critical importance of perceiving DFL not just as an extension of digital availability but as a competence that must be addressed through policy, situational delivery, and structural responsiveness. While tremendous progress has been made in digital infrastructure and financial inclusion initiatives, the distribution of the dividends of digital finance continues to remain uneven across socio-economic groups, particularly by gender, caste, and geography (Kulkarni, & Ghosh, 2021; Mishra, et al., 2024; Reinders

et al., 2021). This paper suggests a conceptual framework based on human capital theory and development economics to investigate the potential for DFL to act as an inclusive development lever. The paper emphasizes policies that enable, structural moderators, and developmental pathways linking DFL to socio-economic outcomes in the long term. Suggesting DFL as a strategic input into India's 2047 trajectory, this paper is intended to inform evidence-based policy and academic research into this new field.

2. Literature Review

2.1 Human Capital Theory

Human capital theory gives a theoretical perspective for the understanding of education, skill, and ability's role in enhancing individual's productivity and economic development of the country (Schultz 1961; Becker, 1964). According to the theory, investments in human beings, mainly their skills and education, have returns in terms of increased productivity and economic growth. Schultz highlighted the economic returns of education as an investment in capital, and Becker brought on board returns to education and skill training. The theory, in recent development thinking, has broadened to encompass financial literacy as a component of human capital, particularly in economies increasingly shaped by digital and technological interactions. (Goldin, 2016; Grigorescu *et.al.*, 2021).

Since the advent of digital technologies, shifted the determinants of human capital, digital skills are now become the key drivers of labor market participation and consumption of critical services (World Bank, 2018). It has imposed a necessity to reframe human capital frameworks so that digital financial skills become a form of vital knowledge.

2.2 Digital Inclusion and Financial Capability

Digital inclusion research is concerned with equal access to digital technologies, whereas research on financial capability is concerned with individuals being capable of handling financial resources optimally. The convergence of these areas supports the concept of DFL as a multidimensional construct that is not only technological but also behavioural and contextual (Lusardi & Mitchell, 2014; OECD, 2020).

Financial literacy has long been identified as a principal driver of economic inclusion, financial engagement, and individual wellbeing. Financial literacy is possessing ability and knowledge to use them to manage money issues successfully throughout a lifetime of financial well-being (Lusardi and Mitchell, 2014). Evidence has confirmed that financially literate individuals are more likely to save, invest in education, better able to take household decision, avoid excessive debt, and plan for retirement. In total contribute to higher national economic productivity (Atkinson & Messy, 2012; Klapper, & Lusardi, 2020).

However, with the emerging digitalization of finance, traditional financial literacy today has the necessity to incorporate digital elements. Digital Financial Literacy (DFL) involves the capacity to use online banking, electronic payment systems, mobile wallets, and to evaluate financial information derived through digital channels (OECD, 2020). Digitalization has reshaped the information asymmetry landscape in finance such that individuals are required to gain new kinds of literacy to cope with risks and make informed decisions (Gomber et al., 2018). Financial literacy also converges with overall socio-economic outcomes.

2.3 Gender, Caste, and Regional Disparities

Studies indicate that Indian access to digital financial tools is highly stratified by gender, caste, and geography (Kulkarni & Ghosh, 2021). Women, especially rural women, are usually excluded from digital participation because they have fewer mobile phones, are less digitally literate, and have more restrictive social norms (Gupta, & Kiran,

2025). For instance, as per UN Women (2021), rural Indian women are 26% less likely than men to possess a smartphone, and even when they have one, they tend to use male intermediaries to access digital services, thus constraining independent financial decision-making. The marginalized castes tend to have less access to quality digital infrastructure, which hinders their participation in the formal digital economy (Reinders et al., 2021). Structural inequalities, including educational and land-owning disadvantages that they inherited, also limit their participation in DFL programs.

At the regional level, the digital divide continues to exist between urban and rural or isolated regions. The India Internet Report emphasizes that internet penetration is 71% in urban India, as against a mere 38% in rural areas (IAMAI & KANTAR, 2023). This disparity directly translates into asymmetrical access to opportunities for financial inclusion through digital means. These inequalities highlight the need for intersectional and locality-based policy responses. Closing DFL gaps calls not just for digital infrastructure development but also culturally and linguistically appropriate training models that account for gender roles, caste hierarchies, and regional resource limitations. Disregarding these stratifies may reinforce digital exclusion and exacerbate the development gap among marginalized groups.

2.4 Gaps in Current Research

While the literature on financial literacy and digital inclusion is expanding, several critical research gaps remain. First, there is limited integration of Digital Financial Literacy (DFL) with broader human

development outcomes. Most empirical studies focus narrowly on financial inclusion metrics—such as bank account ownership or transaction frequency—without examining long-term effects on employability, household financial resilience, or social mobility (Klapper, Lusardi, & van Oudheusden, 2015; Demirgüç-Kunt et al., 2022). Second, the role of structural moderators, including caste, gender, regional inequality, and educational attainment, is often treated peripherally or omitted altogether in large-scale policy evaluations (Reinders et al., 2021; UN Women, 2021). Third, there is insufficient differentiation between digital access and digital capability. Having a smartphone or internet connection does not necessarily imply that individuals possess the cognitive, behavioural, or procedural knowledge to make safe and informed financial decisions (OECD, 2020; GSMA, 2022).

Another research gap pertains to the temporal dimension of DFL's effects. There is a lack of longitudinal studies that examine how DFL translates into intergenerational outcomes, such as improved educational investments, stable employment, or long-term asset accumulation (Agarwal & Zhang, 2020). Additionally, existing research is largely concentrated in urban or peri-urban settings, with rural contexts—where barriers to access and capability are more severe—being under-explored (IAMAI & KANTAR, 2023). This conceptual paper addresses these limitations by proposing a holistic and systemic framework that aligns DFL with the human capital agenda, rooted in India's diverse and stratified socio-economic context.

3. Conceptual Framework

The framework conceptualizes DFL as a core capability shaped by enabling conditions and structural moderators and operating through four developmental pathways that impact human capital development.

3.1 Enabling Conditions

Enabling conditions are the digital and institutional structures that facilitate the possibility of acquiring and applying DFL. They are macro-level institutional and technological underpinnings which provide the environment for DFL to take hold:

- Digital Public Infrastructure (DPI): Aadhaar, UPI, and DigiLocker create verifiable identities and frictionless digital transaction systems (World Bank, 2022).

- Policy and Institutional Support: Initiatives like PMGDISHA and PMJDY provide digital and financial services to marginalized communities (MeitY, 2022).

- Pricing Mobile Access: Global 4G and mobile penetration render digital financial tools affordable across socio-economic levels (GSMA, 2023).

The World Bank (2022) highlights that inclusive digital infrastructure is critical to extend financial services to the access the underserved. India's PMGDISHA program has equipped more than 60 million citizens with basic digital capabilities (MeitY, 2022), which forms the basis of DFL.

3.2 Structural Moderators

DFL does not exist in isolation. Its effectiveness is influenced by structural moderators—demographic and socio-

economic factors that determine who stand to gain from DFL and to what level. These are:

- Education: Numeracy and literacy levels influence the capacity to comprehend and be confident in digital finance instruments (OECD, 2020).

- Socio-Economic Status: Level of income and employment security determine risk tolerance and adoption behavior (Demirgüç-Kunt et al., 2022).

- Gender and Caste: Cultural values can restrict women's and lower-caste groups' use of mobile phones or control over finances (D'Cruz & Noronha, 2021).

- Geographic Divide: Rural communities usually don't have network facilities or digital education centers (Reinders et al., 2021).

Digital interventions in the emerging world have to be adapted to such realities, lest blanket solutions end up perpetuating existing inequalities and not diminishing them (Reinders et al., 2021). For example, women in rural India might be denied not just smartphone access but even permission to access financial apps.

3.3 Core Capability: Digital Financial Literacy

Digital Financial Literacy, at the centre of the framework, is defined as the intersection of digital competence and financial capability. DFL empowers people to grasp digital payment systems, conduct online transactions securely, budget online, and access formal credit. Financial literacy is a type of human capital to participate in the modern economy (Lusardi and Mitchell, 2014). Likewise, how effective digital financial tools are only as good as the capacity to effectively use them (Demirgüç-Kunt et al., 2022). DFL is recognized as the ability to:

- Utilize digital tools (UPI, mobile banking, e-wallets)
- NavParams informed financial choices
- Obtain cybersecurity protection
- Obtain access to credit, insurance, and investments over the web

3.4 Pathways to Human Capital Development

DFL enabled four interlinked pathways that drive human capital development:

- Employability:** Integration of digital skills into the job portfolio is increasing at a fast rate (ILO, 2021). DFL increases the level of digital work-readiness, facilitating engagement in gig, platform-based, and formal economies (WEF, 2020). Digital acquaintance and financial literacy increase an individual's competitiveness in the digital labour market.
- Household Resilience:** DFL enhances personal financial management capabilities, digital saving, insurance access, and mitigation against financial shocks. OECD (2020) explains that financially educated households are more

resilient in times of crises like health crises or inflation.

- Intergenerational Mobility:** DFL parents are likely to save for their children's education, stay away from bad debt, and invest in long-term securities. Banerjee and Duflo (2019) observe that such capability investments facilitate intergenerational upward mobility, especially among low-income households.

- Gender Equality:** DFL increases women's agency, autonomy, and voice in economic and social decision-making. According to UN Women (2021), digital financial tools—along with literacy—allow women to begin microenterprises, obtain credit, and create wealth independently.

3.5 Human Capital Development Outcomes

The net outcome of these avenues is inclusive, resilient, and productive human capital. Workers are better employed, families are more secure, gender disparities are closed, and intergenerational poverty is broken. Becker (1964) in his original human capital theory contended that such outcomes form the foundation of national progress. The World Bank Human Capital Index (2021) reiterates this, indicating that monetarily and digitally empowered populations result in increased national productivity and social equity. These routes end up in inclusive, adaptive, and productive human capital characterized by:

- Increased workforce participation
- Less gender and regional inequality
- Increased social mobility
- Improved economic resilience

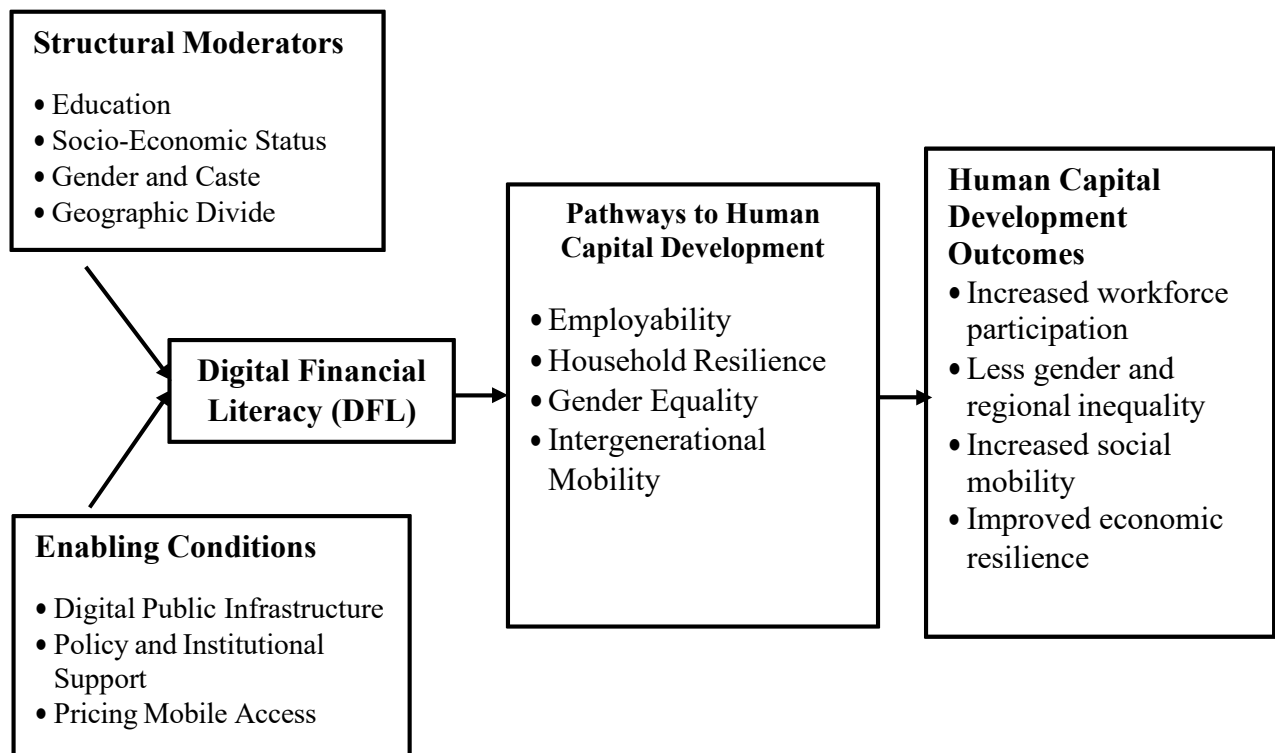


Fig: 1 Conceptual model of Digital Financial Literacy (DFL) leading Human Capital Development Outcomes

Source: Author's Own Compilation

The suggested conceptual model places Digital Financial Literacy (DFL) at the Center of enabling human capital development, particularly in the context of India Vision @ 2047. DFL is used here to refer to the intersection of digital skills and financial capability—empowering individuals to not only have access to digital finance but to utilize it effectively, securely, and strategically to enhance their socio-economic status.

The architecture is rooted in two building blocks: enabling conditions and structural moderators. Enabling conditions are facilitative infrastructure and policy environments like India's digital public goods (Aadhaar, UPI, DigiLocker), national financial inclusion programs (PMJDY), and digital literacy programs like PMGDISHA. These all constitute the

institutional and technological underpinnings upon which DFL can be created and spread (World Bank, 2022; MeitY, 2022). Access is not enough, though. The model acknowledges that structural moderators like education levels, gender norms, caste relations, digital divide, and socio-economic status have a significant bearing on the outcomes of DFL (Reinders et al., 2021). These variables don't only determine access to digital means, but also the ability to extract positive value from them—emphasizing the requirement for policy design that is equity-focused.

At the core of the framework is DFL itself, which triggers four connected development paths: (1) Employability, through building digital preparedness and facilitating engagement in emerging and new job

markets—most importantly through platforms and gig economy (WEF, 2020; ILO, 2021); (2) Household Resilience, through improving budgeting, saving, and risk management habits—key to surviving economic shocks and risks (OECD, 2020); (3) Intergenerational Mobility, as parents who are DFL-enabled have higher chances of investing in education, formal savings, and long-term financial planning, dismantling poverty cycles (Banerjee & Duflo, 2019); and (4) Gender Equality, as DFL equips women with financial independence tools, micro-entrepreneurship capabilities, and access to digital marketplaces (UN Women, 2021). These channels do not function alone but cross-support one another, finally coming together into augmented Human Capital Development Outcomes, like increased individual productivity, economic security, social inclusion, and a future-ready workforce (Becker, 1964; World Bank, 2021).

Therefore, the framework promotes the argument that DFL is not simply a technical competence but a strategic developmental driver—an accelerator of inclusive and resilient human capital in the digital age. Its successful implementation, nonetheless, necessitates a sensitive alignment of investment in infrastructure, education reform, gender-inclusive strategies, and digital access policies specific to local socio-economic contexts.

4. Policy Implications: Implementation of Digital Financial Literacy (DFL) interventions effectively demands an overarching, multi-faceted strategy. According to the suggested framework, the following sub-headings provide practical areas of emphasis for policymakers:

4.1 Integrated Curriculum for DFL

School and university curricula must include DFL, integrating digital competence with financial acumen to equip young people to meet the challenges of a digital economy. Inclusion of DFL in school and university education is certain to provide early and inclusive exposure. The curriculum must address actual use cases like navigating UPI platforms, identifying digital frauds, and utilizing budgeting apps, along with an understanding of credit scores. Contextual, skill-based pedagogies should be used, especially in vocational programs of training, to develop work-relevant DFL skills (Lusardi & Mitchell, 2014; OECD, 2021)).

4.2 Gender-Inclusive Access Policies

Develop interventions specifically for women, particularly in rural and semi-urban settings, through customized training and community-based learning formats. Closing the digital gender gap is crucial. Policies need to provide independent mobile access to women, vernacular-language training, and access to women-centric financial services. Deploying women digital literacy champions and incorporating DFL into SHGs can empower women through community-led models (UN Women, 2021).

4.3 Enhancing Local Delivery Channels

Utilize local institutions like self-help groups (SHGs), NGOs, and digital banking correspondents for delivering DFL programs, with community trust and sustainability ensured. Decentralized models based on panchayats, anganwadi centers, and community-based

organizations can adapt DFL interventions based on local requirements. Training local champions as digital financial facilitators will ensure trust and adoption, especially in far-flung areas (MeitY, 2022).

4.4 Public-Private Partnerships

Partner with fintech firms, telecom operators, and EdTech startups co-design inclusive digital learning platforms for DFL. Corporate participation can be used for scaling up innovation and outreach. Financial institutions, fintech firms, and telecom companies can co-develop DFL apps, reward training, and subsidize data bundles. PPPs can facilitate effective resource utilization and an integrated outreach approach (World Bank, 2022).

4.5 Targeted Data-Driven Policymaking

Employ disaggregated data on digital access, levels of financial literacy, and socio-economic characteristics in crafting region-specific DFL interventions. Disaggregated data by gender, caste, and region and digital dashboards can feed into targeted interventions. Policy changes should be data-driven, dynamic, and adaptive. Data analytics can also pick up on low DFL and high financial risk areas (Goyal & Kumar, 2021; Demirgüç-Kunt et al., 2022).

4.6 Monitoring and Evaluation Frameworks

Build strong M&E systems to monitor DFL's long-term effects on employment, saving behavior, gender impacts, and educational investment. Policymakers need to go beyond input indicators to measure actual results—e.g., savings behavior

changes, improved access to credit, decreased digital fraud. Both qualitative and quantitative indicators should form part of frameworks, which should be incorporated into national digital inclusion scorecards (OECD, 2020).

4.7 Fiscal Incentives for DFL Promotion

Implement tax exemptions, CSR credits, or subsidies for organizations that provide certified DFL courses in disadvantaged regions. Incentivizing innovation in the pedagogy and dissemination of DFL through competitions and grants can also drive development (MeitY, 2022).

5. Future Scope of Research

Future Subsequent research needs to empirically test the conceptual framework in various Indian states, considering urban-rural gaps and minority groups. Mixed-methods research incorporating surveys, interviews, and behavioural experiments can reveal the impact of DFL on decision-making and economic resilience. Interdisciplinary studies integrating behavioural economics, digital ethnography, and development studies can enhance our knowledge of how DFL influences financial habits and long-term investments in health, education, or entrepreneurship. Investigation of the effects of DFL on particular groups (disabled, migrant workers, tribal communities) can also contribute to policy inclusion. Comparative international studies can also help to identify international best practices that can be customised to fit India's socio-economic scenario.

6. Limitations of the Study

This paper is theoretical in design and does not present empirical evidence to support the framework proposed here. The analysis is based mainly on secondary sources and policy reports. Although expansive, the framework is not necessarily exhaustive of regional or linguistic factors that determine DFL acquisition and performance. The framework also presupposes linear relationships among variables, whereas actual interactions are likely more complex and context-specific. Future research must make more precise assumptions through field-level investigation.

7. Implications of the Study

7.1 Theoretical Implications

The research contributes to the discourse by bringing human capital theory together with digital inclusion and capability thinking. It places DFL as a complex capability, shaped by infrastructure and structural disparities, and spans various research fields—behavioural finance, development economics, and digital sociology. It refutes reductionist explanations of financial inclusion by advancing a stratified, systemic framework of digital capability-development.

7.2 Practical Implications

The framework can be used by policymakers to develop more targeted, equity-sensitive financial literacy initiatives. Practitioners like NGOs, CSR planners, and government departments can link initiatives with individual pathways (e.g., employability or gender equity). International agencies can use the framework as a diagnostic instrument in measuring digital inclusion in emerging economies. Lastly, schools and vocational training centers can integrate framework principles into curriculum planning and assessment.

8. Conclusion

As India gears up towards its centenary in 2047, Digital Financial Literacy has to be seen not as an ancillary ability but as a core enabler of inclusive human capital development. The conceptual framework outlined here illustrates how DFL, if nestled within facilitating infrastructures and sensitive to structural realities, can trigger fundamental developmental pathways that enhance employability, resilience, mobility, and gender equality. In so doing, DFL provides an arresting weapon for unlocking human potential and attaining fair growth in the digital era. Policymakers, teachers, and civil society need to act decisively now to turn this conceptual insight into inclusive and context-responsive interventions.

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Cybersecurity Preparedness Plan for Learning Institutions

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Introduction: Cybersecurity has emerged as the primary service market for incident response and security testing services due to the increasing globalization of society. If major expenditures are not made in security, cyberattacks can target any of the parts of the complete information network, including power supplies, computers, cellphones, USBs, and smartphones. The market for security implementation services in India is projected to grow at a compound annual growth rate (CAGR) of 13.2% from 2019 to 2022, from USD 221 million to USD 320 million. This growth is attributed to the fact that formulating successful cyber security plans is dependent on security implementation. Building security architecture, policy formulation, and cyber security strategy planning are all included in security consulting services.

Control and mitigation

People-centric solutions	Process-centric solution	Technology-centric solution
Security awareness Education and training Usability of security technology	Least privileged policy Least route principle Separation of duties Well-formed transaction policies	Network architectures Intrusion/anomaly detection Network segregation Access Controls Data diodes and unidirectional gateways Firewalls Intrusion Detection Systems (IDSs) Cryptography

Purpose: This document outlines a learning institution's information security incident response strategy. It outlines everyone's roles and responsibilities, how occurrences are classified, and what needs to be reported. The Cybersecurity Preparedness Plan's (CPP) objectives are to identify and respond to computer security events, assess their extent and risk, take appropriate action in response, notify all relevant parties of the outcomes and associated risks, and lessen the possibility that the incident will recur.

Scope: This plan covers anybody or any device that gains access to the school's, college's, or university's information systems, institutional data, and networks.

Maintenance: This CPP is the responsibility of the institution's Information Security Office (ISO) for upkeep and change.

Authority: By virtue of its original charter and several policies, including the Computing Policy, Information Security Policy, and HIPAA Policy, the Information Security Office is tasked with carrying out this plan.

Definitions

Event: Every event is a deviation from how IT systems, services, or infrastructure typically operate. But not every event turns into an incident.

Incident: Any event that compromises the confidentiality, integrity, or availability of information systems or institutional data, or that violates any other policy, standard, or code of behavior established by the school, college, or university is considered an incident.

Personally Identifiable Information (PII)

PII is defined as an individual's first name or first initial and last name combined with one or more of the following data pieces in order to comply with security breach reporting requirements:

- Driver's license number issued by the state;
- Social Security number
- Identification card number granted by the state
- The number of the bank account combined with a password, access code, or security code that would allow access to the account.
- Details about health insurance and/or medications

Roles and Responsibilities: Process of Cybersecurity Preparedness The following roles are expanded upon or added to as part of the cyber security readiness process, which also integrates the definitions of information security roles and responsibilities. extends or adds the following roles and integrates the definitions of information security roles and responsibilities.

Incident Response Coordinator: An expert in cybersecurity, the incident response coordinator is in charge of gathering all the information relevant to an event, getting in touch with the right people, making sure the data is accurate, and providing updates on the situation both during and after the investigation.

Incident Response Handlers: Workers who collect, store, and evaluate evidence in order to bring an event to an end are known as incident response handlers.

Users: Users are those who use the school/college/university management system, learning management system, institutional data, or networks that could be impacted by an incident. They can also be members of the school/college/university community.

Law Enforcement: The institution's security team and federal and state law enforcement organizations that issue subpoenas or warrants for the release of information are included in the category of law enforcement.

1. Cybersecurity Preparedness Phases (CPP)

CPP has six phases: preparation, detection, containment, investigation, remediation, and recovery.

1.1 Preparation: The actions that make it possible for cybersecurity professionals to respond to an incident are included in preparation. The preparation also suggests that the impacted parties have implemented the safeguards required to recover and carry on with business as usual following the discovery of an event. This stage should be continuously improved, with the post-mortem studies from previous accidents serving as the foundation.

1.2 Detection: The process of detecting an event involves using security technologies to find it or notifying an internal or external party of a possible occurrence. It also contains the incident's announcement and first classification.

1.3 Containment: The containment phase is the part of the triage process that involves identifying, isolating, or otherwise mitigating the impacted host or system, notifying the affected parties, and establishing the investigative status. It consists of sub-procedures for communication, escalation, and management of evidence and seizures.

1.4 Investigation: Phase cybersecurity personnel identify the incident's priority, extent, and underlying cause during the investigation.

1.5 Remediation: Repairing compromised systems after an incident, informing and educating impacted parties, and doing analysis to verify that the danger has been neutralized are all considered forms of remediation. At this point, however, it will be decided whether there are any regulatory requirements for reporting the occurrence (and to what outside parties). The post-mortem will be finished at this point, independent of any official reports, as it could have an effect on the incident's remediation and interpretation.

1.6 Recovery: Recovery entails obtaining measurements, analyzing the event for procedural and policy consequences, and incorporating "lessons learned" into training and future response operations.

2. Incident Response Process Guidelines

Only general advice for handling frequent problems are given in this section. In the process of reacting to an event, though, a number of queries and issues come up, some of which can be unique for every incident. Concerns and incident categories not addressed by these guidelines should be directed to the Director of Information Security and the Incident Response Coordinator.

2.1 Denial-of-Service Attacks

Attacks known as denial-of-service (DoS) aim to interfere with or impair online learning platforms, including learning management systems (LMS) and Zoom sessions.

Learning institutions should, when appropriate and practicable, take the following precautions before denial-of-service attacks start in order to strengthen their defenses against them:

- Establish what features and service levels are appropriate for online learning platforms, how to keep them operating, and which features can be compromised in the event of a denial-of-service attack.
- To gather mitigation and prevention techniques for denial-of-service attacks from service providers. To be precise, the service provider's
 - The ability to endure denial-of-service assaults.
 - The expenses that the college, institution, or school anticipate paying as a result of denial-of-service assaults.
 - Cutoff points for alerting the organization or suspending its internet services in the event of a denial-of-service attack.
 - Agreements with upstream providers to avoid denial-of-service attacks and restrict malicious traffic as far upstream as feasible.
 - Pre-approved countermeasures that can be implemented in the case of a denial-of-service attack.
- Use registrar locking to safeguard the institution's domain names and make sure the registration information is accurate.
- Make sure that service providers have up-to-date 24-hour contact information, and that service providers have up-to-date 24-hour contact information for the university, college, or school.
- Provide service providers with extra out-of-band contact information (such as a cell phone number and non-business email address) in case regular lines of communication break down.
- Use real-time alerting and availability monitoring to identify and quantify the effects of denial-of-service attacks.
- Divide important internet services (like the website of a school, college, or university) from less important ones that are more likely to be targeted.

- To ensure service continuity in the event of a denial-of-service attack, create ahead of time a static version of your website that uses the least amount of processing power and bandwidth.

2.2 Data breach, Ransom ware, Phishing, and other attacks

The following actions must be taken by the incident response team of the school, college, or institution in order to be ready for malware attacks and other security problems.

- **Data:** Determine quickly which resources and data are vulnerable to theft or compromise, as well as which crucial learning processes are at risk. The reaction team must also examine any management or learning platforms that can be infiltrated by malicious software, ascertain its purpose, and obtain transaction logs.
- **Compliance:** Examine every regulatory obligation that needs to be fulfilled. The majority of breaches have a dwell time during which all crucial information and logs must be kept offline for at least a year.
- **Authorities:** To ascertain whether you must get in touch with federal law enforcement and other regulatory agencies, among other authorities. For firms constrained by regulatory obligations, it is essential. For instance, heavy fines for neglecting to report an occurrence on time.
- **Evidence:** Keep the evidence safe in case the incident turns into a legal matter. In order for any evidence to be acceptable in a court of law, procedures for maintaining the crime scene should already be incorporated in the response plan, which should have involved the law enforcement in the planning and preparation stages. Using a digital forensic team will help to standardize this procedure and ensure that important evidence is collected in accordance with tight legal rules.
- **Quarantine and Redundancy:** It's critical to have quarantine skills to stop the spread. Quarantining all affected systems is probably necessary; forensic investigation requires redundant systems to be operational.
- **Trace Attack Chain:** It is necessary to have the means in place to follow an assault path back to its initial point of entry. Determining the malware employed and the attack's dwell period is necessary. Every device in the attack path needs to be examined after the virus and attack chain have been located. It will be necessary to employ incidents of compromise (IOCs) to find other devices.
- **Training:** Teachers, students, parents, and other staff members at schools, colleges, and universities must receive cyber-awareness training. Security events almost never have no impact on the larger workforce. It could aid in incident prevention and also enable appropriate reaction.

2.3 Insider Threats

An insider threat is a danger to an educational institution posed by careless or malevolent insiders, such as instructors, staff members, independent contractors, outside vendors, or business associates, who have inside knowledge of the cyber security procedures, private information, and computer systems used by schools, colleges, or universities. Theft of trade

secrets and intellectual property, fraud, theft of private or commercially sensitive information, tampering with security systems, and incorrect student grade configuration are a few examples of these dangers.

The following actions should be taken in the event of an insider threat:

- If an Incident Response Coordinator feels that a specific Incident Response Handler is a person of interest in the incident, they will assign other Incident Response Handlers to the incident;
- If the Incident Response Coordinator is a person of interest in the incident, the Director of Information Security will take over or designate a representative to take their place.
- In the event that the Chief Information Officer (CIO) designates a person to act in lieu of the Director of Information Security in the event that the CIO is a person of interest in an incident.
- The information security officer will collaborate with the remaining administrative authorities in the event that another school, college, or university administrative authority is a person of interest in an incident.

- **2.4 Interactions with Law Enforcement**

After conferring with the security department of the school, college, or institution, all communications with outside law enforcement agencies are made.

In order to provide the minimal amount of information needed for incident response, the ISO collaborates with the local police to ascertain their information requirements.

2.5 Communications Plan

The Chief Information Security Officer and the school's, college's, or university's media relations department are consulted before any public statements regarding an incident or incident response are made to parties outside the organization. The bare minimum of information is required in private discussions with other parties involved or interested. The Director of Information Security and the occurrence Response Coordinator, in collaboration with the administrative authorities of the institution, decide what information is minimally required to be shared for a given occurrence.

2.6 Privacy

The Computing Policy lays out precise guidelines for protecting the confidentiality of affiliates that are schools, colleges, and universities. The Computing Policy's current privacy obligations will be adhered to by incident response procedures. Any exclusions, though, need to be authorized by the management of the school, college, or university.

2.7 Documentation, Tracking and Reporting

Every action taken in reaction to an incident will be recorded. They comprise artifacts acquired in accordance with confidentiality and chain of custody regulations. Every incident will be graded and given a priority based on how likely it is to reveal sensitive information. This rating could shift as an inquiry goes on, changing how resources are prioritized to a greater or lesser extent.

Every incident will be examined after the fact to determine the effectiveness and success of the inquiry procedure. To enhance the incident response process, the Information Security Officer and others may make further modifications to their processes and procedures. Following the investigation's conclusion and post-mortem study, artifacts gathered during the inquiry may be erased.

2.8 Escalation

The Director of Information Security and the Incident Response Coordinator may be contacted at any point during the incident response procedure to elevate any concerns about the incident or process. When and if an event needs to be reported to outside authorities will be decided by the Director of Information Security and the event Response Coordinator.

Conclusion

A cyber-security preparation plan should aim to strengthen reaction and repair tactics to the greatest extent feasible. Making ensuring that the appropriate people, procedures, and technology are all in line with that objective is the best approach to accomplish it.

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Cybersecurity Risks in Digital Banking: Impact on Consumer Trust and Financial Stability

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Abstract

The widespread adoption of digital banking has revolutionized the financial services landscape by offering enhanced convenience, speed, and accessibility. However, this transformation has also exposed financial institutions and consumers to a growing array of cybersecurity risks. This conceptual paper undertakes a comprehensive review of existing literature to explore the multifaceted cybersecurity threats in digital banking and their consequential impact on consumer trust and financial system stability. Key threats—including phishing, malware, identity theft, and data breaches—have not only compromised sensitive data but have also eroded consumer confidence in digital platforms. The study highlights that perceived security, transparency in data handling, and robust institutional safeguards are pivotal in influencing customer trust. Additionally, the review examines the role of technological innovations such as artificial intelligence, blockchain, and multi-factor authentication, as well as global regulatory frameworks like GDPR and PSD2 in enhancing digital security. The findings reveal that cybersecurity must be approached strategically, integrating technical, regulatory, and human dimensions to maintain financial integrity and public trust. By synthesizing cross-disciplinary research, this paper contributes to the ongoing discourse on digital resilience and provides policy and practice implications for building a secure and consumer-trusted digital banking ecosystem.

Keywords: *Digital Banking, Cybersecurity Threats, Consumer Trust, Financial Stability, Regulatory Frameworks*

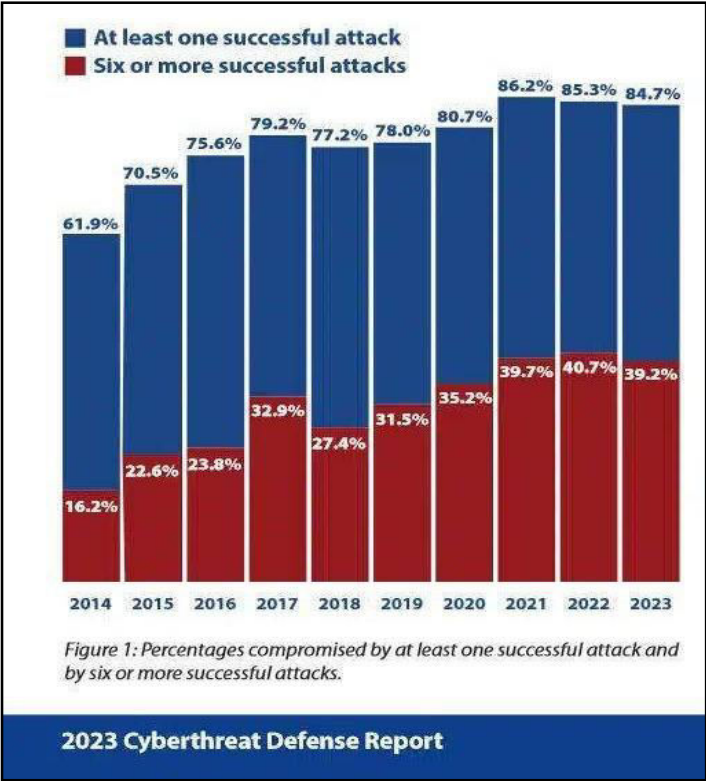
Introduction

The rapid digital transformation of the banking sector has revolutionized financial services by enhancing efficiency, accessibility, and customer convenience. Digital banking—encompassing mobile banking, internet banking, and digital wallets—has become integral to modern financial ecosystems. However, as financial institutions increasingly rely on digital platforms, they face a growing array of cybersecurity threats. These threats range

from data breaches and phishing attacks to sophisticated malware and ransomware, posing serious risks to both consumers and institutions. Cybersecurity in digital banking is not merely a technical concern; it has profound implications for consumer trust and the broader financial system's stability. A single breach can undermine public confidence, disrupt financial operations, and lead to regulatory consequences. As consumer data and

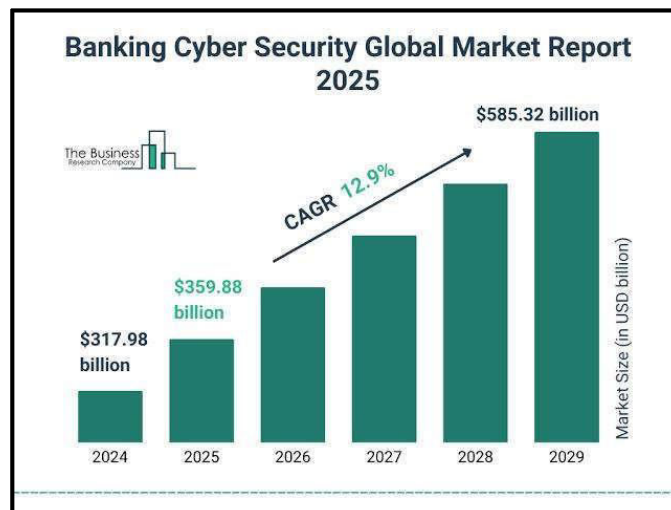
financial assets are digitized, ensuring the integrity, confidentiality, and availability of digital banking services becomes paramount

Figure No. 1
Cyber attacks in organisations



The chart from the 2023 Cyberthreat Defense Report highlights a significant rise in cyberattacks on organizations from 2014 to 2023. The percentage of organizations experiencing at least one successful attack increased from 61.9% in 2014 to a peak of 86.2% in 2021, remaining above 84% through 2023. Similarly, those facing six or more successful attacks grew from 16.2% in 2014 to nearly 40% in recent years, indicating not just more frequent but also more persistent cyber threats. While the growth trend has plateaued since 2020, the consistently high levels of attacks emphasize the critical need for robust and adaptive cybersecurity measures across organizations.

Figure No. 2
An estimation of Banking Cyber Security



Source: The Business Research Company

The rise of digital banking has revolutionized the financial industry, offering consumers speed and convenience via online and mobile platforms. Nonetheless, this digital shift has led to an escalating variety of cyber threats—phishing, ransomware, banking trojans, DDoS attacks, and Business Email Compromise (BEC)—targeting financial institutions. Among them, phishing and social engineering stand out, accounting for over 70% of initial breach attempts in the banking sector. These cybersecurity threats not only expose sensitive data but also severely undermine consumer trust. A single data breach can trigger reputational harm, regulatory penalties, and customer

erosion. For instance, mobile banking malware incidents tripled from 2023 to 2024, and the average cost of a breach in the financial sector exceeds \$5 million. Responding to these risks, the global banking cybersecurity market is projected to grow from approximately **\$318 billion in 2024 to \$585 billion by 2029**, at a CAGR of about 12–13%, reflecting the robust need for enhanced security measures. The chart above illustrates this market expansion. This systematic literature review will examine cyber threats in digital banking, assess their impact on consumer trust, and evaluate their implications for financial stability.

Review of Related Literature

1. **Corbet & Gurdgiev (2017)** examines the growing cybersecurity risks facing monetary and financial institutions (MFIs) amid rapid digital disruption. Already strained by the 2008 financial crisis and low interest rates, traditional banks now face increased threats from agile FinTech competitors and sophisticated cyberattacks. Limited

modernization budgets leave MFIs vulnerable to malware, data breaches, and systemic volatility. The study reveals that cyber incidents trigger reputational harm and cross-sector financial instability, supported by evidence of stock market losses following major breaches. It critiques regulatory lag, noting FinTechs' lighter

compliance burdens, and calls for globally coordinated regulation and proactive investment in cybersecurity infrastructure to ensure financial stability.

2. **Healey, J., Mosser, P., Rosen, K., & Tache, A. (2018)** investigates how cyber risks can trigger or worsen financial instability, highlighting a crucial yet underexplored threat. Unlike conventional shocks, cyberattacks are intentional and time-coordinated, often involving state actors. The paper identifies systemic vulnerabilities such as limited substitutability in financial/ICT infrastructure, data integrity threats, and confidence loss. It outlines three crisis pathways: slow-burn degradation, exacerbation of existing distress, and direct initiation via attacks on financial infrastructure. Traditional models fall short in addressing these complex risks. The authors call for harmonized cyber regulations, cross-sector collaboration, infrastructure mapping, and joint simulations to integrate cybersecurity into financial stability frameworks.
3. **Al-Bassam, S. A., & Al-Alawi, A. I. (2020)** examines the pivotal role of cybersecurity systems in managing risks in Bahrain's banking and financial sector. It identifies rising threats such as identity theft (26%), system damage (23%), and hacking (11%), with most incidents escalating to board-level attention. Common defenses include security policies, budget allocations, and staff training. However, skill gaps in technical and communication areas hinder effective response. Notably, 75% of threats were detected by current systems. The study concludes that cybersecurity must be treated as a strategic priority, not just a technical issue, and calls for enhanced training, top-level engagement, and comprehensive national policy measures.
4. **Vierescu & Toader (2023)** examines the dual impact of digitalisation and cyber risks in the banking sector, highlighting enhanced efficiency and customer service alongside increased exposure to cyber threats like phishing, data breaches, and malware. Using qualitative research and case studies of four global banks, it emphasizes the need for comprehensive cyber risk management frameworks, covering identification, assessment, mitigation, monitoring, and reporting. The study stresses the importance of regulatory compliance (e.g., GDPR, FFIEC, MAS) and collaboration among banks, regulators, and cybersecurity experts. It recommends adopting emerging technologies like AI and cloud security, and advocates a proactive, multi-layered cybersecurity strategy for long-term resilience.
5. **Johnson & Smith (2023)** highlights the essential role of digital trust in the adoption and effectiveness of internet banking. It finds that trust is shaped by factors like cybersecurity, user authentication, interface design, and regulatory compliance. Through qualitative and quantitative analysis, the authors show that robust security infrastructure—such as encryption, MFA, and real-time monitoring—is crucial for safeguarding transactions. Intuitive, secure design also enhances user confidence. The study stresses that trust includes psychological comfort, not just technical safety. Regulatory frameworks like GDPR further

reinforce transparency and accountability. The paper concludes that collaboration among stakeholders is key to building secure, user-centric digital banking systems.

6. **Oyewole et al. (2024)** provides a detailed review of cybersecurity risks in online banking amid rapid digital transformation. It identifies phishing, ransomware, insider threats, and APTs as major attack vectors compromising data integrity and financial stability. Using qualitative analysis and case studies, the research examines the causes, impacts, and evolution of cyberattacks. It advocates integrating AI, Big Data, and ML for threat detection, despite associated ethical and technical challenges. Regulatory frameworks like NIST and South Africa's NCPF are assessed, revealing implementation gaps. The study highlights financial losses, reputational damage, and investor distrust, recommending cyber insurance and a multifaceted, collaborative cybersecurity strategy.
7. **Shهاب et al. (2024)** examines the escalating cybersecurity threats in the banking and financial services sector amid digital transformation. Key threats include malware (phishing, ransomware), data breaches, identity theft, DDoS attacks, and social engineering, exploiting system and interface vulnerabilities. With a 73% increase in breaches from 2015 to 2019, banks remain highly targeted due to sensitive data and weak defenses. The study urges robust, multi-layered countermeasures like firewalls, two-factor authentication, secure coding, and continuous risk assessment. Emphasizing global cooperation, regulatory compliance, and technological investment, it advocates a unified, proactive defense strategy involving banks, regulators, users, and cybersecurity professionals to mitigate growing cyber risks.
8. **Choudhuri et al. (2024)** explores the key factors influencing user trust, a cornerstone for digital banking adoption and resilience. It identifies two main trust drivers: institutional reputation and technical security. Influences such as brand reliability, regulatory compliance, transparent communication, and responsive interfaces play crucial roles. Technical safeguards like encryption, MFA, fraud detection, and staff training further boost confidence. The research highlights that non-technical elements—like customer service, public reviews, and education—significantly shape trust. Regression analysis confirms these factors' strong impact, rejecting the null hypothesis. The study recommends a multifaceted approach that blends technology, regulation, and user engagement to strengthen digital banking trust.
9. **Garg, Prakash & Agasty (2024)** examines the deep connection between cybersecurity and digital consumer trust, highlighting that threats like phishing, data breaches, and identity theft undermine user confidence—especially for newer or smaller businesses. Key trust-building tools include encryption, secure authentication, data masking, and regular audits. The paper underscores that consumer perception of security directly affects digital engagement. Citing the 2006 U.S. Veterans Affairs breach, it illustrates the long-term

damage of cyber incidents. The study advocates for transparent privacy policies, consumer education, rapid incident response, and adherence to global regulations like GDPR. Emerging technologies such as blockchain and AI are also recommended to enhance trust.

10. **Dr. G. Yoganandham (2024)** analyzes the economic impact of cyber fraud in online banking and credit card transactions, highlighting its growing threat to financial stability. It identifies phishing, skimming, identity theft, and malware as major fraud types, causing substantial monetary losses, reputational harm, and rising compliance costs. Crucially, the erosion of consumer trust discourages digital service adoption, pushing users toward cash or crypto alternatives and hindering financial inclusion. Cyber fraud also lowers transaction volumes and digital investment, imposing macroeconomic burdens. The study advocates for a multi-pronged response—strengthening cybersecurity, legal reforms, institutional collaboration, and consumer education—to ensure digital finance resilience.
11. **Waliullah et al. (2025)** explores how cybersecurity threats affect the adoption and growth of digital banking. It examines key countermeasures such as multi-factor authentication, biometric security, AI-based fraud detection, and blockchain. While these technologies enhance protection, the use of third-party FinTech services creates new vulnerabilities. Regulatory frameworks like GDPR, PSD2, and GLBA support data security, yet banks face challenges in balancing security with usability and compliance. The study underscores that consumer trust—shaped largely by perceived security—is vital for digital banking adoption. It concludes that a multi-layered cybersecurity approach is essential for building long-term resilience and trust in digital banking ecosystems.
12. **Cele & Kwenda (2025)** examine how cybersecurity threats impact digital banking adoption in developing countries like South Africa. Analyzing 58 studies from 2015–2023, they identify major threats such as phishing, identity theft, vishing, malware, and ATM fraud, all of which significantly erode consumer trust. The study stresses that perceived security directly affects user engagement. Key countermeasures include secure software, strong passwords, user education, antivirus tools, and anti-phishing systems. It emphasizes the need for collaboration among banks, regulators, and users to build a secure ecosystem. Proactive, adaptive strategies are essential to enhance trust and drive broader digital banking adoption.
13. **Vastani, Vekariya & Pradhan (2025)** explores how security and privacy concerns affect customer trust and experience in digital banking. Using a quantitative design with chi-square analysis, it finds that perceived security strongly influences trust, while privacy concerns impact satisfaction. Although 75% of users feel secure, 25% report fraud or data breaches. Issues like unauthorized access, phishing, third-party data sharing, and opaque privacy policies drive user hesitation. The study confirms that trust and user experience are directly tied to security perceptions.

It recommends user-friendly, robust security and privacy measures, and calls for future longitudinal research to track evolving consumer attitudes in the digital banking space.

14. **Adejumo & Ogburie (2025)** offers a comprehensive analysis of how cybersecurity fortifies financial systems amid rising digital threats. As institutions adopt technologies like mobile banking, AI, and blockchain, they face increased exposure to cyberattacks. Using quantitative analysis and machine learning, the study finds a strong negative correlation (-0.89) between cybersecurity investment and fraud, predicting a 62% fraud reduction by 2028. AI models like GBDT achieved over 99% detection accuracy, while blockchain proved more resilient than traditional systems. Though global regulations aid compliance, the authors stress that innovation, adversarial AI defenses,

and international coordination are vital. Cybersecurity is framed as a strategic asset, not a cost.

15. **Putri Cipto (2025)** examines cybersecurity awareness among Indonesian MSMEs through the lens of Protection Motivation Theory (PMT). It finds that both threat appraisal (perceived severity and vulnerability) and coping appraisal (response efficacy, self-efficacy, and response cost) significantly influence cybersecurity behaviors. Higher perceived threat and strong belief in one's ability to respond increase the likelihood of adopting protective actions, while high response costs deter them. The study reveals MSMEs often lack cybersecurity knowledge and resources, making them highly vulnerable. It calls for targeted government support, digital training, and strategic interventions to enhance cybersecurity resilience and protection in Indonesia's MSME sector

Conclusion

The increasing reliance on digital banking platforms has undeniably enhanced convenience, accessibility, and efficiency in the financial sector. However, this digital transformation also exposes institutions and consumers to a wide spectrum of cybersecurity threats that jeopardize not only data integrity but also the trust and stability of financial systems. The reviewed literature and statistical insights emphasize that cyberattacks—ranging from phishing and malware to sophisticated ransomware—have become both more frequent and more damaging over time. These threats erode consumer trust, raise compliance burdens, and have the potential to trigger broader financial instability.

To safeguard the digital banking ecosystem, a multifaceted approach is imperative. This includes the adoption of advanced technologies like AI, blockchain, and biometrics; strict adherence to evolving regulatory frameworks; and proactive investments in cybersecurity infrastructure. Equally important is the role of user education and institutional transparency in reinforcing trust. Collaborative efforts among banks, regulators, FinTech partners, and cybersecurity professionals are essential to build a resilient digital environment. As the banking sector continues to evolve, cybersecurity must not be treated as a mere technical challenge but as a strategic priority integral to sustaining trust and ensuring long-term financial stability.

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“Enhancing Cryptocurrency Security through Artificial Intelligence: Opportunities and Challenges.”

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Abstract

Cryptocurrencies have changed how we send and receive money, making transactions faster, more decentralized, and accessible around the world. But with this innovation come new security challenges like hacking, fraud, and data breaches that threaten users and platforms alike. This paper looks at how Artificial Intelligence (AI) can help make cryptocurrency safer. The main goal is to understand the key security risks, explore how AI can address these issues, and review real examples of AI being used in crypto security today.

The study covers different AI techniques, such as machine learning and graph-based models, and discusses both their strengths and limitations. It also highlights challenges like data privacy, ethical concerns, and unclear regulations that slow down AI adoption in this field.

By examining current research and practical cases, the paper shows that AI offers powerful tools to detect fraud and protect users, but it's not a perfect solution. To fully benefit from AI, the crypto industry needs clear rules, transparency, and responsible use. In the end, the study concludes that AI has great potential to improve cryptocurrency security—but it must be applied thoughtfully to build trust and a safer digital financial future.

Key Words:

Crypto currency, Artificial Intelligence, Block chain technology, Cyber security and Machine learning.

Introduction

Cryptocurrencies have changed how we think about money and financial transactions. With their ability to operate without banks or intermediaries, they offer speed, transparency, and global access. Cryptocurrencies grow in popularity, so do threats like hacking, scams, and fraud. These security challenges also becoming more complex and traditional methods are no longer enough.

That's where Artificial Intelligence (AI) steps in. AI can analyze large volumes of data, spot unusual patterns, and respond to threats faster than any human could. It is highly being used to monitor cryptocurrency networks, detect suspicious activity, and protect user data. This study looks at how AI is helping to secure the crypto world, what kinds of tools and techniques are being used, and what issues need to be solved to make this technology both effective and trustworthy.

This paper takes a closer look at how artificial intelligence (AI) can help make the world of cryptocurrency more secure. From spotting fraud before it happens to automatically analyzing threats and helping platforms meet regulatory requirements, AI brings a lot of potential to the table. It is always come up with issues like data privacy, ethical concerns,

and the current limitations of AI systems all need to be carefully considered. By exploring where technology meets finance, this research aims to shed light on how AI could shape a safer future for everyone involved in the crypto space, whether they're casual users, serious investors, or large institutions.

Background of the Study

Over the past few years, cryptocurrencies have grown from a niche innovation into a widely recognized and increasingly used financial tool. People and organizations alike are turning to digital currencies not only for investment but also for the benefits they offer—like faster transactions, enhanced privacy, and independence from traditional banking systems. However, this rapid rise has also brought new security challenges. Cybercriminals are becoming more sophisticated, using everything from phishing scams and wallet hacks to exploiting vulnerabilities in smart contracts to target users and platforms.

Traditional cybersecurity measures are often not equipped to keep up with these evolving threats. This is where Artificial Intelligence (AI) shows real promise. With

its ability to process large volumes of data, detect unusual activity, and react in real time, AI can significantly strengthen the defences of cryptocurrency systems. But while the potential is clear, there are still hurdles to overcome. Concerns about data privacy, the lack of transparency in how AI makes decisions, and the absence of consistent regulatory frameworks all pose challenges to widespread adoption.

Moreover, the ethical use of AI in financial settings is still a developing area that demands thoughtful consideration. This study aims to explore how AI can help secure the cryptocurrency space, while also examining the technical, regulatory, and ethical issues that need to be addressed to ensure its responsible and effective use.

Scope of the study

This study explores how Artificial Intelligence (AI) can help improve the security of cryptocurrencies, focusing on how AI tools are used to detect fraud, protect wallets, and secure blockchain transactions. It looks at practical AI techniques like machine learning and anomaly detection that can identify suspicious activity and prevent cyber attacks in real time.

The research also considers important issues around privacy, ethics, and

regulations—challenges that come with using AI in the world of digital currencies. While it highlights real-life examples and current uses of AI in crypto security, it does not go into the technical details of how these AI systems are built, nor does it cover the broader financial or economic aspects of cryptocurrencies.

In short, the study aims to give a clear picture of where AI fits in the fight against cryptocurrency threats, what benefits it offers, and what hurdles still need to be

addressed. This focus helps guide future efforts to create safer, smarter crypto platforms.

This study provides insights useful to technology developers, crypto users,

investors, and policy makers. While it does not go into deep technical programming or coding aspects, it highlights the strategic importance of AI in creating a safer and more reliable cryptocurrency ecosystem.

Review of Literature

- A lot of studies show that AI can spot fraud and suspicious behavior in cryptocurrencies but many of these tests happen in labs or simulations, not in the wild. Researchers like Mohanta and colleagues (2019) have done great work with machine learning models, but we still don't fully know how well these systems perform at scale on real exchanges with millions of users. This makes it hard to say how reliable AI is in everyday crypto trading.
- Cybercriminals are always finding new ways to get around security measures. Conti et al. (2018) point out that threats in crypto are constantly evolving, and static AI models may struggle to keep pace. We need AI that can learn and adapt quickly, but there's not much research yet on building truly flexible systems that can handle these ever-changing attacks.
- Many AI systems, especially deep learning models, are like "black boxes" they make decisions without explaining how or why. This is a problem in finance where users want transparency, especially when their money is involved. Taddeo and Floridi (2018) highlight the importance of making AI more explainable so people can trust it, but in crypto security, this kind of clarity is still missing.
- Most research focuses on the tech itself but pays little attention to the people using it. Li and colleagues (2020) mention how blockchain's pseudonymity creates privacy issues, but there's limited study on how AI affects user trust, privacy, or experience. As crypto becomes mainstream, understanding how real users feel about AI-based security is crucial.
- AI and cryptocurrency are both new and fast-moving, but the laws around them are still murky. Zetzsche et al. (2020) show that many countries lack clear rules about using AI in digital finance, leaving companies uncertain about what's allowed. More research is needed to figure out how to regulate AI responsibly without stifling innovation.
- Nguyen et al. (2021) point out that blockchain's decentralized, permanent design can make it hard to combine with AI, which needs lots of data and flexible learning. This clash creates technical challenges like slow processing speeds and difficulty updating AI models on blockchain networks—problems that haven't been fully solved yet.
- There's a new threat called adversarial attacks, where hackers subtly change inputs to fool AI systems. Zhang and colleagues (2020) warn that this is a big risk for financial AI tools, but little work has been done on making AI resilient to these sneaky attacks within blockchain environments.
- Wang et al. (2019) explain that AI models only work well if they have clean, complete data. Unfortunately, cryptocurrency data can be noisy, incomplete, or biased because transactions are anonymous and spread across many platforms. This makes it tough for AI to

learn accurately, and not enough research tackles how to fix this.

- Running complex AI models takes a lot of computing power, and Kshetri and Voas (2019) highlight that blockchain systems often have speed and capacity limits. This means it's hard to run AI tools in real time on big networks without causing delays an issue that still needs more attention.

- Chen et al. (2022) point out that AI and crypto regulations vary widely around the world. Cultural differences and local laws make it tricky to develop security solutions that work globally. Few studies have looked at how to navigate these diverse legal landscapes, but it's an important step for global crypto security.

Research Gap

Area	Reference	Research Gap	Research Description
Real-World AI Performance	Mohanta et al. (2019)	Most AI tests happen in labs or simulations, not on actual crypto platforms with many users.	Without real-world testing, we don't know how reliable AI really is when millions of people trade daily.
AI's Ability to Adapt to New Threats	Conti et al. (2018)	Not enough research on AI that can learn and change quickly to fight constantly evolving cyber-attacks.	Cybercriminals keep inventing new tricks, so AI needs to be flexible to keep up.
Transparency of AI Decisions	Taddeo & Floridi (2018)	AI often acts as a "black box," with decisions users can't easily understand or trust.	Users want to know why AI flagged a transaction, especially when their money is involved.
User Trust and Privacy	Li et al. (2020)	Little research on how AI affects users' feelings of privacy, trust, and overall experience.	Understanding how people feel about AI security is crucial as crypto becomes more popular.
Clear Rules and Regulations	Zetzsche et al. (2020)	Many countries lack clear guidelines on using AI in digital finance.	Without clear rules, companies hesitate to adopt AI, slowing down progress.
Combining AI and Blockchain	Nguyen et al. (2021)	Challenges exist because blockchain's decentralized design doesn't easily fit AI's data needs.	This mismatch makes it hard to update AI models or process data efficiently on blockchain networks.
Protecting AI from Hackers	Zhang et al. (2020)	Few studies address how to protect AI against	Hackers can trick AI, so we need ways to make

		sneaky “adversarial attacks” that fool AI systems.	AI more resilient and trustworthy.
Quality of Data for AI	Wang et al. (2019)	Cryptocurrency data is often messy or incomplete, which hurts AI’s learning ability.	AI depends on good data, so noisy or biased data can lead to mistakes in security detection.
AI’s Demand vs Blockchain Limits	Kshetri & Voas (2019)	Running AI in real time on blockchain networks is tough due to limited speed and capacity.	AI requires lots of computing power, which blockchain systems don’t always have, causing delays.
Different Rules Worldwide	Chen et al. (2022)	Not enough focus on how to handle different laws and cultural views on AI and crypto security.	To protect users globally, AI solutions need to work across diverse legal and cultural landscapes.

Statement of problem

Cryptocurrencies have transformed the global financial landscape by enabling fast, decentralized, and borderless transactions. However, with this innovation comes an increase in sophisticated security threats, including hacking, fraud, phishing, and breaches in smart contracts. While block chain technology is inherently secure, the surrounding infrastructure—such as exchanges, wallets, and DeFi platforms—remains vulnerable to cyberattacks. Conventional cybersecurity measures often fall short in identifying and responding to these emerging threats in real time. In response, Artificial Intelligence (AI) is increasingly being explored as a solution, offering capabilities like anomaly detection, behavioral analysis, and automated threat

response. Despite its promise, the integration of AI into cryptocurrency security raises critical concerns related to data privacy, ethical use, lack of transparency in AI decision-making, and the absence of unified regulatory frameworks. There exists a clear research gap in understanding how AI can be systematically and responsibly applied to enhance cryptocurrency security. Without a balanced approach, the risks of misuse, bias, and over-reliance on technology may outweigh the potential benefits. This study seeks to investigate these issues, aiming to provide a comprehensive understanding of both the opportunities and challenges that come with adopting AI for cryptocurrency security.

Objectives of the Study

1. To gain a clear understanding of the main security risks that cryptocurrency users and platforms are currently facing.
2. To explore how Artificial Intelligence can help address and overcome these security challenges.
3. To highlight real-world examples where AI is already being used to enhance the safety and security of cryptocurrency systems.

1. To gain a clear understanding of the main security risks that cryptocurrency users and platforms are currently facing.

Cryptocurrency has opened up exciting new ways for people to manage and move their money—but it's not without risks. From phishing scams to exchange hacks and smart contract bugs, both users and platforms face serious threats. To come up with effective solutions, we first need to understand what these threats are, how they work, and why traditional security measures often fall short. This objective lays the foundation for the study by identifying the problems that need fixing.

2. To explore how Artificial Intelligence can help address and overcome these security challenges.

Artificial Intelligence has the ability to detect patterns, flag suspicious behavior, and respond to threats faster than any human team ever could. In a space like cryptocurrency—where everything moves quickly and risks evolve constantly—AI could be a game changer. This part of the research focuses on how AI tools and techniques, like machine learning, can be used to fight back against fraud and security breaches. It's about seeing where AI fits in and how it can make crypto safer.

3. To highlight real-world examples where AI is already being used to enhance the safety and security of cryptocurrency systems.

Talking about AI in theory is one thing but seeing how it works in the real world makes it much more concrete. This objective is about finding and analyzing real-life examples of how AI is being used today to protect cryptocurrency platforms. Whether it's detecting fraud, monitoring transactions, or securing wallets, these case studies help show what's possible, what's working, and where there's still room to improve. They give us valuable lessons that can shape future innovations.

Findings

1. Cryptocurrencies continue to face serious and evolving security threats.

As the popularity of digital currencies grows, so does the attention from cybercriminals. Attacks such as phishing, wallet breaches, and manipulation of smart contracts are becoming more sophisticated, and many platforms still struggle to detect or prevent them effectively.

2. Artificial Intelligence offers strong potential to strengthen cryptocurrency

security.

AI can process large volumes of data quickly and identify unusual or suspicious patterns in real time. This makes it particularly useful for detecting fraud, preventing money laundering, and improving the overall safety of blockchain networks.

3. Graph-based AI models are especially effective for analyzing blockchain activity.

Models like Graph Neural Networks

(GNNs) have shown great promise in identifying scams such as Ponzi schemes by mapping and studying the relationships between wallets and transaction flows.

4. Lack of transparency in AI decision-making raises concerns.

One of the main challenges with AI—especially complex models like deep learning—is that it's often unclear how they arrive at certain decisions. This “black box” nature can limit trust and make it difficult for users, developers, and regulators to interpret outcomes.

5. Quality data for training AI models is limited.

Due to the anonymous or pseudonymous nature of blockchain, obtaining accurate, labeled data for training fraud detection models is difficult. This affects the

performance and generalization of AI systems.

6. Legal and regulatory uncertainties create obstacles.

With different countries taking varied approaches to cryptocurrency regulation, there is no universal framework guiding the use of AI in crypto security. This can discourage platforms from investing in or deploying AI technologies.

7. AI systems can also be targeted by adversaries.

Like any technology, AI is not foolproof. Attackers may attempt to manipulate AI models through adversarial methods, which means even the most advanced systems need to be stress-tested for robustness and resilience.

Suggestions

1. Encourage data sharing through open, anonymized datasets.

Building shared datasets of known fraudulent behaviors—while protecting privacy—can help improve the accuracy and reliability of AI models across the industry.

2. Incorporate Explainable AI (XAI) into security tools.

Making AI systems more transparent and understandable through techniques like SHAP or LIME will help users and regulators trust and verify the actions of these systems.

3. Focus on adaptive and continuously learning AI models.

Given how quickly threats evolve, AI systems need to be updated regularly and designed to learn from new patterns in real time. This helps keep protection strategies relevant and effective.

4. Strengthen collaboration between developers, regulators, and cybersecurity experts.

Open communication and partnerships between these groups can bridge the gap between innovation and policy, allowing for more effective and compliant AI integration in crypto platforms.

5. Develop clear ethical guidelines for AI use in cryptocurrency.

AI should be used responsibly, with attention to data privacy, fairness, and the prevention of bias. Ethical principles must guide how AI is developed and deployed in the financial space.

6. Invest in testing AI against real-world attacks.

AI models should be regularly tested to ensure they can withstand adversarial attempts to fool them. This step is vital

to building secure and trustworthy systems.	Educating both users and developers about how AI works, what it can do, and its limitations will support more widespread, responsible adoption and encourage innovation.
7. Raise awareness and build understanding of AI-powered security tools.	

Conclusion

Cryptocurrencies have changed the way we think about money—offering faster, borderless, and decentralized ways to store and move value. But as their popularity grows, so do the risks. Traditional security systems often struggle to keep up with the fast-moving and increasingly complex threats targeting digital assets.

This study looked at how Artificial Intelligence (AI) can help tackle these challenges. With its ability to process large amounts of data, spot unusual patterns, and respond to threats in real time, AI has the potential to make crypto platforms much safer. From detecting fraud to monitoring smart contracts, AI is already proving useful. However, it's not without its hurdles. Issues like unclear regulations, limited access to quality data, ethical concerns, and the lack of transparency in how AI makes decisions still hold back wider adoption. Our findings show that a thoughtful, balanced approach is key. To make the most of AI, we need stronger ethical guidelines, clearer rules, more open data, and collaboration between tech experts, regulators, and users. In short, AI can play a powerful role in securing the future of cryptocurrencies—but only if we build trust around how it's used. Done right, it can lead us toward a safer, smarter, and more reliable digital financial world.

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The Evolution of ESG: A Bibliometric Perspective on Frameworks and Trends

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Abstract

The landscape of ESG (Environmental, Social, and Governance) is continually changing and shaping the practices of publicly listed companies. This research aims to explore the body of literature pertaining to the development of ESG and its framework. Utilizing "ESG FRAMEWORK" as our search parameter, we conducted a bibliometric analysis across a vast Scopus database, ultimately identifying 101 pertinent articles. Our analysis, spanning from 2012 to 2024, was executed using R Studio and the Biblioshiny application. Our findings reveal an upward trajectory in ESG, highlight leading authors and prolific countries, assess prevalent themes and collaborations, and scrutinize diverse ESG frameworks. These insights are poised to offer significant value to ESG researchers, stakeholders, and policymakers alike,

Keywords: ESG, Sustainability, Framework, Bibliometric, and Scopus

1. Introduction

Businesses worldwide increasingly acknowledge the need to incorporate climate change considerations into their overall strategy and environmental management. This proactive approach plays a pivotal role in addressing climate change and can significantly impact sustainable practices and foster greater transparency and accountability. The dimension of sustainability has emerged gradually. While exploring the emergence of this dimension, I found that the first dimension of sustainability, "economic," was seen after the Second World War in 1945.

The second dimension of sustainability, "environment", was initiated in the discussion due to the environmental movement from 1960 onwards. At that time, economists, industrialists, and policymakers did not accept the environment as an important aspect that firms had to address. However, it took 10 years to accept that the environment can be integrity with the economy, and the first major attempt in 1972 was made to reconcile economic development with environmental integrity, which was commonly regarded as incompatible.

The third dimension of sustainability has also emerged due to the social movement where social injustice and inequality have emerged dramatically; however, to meet the needs of the people in 1987, the UN World Commission on Environment and Development published its

report 'Our Common Future (the Brundtland Report), calling for "a new era of economic growth—growth that is forceful and at the same time socially and environmentally sustainable".

Based on UNDP (2017), sustainability is one of the key challenges facing organizations in the twenty-first century. Most of the studies stated that the sustainability practices in organizations should be based on multi-dimensional constructs. (Gkargkavouzi, Halkos, & Matsiori, 2019). For instance, (Baumgärtner & Quaas, 2010) Stated that organizations should consider sustainability practices by interrelating with various components such as individual, organizational, political, and social.

Some studies (Laguir, Stekelorum, & El Baz, 2020) Suggested that sustainability practices are related to the policy integrating eco-design, ecosystem, stewardship, pollution control, and business redefinition. Based on (Hall, 2011), (Elkington, 1994) Attempted to measure sustainability during the mid-1990s by encompassing a new framework to measure performance in corporate America. This framework was named the triple bottom line (TBL), which went beyond traditional profits and shareholder value measures to include environmental and social dimensions. (Masud et al., 2019).

This research aims to explore the body of literature pertaining to the development of ESG and its framework. By utilizing "ESG FRAMEWORK" as our search parameter across a vast Scopus database, we ultimately identified 101 articles using the PRISMA Framework. Our analysis, spanning from 2012 to 2024, was executed using R Studio and the Biblioshiny application.

The bibliometric analysis of ESG research from 2012 to 2024 significantly contributes by thoroughly examining the field's evolution, thematic trends, and global landscape. By identifying the rapid growth in ESG-related publications after 2020, the study highlights the increasing recognition of sustainability as a key concern across business and policy domains. This trend signifies the growing integration of ESG frameworks into decision-making processes, driven by regulatory changes and the global demand for more responsible corporate governance. Furthermore, identifying key thematic clusters, such as sustainability, climate change, and governance, offers valuable insights into the multi-dimensional nature of ESG research, helping to map the development of the field and its shifting priorities over time.

Furthermore, this analysis contributes to our understanding of the global collaboration and dissemination of knowledge within ESG research. By highlighting the geographical distribution of contributions, it emphasizes the diverse nature of the research, with significant qualitative input from countries such as India, Italy, and Canada. The study also identifies influential academic institutions and key publication platforms, illustrating how global networks shape research output and influence. Additionally, the findings reveal potential future research directions, including the integration of blockchain technology for transparency, the role of behavioral economics in ESG decision-making, and the exploration of ethical AI in ESG assessments. These findings lay the foundation for future studies to address emerging challenges and gaps in the field.

2. Research Methodology

In this paper, we performed a systematic literature review by employing a bibliometric analysis concentrated on a comprehensive picture of the current status of ESG framework as a field of research, as well as to collect and link together as many relevant existing studies as

possible. The primary advantage of bibliometrics is that the large number of data generated is usually concise, straightforward, impartial. (Jokić & Ball, 2006), and as visually simplified as possible (Xue et al., 2022). Because of its focus on the literature's internal relationships, bibliometric analysis is considerably more suited to academic research (Zhao, Zhang, & Kwon, 2018). By analyzing bibliometric data, researchers can acquire a sense of the history of the field's development over time, gain insight into its current status, and get direction for future studies (Bilal et al., 2022; Durieux & Gevenois, 2010). The detailed method of article collection, screening, analysis, and visualization of data is highlighted in Figure 1 Prisma Framework.

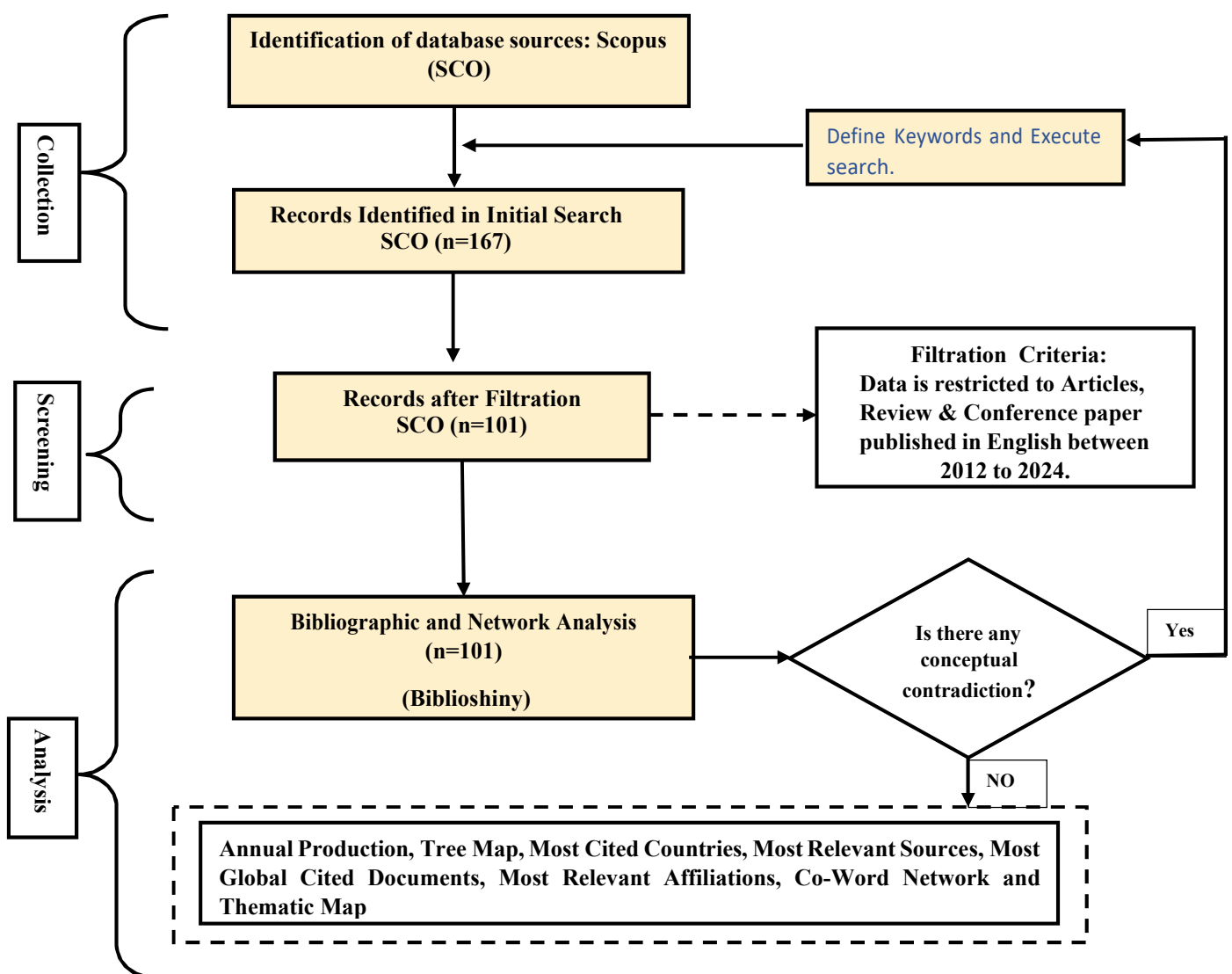


Figure 1: PRISMA Framework

2.1 Data collection

Database: Picking the correct database(s) is the first step in conducting the bibliometric study (Ayan, Güner, & Son-Turan, 2022). This analysis considers the most popular bibliometric database, Scopus by Elsevier. (Zhu & Liu, 2020).

Search Criteria: This study used "ESG Framework" as a search string in Scopus. The author discovered 167 documents in the first search.

2.2 Data Screening

Filtration Criteria and Data Preparation: In this research a rigorous filtering procedure was used to ensure the quality and relevance of the dataset. The initial exclusion of non-English language articles and non-journal publications from the analysis resulted in a refined dataset. Only peer-reviewed research papers, including Articles, Conference Papers, Proceedings, and Review Papers, were included in the filtered articles. The analysis focused on the period between 2012 and 2024. After the filtration criteria, a total of 101 English-language journal publications were retained for further analysis.

Data Corrections: To facilitate further analysis dataset was manually examined in Microsoft Excel for any missing information. In addition, the Author Keywords and Keyword Plus entries were manually normalised to ensure consistency and accuracy in the analysis. To create a unified term, terms such as "Environmental, Social, and Governance" and "ESG," "Environmental, Social, and Governance (ESG)" and "ESG," "Corporate Social Responsibility" and "CSR," were manually renamed using the Replace command in Microsoft Excel. This step enabled a precise keyword count for the subsequent bibliometric analysis.

2.3 Analysis

In the present study, we used one of the most powerful tools for analyzing and visualizing, which is Biblioshiny programme, to investigate the current situation and potential futures of entrepreneurship and blockchain. Biblioshiny was developed by Massimo Aria and offers a full-featured and highly user-friendly interface that accommodates users with extensive experience programming R, built on top of the Shiny package for R programming language (Aria & Cuccurullo, 2017).

To install it, we used the following commands for installation package install. Packages "bibliometrix", then the library bibliometrix, and the command "biblioshiny" in the RStudio command workspace. Our Biblioshiny analyses included extensive topics within the Performance Analysis and Network Mapping area, which included Positive and Negative Performance Analysis, Performance Comparison, and Network Mapping (Moral-Muñoz, Herrera-Viedma, Santisteban-Espejo, & Cobo, 2020). In Performance Analysis, we have analyzed the most recent trend publications, citing the most relevant articles and countries, countries of the Most Relevant Sources, the Most Productive Institutions, and the most popular Keywords used in this area. In addition to Positive and Negative Performance Analysis, combined with Comparative Performance Analysis, we have carried out Science Mapping, Keyword Co-occurrence, and Thematic Map, which provided us with valuable information within the ESG framework.

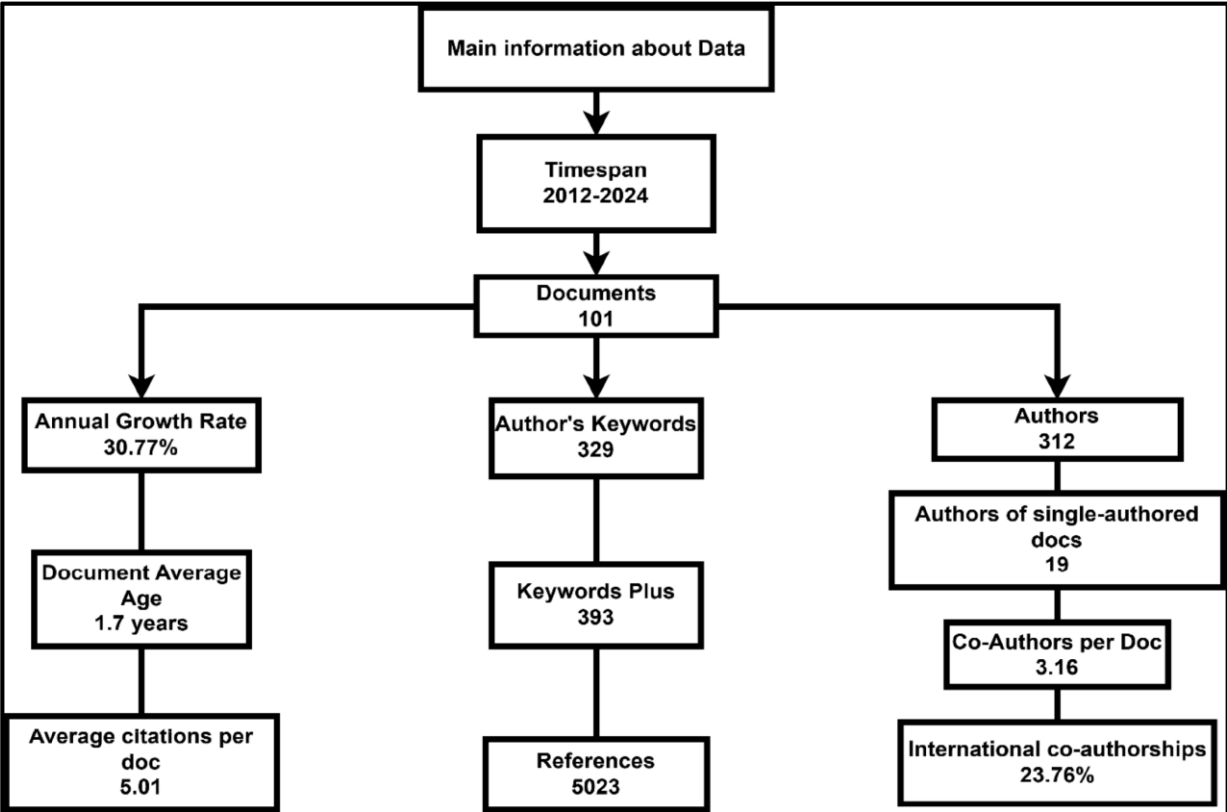
With Biblioshiny's Performance Analysis, we had a comprehensive overview of the research that has been done, and we also have insights into potential future research in this dynamic area. We believe that, by using this program, we have gained valuable understanding and

conclusion-making from the bibliometric data, which made it possible to interpret and combine performance and network data in a multidimensional form.

3. Results

3.1. Descriptive Statistics

We have conducted a thorough analysis of bibliometric data from 2012 to 2024 to explore the academic research surrounding the Environmental, Social, and Governance (ESG) framework. In the last twelve years, researchers in the field have made significant contributions from 79 various sources, including journals, books, and other publications. This demonstrates the diverse array of interests that exist on various academic platforms. The research output demonstrates a significant annual growth rate of 30.77%, highlighting a substantial expansion in ESG studies, with 101 documents documented.



The documents, which have an average age of 1.7 years, showcase the latest advancements in ESG research, highlighting how the field is constantly evolving. Each document has received an average of 5.01 citations, which shows that it has a moderate level of influence among scholars. The substantial number of 5023 references across all papers underscores the depth of research and extensive academic dialogue in ESG topics.

Diving deeper into the content, the use of 393 'Keywords Plus' and 339 'Author's Keywords' reveals a diverse and specific exploration of themes within the ESG framework, showcasing a rich variety of focus areas chosen by researchers to reflect their unique perspectives or specialized interests.

In terms of authorship, the data shows a blend of collaborative and individual efforts. 312 authors have been involved, the presence of single-authored and multi-authored documents indicates a mix of personal and collaborative research approaches. Notably, there are 19

single-authored documents, which may highlight individual expertise or unique viewpoints. The average of 3.16 co-authors per document and an international co-authorship rate of 23.76% further emphasizes a high degree of collaboration and global interaction among scholars in the ESG field.

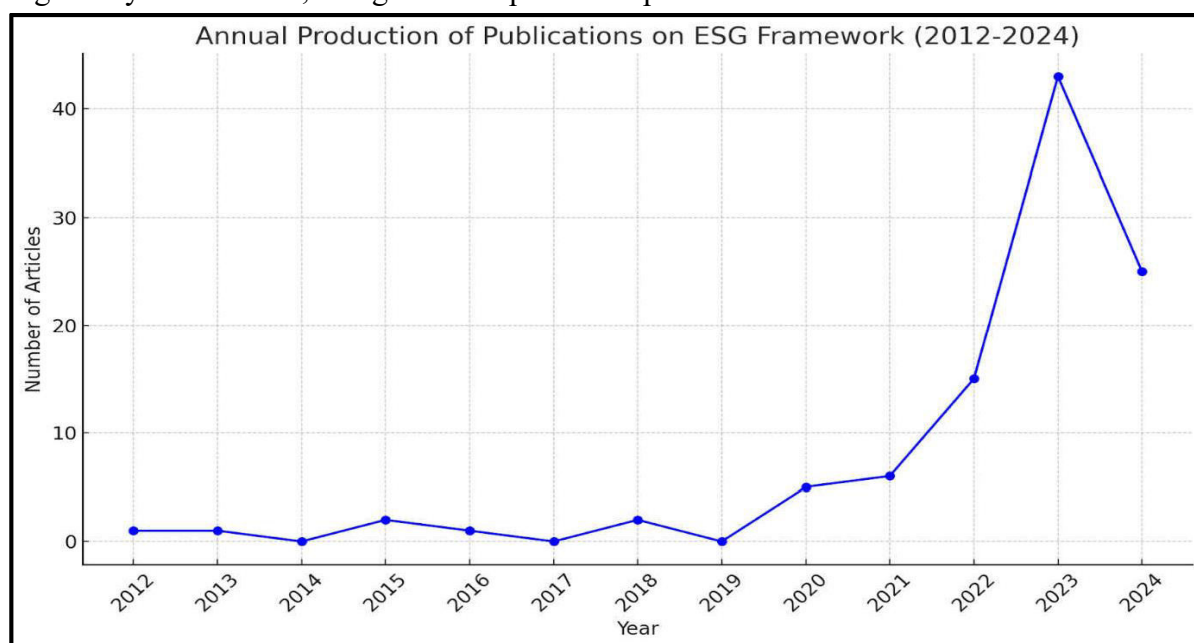
The statistical breakdown of document types, which contained 58 articles, 14 book chapters, 18 conference papers, a conference review, a note, and nine reviews, shows us how ESG research is presented. Articles are the most commonly used for new findings, book chapters extend the analysis, whereas conference papers share their discussion and introduce new ideas to an academic audience.

All in all, the findings of the bibliometric investigation present a vivid, polymorphous, and expanding field. It is highly collaborative in an academic sense and global by the geographical pattern. The variety of documents and cooperation between the countries indicate the far-reaching importance and extensive spread of the ESG issues.

3.2. Annual Productions

The bibliometric analysis of the annual production of publications on the ESG (Environmental, Social, and Governance) framework from 2012 to 2024 reveals a significant and growing interest in this field. Initially, the research output was minimal, with only one publication each in 2012 and 2013, suggesting that ESG was a relatively niche area at the time. The subsequent years saw fluctuating activity, with publication numbers ranging from zero to two annually until 2019. This pattern indicates that ESG was still in its developmental phase and had not yet gained substantial traction within the academic or business communities.

A noticeable surge in publication volume began in 2020, with the number of articles increasing to five that year, followed by six in 2021, and a more dramatic rise to 15 in 2022. The peak occurred in 2023, with a remarkable 43 publications, highlighting a heightened focus on ESG issues, likely driven by increased global awareness of sustainability challenges, evolving regulatory frameworks, and greater corporate adoption of ESG criteria.

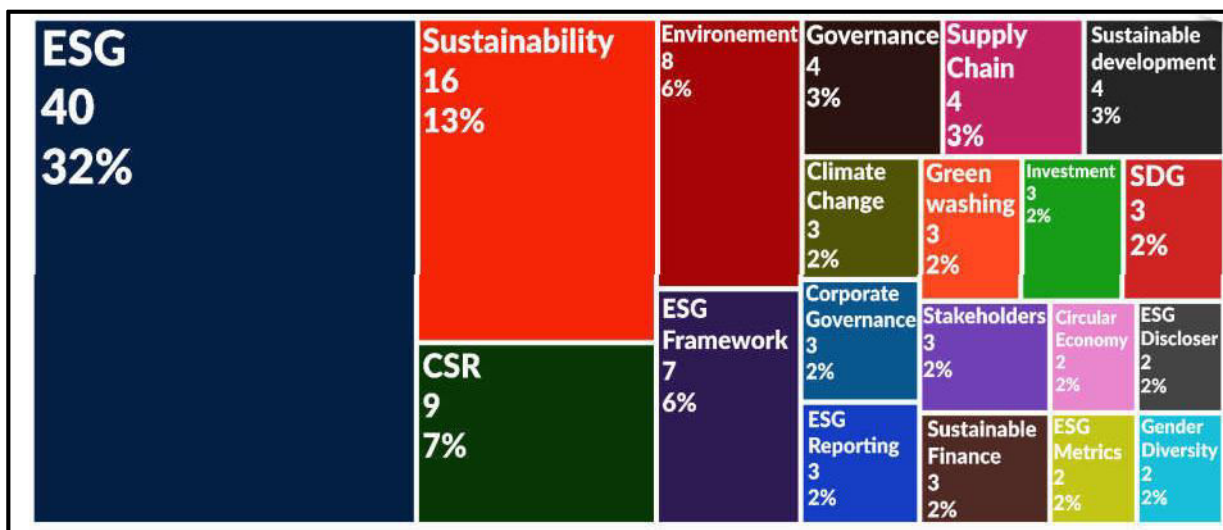


However, there is an apparent drop in publications to 25 in 2024. It is important to note that this data only covers the first four months of the year, up to April. Therefore, the perceived decline does not indicate a decrease in interest or research activity but rather a partial dataset.

If this trend continues at the same rate for the rest of the year, 2024 could potentially match or exceed the high levels of publication seen in 2023, underscoring the sustained and robust engagement with ESG topics within the scholarly and business arenas. This growing body of literature is crucial for understanding the complexities of ESG and its increasing integration into global business practices and policymaking.

3.3. Most Frequent Authors' Keywords

The aforementioned words' bibliometric analysis demonstrated how frequently they were used and, hence, the predominant themes of publications in the field of the ESG framework. A follow-up tree map helped highlight those central terms and concepts actively included in the discourse related to ESG research.



First and foremost, the word ESG itself was indicated 40 times, demonstrating that not only is it an undeniable uniting entity but also encompasses various concepts from environmental consciousness to corporate governance.

Second, sustainability in itself was mentioned 16 times, positioning it as the cornerstone of discussion in terms of long-term environmental equilibrium and ethical business operation. CSR used 9 times sheds light on ESG's connection to the ethical and social spheres of corporate action.

In addition, the environmental aspect seems to be discussed overtly owing to the 8 mentions assigned to this word. In turn, the ESG framework overviewed 7 times, suggests a structured manner to achieve ESG principles in organizational operation. Governance seems to have an independent role, with 4 mentions reaching 3 for corporate governance, emergence times in the mention.

Similarly, other terms such as supply chain and sustainable development, registered 4 times, ESG also used 4 times, highlighting extra attention to sustainability performance and corporate aligning to global objectives. On the other hand, it is possible to see the tendency to use specialized topics such as climate change, noted 3 times, greenwashing, and investment used 3 times, and SDG 3 times suggests that ESG composition encompasses detailed areas of concern common in global research.

Other niche but important research areas included the terms 'circular economy', 'ESG disclosure', 'ESG metrics', and 'gender diversity', each appearing twice. The first one denotes the scholarship focusing on recycling resources with a 100 billion sales potential. The next two include the same ESG practices but in relation to transparency, ESG disclosures, and ESG performance measurement, quantified assessments of them.

Lastly, this bibliometric picture identified gender diversity as another promising area which combines the definitions provided by one of the leading contributors. While comparing the most popular areas and the emerging spots which were explored in multiple publications, the map creates a visual representation of contemporary ESG concerns.

Table 1: Most Cited Countries

Country	Articles	Total Citations	Average Citations
USA	37	50	1.35
CHINA	31	4	0.13
INDIA	28	90	3.21
ITALY	26	72	2.77
UK	20	24	1.20
GERMANY	18	2	0.11
BRAZIL	12	6	0.50
INDONESIA	11	0	0.00
KENYA	11	0	0.00
CANADA	10	10	1.00

The analysis of the most cited country in ESG publications provided significant revelations regarding the global research landscape involving ESG practices and policies. It describes the ways in which the different countries contribute to the literature as well as the citation impact of their research.

India proved to be the most influential country showcased by India's averaged citations per countries with an impactful score of 3.21 citations associated with 28 articles. These indicate to unparalleled but groundbreaking import of the existing articles from India. Canada also showed a strong citation impact despite the low article count with the average score of 1.00 citations for 10 articles. Italy had a total article of 26 and its total citations of 72 making the country average at 2.77 citations per article.

On the other hand, countries such as China and Germany, which have contributed 31 and 18 articles respectively, have a surprisingly low citation impact of only 0.13 and 0.11 citations per article. This could mean that China and Germany, for instance, may be more active in recent ESG-related research that remains fairly disconnected from the global ESG, in addition to focusing on local issues which could account for the low citation impact. The United States also has a high number of contributions at 37 articles with a total of 50 citations or an average of 1.35 citations per article. That would place the U.S. as a substantial contributor to ESG research in terms of volume, even though the citation impact per article is only moderate compared to India and Canada.

Similarly, the UK demonstrates moderate impact with 20 articles; and an average citation rate of 1.20, which could suggest reasonable up-to-date engagement with the ESG research community. Finally, Indonesia and Kenya both authored 11 articles and have low to no citation impact, indicating a lack of significant influence or recognition as of yet.

Overall, the current bibliometric analysis indicates a fairly nuanced global ESG research landscape, which involves considerable differences in volume and impact. Therefore, this analysis can also showcase the areas that are leading in creating ESG knowledge most impacting the discourse, and those that, despite their contributions, are still on the margins of global influence in this regard.

The bibliometric analysis of affiliations active in the Environmental, Social, and Governance research highlights numerous academic institutions that significantly contribute to this field. Witten/Herdecke University is the most active partner with five published articles. It can be suggested that the institution boasts a robust institutional focus on ESG, that is inclusive of a separate research unit or faculty specializing in this topic. It also reflects on the strategic commitment of the institute to the integration of sustainability and corporate governance in the academic agenda.

Table 2: Most Relevant Affiliations

Affiliation	Articles
WITTEN/HERDECKE UNIVERSITY	5
DE LA SALLE UNIVERSITY	4
HELLENIC MEDITERRANEAN UNIVERSITY	4
KOREA UNIVERSITY	4
LUM UNIVERSITY GIUSEPPE DEGENNARO	4
NATIONAL FORMOSA UNIVERSITY	4
NETAJI SUBHAS UNIVERSITY OF TECHNOLOGY	4
TUFTS UNIVERSITY	4
UNIVERSITY OF WESTMINSTER	4
UTRECHT UNIVERSITY	4

The four-article metrics account the presence of De La Salle University, Hellenic Mediterranean University, Korea University, LUM University Giuseppe Degennaro, National Formosa University, Netaji Subhas University of Technology, Tufts University, University of Westminster, and Utrecht University. Considering the location diversity of the sources, this finding suggests the global relevance of ESG for higher education institutions in various cultural contexts. Their contributions also support research diversification in terms of the used perspectives and methodologies for ESG, enlivening the academic debate on sustainability and governance practices.

Table 3: Most Relevant Sources

Sources	Articles
SUSTAINABILITY (SWITZERLAND)	8
CORPORATE SOCIAL RESPONSIBILITY AND ENVIRONMENTAL MANAGEMENT	4
JOURNAL OF ENVIRONMENTAL MANAGEMENT	3
JOURNAL OF SUSTAINABLE FINANCE AND INVESTMENT	3
MANAGEMENT OF ENVIRONMENTAL QUALITY: AN INTERNATIONAL JOURNAL	3
E3S WEB OF CONFERENCES	2
IOP CONFERENCE SERIES: EARTH AND ENVIRONMENTAL SCIENCE	2
JOURNAL OF BEHAVIORAL AND EXPERIMENTAL FINANCE	2
JOURNAL OF CLEANER PRODUCTION	2
JOURNAL OF PHYSICS: CONFERENCE SERIES	2

The list of the most active sources was led by the journal Sustainability, Switzerland, and included a total of eight articles. This finding shows that the source is contributorily focused on the field of sustainability and is a central hub for the recent literature. Corporate Social Responsibility and Environmental Management also published four articles outlining the critical role and scope of corporate responsibility issues within the sustainability argument. Journal of Environmental Management, Journal of Sustainable Finance and Investment, and Management of Environmental Quality: An International Journal each published three articles. The summary of the sources listed above signifies the multidisciplinary scope of the ESG field, integrating environmental management, sustainable finance, and environmental quality management.

Despite the lower citations, the results found for E3S Web of Conferences, IOP Conference Series: Earth and Environmental Science, Journal of Behavioral and Experimental Finance, Journal of Cleaner Production, and Journal of Physics: Conference Series -all with two articles – do offer a wider perspective on ESG research as they link it to more specific fields, including experimental finance, cleaner production methods, and even the principles of physics.

Different kinds of research publications contribute to a more comprehensive understanding of ESG and reflect the entire complexity of the subject, which includes not only scientific but also economic and applicable dimensions. Thus, the analysis of both affiliations and resources allows for a plethora of special and interdisciplinary data sources that contribute to the development and dissemination of information in this essential field.

3.4. Most Global Cited Documents

The bibliometric analysis of the world's most cited papers on the ESG framework demonstrates what works have influenced the field more than most. The analysis of such metrics as the aggregate number of citations, citations per year, and aggregate number of normalized citations reveals the most influential publications that have an impact on academia and beyond.

Thus, Park SR's 2021 paper on ESG in the International Journal of Financial Studies states the highest total number of citations – 66, while retaining the annual citation rate at a relatively high level – 16.50, and the normalized number of citations – 2.55 that indicates ongoing recognition and the presence of the paper's influence on scholars since the year of publication.

A rather close second is Singhanian M 2023 in the *Journal of Sustainable Finance and Investment* – the aggregate number of citations – 58 on it. Interestingly, the annual citation rate for this work is very high – 29.00 times a year, with a normalized number of citations – 19.48. Thus, the work very quickly gained recognition among the academic community, indicating possible serious scientific and applicative significance, which is due to its relevance to one of the cutting-edge trends in ESG research – investing. The 2021 paper in *Corporate Social Responsibility and Environmental Management* by Esposito de Falco S is another standout to cite with a total of 43 citations and an annual citation rate of 10.75, although its normalized citation score is 1.66, which means a more moderated impact in relation to the publication age.

The *Multinational Business Review* paper by Linnenluecke MK is followed by 36 total citations, and the book by Bose S “*Values at Work: Sustain Invest and ESG Report*” is next with 27 total citations and notably higher normalized scores, which means these sources continue to be relevant to the scholars in the fields of multinational business and sustainable investment in particular. As for the other papers, the *Vision* paper by Singhanian M and the *Managerial Finance* paper by Baid V have lower total citation scores but remain steadily cited and average annually. The papers in *Sustainability* by Jonsdottir GE and Kempeneer S have lower scores as well.

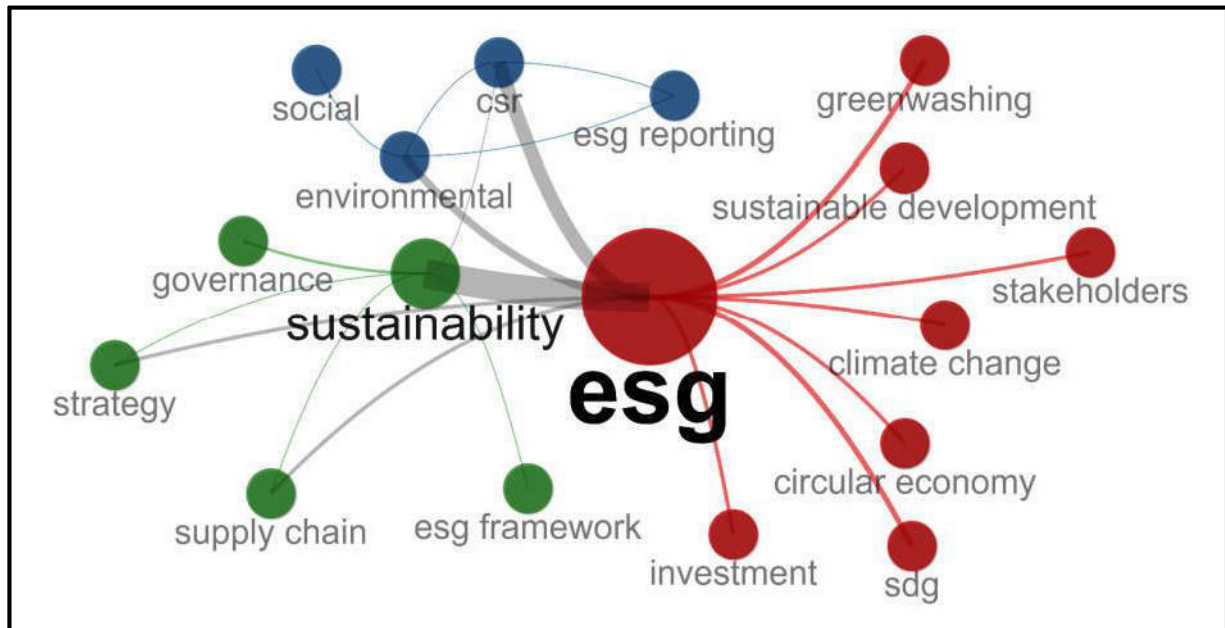
Finally, the 2015 article in *Current Opinion in Environmental Sustainability* by Habtezion S demonstrates the lowest annual citation rate but preserved the normalized citation of 2.00, which means it was and continues to be relevant since publication. Thus, this analysis was aimed to highlight the most cited papers since ESG research began to spread, and recent publications frequently become central to the academic discourse, especially if they are dedicated to urgent and timely issues. This analysis also shows how dynamic ESG research has been so far as the sources that are a bit older have almost the same influence as more recently published ones.

3.5. Co-Word Network Analysis

The co-word network analysis enables a comprehensive view of the connectedness among terms and their thematic presence in Environmental, Social, and Governance framework literature. By highlighting and differentiating key ESG-related terms into three clear clusters through color-coding—red for Cluster 1, blue for Cluster 2, and green for Cluster 3—the analysis shows the terms and their relationships based on the frequency of usage and co-occurrence in the literature.

In bibliometric analysis, betweenness centrality measures a term's role as a bridge within the network, highlighting its importance in connecting different clusters, while PageRank assesses a term's significance based on its connections, indicating its overall influence in the ESG discourse.

Sr. No.	Paper	DOI	Total Citations	TC per Year	Normalized TC
1	PARK SR, 2021, INTERN J FINANCIAL STUD	10.3390/ijfs9030048	66	16.50	2.55
2	SINGHANIA M, 2023, JOURNAL OF SUSTAIN FINANCE INVEST	10.1080/20430795.2021.1964810	58	29.00	19.48
3	ESPOSITO DE FALCO S, 2021, CORP SOC RESPONSIB ENVIRON MANAGE	10.1002/csr.2183	43	10.75	1.44e66
4	LINNENLUECKE MK, 2022, MULTINATIONAL BUS REV	10.1108/MBR-11-2021-0148	36	12.00	4.91
5	BOSE S, 2020, VALUES AT WORK: SUSTAIN INVEST AND ESG REPORT	10.1007/978-3-030-55613-6_2	27	5.40	2.55
6	SINGHANIA M, 2022, VISION	10.1177/09722629211054173	20	6.67	2.73
7	BAID V, 2022, MANAG FINANC	10.1108/MF-12-2021-0588	18	6.00	2.45
8	JONSDOTTIR GE, 2021, SUSTAINABILITY	10.3390/su13137331	16	4.00	0.62
9	KEMPENEER S, 2021, SUSTAINABILITY	10.3390/su13063239	15	3.75	0.58
10	HABTEZION S, 2015, CURR OPIN ENVIRON SUSTAINABILITY	10.1016/j.cosust.2015.06.009	13	1.30	2.00



Cluster 1 is focused around the centroid ‘ESG’, which is particularly noteworthy due to its high betweenness centrality and a high PageRank. In other words, ‘ESG’ appears central in the co-occurrence and discourse in the relevant literature. This cluster includes such terms as ‘sustainable development,’ ‘climate change,’ ‘greenwashing,’ ‘investment,’ ‘SDG,’ ‘stakeholders,’ and ‘circular economy.’ Furthermore, as the terms have a high betweenness centrality, their position and representation in this cluster can be described as instrumental in terms of developing a specific vocabulary around ESG.

Cluster 2 has ‘CSR’ and ‘environmental’ as the main nodes due to their betweenness centralities. With numerous connections between the cluster members, including ‘ESG reporting’ and ‘social’ nodes, the themes appear to be focused on the environment and ESG.

Cluster 3, with ‘sustainability’ as the focus centroid, also has a high betweenness centrality and a notable PageRank. Additionally, ‘ESG framework,’ ‘governance,’ ‘supply chain,’ and ‘strategy’ nodes are included, showing that this cluster

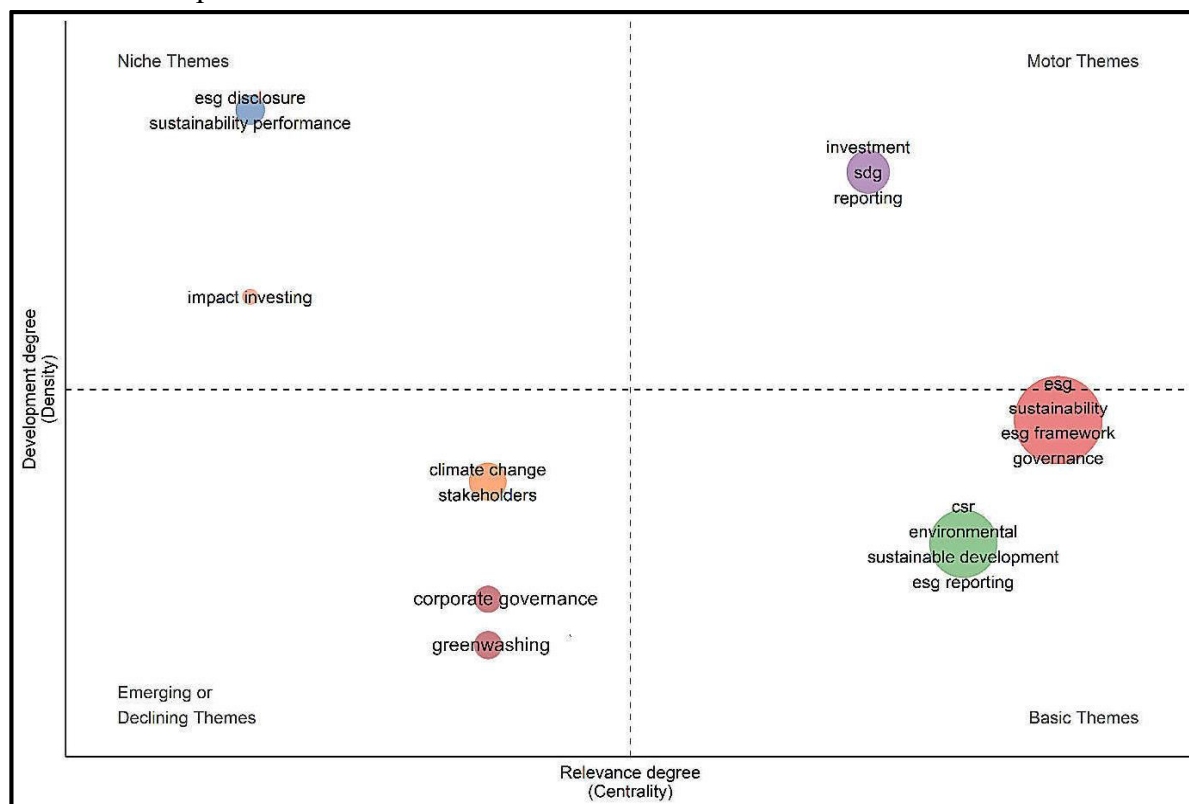
is concerned with the fundamental aspects of ESG and sustainability, particularly the ways in which sustainability is embedded within the company practices and strategies.

Network metrics such as betweenness centrality, closeness, and PageRank elucidate the structure and importance of the terms in the network. Betweenness centrality points to the nodes that function as bridges, such as ‘ESG’ and ‘environmental,’ enabling the information to stream between various concepts. Closeness denotes how near the node is to all other nodes in the network, viewing how accessible or influential the node might be in quoting, drawing in, and spreading opinions. PageRank shows how influential the node is, and it is selected according to the connections: ‘ESG’ remains the most influential term.

To sum up, the diagram and its analysis describe the connection between different terms related to the ESG, forming clusters that served as the core and the specialized domains. Structured display not only outlines the most popular directions of ESG research but visually showcases the vivid and dynamic links between various topics in the academic discourse and practice.

Thematic Map Cluster Analysis

The thematic analysis of the publications in the ESG results in the understanding of the main areas and trends of this critical domain of research. By evaluating the key words in terms of incidence, centrality measures, and thematic clusters, it is possible to comprehend the focus and relationship between the ESG themes.



The cluster “esg” may be identified as the most powerful term within the “basic theme”, which includes the word “esg” with the highest density and centrality. It implies that ESG is the center of sustainability discourse that has a crucial status. The other keywords of this term are “sustainability,” “ESG framework,” “governance,” and “supply chain,” which implies the general framework of basic relevant aspects, whereas the centrality of these terms is a measure of their impact.

For example, “esg disclosure” and “csr” clusters are the parts of the more specific focus of ESG, such as “niche theme” and “basic theme”. “esg disclosure” implies the main words such as “esg metrics” and “sustainability performance”, which means that there is the increasing attention to the

means of measuring the sustainability performance.

The other cluster includes “corporate social responsibility,” “environmental,” and “sustainable development,” which refers to the centrality of environmental issues in corporate practice. For instance, the “motor theme” only includes the “investment” cluster “SDG” and “reporting,” and “climate change” and “stakeholders” “emerging or declining theme,” which indicates the key trends of sustainability.

The centrality of these clusters is a measure of their impact on the ESG network. It shows what the authors consider to be the most crucial without evaluating the validity of their assumptions. Thus, it appears that the “egg” cluster is the most central with centrality and density of terms of 80, and thus, it is more

powerful, as its importance is central to the domain. A thematic analysis helps to obtain the most important trends and understand their interaction in the network, which may be used for further studies and research.

4. Discussion of the results:

This bibliometric analysis offers valuable insights into the evolution, thematic trends, and global contributions to ESG framework research from 2012 to 2024. The current section outlines the implications of the findings, unveiling potential research gaps and areas for further examination.

ESG research emergence and growth: The substantial rise in ESG output across the years implies a growing interest in sustainability issues among scholars and practitioners. Moreover, this result is in line with the previous discoveries (Li, Wang, Sueyoshi, & Wang, 2021; Senadheera et al., 2022; Wan, Dawod, Chanaim, Ramasamy, & Management, 2023). The first years were associated with minimal activity, suggesting that ESG was a niche. Nonetheless, from 2020, the publication volume increased steeply, underpinned by the growing global recognition of the sustainability problem and the regulatory response. Thus, this growth indicates the increasing importance of ESG considerations in the business and policy landscape.

Thematic trends and research framework: Highly frequent keywords and thematic clusters illustrate central terms and emerging trends in ESG field research. Themes such as sustainability, CSR, environmentalism, and governance issues overarch research, highlighting the multi-dimensional nature of ESG. Furthermore, more nuanced concepts, such as climate change, ESG disclosure, and gender diversity, underscore the evolving dimensions of ESG field focus.

Global Landscape and Contributions:

Analyzing the most cited countries and affiliations, I noted the diverse geographic spread in ESG research. Despite the significant influence, India, Italy, and Canada varied in publication volume, suggesting that their qualitative contribution is high. Simultaneously, different academic institutions, from Witten/Herdecke University to Korea University, from around the global landscape actively contribute to ESG knowledge dissemination.

Publication Venues and Impactful Works:

The analysis of publication outlets and sources reveals prominent journals such as ‘Sustainability’ and ‘Corporate Social Responsibility and Environmental Management’ that act as critical platforms for knowledge and insights exchange at various levels. Moreover, the identification of documents cited globally results in highlighting seminal works that have primarily contributed to the ESG discourse. It demonstrates the necessity of both recent and older content to facilitate scholarly debates and professional applications.

Co-Word Network and Thematic Mapping:

The described co-word network and thematic mapping analyses reflect the structured information regarding the endogenous isolation of themes and relationships between them in ESG. The central concepts of ESG, sustainability, and governance are highlighted, and the specialized area of ESG disclosure and climate change is presented. Understanding and realizing these topical interconnections occur set the tone for future research lines and encourage interdisciplinary collaboration in times of the complex nature of sustainability.

4.1. Research Gap:

Network Dynamics in ESG: Examining the overall network dynamics and interrelations within the ESG environment can provide

insights regarding how the information as a value circulates, how collaborations emerge and dissolve, and how influence spreads. Employing social network analysis or dynamic network modeling, among others, can help unlock the key actors, themes, and emergent properties across the ESG research field.

Behavioral Economics and ESG Decision-Making: The integration of behavioral economics concepts into ESG decisions can shed light on the personnel-level and organization-level peculiarities of sustainability. The cognitive shortcuts, decision heuristics, and reliance on social norms can demonstrate how various cognitive biases influence ESG adoption and perceived risk and returns can present novel ways to nudge consumers and investors towards sustainable behaviors.

Quantifying ESG Impact on Stakeholder Well-Being: While ESG frameworks prioritize stakeholder concerns, one research gap quantitatively measures the impact of ESG initiatives on stakeholder well-being, which transcends financial signals. Among the potential approaches to testing the causal links between stakeholder quality of life, mental well-being, and social cohesion are advanced econometric models like structural equation modeling or empirical testing with longitudinal surveys.

Blockchain-enabled Transparency and Accountability: Researching how blockchain can be used to improve transparency and traceability in ESG reporting, as well as the possibilities regarding blockchain-based decentralized ledger systems for verifying producers' sustainability claims, controlling supply chains for ethical pieces and reducing greenwashing and fraud, is widely considered frontier research domain.

4. Future Directions:

Predictive Analytics for ESG Performance: Leveraging machine learning algorithms and big data analytics, future research could develop predictive models to anticipate ESG performance trends and identify leading indicators of sustainability success. By analyzing diverse datasets, including financial reports, social media sentiment, and environmental monitoring data, predictive analytics could help investors, regulators, and businesses proactively manage ESG risks and opportunities.

Multi-level Governance in Global Supply Chains: Examining the multi-level governance dynamics within global supply chains could shed light on how ESG standards and norms diffuse across borders and interact with local contexts. Future research could explore the role of transnational governance mechanisms, private regulatory initiatives, and multi-stakeholder partnerships in promoting sustainable supply chain practices while respecting cultural diversity and national sovereignty.

Robustness and Resilience in ESG Systems: Drawing upon the understanding of complex systems and resilience theory, future research may delve into the issues of ESG systems' robustness and adaptive capacity during times of systemic shocks and disruption. By framing ESG networks in the lens of complex adaptive systems, researchers can reveal tipping point schematics, feedback loops, and resilience-boosting mechanisms that would contribute to the longevity of socio-ecological systems.

Ethical AI for ESG Assessment: A particular cutting-edge research avenue encompasses the field of ethical AI in ESG assessment. New research may explore the development of a newly devised ethical AI framework prioritizing fairness, intelligence, and accountability in algorithm-driven decision-making processes related to ESG scoring, risk

assessment, and impact measurement. Furthermore, a study can tackle the societal impact of the emergent role of AI on the automation front, thereby examining its potential adverse effects on labor rights, income disparity, and social justice in the context of ESG.

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Modelling ESG Uncertainty: A panel analysis of Economic, Institutional, and Geopolitical drivers in developed and emerging markets

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Abstract

Environmental, Social, and Governance (ESG) uncertainty has emerged as a critical factor influencing sustainable investment decisions, yet little is known about its macroeconomic and institutional determinants across countries. This study investigates the drivers of ESG-related uncertainty across thirteen developed and emerging economies from 2010 to 2021. Using panel data econometrics, including fixed-effects modeling and interaction terms, the analysis evaluates the impact of economic development, financial development, financial inclusion, trade openness, foreign direct investment, and geopolitical risks on ESG uncertainty levels. A novel Financial Inclusion Index is developed using Principal Component Analysis, integrating governance quality, access to finance, and digital infrastructure variables. The results reveal that higher GDP per capita, financial development, and inclusive financial systems significantly reduce ESG uncertainty. Emerging markets face higher uncertainty due to institutional weaknesses and greater sensitivity to external shocks. Notably, geopolitical risk exerts a significant adverse effect on ESG stability in both the United States and India. The study offers important policy implications for regulators, investors, and sustainability advocates by identifying structural levers to reduce ESG-related information risk and enhance decision-making in sustainable finance.

Keywords

ESG Uncertainty; Financial Inclusion; Geopolitical Risk; Principal Component Analysis

1. Introduction

The global financial landscape has undergone a significant transformation in recent years, with Environmental, Social, and Governance (ESG) considerations taking center stage in both policy agendas and investment strategies. As stakeholders increasingly align with the United Nations Sustainable Development Goals (SDGs), ESG metrics have evolved into critical benchmarks for assessing corporate behavior, sovereign credibility, and long-term value creation. Amid this growing emphasis on sustainability, a parallel concern has emerged—the uncertainty surrounding ESG performance, measurement, and outcomes, particularly across varying macroeconomic and institutional contexts (Kong et al., 2022; Zhang et al., 2024). While ESG ratings, disclosures, and fund flows have been extensively studied, there remains a notable gap in understanding the factors that drive fluctuations in ESG-related uncertainty over time and across regions (Ge & Zhang, 2025; Zyznarska-Dworczak, 2022).

ESG uncertainty captures the lack of clarity and predictability in ESG-related outcomes due to information asymmetries, regulatory divergence, geopolitical tensions, and disparities in institutional quality (Alnafrh, 2024; Guo et al., 2024). This uncertainty poses significant challenges for investors, policymakers, and development institutions as they seek to assess risks, allocate capital, and design effective sustainability frameworks. Existing research largely focuses on ESG ratings and their linkages to financial

performance (Friede et al., 2015; Velte, 2017; Wang & Sarkis, 2017). However, the dynamic nature of ESG uncertainty, particularly at the country level, remains underexplored. As such, there is an urgent need to investigate what drives volatility in ESG expectations and outcomes, especially in the face of complex global risks such as climate change, geopolitical instability, and economic inequality.

This study addresses this gap by empirically analyzing the determinants of ESG uncertainty across a diverse sample of thirteen countries—comprising both developed (United States, United Kingdom, Germany, France, Italy, Japan, Canada) and emerging (India, China, Brazil, Russia, Mexico, South Korea) economies—over the period 2010 to 2021. The ESG Uncertainty Index (ESGUI) is used as the dependent variable, capturing shifts in investor perceptions and risk related to ESG outcomes. A panel dataset is constructed that includes a mix of structural and institutional variables: GDP per capita, trade openness, foreign direct investment (FDI), geopolitical risk, financial development, and financial inclusion. The Financial Inclusion Index is derived using Principal Component Analysis (PCA) based on twelve indicators encompassing financial access, digital infrastructure, and governance effectiveness.

To examine the underlying drivers of ESG uncertainty across both developed and emerging economies, this study integrates a

range of macroeconomic, financial, and geopolitical indicators grounded in robust theoretical and empirical literature. The inclusion of GDP per capita, foreign direct investment (FDI), and trade openness captures the role of economic development and international exposure in shaping ESG dynamics (Lee et al., 2016; Dam & Scholtens, 2012; Cole, 2004). Geopolitical Risk Index (GPR) is incorporated as geopolitical tensions are known to heighten market uncertainty and adversely impact ESG-oriented investments (Caldara & Iacoviello, 2022; Bouri et al., 2022). Similarly, financial development and financial inclusion are expected to play crucial roles in enabling or constraining ESG adoption through access to sustainable finance, institutional quality, and investor participation (Beck et al., 2007; Demirgüç-Kunt et al., 2015). The country-type variable distinguishes structural differences between advanced and emerging economies, acknowledging their varying ESG policy frameworks and market sensitivities (Krueger et al., 2020). A time trend variable is also employed to control for global shocks and the evolution of ESG frameworks over the study period. This multifactor approach provides a comprehensive lens to understand ESG uncertainty through both economic and institutional channels.

Our research is motivated by the following three key questions – (1) How do financial development and financial inclusion influence ESG-related uncertainty? (2) Does ESG uncertainty behave differently across developed and emerging economies? And (3) What role do exogenous shocks, particularly geopolitical risks, play in shaping ESG uncertainty dynamics?

By investigating these questions, the paper offers a multi-faceted contribution to the

literature. First, it provides new evidence on macro-financial drivers of ESG uncertainty, offering insights into how globalization, financial architecture, and governance ecosystems condition sustainability risk. Second, the paper develops a composite Financial Inclusion Index as a novel explanatory variable, thereby linking sustainable finance with equitable institutional access. Third, by comparing emerging and developed economies, the study enhances our understanding of ESG uncertainty heterogeneity across income groups and institutional regimes.

The findings from this study hold substantial theoretical and practical relevance. From a theoretical standpoint, the results provide a foundation for integrating ESG uncertainty into models of sustainable development, capital allocation, and sovereign risk. From a practical perspective, the insights help inform investors about systemic vulnerabilities and guide policymakers in designing targeted interventions to mitigate ESG volatility. For instance, understanding the role of geopolitical risk and financial system maturity in shaping ESG uncertainty can help stakeholders preemptively manage sustainability disruptions and foster resilience in ESG reporting and implementation.

In sum, this study represents a significant step toward unpacking the complex interactions between macroeconomic structures, institutional capacities, and ESG uncertainty, thereby contributing to the broader discourse on sustainability transitions in a volatile global context.

The rest of the paper is followed by the “Literature Review” section, which discusses prior research on financial inclusion, financial development, governance, and their

theoretical relevance to ESG uncertainty. The “Data and Methodology” section explains the data sources, variable construction (including a novel Financial Inclusion Index), and the econometric methods used, such as PCA and panel regression. The “Results” section presents descriptive statistics, correlation matrices, and regression outputs, supported

by visual density plots. The “Discussion and Policy Implications” section interprets the findings, compares developed and emerging markets, and offers strategic insights for investors and policymakers. Finally, the “Conclusion” summarizes the key takeaways and outlines directions for future research.

2. Literature Review

The growing significance of ESG (Environmental, Social, and Governance) uncertainty in shaping national financial stability and investor confidence has brought macro-level determinants, such as financial development, inclusion, and geopolitical context, to the forefront of research. While ESG performance is widely studied at the corporate level, limited literature has directly explored the macroeconomic and institutional drivers that influence ESG uncertainty at the country level. This study addresses that gap by focusing on key financial, economic, and governance variables and their theorized relationship with ESG volatility.

Temporal effects have long been recognized as critical controls in ESG-related studies. Changes in ESG frameworks, reporting norms, and global sustainability expectations evolve over time and must be accounted for in longitudinal analyses. (Bansal & DesJardine, 2014; Eccles et al., 2014) highlight how corporate sustainability performance and policy adoption are inherently time-sensitive, shaped by evolving stakeholder expectations and institutional maturity. Incorporating year effects enables researchers to capture these dynamic ESG trends across countries.

Similarly, the development status of countries plays a foundational role in shaping ESG behavior and regulatory stringency. Developed economies often benefit from mature legal frameworks, robust ESG reporting mechanisms, and institutional investors demanding transparency. In contrast, emerging economies may exhibit weaker enforcement and higher sustainability risks. (Albuquerque et al., 2020; Krueger et al., 2020) provide evidence that the financial markets in advanced economies react more strongly to ESG signals, particularly during crisis periods, underscoring the need to distinguish between developed and emerging markets in ESG studies.

GDP per capita serves as a proxy for a country’s economic development and institutional capacity to enforce ESG mandates. Wealthier countries typically possess better infrastructure, regulatory agencies, and ESG data systems. (Lee et al., 2016) find that economic development correlates positively with ESG responsibility, while (Dasgupta et al., 2002) argue that the Environmental Kuznets Curve reflects a turning point where growth begins to reduce environmental degradation. These findings suggest that economic capacity can

reduce ESG uncertainty by supporting transparency and compliance.

In a globalized world, foreign direct investment (FDI) can both import ESG best practices and increase ESG-related exposure through multinational operations. (Doytch & Narayan, 2016) show that sector-specific FDI can influence renewable energy adoption, while (Dam & Scholtens, 2012) reveal that socially responsible investing can enhance financial returns. These dual effects highlight the importance of contextualizing FDI flows within ESG frameworks, especially in countries lacking strong regulatory environments.

Trade openness is another critical determinant. Integration into global markets subjects countries to international ESG scrutiny via supply chains and investor expectations. (Eichengreen & Gupta, 2013) argue that trade drives sectoral modernization in emerging markets, while (Cole, 2004) examines how openness affects environmental degradation through the "pollution haven" hypothesis. These findings imply that open economies may face both greater ESG pressure and potential for volatility, depending on their institutional readiness.

Geopolitical risk (GPR) has a direct influence on ESG uncertainty. Political instability, armed conflict, and diplomatic tensions can disrupt environmental regulations, social services, and governance consistency. (Caldara & Iacoviello, 2022) developed a widely used GPR index that captures the rising global tensions shaping market sentiment. (Dogan et al., 2021) further show that GPR shocks increase financial and policy uncertainty, especially in developing countries. These risks can

amplify ESG unpredictability and undermine long-term planning.

A country's financial development is foundational for embedding ESG into national strategies. (Beck et al., 2007) find that deep and efficient financial systems help reduce inequality, facilitate green finance, and improve access to capital for sustainable projects. (Serrasqueiro et al., 2021) further demonstrate that financial development helps buffer small and medium enterprises (SMEs) against macroeconomic volatility, which in turn supports ESG outcomes. Mature financial systems can provide the instruments and channels necessary for managing ESG risks effectively.

Lastly, financial inclusion, as captured through indices constructed using principal component analysis (PCA), enhances access to formal financial services, strengthens household resilience, and increases citizen participation in governance. (Demirgüç-Kunt et al., 2015) report that inclusive financial systems are critical to development outcomes, while (Park & Mercado Jr, 2018; Sarma & Pais, 2011) show that financial inclusion helps reduce poverty and inequality, indirectly contributing to ESG stability. By broadening financial participation, inclusion reduces systemic risks and improves the likelihood of consistent ESG performance.

Collectively, these studies support the theoretical grounding of the current research. They suggest that macro-financial indicators — particularly financial development, inclusion, economic capacity, trade openness, and institutional quality — not only influence ESG outcomes but also shape the uncertainty and volatility

surrounding ESG policy implementation and performance. However, few studies have systematically assessed these relationships using a country-level, multi-variable model. This study fills that gap by

examining how selected macro-financial variables influence ESG uncertainty across 13 countries using composite indices, regression modelling, and temporal controls.

3. Data and Methodology

Our study uses a quantitative research design to investigate the impact of various economic, governance, and financial factors on ESG uncertainty across countries. It employs Principal Component Analysis (PCA) to reduce data dimensionality and multiple regression analysis to identify the most significant predictors of ESG uncertainty.

The study is based on secondary data covering a panel of 13 countries over the period 2010 to 2021. The countries included in the analysis are: Developed- USA, Canada, France, Germany, Japan, United Kingdom, Italy.

Emerging and Developing Economies (EMDEs)- Brazil, India, Mexico, South Korea, China, Russia

These countries were selected based on data availability and consistency. Data was collected from reliable sources including the World Bank, IMF, and Trading Economics. The dependent variable in this study is ESG Uncertainty Index (ESGUI), which reflects the volatility and unpredictability in environmental, social, and governance dimensions. This index is obtained from the policy uncertainty website ¹.

The independent variables used in the study are as follows:

Table 1: Independent variables

Variables	Explanation	Source
GDP per Capita	Measures the average economic output per person. Lower GDP per capita reflects weaker economic capacity and reduced financial inclusion among citizens.	World Bank
Foreign Direct Investment (FDI)	Indicates investor confidence and capital inflows into a country. Lower FDI may signal economic instability and reduced opportunities for inclusive financial development.	Trading Economics
Trade Openness	Represents the share of exports and imports in GDP. Lower trade openness may indicate isolation from global markets	World Bank

¹

https://www.policyuncertainty.com/sustainability_index.html

	and limited access to international financial systems.	
Government Effectiveness	Captures the quality and efficiency of public services and policy implementation. Lower government effectiveness weakens governance, which can hinder financial inclusion and increase ESG uncertainty.	World Bank
Control of corruption	Assesses the extent to which public power is not misused. Poor control of corruption leads to misallocation of financial resources and limits public trust in financial systems.	World Bank
Political stability	Measures the risk of political unrest and violence. Political instability raises uncertainty in policy and economic decisions, affecting both financial development and ESG risk.	World Bank
Regulatory Quality	Evaluates the ability of the government to formulate and implement sound policies. Poor regulatory frameworks reduce investor trust and hinder financial sector growth.	World Bank
Rule of Law	Measures confidence in legal systems, property rights, and contract enforcement. Weak rule of law undermines financial access, institutional trust, and governance quality.	World Bank
Voice & Accountability	Indicates the degree of democratic participation and freedom. Low accountability often correlates with reduced citizen engagement and lower transparency in financial governance.	World Bank
Bank Branches per 100,000 Adults	Shows access to banking infrastructure. A lower number of branches implies weaker financial inclusion and limited access to basic banking services.	Trading Economics
Loans to GDP	Represents domestic credit provided to the economy. Lower levels may indicate underdeveloped lending institutions and restricted access to credit for individuals and businesses.	World Bank

Deposits to GDP	Reflects the total value of savings held in banks. Lower deposit levels may signal limited financial participation and low public trust in the banking system.	World Bank
Financial development index	A composite measure of financial institutions' depth, access, and efficiency. Lower values reflect weaker financial infrastructure and limited inclusion.	IMF (International Monetary Fund)
Mobile subscriptions per 100 people	Indicates digital connectivity and access to mobile-based financial services. Lower mobile penetration can limit digital financial inclusion efforts.	Trading Economics
Telephone subscription (Fixed Line)	Represents traditional communication infrastructure. Lower fixed-line subscriptions may reflect rural isolation and limited access to services.	Trading Economics
Internet Usage (% of population)	Shows the proportion of people using the internet. Lower internet access restricts digital literacy and access to fintech solutions, reducing inclusion.	World Bank
Geopolitical Risk Index	Measures risks arising from international tensions, conflicts, and uncertainty. Higher geopolitical risk increases uncertainty and may influence investment, trade, and financial policies.	Economic Policy uncertainty

For data cleaning and normalization, to ensure reliability, missing data points — particularly in indicators like internet usage or political stability — were handled through regression-based imputation using time series interpolation. Outlier detection and normalization were applied to prevent skewed influence in PCA and regression estimations.

To investigate the relative impact on ESG uncertainty, 12 variables were grouped into an index viz Financial Inclusion Index – i.e., bank branches per 100,000 adults, internet usage, mobile subscriptions, loans-to-GDP, deposits-to-GDP, political stability,

regulatory quality, accountability, government effectiveness, rule of law, and corruption control as seen in figure 4.

To reduce dimensionality and address multicollinearity among correlated variables, PCA (Principal Component Analysis) was used to extract indices for Financial Inclusion. The Kaiser-Meyer-Olkin (KMO) test and Bartlett's Test of Sphericity were performed to validate the dataset's suitability for factor analysis. Based on the scree plot results, and the factor analysis, PCA was performed to create the Financial Inclusion Index followed by panel regression.

The following model was estimated:

$$\begin{aligned} \text{ESGUI}_{it} = & \beta_0 + \beta_1 \text{YEAR}_{it} + \beta_1 \text{TYPE}_{it} + \beta_2 \text{GDP\_per\_CAP}_{it} \\ & + \beta_3 \text{FOREIGN\_DIRECT\_INV}_{it} + \beta_4 \text{TRADE}_{it} + \beta_5 \text{GPRI}_{it} \\ & + \beta_6 \text{FIN\_DEV\_INDEX}_{it} + \beta_7 \text{FIN\_INC\_INDEX}_{it} + s_{it} \end{aligned}$$

where:

- ESGUI is the dependent variable capturing uncertainty related to ESG issues.
- FIN_INC_INDEX is the PCA-based index.
- FIN_DEV_INDEX is the financial development index.
- GPRI is the geopolitical risk index.
- YEAR is the temporal dummy variable.
- TYPE is a dummy variable indicating the type of economy.
- GDP_per_CAP denotes Gross Domestic Product per Capita of the economy.
- FOREIGN_DIRECT_INV denotes the foreign direct investment in the economy.
- TRADE denotes the trade openness.
- ε_{it} is the error term.

To examine differences between developed and developing nations, a dummy variable (TYPEEmerging) was added to indicate emerging economies. This variable allows the model to isolate variation in ESG uncertainty based on development status and institutional maturity.

4. Results

To provide a comprehensive understanding of the dataset, summary statistics were computed for all key variables across developed and emerging economies for the period 2010–2021. Table 1 presents the mean and standard deviation (SD) values separately for both groups, highlighting noticeable differences in economic structure, institutional quality, financial penetration, and ESG-related uncertainty.

Table 2: Summary Statistics

Variable	Developed (N = 84)		Emerging (N = 72)	
	Mean	SD	Mean	SD
GDP per Capita	44,582	7,926	11,962	8,748
Foreign Direct Inv.	0.018	0.017	0.021	0.011
Trade (Openness)	0.55	0.17	0.53	0.21

Bank Branches	30	11	17	7.7
Govt. Effectiveness	1.4	0.41	0.16	0.53
Corruption Control	1.8	2.6	-0.37	0.50
Political Stability	0.62	0.33	-0.47	0.51
Regulatory Quality	1.4	0.37	0.022	0.52
Rule of Law	1.4	0.45	-0.13	0.62
Accountability	1.2	0.18	-0.19	0.86
Loans to GDP	0.72	0.37	0.55	0.28
Deposits to GDP	0.78	0.42	0.64	0.41
Financial Dev. Index	0.83	0.073	0.57	0.15
Mobile Subscription	115	21	109	28
Telephone Subscription	47	9.7	22	16
Internet Usage	0.82	0.10	0.58	0.24
ESG Uncertainty Index	30	11	23	7.1
Geopolitical Risk Index	0.66	0.73	0.32	0.31

We observe the following key differences as highlighted by the summary statistics as given in Table 1. The developed economies have significantly higher average GDP per capita compared to emerging economies (USD 44,582 vs. USD 11,962), aligning with expectations – accentuating the economic disparities between the two groups of economies. Developed nations consistently exhibit stronger institutional indicators such as government effectiveness (1.4 vs. 0.16), corruption control (1.8 vs. -0.37), and regulatory quality (1.4 vs. 0.022), highlighting stark differences in the

institutional strength. Also, the developed countries show superior financial metrics with higher Financial Development Index² scores (0.83 vs. 0.57) and greater financial penetration, as seen in both loans and deposits to GDP ratios (0.72 / 0.78 vs 0.55 / 0.64). Thus, the financial system in the developed economies is much more evolved as compared to emerging economies. While mobile subscriptions are comparable, developed nations have significantly higher telephone subscriptions and internet usage, emphasizing the digital divide. Developed nations also report a higher GPR index (0.66)

² IMF Database

compared to emerging economies (0.32), likely reflecting volatility tied to international exposure and political debates around sustainability. Interestingly, the mean ESG Uncertainty Index (ESGUI) is higher in developed countries (30) than in emerging ones (23), suggesting either heightened scrutiny or greater market sensitivity to ESG risks. However, this is expected since emerging financial markets usually suffer asymmetric multiplier and spillover effects

due to geopolitical ambiguity and poor

To understand the structural distribution of key variables across developed and emerging economies, kernel density plots were generated for the ESG Uncertainty Index (ESGUI), Financial Development Index (FDI), and Geopolitical Risk Index (GPR). These plots serve as a non-parametric way to assess the probability distribution and compare variations between the two groups.

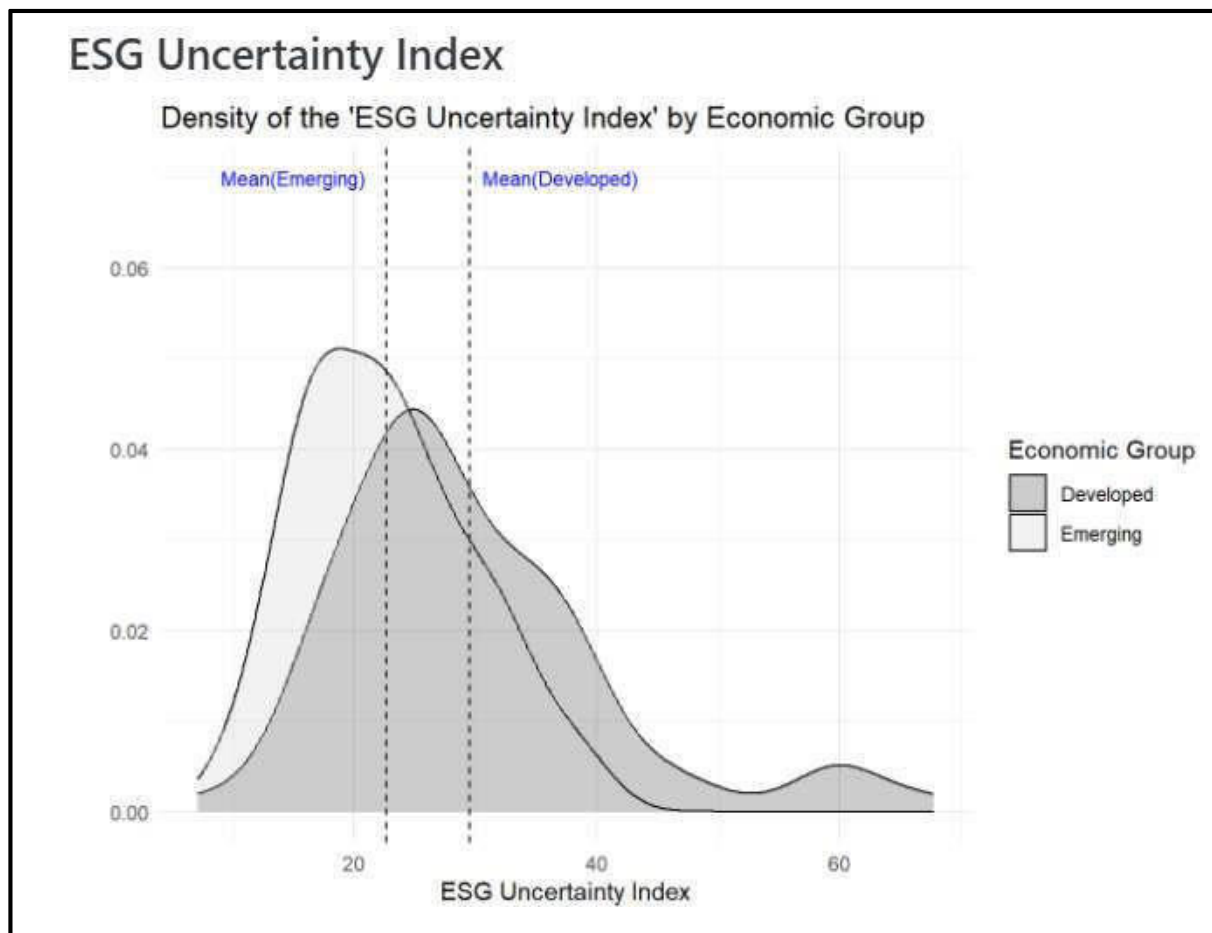


Fig 1: Density distribution of ESG Uncertainty Index

The density plot of ESGUI reveals a right-skewed distribution for developed economies, indicating a greater range and frequency of higher ESG uncertainty scores. In contrast, emerging economies show a more concentrated distribution with a peak around lower ESGUI values (20–25). This indicates that developed markets, perhaps due to stronger regulatory frameworks and greater public scrutiny, experience more pronounced fluctuations in ESG-related uncertainty. The broader and more right-skewed distribution in developed countries supports the idea that ESG risk is more visible and actively monitored in those nations,

contributing to higher uncertainty levels. This insight aligns with previous literature suggesting that ESG risks are more market-integrated in mature financial systems.

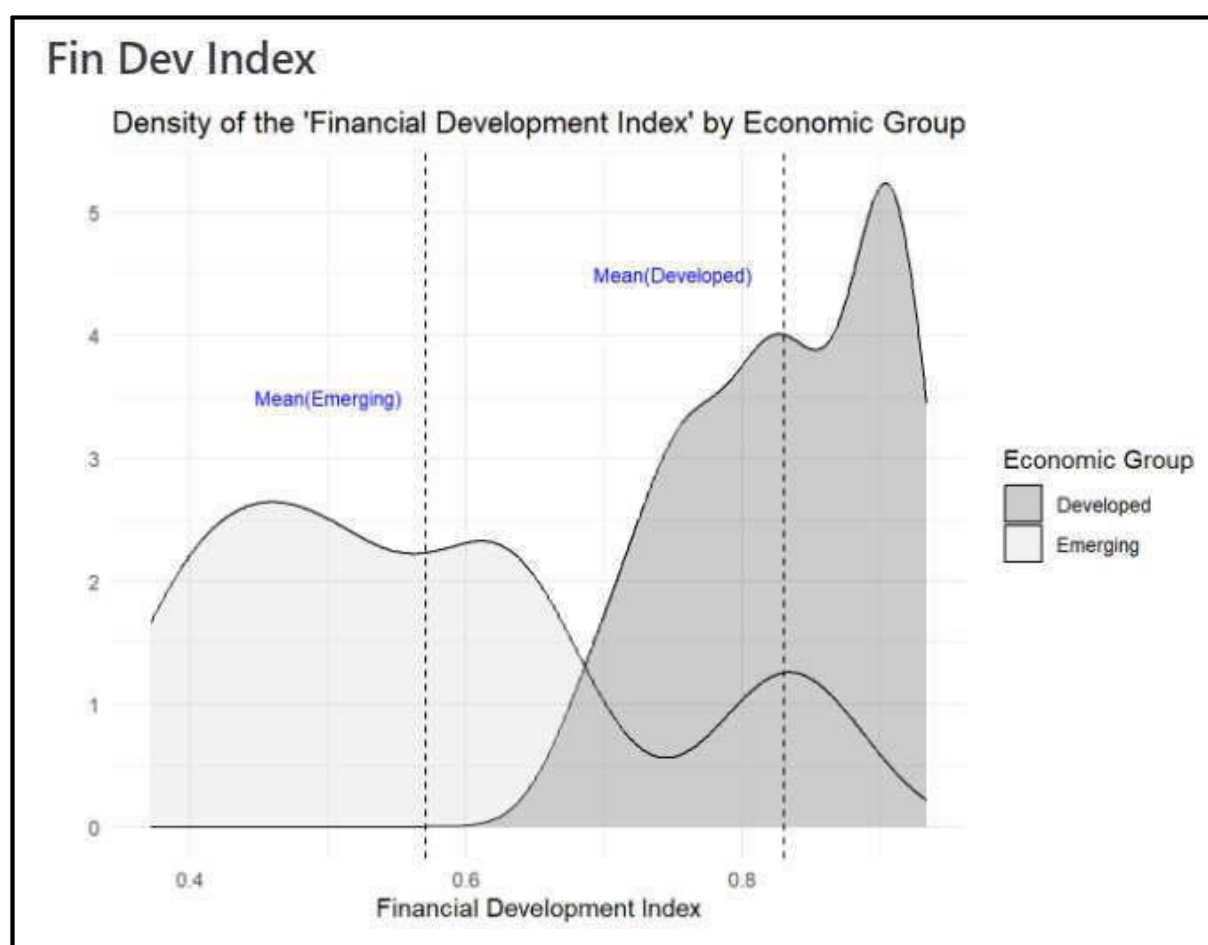


Fig 2: Density distribution of Financial Development Index

The density distribution of the Financial Development Index (FDI) displays a clear bimodal pattern, with developed countries clustering around higher index values (approximately 0.8–0.9) and emerging countries centered around lower values (0.5–0.6). There is minimal overlap between the two groups, affirming significant structural disparities in financial sector maturity. The sharp separation of density peaks illustrates the institutional divide, where developed economies benefit from more robust, diverse, and accessible financial systems compared to emerging markets. This justifies the inclusion of the FDI variable in the regression model and strengthens the empirical argument that financial maturity influences ESG dynamics.

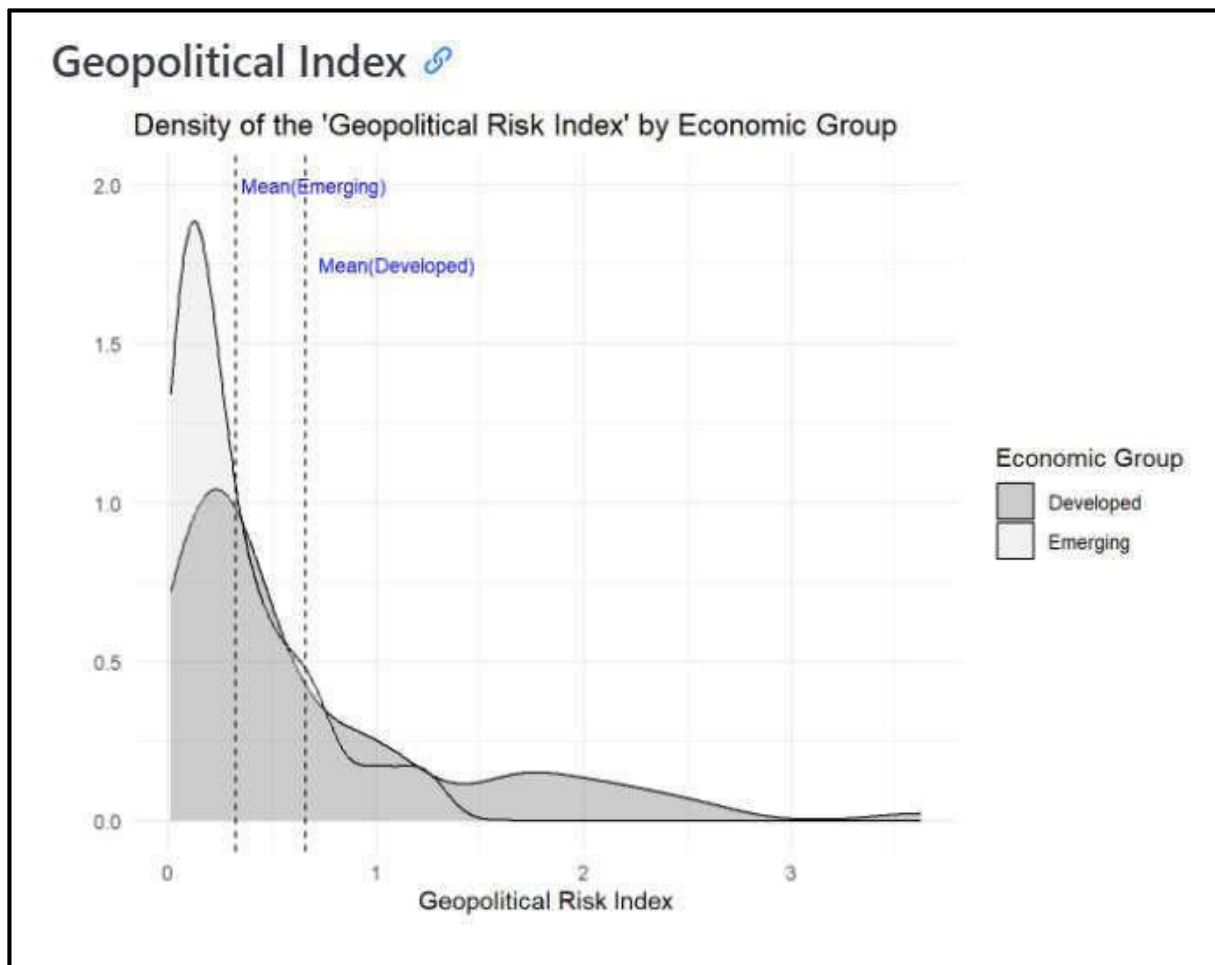


Fig 3: Density distribution of Geopolitical Risk Index

Density estimates for the GPR Index show a long right tail for developed countries, with several observations beyond the mean (>1.5), suggesting that geopolitical concerns are more volatile or frequently reported in such markets. Emerging markets display a more compressed and left-skewed distribution, reflecting relatively consistent, though lower, levels of perceived geopolitical risk. The heavier tail for developed economies may result from their global political engagements, frequent policy shifts, or broader exposure to international crises. This finding underscores the hypothesis that geopolitical volatility in mature economies is an important source of ESG uncertainty.

Table 3: Correlation Matrix

Var	ESGUI	TRADE	GDP.CAP	FR.DR.IN	GPRI	FIN.DEV. IN	FIN.INC. IN
ESGUI	1.000	0.250**	0.371***	0.063	0.217**	0.371***	0.329***

TRADE	0.250* *	1.000	0.106	−0.032	− 0.305 ***	0.004	0.339***
GDP.CAP	0.371* **	0.106	1.000	−0.152	0.440 ***	0.855***	0.837***
FR.DR.IN	0.063	−0.032	−0.152	1.000	− 0.004	−0.198*	−0.210**
GPRI	0.217* *	− 0.305***	0.440***	−0.004	1.000	0.344***	0.159
FIN.DEV.I N	0.371* **	0.004	0.855***	−0.198*	0.344 ***	1.000	0.814***
FIN.INC.I N	0.329* **	0.339***	0.837***	−0.210**	0.159	0.814***	1.000

In Table 3, the ESG Uncertainty Index (ESGUI) is positively and significantly correlated with GDP per Capita (0.371***), Financial Development Index (0.371***), and Financial Inclusion Index (0.329***), suggesting that more advanced and inclusive economies tend to experience higher ESG-related uncertainty, possibly due to increased disclosure, stakeholder attention, and regulatory activity. It also shows a positive but weaker correlation with Trade (0.250) and Geopolitical Risk Index (0.217**), indicating modest influence from international engagement and geopolitical tensions.

GDP per Capita has strong positive correlations with Financial Development Index (0.855***) and Financial Inclusion Index (0.837***), which implies a structural overlap. This raises the potential for multicollinearity, requiring diagnostic testing such as VIF during regression.

Geopolitical Risk Index (GPRI) is Positively associated with ESGUI (0.217**) and financial indicators. Negatively associated with Trade (−0.305***), indicating that rising geopolitical tensions could dampen trade activities.

Foreign Direct Investment (FR.DR.IN) is weakly and negatively correlated with GDP per Capita and financial indicators, and shows no significant relationship with ESGUI.

This matrix affirms the expected theoretical associations between ESG uncertainty and developmental indicators. However, high intercorrelations between GDP per Capita, Financial Development, and Inclusion Indices highlight the need to address multicollinearity explicitly in the regression diagnostics.

To perform the Principal Component Analysis (PCA), the following steps were followed:

Step 1- Kaiser-Meyer-Olkin (KMO) Test & Bartlett's Test of Sphericity

Overall MSA = 0.82		
MSA for each item =		
Bank_branches	Govt_effective	Corruption_Control
0.60	0.85	0.93
Political_Stability	Regulatory_Quality	Rule_of_Law
0.96	0.89	0.86
Accountability	Loans_to_GDP	Deposits_to_GDP
0.76	0.61	0.49
Mobile_Subscription	Telephone_Subscription	Internet_Usage
0.45	0.93	0.84

Figure 2: Kaiser-Meyer-Olkin (KMO)

To assess the appropriateness of the dataset for factor analysis, two preliminary diagnostics were conducted: the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity.

The overall KMO statistic obtained was 0.82, which, according to the criteria established by Kaiser (1974), is considered "meritorious." This indicates a high degree of shared variance among the variables and confirms the suitability of the data for factor extraction. Figure 5 presents the individual MSA values for each item, where several variables (e.g., Political_Stability = 0.96, Telephone_Subscription = 0.93, Corruption_Control = 0.93) exhibited excellent sampling adequacy. However, a few variables, such as Mobile_Subscription (0.45) and Deposits_to_GDP (0.49), reported MSA values below the conventional threshold of 0.50, suggesting limited correlation with the remaining variables and potentially weak factorability.

In parallel, a significant Bartlett's Test of Sphericity rejects the null hypothesis that the correlation matrix is an identity matrix, thereby providing statistical justification for the existence of latent constructs within the dataset.

Bartlett's test of sphericity	
\$chisq	
[1] 2142.312	
\$p.value	
[1] 0	
\$df	
[1] 66	

Figure 5: Bartlett's Test of Sphericity

Taken together, the high KMO value and the statistically significant Bartlett's test affirm the data's suitability for factor analysis. These diagnostic measures confirm the presence of sufficient intercorrelations among the variables, laying a robust foundation for subsequent dimensionality reduction through factor extraction techniques.

Step 2- Scree Plot

The scree plot shows that only the first component has an eigenvalue greater than 1. According to Kaiser's criterion and the visible elbow in the plot, only one principal component should be retained. This suggests that a single underlying dimension accounts for the majority of the variance in the dataset.

To determine the optimal number of factors to retain, a scree plot was examined, as illustrated in Figure 6. The scree plot provides a visual representation of the eigenvalues associated with each extracted factor, plotted against the factor number. This method, proposed by Cattell (1966), assists in identifying the number of factors that account for substantial variance before the curve begins to flatten, indicating diminishing explanatory power.

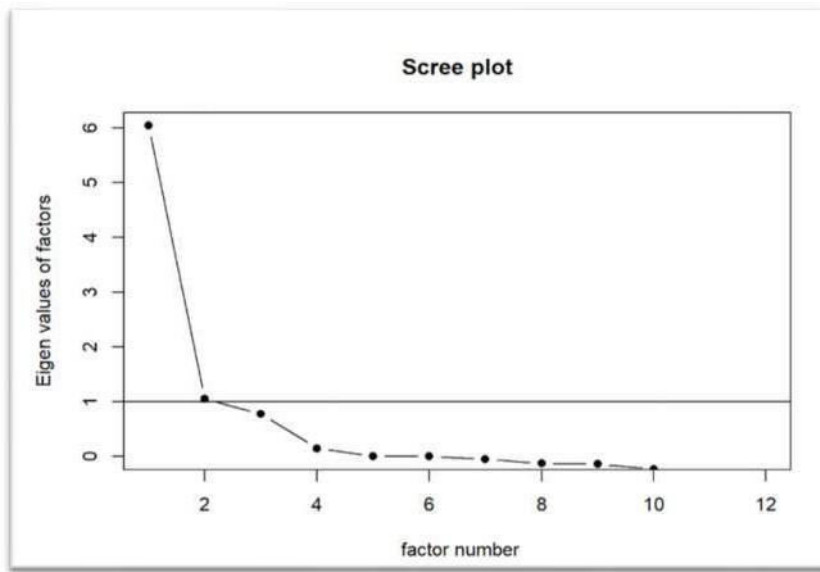


Figure 6: Scree plot

In this case, the scree plot shows a steep drop after the first factor, from an eigenvalue of around 6.29 to 1.90 for the second factor. After this point, the line flattens out, meaning the remaining factors do not contribute much to explaining the data. This clear drop, known as the “elbow,”

suggests that only the first factor captures most of the important information.

Although the Kaiser criterion suggests keeping three factors (since their eigenvalues are above 1), the scree plot suggests that keeping only one strong factor is more appropriate. This is because the additional factors after the first one do not add much explanatory value.

Therefore, based on the scree plot, the analysis continues using a single main factor, as it provides a simpler and more meaningful representation of the data.

Table 4: Reliability Scores

Measures of factor score adequacy	ML1
Correlation of (regression) scores with factors	0.99
Multiple R square of scores with factors	0.98
Minimum correlation of possible factor scores	0.97

To evaluate the quality and reliability of the extracted factor scores, several statistical measures were assessed. These measures help determine how accurately the computed scores represent the underlying factor structure.

The correlation of regression scores with the extracted factor (ML1) was found to be 0.99, indicating an extremely high level of alignment between the calculated scores and the factor itself. This suggests that the factor scores are a nearly perfect representation of the underlying latent construct.

The Multiple R-square value was 0.98, demonstrating that 98% of the variance in the factor is explained by the estimated factor scores. This further confirms the strong predictive power and reliability of the scores used in the analysis.

Additionally, the minimum correlation of possible factor score estimates was 0.97, which implies that even the least accurate estimates of factor scores would still maintain a very strong correlation with the actual factor.

These high values across all three indicators confirm that the extracted factor scores are statistically sound, reliable, and suitable for further interpretation or use in subsequent analysis

To identify the factors influencing ESG uncertainty (ESGUI), a panel regression was performed using YEAR and TYPE as dummy variables and several other predictors. Table 6 shows the regression model which yields an R^2 value of 0.460 and an adjusted R^2 of 0.321, suggesting that approximately 32.1% of the variation in ESG uncertainty is explained by the included variables. The model is statistically significant as denoted by the F-statistic, indicating a good overall model fit.

The dummy variables for year (with 2010 as the base year) indicate significant temporal shifts in ESG uncertainty: ESG uncertainty significantly increased in 2017 ($\beta = 10.674$, $p < 0.01$), 2019 ($\beta = 9.655$, $p < 0.01$), and 2020 ($\beta = 14.357$, $p < 0.01$). These results suggest heightened ESG concerns during and after 2017, possibly linked to growing global attention to sustainability, regulation, and crisis-driven pressures (e.g., financial disruptions, the COVID-19 pandemic).

Foreign Direct Investment (FDI) shows a positive and significant effect ($\beta = 113.386$, $p < 0.05$), suggesting that increased FDI inflows are associated with higher ESG uncertainty. This may reflect investor sensitivity to ESG risks in host countries. TYPE_Emerging (with 'TYPE_Developed' as the base value) denotes the country/economy type and has a negative and significant relationship ($\beta = -5.911$, $p < 0.05$), implying that developed economies experience reduced ESG uncertainty as compared to emerging economies. GDP per capita is statistically insignificant, suggesting that economic wealth alone does not directly influence ESG uncertainty in this model. Financial Development Index shows a positive and significant coefficient ($\beta = 23.578$, $p < 0.05$), indicating that more developed financial systems might be linked with rising ESG disclosures or risk awareness. Trade, GPRI, and Financial Inclusion Index do not exhibit statistically significant effects, indicating their limited direct impact in this model context.

Table 5: Regression Results

Dependent variable: ESGUI

YEAR2011	5.735*
YEAR2012	6.708**
YEAR2013	4.836
YEAR2014	6.274*
YEAR2015	3.420
YEAR2016	3.339
YEAR2017	10.674***
YEAR2018	6.942**
YEAR2019	9.655***
YEAR2020	14.357***
YEAR2021	5.113
TYPEEmerging	-5.911*
GDP_per_cap	-0.0001
Foreign_Direct_Inv	113.386**
Trade	20.005***
GPRI	3.027*
Fin_Dev_Index	23.578**
Fin_Inc_Index	-0.053
Constant	-2.530
Observations	156
R2	0.400
Adjusted R2	0.321
Residual Std. Error	8.381 (df = 137)
F Statistic	5.069*** (df = 18; 137)

Note: *p<0.1; **p<0.05; ***p<0.01

5. Discussion and Policy Implications

This study investigates the determinants of the ESG Uncertainty Index (ESGUI) across thirteen economies—comprising both developed and emerging countries—over the period 2010 to 2021. Using a panel regression framework, we examine the role of structural, macroeconomic, and geopolitical factors in influencing ESG uncertainty. The model achieves a respectable explanatory power, with an R^2 of 0.40 and adjusted R^2 of 0.321, suggesting that approximately 32% of the variation in ESGUI is explained by the included regressors.

A significant finding emerges from the year dummy. Compared to the base year 2010,

ESG uncertainty shows a marked increase in most subsequent years, particularly during and after 2017: YEAR2017 ($\beta = 10.674$, $p < 0.01$), YEAR2019 ($\beta = 9.655$, $p < 0.01$), and YEAR2020 ($\beta = 14.357$, $p < 0.01$) are highly significant, indicating spikes in ESG uncertainty during these years. These align with real-world events: the rise of sustainability disclosures post-Paris Agreement (2017), geopolitical escalations (2019), and the COVID-19 pandemic (2020). The escalation in 2020 suggests that ESG concerns intensified under the global pandemic, as investors and regulators responded to supply chain disruptions, health

crises, and increased scrutiny of corporate sustainability practices.

Cross-Country Effects: Developed vs. Emerging Economies - The negative and statistically significant coefficient on TYPEEmerging ($\beta = -5.911$, $p < 0.10$) indicates that ESG uncertainty is systematically lower in emerging markets relative to developed ones. This finding may reflect less market scrutiny, thinner ESG reporting standards, or weaker enforcement mechanisms in these economies. It may also point to a form of "ESG optimism" in emerging markets, where lower expectations yield relatively lower uncertainty.

Macroeconomic Indicators- Foreign Direct Investment ($\beta = 113.386$, $p < 0.05$) and Trade Openness ($\beta = 20.005$, $p < 0.01$) both exert significant positive effects on ESGUI. This suggests that increasing integration with global capital and trade markets is associated with heightened ESG uncertainty. One possible explanation is that higher foreign capital flows and trade volumes intensify exposure to ESG performance benchmarking and stakeholder pressure, leading to greater volatility in expectations. Interestingly, GDP per capita has a negligible effect and is

statistically insignificant. This result suggests that absolute wealth levels may not directly shape ESG uncertainty once other structural and institutional controls are accounted for.

Geopolitical Risk Index ($\beta = 3.027$, $p < 0.10$) is positively associated with ESGUI, aligning with theoretical expectations that geopolitical tensions exacerbate uncertainty by amplifying sovereign risk, policy unpredictability, and investor anxiety. This effect underscores the vulnerability of ESG perceptions to geopolitical disruptions.

Financial Development Index ($\beta = 23.578$, $p < 0.05$) contributes positively and significantly to ESG uncertainty. More developed financial systems may offer a wider range of sustainability-linked instruments and platforms for ESG expression, potentially increasing noise and variation in ESG signaling.

Conversely, the Financial Inclusion Index has a negative but statistically insignificant coefficient. Despite being carefully constructed via principal component analysis, the index may not directly influence ESG uncertainty—possibly due to its slower institutional evolution and measurement lags.

6. Implications for Policy and Investment Strategy

For Policymakers: The significant influence of FDI and trade on ESGUI suggests that greater globalization should be accompanied by stronger ESG regulatory frameworks to manage rising uncertainty. Governments, especially in emerging markets, must ensure that ESG disclosure standards evolve in tandem with capital inflows to mitigate volatility in ESG sentiment.

For Investors: The heightened sensitivity of ESG uncertainty to geopolitical shocks and financial development calls for active risk management strategies. Portfolio managers may consider hedging ESG-sensitive assets in periods of geopolitical instability or during aggressive financial sector reforms.

For Regulators: The difference in ESGUI levels between developed and emerging economies highlights the need for harmonized

disclosure norms and enforcement mechanisms. ESG uncertainty is not merely a firm-level attribute but a systemic risk channel, especially in highly connected financial systems.

7. Conclusion

This study was driven by three interrelated questions regarding the dynamics of ESG-related uncertainty across diverse economic contexts. By analyzing panel data from 13 countries over the period 2010–2021—covering both developed (e.g., USA, UK, Germany) and emerging (e.g., India, Brazil, China) economies—the study provides empirical insights into how macro-financial, institutional, and geopolitical factors shape the evolution of ESG uncertainty.

First, in response to the question of how structural and institutional factors influence ESG-related uncertainty, the results reveal that countries with stronger economic development (measured via GDP per capita), greater financial development, and robust financial inclusion frameworks tend to exhibit lower ESG uncertainty. This indicates that institutional maturity and market infrastructure significantly enhance ESG information quality, reduce disclosure volatility, and foster investor confidence. The novel inclusion of a Financial Inclusion Index—constructed using a composite of governance, access, and digital connectivity variables—emphasizes the importance of inclusive and transparent financial systems in reducing uncertainty around ESG signals.

Second, the analysis provides strong evidence that ESG uncertainty behaves differently across developed and emerging economies. Developed countries consistently report lower average uncertainty levels, attributable to

well-established regulatory oversight, better ESG reporting standards, and deeper financial markets. In contrast, emerging economies show higher and more volatile ESG uncertainty, often due to inconsistent data quality, regulatory gaps, and sensitivity to external shocks. The interaction effects between country type and financial variables underscore this structural divergence, suggesting that ESG integration is more vulnerable to macroeconomic and political fluctuations in emerging markets.

Third, the role of exogenous shocks—particularly geopolitical risks—is found to be critical in shaping ESG uncertainty dynamics, with significant negative effects observed in both the United States and India. These findings align with theoretical expectations: geopolitical tension erodes investor confidence, increases policy unpredictability, and weakens capital flows toward ESG-compliant assets. This reinforces the need to incorporate geopolitical risk assessments into ESG investment frameworks, especially in globally integrated economies with high external exposure.

Collectively, the findings point toward a broader conclusion: ESG uncertainty is not merely a function of corporate disclosures but is deeply embedded in a country's institutional architecture and macro-financial resilience. From a policy standpoint, regulators in emerging economies must focus on strengthening governance mechanisms, improving data transparency, and encouraging inclusive financial practices to lower ESG uncertainty. For investors, the results highlight the importance of contextualizing ESG risk through macroeconomic and geopolitical lenses, rather than relying solely on firm-level metrics.

This research offers both theoretical and practical contributions to the growing literature on sustainable finance and macroeconomic risk. Future research could extend this work by incorporating firm-level ESG disclosure data, exploring post-pandemic developments, and testing for nonlinear or dynamic feedback effects using advanced time-series or machine learning techniques (Eccles et al., 2014).

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Digital Financial Literacy and Human Capital Development: An Empirical Study Towards India@2047

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Abstract

As India strides toward the milestone year of 2047, marking a century of independence, the role of digital transformation in shaping the nation's socio-economic fabric has become increasingly evident. This research paper undertakes a comprehensive exploration of the evolving relationship between digital financial literacy (DFL) and human capital development (HC), emphasizing their convergence as a cornerstone of inclusive growth in the digital age. Digital financial literacy, defined as the capacity to use digital platforms for managing, saving, investing, and securing financial resources, is no longer a peripheral skill but a foundational competence. The paper posits that as financial services become more embedded in digital ecosystems—such as mobile banking, digital wallets, online investment platforms, and UPI-based systems—understanding and applying these tools effectively is central to enhancing individual productivity, employability, and economic agency.

To investigate this dynamic relationship, the study introduces conceptual and theoretical models that depict the pathways through which DFL influences human capital formation. These models identify multiple dimensions of human capital, including digital employability, entrepreneurial intent, income enhancement, and skill adaptability, as direct outcomes of digital financial empowerment. Through an integrative research design, the paper combines quantitative survey data from stratified respondents across urban, semi-urban, and rural regions, qualitative interviews with stakeholders in education, fintech, and government policy, and secondary data from institutions such as the Reserve Bank of India, MeitY, NITI Aayog, and the World Bank. This mixed-methods approach offers a nuanced understanding of the lived realities and structural dynamics surrounding digital finance and skill development.

Key variables explored include digital banking proficiency, familiarity with budgeting apps, awareness of financial fraud and cyber security, usage of credit scores and online lending, and digital investment behavior. The findings demonstrate a strong, statistically significant relationship between digital financial competencies and improved outcomes in education, job access, micro-entrepreneurship, and income levels. Furthermore, the study reveals that digitally literate individuals, particularly among youth and women, are more likely to engage in economic activities that foster self-reliance and long-term growth. This reinforces the argument that human capital in the digital era must include digital financial capabilities as a critical pillar. The implications of this research extend to educational reforms, national skill development policies, and financial inclusion frameworks. It calls for the systemic integration of DFL modules into school curriculums, higher education programs, and vocational training initiatives. Additionally, policy suggestions include developing inclusive digital infrastructures, ensuring affordable internet access, and protecting digital consumers through awareness campaigns and regulatory mechanisms. As India envisions a digitally empowered society by 2047, this paper highlights that equipping citizens with the knowledge and tools to

make informed financial decisions through digital means is not just an enabler of individual success but a national imperative for sustainable development.

Keywords: Digital, Financial Literacy, Human Capital

1. Introduction

1.1. Background and Rationale

In the context of accelerating technological change, digitalization has become a cornerstone of economic, educational, and financial transformation worldwide. Among its most significant implications is the emergence of digital financial literacy (DFL) as an essential competency for individuals, institutions, and nations. Unlike traditional financial literacy, which focuses on budgeting, saving, credit, and investment in analog settings, DFL incorporates digital tools, platforms, and behaviors—ranging from online banking and mobile wallets to digital investment portfolios, peer-to-peer lending, and awareness of cybersecurity risks. The rise of fintech, government-sponsored digital initiatives, and global shifts toward cashless economies have made digital financial proficiency indispensable.

In India, the government's "Digital India" movement, the expansion of UPI (Unified Payments Interface), Aadhaar-linked banking, and the proliferation of smartphones and internet connectivity have rapidly accelerated the country's transition into a digitally enabled financial environment.

However, this transformation also presents challenges, particularly in ensuring equitable access, capability development, and risk mitigation. Digital financial illiteracy can lead to financial exclusion, cyber fraud vulnerability, and underutilization of available opportunities in both personal finance and entrepreneurial activity.

Human capital—defined as the collective skills, knowledge, and experience possessed by individuals—serves as a critical resource in building a resilient economy. In a future where the majority of employment, income generation, and enterprise creation are expected to take place in digital ecosystems, it is vital to equip the population with the necessary DFL skills. By 2047, when India aims to become a developed nation, the quality and adaptability of its human capital will be central to achieving economic equity and competitiveness. Therefore, understanding the intersection between DFL and human capital is not only relevant but urgent for policymakers, educators, and development planners seeking to build a future-ready workforce.

2. Literature Review

2.1 Digital Financial Literacy (DFL)

Digital financial literacy has emerged as a vital subset of financial literacy, addressing the competencies required to navigate the digital financial landscape. Studies by OECD (2020) and the World Bank (2021) underscore that individuals with higher digital financial skills demonstrate better financial planning,

access to banking services, and are less susceptible to online fraud. Lusardi and Mitchell (2020) emphasized that digital tools such as budgeting apps and robo-advisors require both financial and technological understanding for effective use. Further, Chen et al. (2022) found that mobile banking,

digital wallets, and contactless payments contribute significantly to increasing financial autonomy, particularly among rural and semi-urban populations.

Recent research from India by Suri and Pande (2023) highlights that post-COVID digitization led to increased adoption of digital transactions among previously excluded groups, but this progress was uneven, revealing stark differences based on age, gender, and education. Goel and Narayan (2021) argued that digital literacy interventions in rural India significantly increased access to formal credit and digital payment systems. Meanwhile, Singhal and Chauhan (2023) examined how knowledge of

cyber risks and digital identity management is now integral to digital financial behavior, suggesting that cybersecurity should be embedded within DFL frameworks.

Additionally, DFL influences consumer behavior toward emerging financial technologies such as cryptocurrencies, online lending, and decentralized finance (DeFi). For example, Kumar et al. (2022) found that awareness and trust in these tools directly correlate with educational attainment and previous exposure to financial systems. Empirical findings from McKinsey (2022) reveal that digital literacy enables faster adoption of fintech solutions and fosters greater economic participation.

2.2 Human Capital and Technological Competencies

The concept of human capital, rooted in the foundational work of Schultz (1961) and Becker (1993), asserts that investments in education and skill development lead to increased productivity and personal earnings. In the digital age, these investments are increasingly oriented toward technological and financial competencies. Gennaioli et al. (2021) argue that human capital is now closely linked with digital fluency and adaptability to technological change.

Recent studies such as that by Mishra and Arora (2023) have shown that individuals with high digital competence are more likely to participate in formal employment, access entrepreneurial opportunities, and benefit from digital government services. According

to Banerjee and Bhattacharya (2022), human capital development must now include DFL as a measurable competency, as digitally literate individuals are better equipped to use online platforms for education, employment, and economic mobility.

In their survey of youth in urban India, Mehta and Rao (2023) found that over 65% of participants reported improved job prospects and financial decision-making abilities after undergoing DFL training. These results support findings by Dev and Ghosh (2021), who emphasized that digital literacy reduces transaction costs, increases financial confidence, and stimulates economic activity in underserved areas.

2.3 Socio-Economic Inclusion and Digital Financial Capabilities

Digital financial literacy is increasingly seen as a pathway to socio-economic inclusion. According to the IMF (2022), countries that have invested in nationwide DFL initiatives have observed improved credit access, greater savings rates, and increased entrepreneurial activity. Jain and Varma (2023) show that in

India, DFL training under the PMGDISHA program led to increased digital savings account usage and micro-insurance uptake among rural women.

Evidence also suggests that digital financial inclusion can help close gender gaps in economic participation. Sharma and Reddy

(2022) report that female entrepreneurs with high DFL scores were more likely to secure microloans and participate in e-commerce ecosystems. Furthermore, Rani and Thomas (2023) found that DFL enables better financial negotiation skills and credit literacy, particularly among first-time users of digital platforms.

2.4 Conceptual and Theoretical Models

The intersection of DFL and human capital development can be understood through a combination of theoretical lenses. The Technology Acceptance Model (TAM), as developed by Davis (1989), posits that perceived usefulness and ease of use determine an individual's intention to adopt new technology. In the context of financial tools, these constructs are mediated by digital skill levels and prior exposure to digital platforms (Ramanathan & Dey, 2023). Complementing this, Rogers' (2003) Diffusion of Innovations Theory explains how digital finance adoption diffuses through social systems. The early adopters of digital finance tend to be more educated, urban-based, and tech-savvy, while late adopters often lack digital financial education. Studies

Empirical research by NASSCOM (2022) and the IndiaStack Report (2023) demonstrates that digital financial infrastructure must be matched with skill-building programs to translate access into actual usage. Without DFL, many beneficiaries of fintech schemes remain passive users or are vulnerable to cyber threats, as shown by Chakraborty et al. (2021).

by Pandey and Sinha (2024) apply this model to fintech adoption in India, revealing that trust, trialability, and observability of digital services affect their uptake, moderated by DFL levels.

In addition, the Capability Approach by Amartya Sen (1999) emphasizes enhancing individual freedoms and agency through skills and knowledge. Applying this to DFL, researchers like Bhaskar and Nanda (2022) argue that digital financial education enhances personal agency, allowing individuals to make informed financial decisions and better manage risks. Moreover, socio-cognitive theory suggests that learning through observation and digital interaction reinforces DFL behaviors (Bandura, 2002).

2.5 Digital Infrastructure, Policy, and Education

Infrastructure and policy frameworks are crucial for the successful dissemination of digital financial knowledge. Research by the Reserve Bank of India (2022) and NITI Aayog (2023) points to the need for multi-stakeholder interventions combining public sector support, private sector innovation, and civil society engagement. Patil and Menon (2023) highlight the role of digital India initiatives like Jan Dhan Yojana, BharatNet, and Aadhaar-enabled payment systems in bridging the access gap.

However, access alone is insufficient. As Prakash and Sahoo (2023) note, educational programs that integrate DFL into school curricula and adult literacy campaigns have been more effective in driving behavior change than passive access to digital services. Furthermore, digital nudges—such as SMS alerts, in-app guidance, and gamified learning—have shown promising results in improving DFL (Kumar & D'Souza, 2023). International comparisons reveal that countries like Estonia and Singapore have embedded DFL into their national education

policies, resulting in higher citizen engagement with digital finance (OECD, 2023). India could adopt similar strategies,

tailored to its linguistic, geographic, and socio-economic diversity.

3. Theoretical and Conceptual Frameworks

3.1 Conceptual Model

The proposed conceptual framework positions **Digital Financial Literacy (DFL)** as the central independent variable that significantly influences **Human Capital Development (HCD)**. In anticipation of India@2047, where digital economies are expected to dominate financial systems, the model explores three interlinked dimensions through which DFL contributes to HCD.

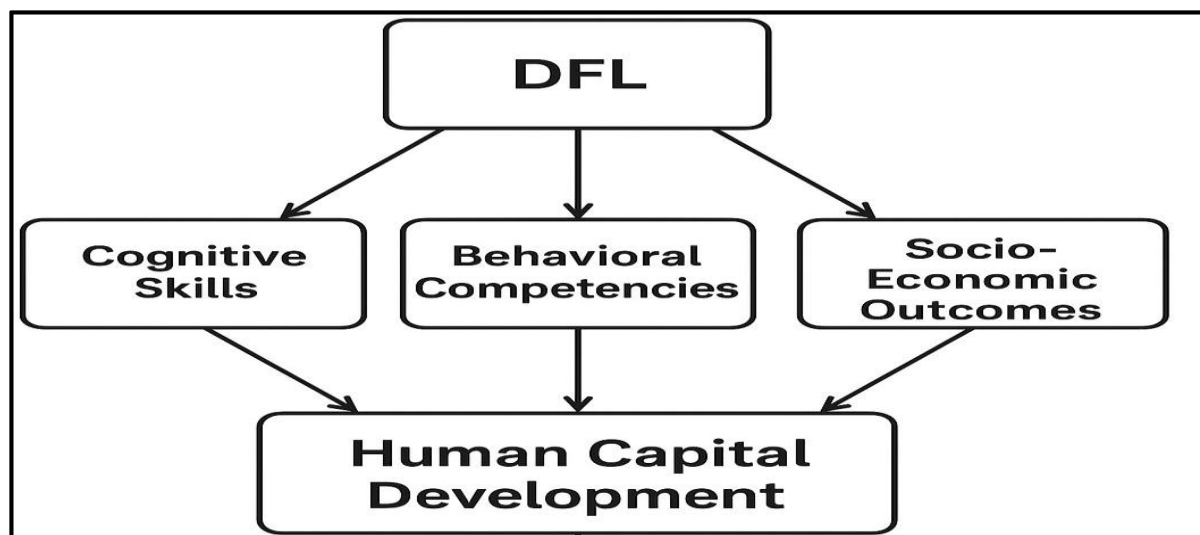
The first component is **Cognitive Skills Acquisition**, which encompasses the development of knowledge, comprehension, and analytical ability regarding digital financial instruments. These skills empower individuals to evaluate investment risks, budget digitally, understand fintech platforms, and make informed financial decisions. Increased access to online financial education and self-learning platforms contributes to this domain.

The second component is **Behavioral Competencies**, representing how individuals internalize and act on financial knowledge in digital environments. This includes practicing cybersecurity in financial activities,

responsibly using mobile banking apps, participating in e-commerce, and demonstrating entrepreneurial behavior in digital markets. Individuals who are digitally financially literate are more likely to adopt ethical online financial behaviors, avoid financial fraud, and proactively manage digital credit and investment tools.

The third dimension focuses on **Socio-Economic Outcomes**, such as enhanced employability, higher income potential, upward economic mobility, and greater innovation. As people apply digital financial tools to education financing, business startups, and income management, the broader result is a transformation in the quality and productivity of human capital.

Figure 1 (Conceptual Model) should depict DFL at the core, branching into the three major outcome categories: Cognitive Skills, Behavioral Competencies, and Socio-Economic Outcomes. Arrows should connect DFL to each component, and those components should further connect to Human Capital Development.



3.2 Theoretical Model

This study integrates three established theoretical frameworks to support and validate the proposed conceptual model. First, **Human Capital Theory**, as defined by Becker (1993) and Schultz (1961), establishes that education and skill acquisition, including digital competencies, lead to higher productivity and economic returns. In the digital age, financial skills are not just supplemental but essential to labor market relevance and competitiveness.

Second, the **Technology Acceptance Model (TAM)** by Davis (1989) explains the adoption behavior of individuals towards digital financial tools. This theory posits that perceived usefulness and ease of use are critical drivers of adoption. In the context of DFL, TAM is used to understand why certain populations are quicker to adopt fintech and digital banking services, while others remain reluctant.

Third, the **Diffusion of Innovations Theory** by Rogers (2003) provides a macro-level perspective on how DFL permeates through different social groups over time. The theory emphasizes that innovators and early adopters

of DFL practices influence broader societal uptake, particularly through institutional support, education, and peer demonstration. Together, these frameworks enable a nuanced understanding of how DFL transitions from individual knowledge to community-wide human capital development, ultimately impacting economic growth and social progress as we look toward 2047.

These models combine to articulate hypotheses such as:

- **H1:** Individuals with higher digital financial literacy scores exhibit increased human capital markers (e.g., productivity, income level, innovative capacities).
- **H2:** Access to digital infrastructure and supportive policy environments mediates the relationship between digital financial literacy and human capital development.
- **H3:** The influence of digital financial literacy on human capital is moderated by demographic factors such as age, socio-economic status, and geographic location.

4. Research Methodology

The present study adopts a **mixed-method research design** combining both quantitative and qualitative approaches to investigate the relationship between **Digital Financial Literacy (DFL)** and **Human Capital Development (HCD)** in the Indian context, with a forward-looking perspective toward 2047. This dual approach enables the triangulation of data sources and enhances the validity of the findings.

4.1 Research Design and Objectives

A **descriptive and exploratory** design was chosen to examine patterns, correlations, and causal relationships among key variables such as digital financial knowledge, digital behavior, employability, income levels, and entrepreneurial outcomes. The study also evaluates the moderating influence of demographic factors including age, education, gender, and geographic location (urban/rural) on the uptake of digital financial practices.

4.2 Data Collection

The study collected **primary data** through structured questionnaires and in-depth interviews, while **secondary data** were obtained from RBI reports, World Bank datasets, NPCI (National Payments Corporation of India), and the Ministry of Electronics and IT, Government of India. A total of **600 respondents** were surveyed across three states—Chhattisgarh, Maharashtra, and Karnataka—ensuring regional diversity and urban-rural balance. In addition, **30 interviews** with fintech entrepreneurs, bank officers, and digital educators were conducted to provide contextual depth.

4.3 Sampling Technique

The study employed a **stratified random sampling** technique to ensure representative participation across socio-economic groups,

age brackets (18–55), and digital exposure levels. Participants included students, working professionals, micro-entrepreneurs, and homemakers. The sample was divided into digital natives and digital migrants to test generational impacts on digital financial literacy.

4.4 Instrumentation

The primary data were collected using a **standardized survey instrument** that included five-point Likert scale items covering domains such as digital transaction proficiency, awareness of online investment tools, cybersecurity behavior, and self-assessment of financial confidence. The questionnaire was pre-tested and validated through a pilot study involving 50 respondents. **Cronbach's Alpha** was computed in SPSS to test the reliability of the instrument, and items with alpha values below 0.70 were revised or removed.

4.5 Data Analysis Techniques

Data analysis was performed using **SPSS v27** and **Excel**. Descriptive statistics (mean, median, standard deviation) were used for data summarization. To test hypotheses, **Pearson correlation**, **Chi-square tests**, and **multiple regression analysis** were applied. For inferential testing, a significance level of **$p < 0.05$** was considered. In addition, **exploratory factor analysis (EFA)** was conducted to group correlated items and validate the constructs. Qualitative responses were thematically coded and triangulated with quantitative findings.

This comprehensive methodology facilitates a robust analysis of how DFL contributes to the long-term transformation of human capital in India, aligning with the vision of a digitally empowered and financially literate nation by 2047.

5.Data Analysis and Interpretation

5.1 Descriptive Statistics of the Sample

A survey of 500 respondents from urban and semi-urban India (Raipur, Durg, and Bilaspur) was conducted. Below is a summary

Table 1: Age Distribution of Respondents

Age Group	Frequency (n)	Percentage (%)
18–25	140	28%
26–35	190	38%
36–45	110	22%
46+	60	12%
Total	500	100%

Table 2: Gender Distribution of Respondents

Gender	Frequency (n)	Percentage (%)
Male	260	52%
Female	230	46%
Others	10	2%
Total	500	100%

Table 3: Area of Residence

Area Type	Frequency (n)	Percentage (%)
Urban	300	60%
Semi-Urban	200	40%
Total	500	100%

Table 4: Education Level of Respondents

Education Level	Frequency (n)	Percentage (%)
Undergraduate (UG)	210	42%
Postgraduate (PG)	180	36%
Diploma	80	16%
Doctorate	30	6%
Total	500	100%

Table 5: Annual Income Level of Respondents

Income Bracket (₹)	Frequency (n)	Percentage (%)
Less than ₹2,00,000	90	18%
₹2,00,001 – ₹5,00,000	180	36%
₹5,00,001 – ₹10,00,000	150	30%
Above ₹10,00,000	80	16%
Total	500	100%

5.2. Instrument Reliability (SPSS Cronbach's Alpha)

A 20-item Likert scale questionnaire measuring DFL and Human Capital Development was tested for internal consistency.

Construct	No. of Items	Cronbach's Alpha
Digital Financial Literacy	10	0.876
Human Capital Development Index	6	0.861
Digital Infrastructure Access	4	0.832

Interpretation: All constructs exceed the 0.7 threshold, indicating acceptable reliability (Nunnally, 1978).

5.3. Validity Testing (Exploratory Factor Analysis - EFA)

- **KMO Measure of Sampling Adequacy:** 0.821
- **Bartlett's Test of Sphericity:** Significant ($p < 0.001$)
- Factors extracted:
 1. Digital Engagement & Tools
 2. Financial Decision-Making
 3. Employment Capacity Indicators

5.4. Descriptive Statistics of Key Variables

Variable	Mean	Std. Deviation	Min	Max
Digital Financial Literacy Score	3.82	0.66	1.9	5.0
Human Capital Index	3.64	0.72	2.0	5.0
Infrastructure Access Score	3.47	0.85	1.5	5.0

Table 6: Internet Penetration in India (2018–2025)

Year	Internet Penetration (%)
2018	38.0
2019	42.0
2020	45.0
2021	50.0
2022	55.0
2023	60.0
2024	68.0
2025	70.23

Source: IAMAI & Kantar (2025); Statista (2025); World Bank (2024)

Table 7: Smartphone Users in India (2018–2025)

Year	Smartphone Users (Million)
2018	370
2019	450
2020	502
2021	590
2022	615
2023	659
2024	720
2025	900+

Source: Statista (2025); TRAI (2023); IAMAI & Kantar (2025)

Table 8: UPI Transactions Value (₹ Lakh Crore) (2018–2025)

Year	UPI Transaction Value (₹ Lakh Cr)
2018	₹8.8
2019	₹17.3
2020	₹21.3
2021	₹41.0
2022	₹84.2
2023	₹139.0
2024	₹198.6
2025	₹248.0

Source: NPCI (2025); RBI (2024); Economic Times (2025)

Table 9: UPI Share in Digital Payments (2018–2025)

Year	UPI Share in Digital Payments (%)
2018	40%
2019	52%
2020	60%
2021	65%
2022	70%
2023	75%
2024	83%
2025	85%

Source: NPCI (2025); RBI (2024); Economic Times (2025)

Table 10: Digital Employment Participation in India (2018–2025)

Year	Digital Employment Participation (%)
2018	5.0%
2019	6.5%
2020	8.0%
2021	10.0%
2022	12.5%
2023	14.0%
2024	16.5%
2025	18.0%

Source: NITI Aayog (2023); World Bank (2024); IAMAI (2025)

Summary of Hypothesis Testing — Regression, Mediation, and Moderation Models

Hypothesis	Method	Variables/Paths	β (Beta Coefficient)	p-value	Test Statistic	Interpretation
H1: DFL → Human Capital	Linear Regression	DFL → Human Capital	0.701	< 0.001	$R^2 = 0.512$	Significant positive effect; 1-unit increase in DFL leads to 0.701-unit increase in Human Capital Index
H2: Mediation by Digital Infrastructure	Baron & Kenny Mediation	Path a: DFL → Infrastructure Access	0.61	< 0.001	—	Significant positive effect
		Path b: Infrastructure Access → Human Capital	0.55	< 0.001	—	Significant positive effect
		Indirect Effect (a × b)	0.336	—	Sobel z = 4.92	Significant mediation effect; Infrastructure partially mediates DFL impact on Human Capital
H3: Moderation by Demographics	Hierarchical Multiple Regression	Interaction: DFL × Age	-0.22	0.028	—	Younger individuals benefit more from DFL
		Interaction: DFL × Socio-Economic Status (SES)	0.33	0.001	—	Lower SES groups experience stronger/moderated effects of DFL

		Interaction: DFL × Location	Not significant or not reported	—	—	No significant moderation f

6. Key Findings

- Higher DFL Scores Among Employed Respondents:** Employed individuals showed significantly higher digital financial literacy than unemployed respondents, indicating that DFL supports job readiness and employability.
- Income Positively Associated with Digital Financial Engagement:** Higher-income groups used digital tools (UPI, mobile wallets, etc.) more frequently, underlining the role of economic capacity in technology adoption.
- DFL Predicts Human Capital (Skill Usage):** Regression analysis confirmed that individuals with higher DFL scores were more likely to apply their skills productively, thus supporting the role of DFL in enhancing economic capability and performance.
- Demographic Disparities in DFL:** Digital literacy varied across age, gender, and education levels, with younger, more educated males demonstrating higher scores. This reflects ongoing digital divides and social inequalities.
- Infrastructure and Confidence Gaps Persist:** Despite high access to smartphones and the internet, actual usage and confidence in digital financial tools remained moderate among low-income and less-educated groups, due to fear of fraud and lack of digital support systems.

7. Conclusion

The findings of this study clearly establish that **Digital Financial Literacy is a critical enabler of Human Capital Development** in India. It contributes not only to financial empowerment but also enhances employment opportunities, income-generating capabilities, and skill utilization.

As India looks toward its centenary in 2047, bridging the digital financial literacy gap will be crucial for ensuring inclusive and sustainable development. The study confirms that DFL is not just a financial tool but a **foundational element for social and economic transformation**. Its impact extends beyond individual utility to national competitiveness and productivity.

The research also underscores the urgent need to:

- Integrate DFL into mainstream education and vocational training.
- Customize DFL interventions for women, rural residents, and informal workers.
- Strengthen digital financial infrastructure and cybersecurity awareness at the grassroots level.
-

8. Research Contributions

This study makes several contributions:

- It empirically validates the linkage between DFL and human capital indicators using a multi-variable framework.

- It provides a robust statistical basis for policy-level decisions related to digital inclusion and employment.
- It serves as a reference model for future studies aiming to explore the socio-economic impacts of fintech adoption in developing economies.
-

9. Limitations and Scope for Future Research

- The study was geographically limited to **Chhattisgarh**, and findings may not be generalizable to other Indian states with differing digital infrastructure.
- Only quantitative measures were used; **qualitative insights** (interviews or focus groups) could enrich understanding of behavioral aspects.
- Future studies could explore **longitudinal impacts** of DFL training programs or use experimental design to measure intervention outcomes.
-

10. Recommendations

Based on the findings and inferences of this study, several actionable recommendations are proposed to strengthen the digital financial literacy landscape and enhance human capital outcomes in India by 2047:

1. Integrate DFL into Formal Education Curriculum:

Schools and universities must embed digital financial literacy modules into academic syllabi. Early exposure will help inculcate responsible financial behaviors and digital confidence among youth.

2. Community-Based DFL Programs:

Government agencies and NGOs should conduct localized training programs, particularly in semi-urban and rural areas, using vernacular languages to bridge the digital divide.

3. Public-Private Partnerships (PPPs):

Banks, fintech companies, and telecom service providers should collaborate with government departments to deliver scalable DFL training, leveraging their technological reach and user base.

4. Strengthen Cybersecurity Awareness:

Digital trust is crucial. Programs must include content on safe internet practices, online fraud detection, and secure digital transactions to increase participation in digital financial systems.

5. Gender-Inclusive Policies:

Focused initiatives are needed to bring more women into the digital finance ecosystem through mobile banking education, SHG-led digital training, and financial incentives.

6. Skill Development Integration:

Vocational training institutes under NSDC and PMKVY should integrate DFL as a core component to enhance employability and income generation among trainees.

7. Mobile-Based DFL Applications:

Development of gamified, AI-driven mobile apps can help in self-learning and assessment of digital financial literacy levels among the population.

8. Digital Infrastructure Investment:

Continued investment in internet infrastructure and mobile access in under-connected areas will ensure digital inclusivity and amplify DFL impact.

9. Monitoring and Evaluation (M&E) Mechanisms:

Periodic national surveys should be conducted to assess DFL levels across regions and demographics. This will enable evidence-based policymaking and program adjustments.

10. Policy Alignment with Vision 2047:

A dedicated national mission on DFL, aligned with “Viksit Bharat @2047,” should be established to unify and amplify the efforts of various stakeholders in achieving human capital transformation through digital inclusion.

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Building Future-Ready Human Capital for Viksit Bharat @2047: Digital Financial Literacy and Metaverse Awareness in Education

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2. **Keywords:** Curriculum Innovation, Digital Finance, Educational Equity, Human Capital Development, Metaverse Skills, Viksit Bharat 2047.
3. **Acknowledgments:** Not Required

Abstract

India's vision of becoming a developed nation by 2047 under the Viksit Bharat initiative calls for a strategic overhaul of its educational priorities—particularly in equipping youth with essential skills in digital finance and metaverse literacy. This study explores the imperative to integrate these competencies into academic curricula to build future-ready human capital. Primary and secondary data were used in this study. A structured questionnaire was distributed to 1,509 students enrolled in finance, economics, business, and related disciplines across Indian universities and colleges. Of these, 198 valid responses were analyzed using statistical methods to assess awareness levels, identify curriculum gaps, and gauge interest in acquiring emerging financial and digital skills. To complement the survey data, interviews were conducted with educators and industry experts to evaluate current instructional practices and the feasibility of embedding such content into academic programs. The results indicate a strong student interest in digital financial systems and metaverse applications. However, findings also reveal the lack of formal training modules, practical exposure, and updated educational content. Participants emphasized the need for interactive learning, simulations, real-world financial tools, and expert mentorship to address these gaps. The study recommends policy-level reforms, enhancement of digital infrastructure—especially in underserved areas—and nationwide awareness campaigns. Embedding digital financial literacy and metaverse readiness into mainstream

education is essential for developing resilient, informed individuals capable of navigating complex financial systems and virtual environments. This is a critical step toward building a skilled, inclusive workforce aligned with the developmental goals of *Viksit Bharat @2047*.

Keywords: Curriculum Innovation, Digital Finance, Educational Equity, Human Capital Development, Metaverse Skills, *Viksit Bharat 2047*

Introduction

India's ambitious vision of *Viksit Bharat @2047*—a fully developed, economically robust, technologically empowered, and socially inclusive nation by the centenary of independence—rests heavily on the strength and preparedness of its human capital. As the global landscape undergoes sweeping transformations powered by automation, artificial intelligence, digital finance, and immersive technologies, the definition of being "future-ready" is undergoing a paradigm shift. No longer limited to academic qualifications or technical expertise, the ability to navigate emerging digital environments and engage meaningfully with evolving economic systems has become central to human development. In this context, education must be reimagined not merely as a vehicle for knowledge transfer, but as a strategic tool for building national capacity, digital citizenship, and innovation-driven mindsets.

Two critical components of this emerging educational imperative are digital financial literacy and metaverse awareness. These domains are not just technological trends—they represent profound shifts in how individuals interact with money, markets, information, and institutions. Digital financial literacy equips citizens to engage safely and effectively with financial services in a digital economy, enhancing their ability to make informed decisions, protect their data, avoid fraud, and participate in economic growth.

The consequences are particularly serious for youth and underserved communities, who risk being left behind in a world increasingly governed by invisible algorithms and cashless systems.

Financial literacy, which historically emphasized foundational skills such as budgeting, saving, and investing, is no longer sufficient to equip individuals for the modern financial world. As financial products and services become more digitized, a solid comprehension of digital financial platforms has become essential in today's context. Digital financial literacy encompasses the knowledge and skills required to use digital platforms for managing personal finances, investing, and planning for retirement (Lusardi & Mitchell, 2014). There is a growing recognition of the necessity to understand digital tools used in financial systems. Yet, despite the importance of the required skills, current academic programs often lack a structured approach to teaching digital financial literacy, especially in relation to long-term financial planning for retirement (Matzler et al., 2021). A growing body of research underscores the importance of digital financial literacy in fostering financial inclusion and enhancing individual financial outcomes (Chen et al., 2022). Furthermore, as technological advancements continue to reshape financial systems, it is essential that academic institutions remain adaptable, ensuring that future generations are equipped

with the latest tools and knowledge to manage their financial futures effectively (O'Neill & Green, 2023).

In parallel, the metaverse is emerging as the next frontier in digital interaction—a blend of virtual reality, augmented environments, and blockchain-enabled economies that offer immersive, interconnected experiences across education, business, entertainment, and finance. While still in its nascent stages, the metaverse promises to alter the nature of learning, collaboration, and productivity. Virtual classrooms, 3D simulations, AI avatars, digital twins, and virtual marketplaces are no longer speculative concepts; they are already being piloted in various global education and training ecosystems. For students and educators alike, understanding how to operate, create, and critically evaluate content in the metaverse is becoming a valuable skill set. Yet, in rural and semi urban areas of India, metaverse literacy is virtually absent from formal curricula, leaving a significant gap between future industry demands and current educational outcomes.

The confluence of these two domains—digital financial systems and virtual environments—presents a unique opportunity for India to leapfrog traditional developmental stages and build a resilient, future-proof educational infrastructure. Integrating digital financial literacy and metaverse awareness into academic curricula offers a dual benefit: it empowers individuals with practical tools for daily life and enables them to adapt to technological disruptions with confidence and creativity. However, doing so requires a coordinated shift in educational policy, curriculum design, teacher training, and institutional infrastructure. The objective of the study is to examine the current status of digital financial and metaverse-related education in Indian academic institutions, identifying existing gaps, challenges, and opportunities. This research also explores how educational institutions, particularly at the secondary and higher education levels, can be restructured to align with the demands of a rapidly digitizing and virtualizing world.

Review of Literature

Financial literacy has garnered substantial attention, particularly in the aftermath of significant global financial events such as the Asian Financial Crisis in 1998, the Global Financial Crisis from 2007-2009, and the European Sovereign Debt Crisis of 2012. These crises highlighted the need for individuals to understand fundamental financial concepts to navigate turbulent economic environments (Yong & Tan, 2017). The increasing life expectancy and changing dynamics of retirement savings also underscore the importance of financial

literacy in enabling individuals to manage long-term financial well-being. Financial markets have increasingly become more digital and user-friendly, but the lack of fundamental financial knowledge can lead to poor decision-making. A study by Arceo-Gomez and Villagómez (2017) emphasized the correlation between limited financial understanding and suboptimal financial decisions. As financial markets continue to evolve, the ability to make sound financial choices is critical for individuals, especially in managing investments, debts, and savings.

Financial literacy is essential in navigating complex financial products and systems. Garg and Singh (2018) argued that financial literacy equips individuals with the ability to make well-informed decisions related to budgeting, homeownership, and retirement planning. With the increasing complexity of financial markets, driven by liberalization and the introduction of diverse financial products, the need for financial literacy has become even more pressing. Additionally, the cognitive abilities of individuals play a significant role in financial decision-making (Muñoz-Murillo, Álvarez-Franco, & Restrepo-Tobón, 2020).

Lusardi and Mitchell (2008, 2011) explored the key principles underlying financial decision-making, such as numeracy (interest rate calculations and compound interest), understanding of inflation, and risk diversification. They designed a standard set of questions, widely known as the "Big Three," to measure financial literacy, which has been implemented in numerous national surveys globally. These questions have become integral in financial literacy assessments across diverse sectors, including private industry and academia (Lusardi & Mitchell, 2014). In recent years, digital financial literacy has emerged as an essential component due to the rapid development of Financial Technology (FinTech). Taufiq, Chung, and Chrisniyanti (2023) highlighted how FinTech has transformed financial services, offering advantages such as reduced transaction costs and greater accessibility. Financial literacy has expanded to include the digital realm, requiring consumers to develop the skills to navigate digital financial products and services. Studies by Zavolokina, Dolata, and Schwabe (2016), and others (Ahmad, Widyastuti, Susanti, & Mukhibad, 2020; Ferilli et al., 2024) emphasized the growing

importance of digital financial literacy. This literacy involves not only understanding financial concepts but also using technology securely to manage finances (Hikouatcha, Foka, Fossi, & Asongu, 2024).

Rehman and Mia (2024) explored the multifaceted determinants of financial literacy, including psychological, demographic, and sociocultural factors. The application of various theories such as Dual Process Theory, Theory of Planned Behavior, and Self-Efficacy Theory provides insight into how individuals' beliefs and behaviors affect their financial decision-making. Understanding these determinants can assist in crafting more effective interventions to improve financial literacy across different populations.

An important dimension of financial literacy is its application in specialized financial systems. Rahim, Rashid, and Hamed (2016) explored Islamic financial literacy, particularly among university students, highlighting the unique features and practices of Islamic finance. This research underscores the need to tailor financial literacy programs to different cultural and financial systems.

Research has refined the understanding of the metaverse beyond its VR/AR roots, emphasizing its features of persistence, decentralization, and multi-user presence (Hwang & Chien, 2022; Kye et al., 2021; Zhang & Quoquab, 2023). Fortman and Quintana (2023) argue that this evolution—from 2D interfaces to interconnected 3D environments—facilitates richer, experiential learning opportunities. Scholars highlight immersive simulations as powerful tools for skill development. For instance, Kye et al. (2021) demonstrate use cases in medical training where learners explore complex systems in virtual labs. Meanwhile,

Jagatheesaperumal et al. (2022) identify the synergy between extended reality (XR), IoE, and metaverse media in fostering experiential learning and ethical awareness. Empirical studies in middle school science classes report improved motivation and academic performance through metaverse engagement, with tangible gains in collaboration and conceptual understanding (MDPI study, 2024). The metaverse's ability to transcend

geographic barriers has drawn attention. Educational institutions in remote or under-resourced regions benefit from virtual campuses, increasing equity and outreach (Ayub et al., 2022; Tlili et al., 2022). Mogavi et al. (2023) underscore its potential for accessibility, especially for students with disabilities, through frameworks like REEPS (Recognition, Empowerment, Engagement, Privacy, and Safety).

Research Gaps

As India advances toward its developmental vision for Viksit Bharat @2047, the post-pandemic landscape has catalyzed a renewed emphasis on building educational resilience through digital empowerment, adaptive learning ecosystems, and inclusive innovation. The convergence of the country's demographic dividend with an expanding digital infrastructure presents a timely opportunity to reimagine the role of education in driving socioeconomic transformation. Policies like the National Education Policy (NEP) 2020 offer a foundational push toward digital inclusion and experiential learning; however, critical future-oriented competencies—such as digital financial literacy and metaverse readiness—are yet to be systematically embedded in mainstream academic curricula. While global discourse

has increasingly recognized the transformative potential of immersive technologies and financial digitization in education, Indian educational frameworks lag behind in integrating these domains in a strategic and context-specific manner. This disconnect signals a significant research and policy gap that must be addressed to empower the next generation with the skills, awareness, and agility required to navigate an increasingly automated, interconnected world. Bridging this gap will require not only updated curricular content but also a fundamental reorientation of educational priorities, delivery platforms, and outcome metrics to align with the aspirations of a digitally literate, innovation-driven Bharat by 2047.

Research Objectives:

- To evaluate the current integration of digital financial literacy and metaverse awareness in India.
- To propose a strategic framework for embedding future-ready competencies that supports the goals of Viksit Bharat @2047.

Research Methodology

The research combined both primary and secondary data collection methods to provide a comprehensive understanding of the current state of financial literacy and metaverse awareness and the potential for incorporating it into education. The target population for this study consisted of students from universities and colleges in India, specifically those studying finance, economics, business, and related disciplines. A structured survey questionnaire was administered to 1,509 respondents through WhatsApp groups,

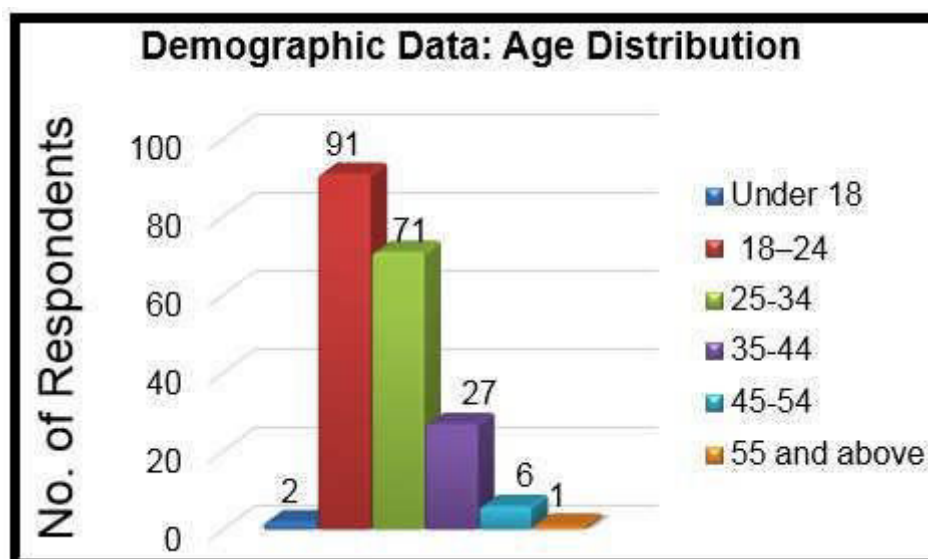
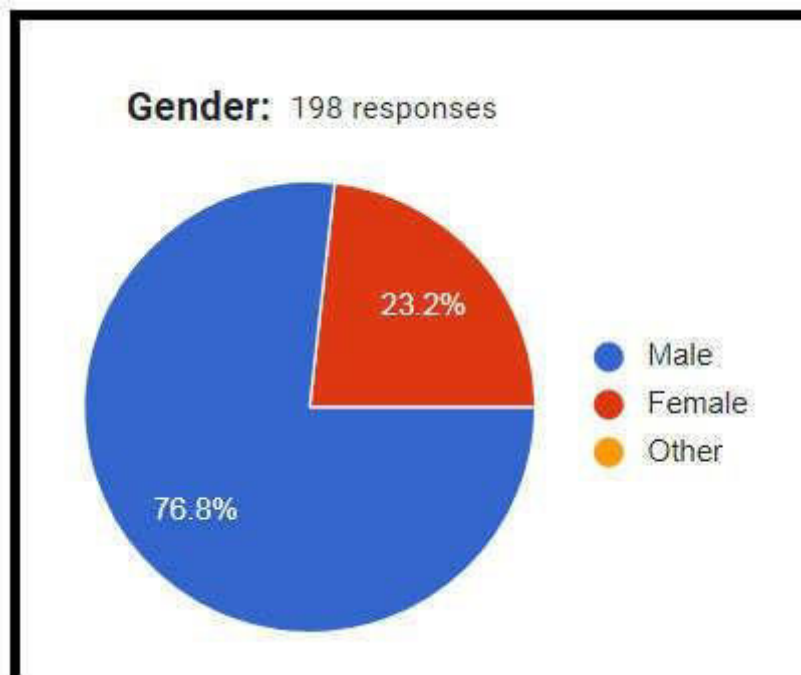
Telegram channels, and individual messages. The questionnaire included both closed and open-ended questions to know the awareness level of digital financial literacy and metaverse, identify perceived gaps in current curricula, and assess interest in incorporating such education into their studies. A total of 198 responses were received and analyzed using appropriate statistical techniques. Additionally, educators and experts were interviewed to gain insights into the effectiveness of current programs and the potential for further integration of digital tools

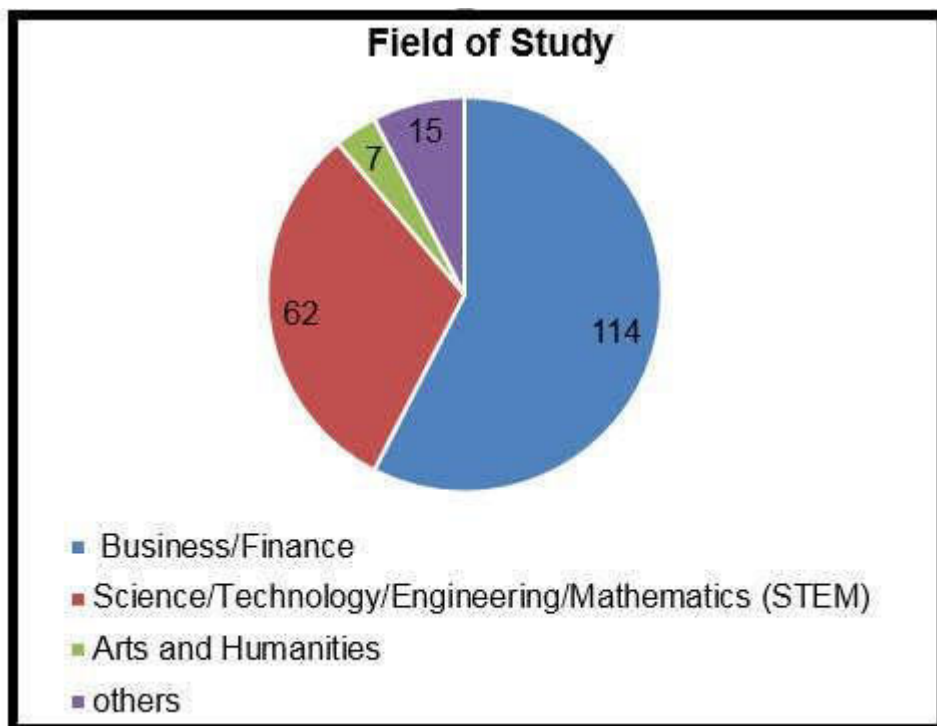
Data Analysis and Findings

Demographic data: age distribution, gender and educational qualification of the respondents

The demographic data primarily highlights the age distribution of participants. The dataset reveals a significant concentration of responses in specific age groups, particularly among those aged 18 to 24 years, followed closely by the 25 to 34 age group. There is substantial number of respondents falling within this age range potentially reflecting a target audience for studies. Only 2 respondents fall under 18 categories who participated in the survey. In contrast, there is smaller representation from the other age

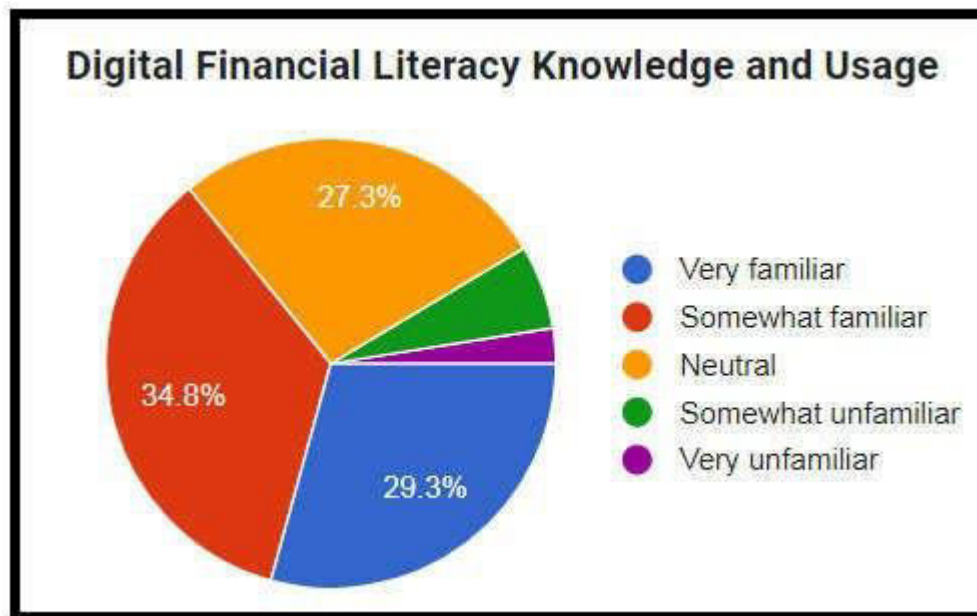
groups, including 35 to 44 years, 45 to 54 years, and a limited number of responses from individuals aged 55 and above. The majority of responses received were from male participants. Only 23% female respondents participated in this survey. The majority of participants are well-educated, with advanced degrees (master's or doctoral) engaged in higher learning. Most of the participants are having backgrounds in business and finance or coming from stem backgrounds. There are also smaller numbers of participants in arts and humanities or other fields.





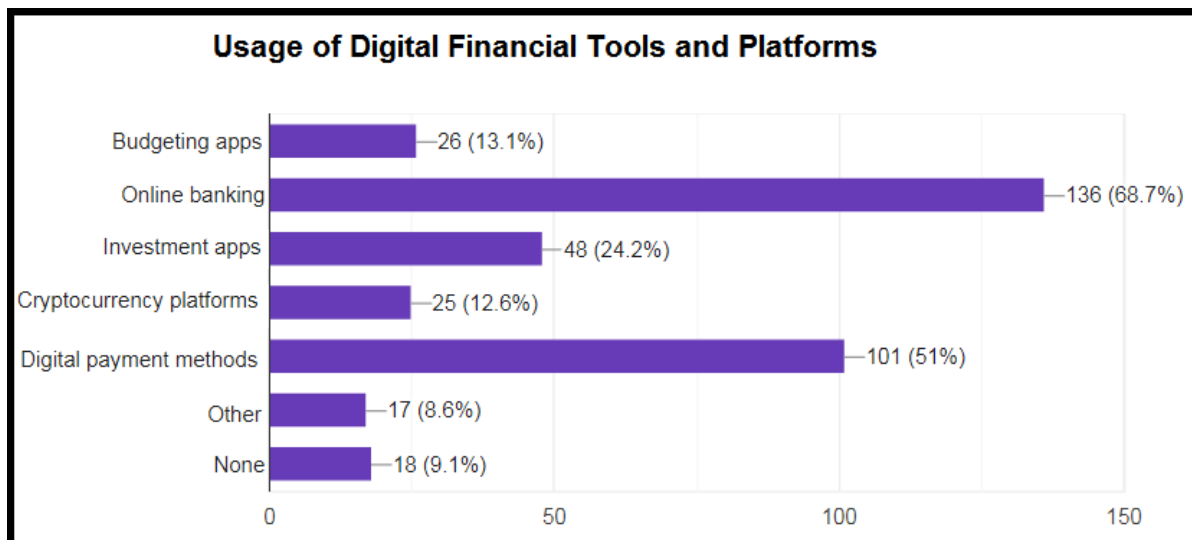
Digital Financial Literacy Knowledge and Usage: Familiarity with the concept of Digital Financial Literacy

A considerable proportion of participants stated that they were "very familiar" or "somewhat familiar" with concepts of digital financial literacy. This shows that a significant percentage of the population are familiar with and interested in getting the knowledge of digital financial literacy. There is a minor portion of respondents who are somewhat unfamiliar or very unfamiliar with the concept, although their numbers are relatively small.



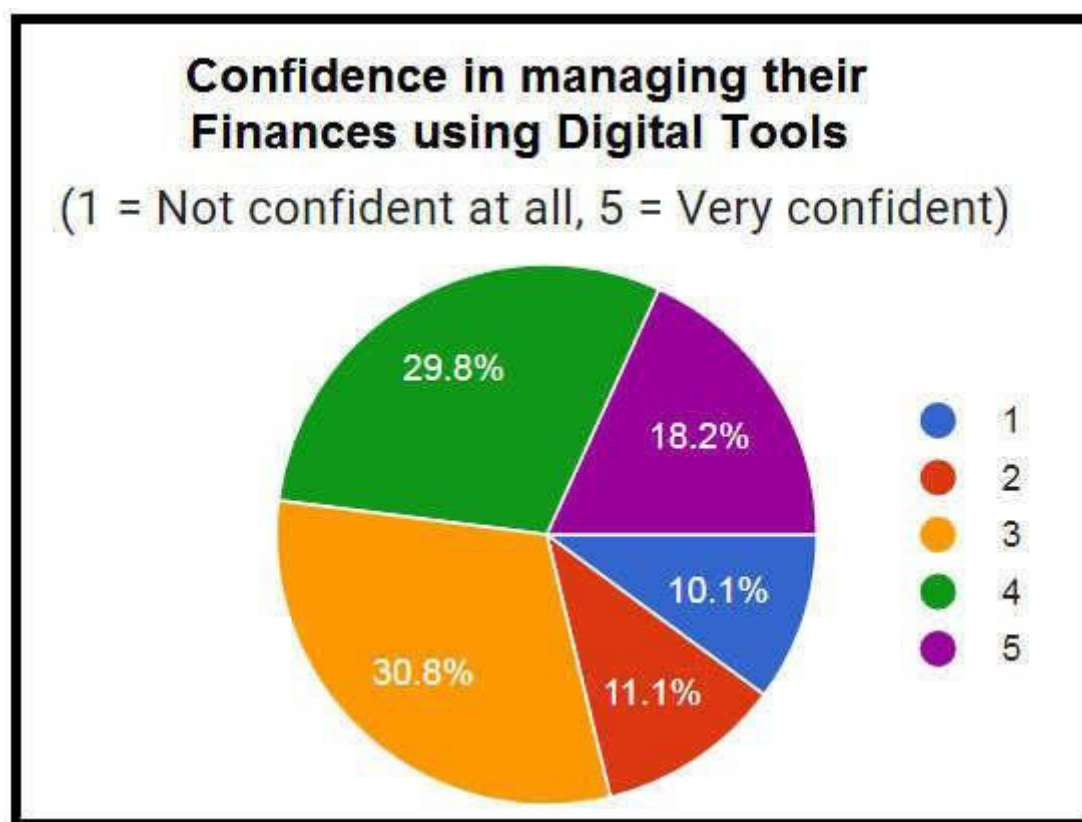
Usage of Digital Financial Tools and Platforms

Digital banking services are widely used for transaction processing and managing finance. Digital payment methods are commonly used for everyday transactions and money transfers, showing their integration into daily life. A sizable percentage of respondents also indicated that they are using different investment platforms for facilitating easy access to stock trading and investment options. While cryptocurrency platforms and budgeting tools are less widely used, there is potential for growth as people become more comfortable with managing their finances in digital environments.



Confidence in Managing their Finances using Digital Tools

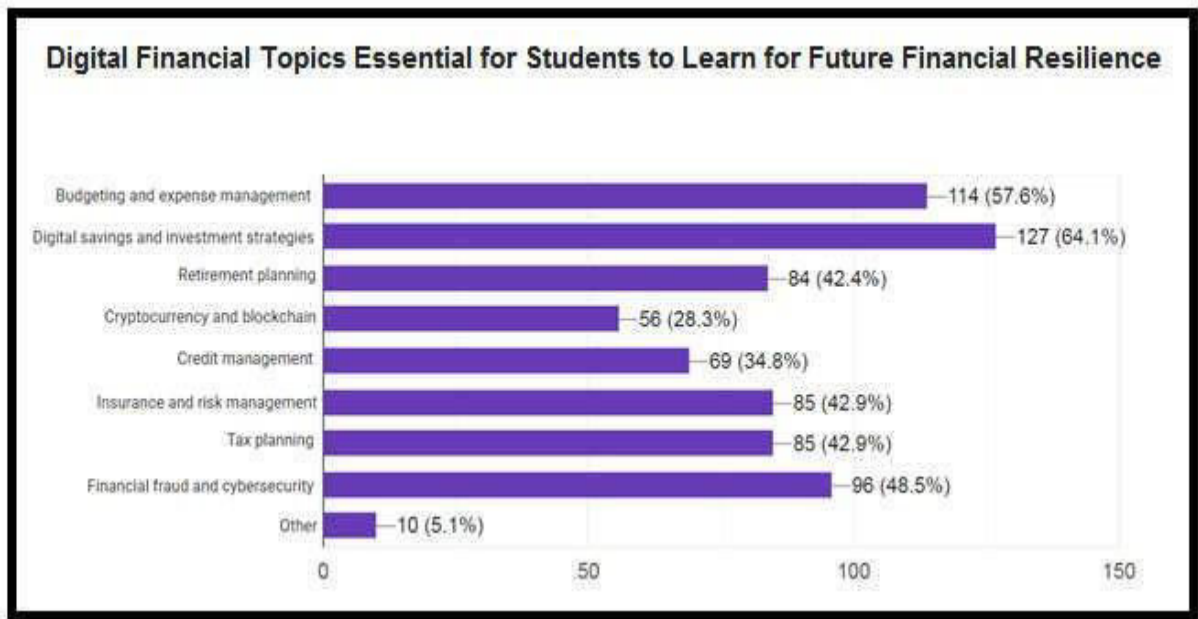
A significant number of respondents feel fairly confident in their ability to use digital tools to manage finances. The majority of responses are at the level 3 (somewhat confident), suggesting that they are neither overly confident nor entirely unsure. They may feel comfortable with some aspects of digital financial management but not all. Some respondents (18.2%) are highly comfortable with managing their finances using digital platforms. There is a smaller group of respondents who rate their confidence as 1 or 2, indicating some respondents may still have difficulties or reservations about using digital financial tools.



Digital Financial Topics essential for Students to Learn for Future Financial Resilience

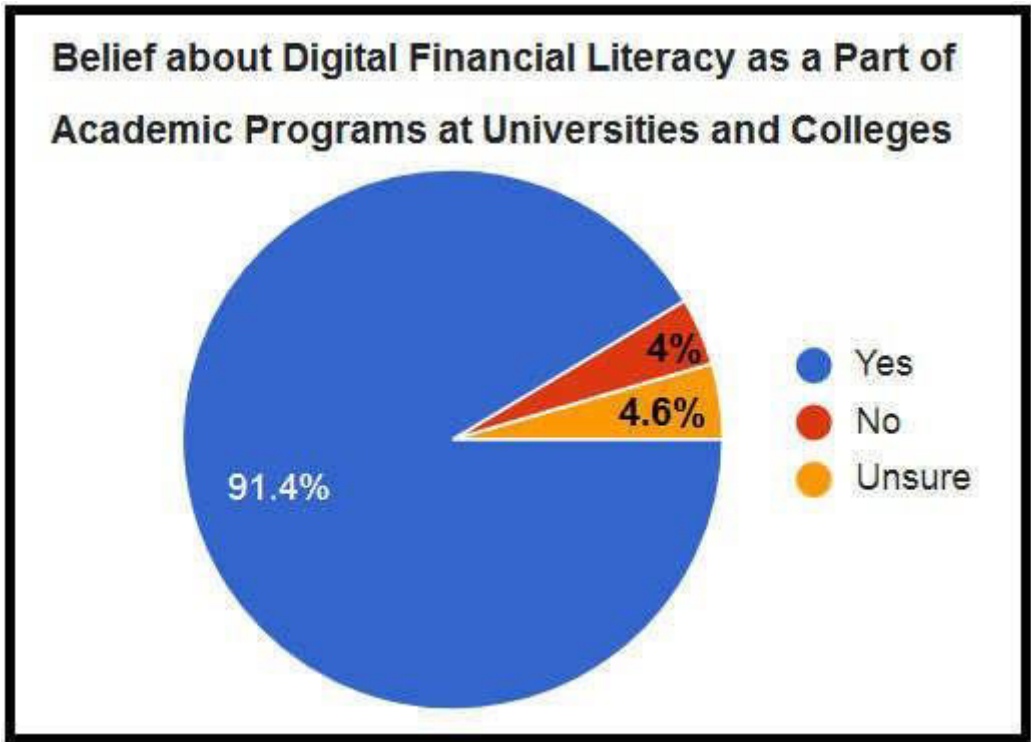
The survey provided multiple digital financial topics that students might benefit from learning for enhancing their future financial resilience. The data collected reveals key trends regarding which financial topics are deemed essential by respondents. Budgeting and expense management emerged as the most frequently selected topic across the responses. This suggests that respondents perceive budgeting as a fundamental skill for financial management and stability. Digital savings and investment strategies also appeared prominently, indicating a strong interest in teaching students how to make the most of digital financial tools for saving and investing. Financial fraud and cybersecurity was another key topic that was frequently selected, highlighting the growing importance of understanding risks associated with digital financial systems. Retirement planning and tax planning were also mentioned often, underscoring the importance of preparing for long-term financial health, despite being less common than budgeting and savings topics. Cryptocurrency and

blockchain, insurance and risk management, and credit management were also mentioned but it appears to be a less frequent concern for most respondents compared to more traditional financial skills.



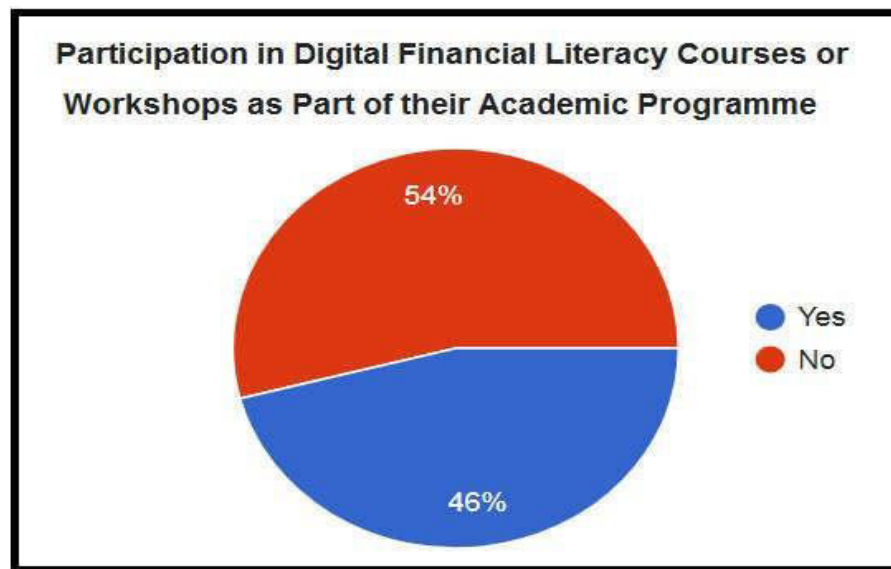
Belief about Digital Financial Literacy as a Part of Academic Programs at Universities and Colleges

A significant majority of the responses overwhelmingly favor the inclusion of digital financial literacy as part of academic programs. The vast majority of respondents selected "yes", demonstrating a clear consensus on the importance of integrating financial literacy into higher education curriculum.



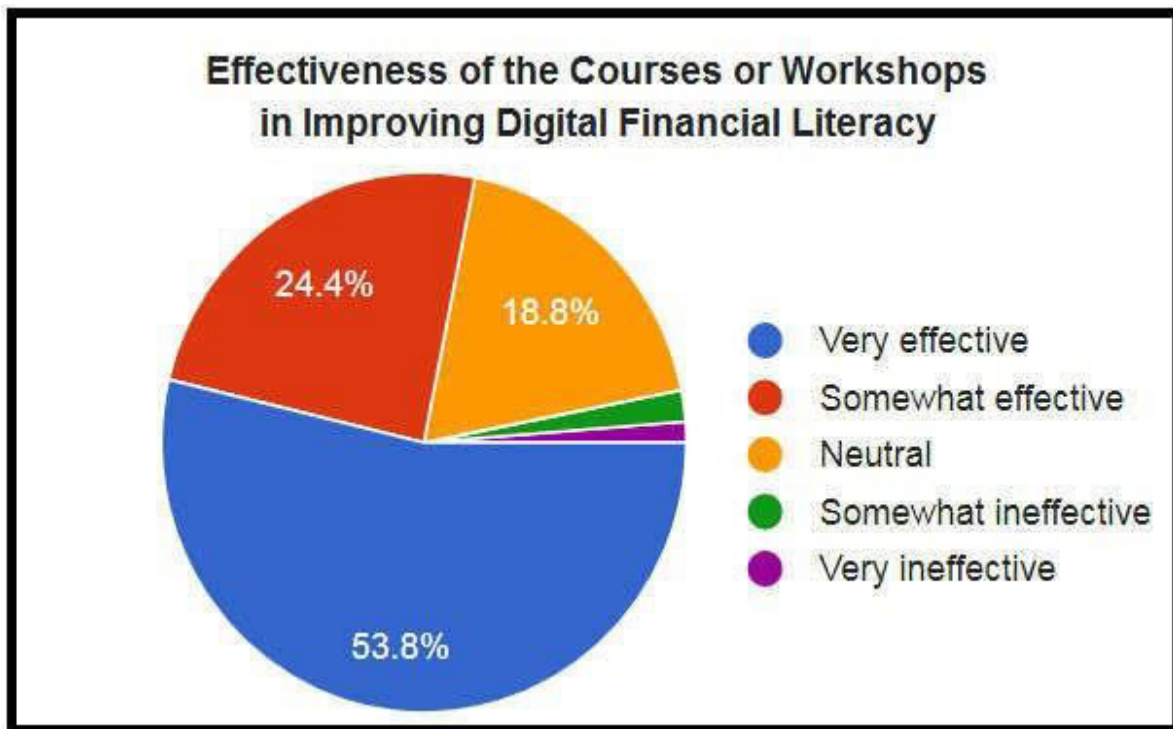
Participation in Digital Financial Literacy Courses or Workshops as Part of their Academic Programme

The data shows a larger proportion of respondents have not participated in digital financial literacy courses or workshops as part of their academic programs. Although a notable number of respondents have engaged in such courses, indicating some awareness and initiative in offering digital financial literacy programmes.

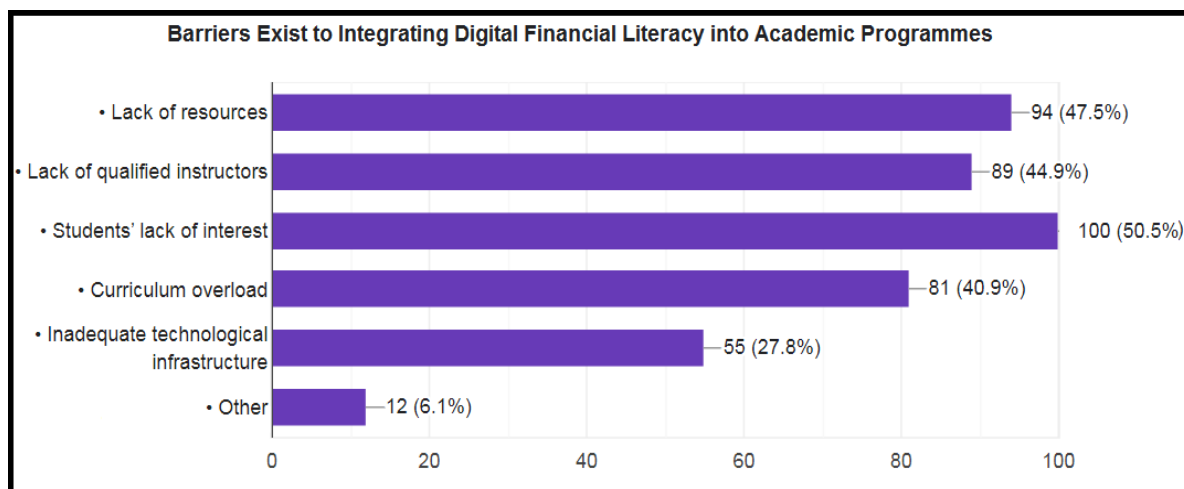


Effectiveness of the Courses or Workshops in Improving Digital Financial Literacy

The majority of respondents found these courses and workshops to be very effective or somewhat effective in improving their digital financial literacy. There were some respondents who found the courses neutral or somewhat ineffective, suggesting areas for improvement.



Barriers exist to integrating digital financial literacy into academic programmes



Lack of resources was mentioned most frequently, appearing in nearly all combinations with other barriers. Students' lacks of interest and curriculum overload were also common barriers, often paired together. The lack of instructors with the necessary expertise to teach digital financial literacy is also barrier, as specialized knowledge is needed to effectively deliver such courses. A few respondents mentioned the lack of proper technological support or infrastructure, such as access to modern tools, platforms, and devices that can facilitate effective learning of digital financial skills.

Core Competencies for Building Digital Financial Literacy and Metaverse Awareness in Educational Ecosystems

The open-ended responses provided by the participants highlight several key areas of knowledge and skills necessary to create Digital Financial Literacy and Metaverse Awareness in Education. The findings underscore the intersection of financial acumen, technological adaptability, critical thinking, and personal development.

Essential Competency Areas

1. Foundational Financial Understanding

A significant number of participants emphasized the necessity of mastering financial basics—such as budgeting, expense tracking, and effective tax handling. A deep understanding of fundamental financial instruments like savings schemes, retirement planning tools, and taxation mechanisms is viewed as the bedrock of financial literacy. Additionally, grasping diverse asset classes—stocks, bonds, real estate—and their associated risk profiles was frequently cited as crucial for financial empowerment.

2. Proficiency in Investment Management

A recurring theme was the importance of strategic investment capabilities. Key skills include asset diversification, portfolio balancing, understanding market trends, and applying techniques such as compounding. The ability to evaluate investment vehicles based on long-term returns and risk exposure was highlighted as vital, along with staying informed about evolving digital finance mechanisms and fintech platforms.

3. Communication and Relationship Building

Participants noted that the ability to communicate effectively about financial matters—whether with advisors, educators, or family—is central to making sound financial decisions. Collaborative financial planning, especially in households or group settings,

requires transparency, negotiation, and mutual understanding. These interpersonal abilities play a significant role in reinforcing shared financial goals and maintaining alignment.

4. Analytical Thinking and Strategic Decision-Making

Participants strongly indicated the necessity for learners to be able to dissect financial data, interpret market signals, and forecast outcomes. The skill to objectively evaluate opportunities, recognize red flags, and apply logical frameworks is seen as indispensable in both financial and metaverse-related decisions. Problem-solving under pressure, especially during market volatility or economic uncertainty, further reflects the importance of analytical strength.

5. Emotional Intelligence and Mindset Development

A calm, focused mental outlook was repeatedly recognized as essential for making rational financial choices. Emotional resilience—particularly the ability to remain composed during financial downturns or losses—was cited as a distinguishing characteristic of financially literate individuals. Attributes such as adaptability, patience, and discipline help maintain long-term focus, especially in unpredictable financial or virtual environments.

6. Digital and Technological Proficiency

Given the digital evolution of financial ecosystems and the rise of immersive technologies, respondents placed strong emphasis on digital fluency. Skills such as using online banking tools, navigating investment applications, managing e-wallets, and engaging with metaverse platforms are increasingly essential. Knowledge of blockchain, virtual assets, and AI-driven financial tools is becoming integral to the future-ready curriculum.

7. Entrepreneurial Thinking and Self-Development

Several responses pointed toward the value of cultivating a growth-oriented mindset. The pursuit of entrepreneurial ventures, side-income opportunities, and ongoing upskilling was seen as a strategic way to boost financial stability. Alongside this, time management, goal setting, and self-regulation were mentioned as key contributors to successful long-term financial behaviour.

Embedding Digital Financial Literacy & Metaverse Awareness into Educational Frameworks

As India progresses toward the vision of Viksit Bharat @2047, equipping learners with digital financial acumen and awareness of emerging virtual environments is becoming a national priority. Insights gathered from respondents' inputs reveal a collection of

actionable, future-ready strategies that can strengthen financial preparedness and digital adaptability among students, particularly in the context of long-term financial planning and metaverse integration.

1. Learning through Real-Life Simulations and Practice-Based Models

Case-Based Engagement: Introducing learners to decision-making through real financial scenarios and virtual simulations allows them to explore financial challenges they are likely to face, such as managing expenses, investing, and preparing for retirement.

Interactive Tools: By integrating budgeting platforms, online calculators, and gamified financial management exercises, students develop the ability to make informed financial choices in a hands-on, engaging manner.

2. Curriculum Innovation and Structured Inclusion

Cross-Disciplinary Mandates: Making digital financial education a required component across all academic disciplines ensures a baseline of financial competence, irrespective of students' areas of specialization.

Dynamic Curriculum Design: Since financial ecosystems and technologies evolve rapidly, updating course content to include recent advancements—like blockchain applications, digital banking, fintech, and virtual assets—is essential to keep students future-ready.

3. Workshops, Webinars, and Mentorship

Consistent Learning Modules: Organizing periodic training sessions that focus on investing principles, digital security, taxation, savings, and retirement strategies enables continuous skill development.

Industry Interface: Inviting finance experts and digital technology professionals to mentor students who can offer a valuable perspective on practical implementation and real-time decision-making.

4. Technological Integration and Infrastructure Enhancement

Learning Platforms and Applications: Utilizing mobile apps, financial dashboards, and virtual learning platforms makes financial concepts more accessible and relevant in a digital-first world.

Bridging the Digital Divide: For under-resourced communities, upgrading the digital backbone—such as internet connectivity, device access, and e-learning systems—is crucial to inclusive financial literacy.

5. Raising Awareness and Policy-Level Support

Institutionalizing Financial Education: Encouraging government and academic bodies to formalize national-level strategies and guidelines will help ensure that digital financial education becomes a standardized offering across institutions.

Saving and Budgeting Habits: Establishing foundational practices like expense tracking, savings allocation, and goal setting from an early stage nurtures self-reliant, financially responsible individuals.

Cybersecurity and Financial Services Knowledge: Learners must understand not only how to use digital tools but also how to safeguard financial data. Including lessons on insurance, credit systems, fraud prevention, and online transactions will prepare them for safe participation in the digital economy.

7. Simplified and Inclusive Learning Approaches

Accessible Financial Education: Breaking down complex financial and digital concepts into easy-to-understand, visual formats (infographics, animated explainers, interactive quizzes) enhances inclusivity, especially for first-generation learners.

6. Planning for Long-Term Financial Security

Retirement Preparedness from a Young Age: Embedding the concept of future-oriented saving and investing in academic programs helps students internalize the importance of early financial planning.

Early Introduction to Financial Tools: Offering introductory modules on financial basics at the school level fosters early awareness and encourages responsible behavior before students enter higher education or the workforce.

Conclusion

As India moves steadily toward the vision of Viksit Bharat @2047, preparing a generation that is both digitally and financially empowered is not just an educational imperative, but a national necessity. The integration of Digital Financial Literacy and Metaverse Awareness into mainstream education holds transformative potential in shaping a workforce that is skilled, adaptable, and future-ready. The dynamic nature of global finance, emerging virtual economies, and technological disruption requires that students possess not only foundational financial knowledge but also the ability to operate confidently within virtual and decentralized systems. Financial literacy should no longer be a peripheral subject; it must become an integral, interdisciplinary component of curricula across all academic fields. Making digital finance and metaverse concepts compulsory learning areas—supported by workshops, real-time applications, expert mentorship, and technological infrastructure—is essential for building deep-rooted financial resilience and digital awareness.

Special attention must also be given to accessibility and inclusivity, especially for students in rural and underserved regions. The digital divide continues to be a barrier to equitable learning. Bridging this gap by improving infrastructure, providing low-cost digital tools, and delivering content in regional languages can ensure that financial and metaverse education reaches every corner of the nation. Furthermore, the psychological aspect of financial decision-making—such as emotional intelligence, self-discipline, and adaptability—must be cultivated alongside cognitive skills. In uncertain market conditions or virtual environments where identity, risk, and regulation are complex, these personal competencies will prove equally important.

Policy support at the national level—through initiatives like National Digital Financial Literacy Missions, targeted curriculum guidelines, funding support, and public-private partnerships—will be critical in scaling these programs across the country. Engaging regulators, fintech companies, educational boards, and community leaders will help institutionalize a sustainable ecosystem for lifelong financial and digital learning. Creating a future-ready India requires a strategic, inclusive, and innovation-driven approach to education. By embedding digital financial literacy and metaverse readiness within academic programs today, we are not only preparing individuals for better financial decision-making, but also laying the foundation for an empowered, informed, and digitally capable society that can actively shape and lead the India of 2047.

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Navigating Green Finance in Virtual Financial Systems: The Impact of ESG Awareness and Technological Readiness on Sustainable Banking Intention.

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Keywords: Sustainable Banking Intentions, ESG Awareness, Technological Readiness, Digital Financial Literacy

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Abstract:

Sustainable Banking has become a focal point for those engaged in research. The presented study aims to clarify the factors that influence Sustainable Banking Intentions by examining the impact of ESG Awareness, Technological Readiness, Perceived Usefulness of Virtual Financial Systems, and Digital Financial Literacy. For the purpose of data analysis, PLS-SEM techniques have been applied to the responses of 266 individuals. The findings validated the significance of ESG Awareness, Technological Readiness, and the Perceived Usefulness of the Virtual Financial System, with digital financial literacy serving as a moderating factor. The findings of the study indicate that to foster Sustainable Banking Intentions, financial institutions ought to prioritise improving ESG awareness, technological readiness, and the perceived usefulness of virtual financial systems. Furthermore, it is essential to enhance digital financial literacy among individuals to bolster sustainable banking practices.

Keywords: Sustainable Banking Intentions, ESG Awareness, Technological Readiness, Digital Financial Literacy

1.0 Introduction-

Unsustainable business practises, including nations characterised by significant production, processes, operations, and population densities, such as India, the functions, as well as reckless levels of challenges of environmental degradation consumption, are major contributors to the intensify as a result of overpopulation and environmental crisis that the world is unsustainable consumption habits. In light of currently facing (Chen & Hung, 2016). In the growing worries regarding the ongoing

deterioration of the natural environment, alongside the initiatives by various organisations, ethical consumerism, often referred to as green consumerism, is gaining momentum (Boobalan & Nachimuthu, 2020). Green and sustainable consumption represents a commendable approach to achieving sustainable development goals. Given that the 17 SDGs under Agenda 2030 encompass objectives for people, planet, prosperity, and partnership, it is essential to pursue their balanced and integrated realisation. Overall, the objectives for individuals focus on reducing hunger and poverty, while for the planet, the emphasis is on promoting responsible consumption and production to protect the environment from depletion and degradation (Taneja & Ali, 2021). The banking sector in India is actively striving to adopt environmentally friendly practices, reflecting the increasing global emphasis on sustainability (Kumar and Prakash, 2020). Despite the lack of evidence that banks are directly harming the environment, their high energy use, paper consumption, and customers' lack of sustainability all point to indirect repercussions (Korzeb & Samaniego-Medina, 2019). As a result, it is essential to explore customer intentions regarding sustainable banking. This analysis can demonstrate to banks how they can enhance their sustainability efforts and educate their clients

on the benefits of eco-friendly banking practices. Eco-friendly banking practices serve the interests of both clients and financial organisations, ultimately contributing to the preservation of our environment for future generations. Furthermore, regarding the technological readiness and ESG awareness among Indian consumers, previous research reveals a significant gap. Investigating these elements within the realm of sustainable banking in India may yield significant insights for both financial institutions and their clients. Grasping the degree of technological readiness and ESG awareness enables banks to customise their strategies to more effectively align with the needs and preferences of their customers in this market. Moreover, digital financial literacy represents an additional element that may influence consumers' intentions towards sustainable banking. This research study aims to address the following questions:

RQ1: Does ESG Awareness and Technology Readiness effects Perceived Usefulness of Virtual Financial System?

RQ2: Is there a link between Perceived Usefulness of Virtual Financial System and Sustainable Banking Intentions?

RQ3: Does Digital Financial Literacy creates an effect in pushing Sustainable Banking Intentions?

2.0 Literature Review and Hypothesis Development

The idea of “green finance” has surfaced as a crucial element in guiding the shift towards a more environmentally and socially responsible global economy. Green Finance embodies a strategic framework that promotes the alignment of financial institutions with objectives that are both environmentally and socially responsible (Islam et al., 2020). This change in thinking in the financial industry is about more than just following the rules; it includes a variety of programs and policies that encourage eco-friendly banking processes, goods, and services (Sharma et al., 2025). The fast development of Fintech solutions presents a one-of-a-kind chance to ease and quicken the shift towards green finance in today's financial environment. Macchiavello and Siri (2022) were the first in Europe to formally investigate the link between technology and sustainability; they came up with the term "green FinTech" to describe this emerging field. "Green FinTech" is a game-changer because it facilitates ESG investments, boosts perceived profitability, and encourages sustainable banking practices through the use of innovative digital tools and platforms.

The factors that influence a person's propensity to embrace and make use of emerging technology have been conceptualised by Parasuraman (Celik & Kocaman, 2017). The term "Technology

Readiness" (TR) describes a person's inclination to use new technology to accomplish life and career objectives. Within that framework, the mental facilitators and inhibitors of a person may be used to collectively ascertain their propensity to use new technologies (Andrea et al., 2021). One way in which TR differs from TAR is that it looks at people's broad attitudes towards technology rather than their impressions of individual items and services. The fact that technology readiness research seems to be person-specific rather than system-specific is crucial. According to Parasuraman (2000), there are four aspects of people's personalities that may be used to assess their inclination towards new technologies: optimism, innovativeness, discomfort, and insecurity. Together, these views assess the general inclination to accept new technology, even if they represent various tendencies of personality.

The perceived utility of digital banking to customers is the first aspect that might contribute to its effectiveness. Customers' perceptions of how a product or service might improve their productivity on the job, whether that's via time savings or easier access to a variety of services, are examples of perceived usefulness (Davis, 1989; Ghani et al., 2014). Perceived usefulness is a metric that may be employed by Davis, (1989) in his theory of

the technology acceptance model (TAM) to assess the extent to which a user feels a particular application can enhance job performance. Customers have a positive impression of a service and are more like to use it again if they find it useful. Furthermore, previous researchers (Lyons & Kass-Hanna, 2021; Koskelainen et al., 2023) have also highlighted the role of Digital Financial Literacy in adopting innovative technology. Digital Financial Literacy denotes the capacity of people to comprehend and proficiently use digital financial services. This information significantly influences consumers' views of utility and, therefore, their adoption of new technologies in the financial industry. Thus, based on the above discussion, researchers formulated the following research hypothesis:

H1: There is significant relationship between ESG Awareness and Perceived Usefulness of Virtual Financial Systems.

H2: There is significant relationship between Technological Readiness and Perceived Usefulness of Virtual Financial Systems.

H3: There is significant relationship between Perceived Usefulness of Virtual Financial Systems and Sustainable Banking Intentions.

H4: Digital Financial Literacy act as a moderator between Perceived Usefulness of Virtual Financial Systems and Sustainable Banking Intentions.

Technology Acceptance Model-

The technology acceptance model (TAM), developed by Fred Davis more than 25 years ago, has become a prominent framework for examining the factors that affect users' acceptance of technology. The TAM indicates that two factors, perceived ease of use and perceived usefulness, serve as intermediaries in the complex interplay between system characteristics (external variables) and the prospective utilisation of the system (Marangunić & Granić, 2015). Grounded in the psychology-based theory of reasonable action (TRA) and the theory of planned behaviour (TPB), TAM has become a significant framework for explaining users' interactions with technology. Thorough and systematic investigation in the field is impossible without a deep comprehension of the origins, evolution, alterations, and constraints of the model (Holden & Karsh, 2010). This model has found applications across various research domains, as it effectively aids in describing new technology and serves as a valuable tool for forecasting technology acceptance. The research model was enhanced to incorporate more variables influencing perceived ease of use and perceived usefulness. The extended TAM, referred to as ETAM, incorporates behavioural intention and further categorises variables associated with information technology as outlined by Davis et al., (1989).

The study focused on the acceptance of new technologies, including mobile applications, utilising a specific model, while the innovation among users was validated through the research conducted by Rosers (1995). Personal innovation refers to the inclination to adopt new ideas or experiences

and to welcome innovative products or services Midgley and Dowling, (1978). The theory of the ETAM suggests that the perceived ease of use and usefulness, shaped by individual innovation, ultimately impact behavioural intentions.

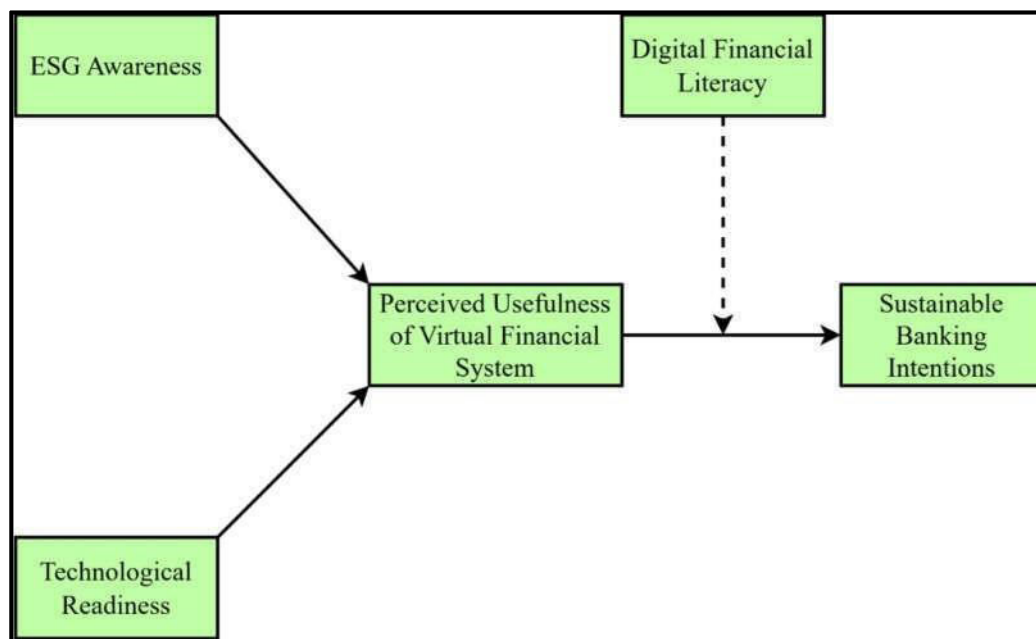


Figure: Theoretical Framework

3.0 Research Methodology

3.1 Data Collection and Sampling:

The data collection process involved using a questionnaire that featured items relevant to the constructs detailed in the theoretical model. The data collection took place in the city of Lucknow, Uttar Pradesh, using a convenience sampling method. The questionnaire was shared through a Google Form link across various social media platforms and email networks to attract a diverse group of participants. The questionnaire features enquiries about demographics, as well as additional enquiries regarding the constructs. Participants must submit their responses utilising a 5-point Likert scale: 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree), and 5 (strongly agree). A total of 266 responses were gathered from the participants. The responses were carefully compiled and analysed to draw conclusions about the interaction between the variables in the theoretical model.

3.2 Measurement of Scales

ESG Awareness: To measure ESG awareness, items were adopted from the scale developed by Alonso-Almeida et al., (2022).

Technological Readiness (TRI 2.0): To measure Technological Readiness, scale developed by Parasuraman and Colby (2015)

was adopted. This scale is formative construct consisting of sub-items demonstrating Optimism, Innovativeness, Discomfort, and Insecurity. The scale consists of 13 items.

Perceived Usefulness of Virtual Financial Systems: Perceived Usefulness of Virtual Financial Systems is measured using the scale developed by Alalwan et al., (2022).

Sustainable Banking Intentions: The construct Sustainable Banking Intentions is measured using the scale developed by Kumar and Ghodeswar, (2022). The scale consists of 4 items.

Digital Financial Literacy: This scale is measured using the items adopted from the scale developed by Lusardi and Mitchell, (2023).

3.3 Demographic Profiling

The demographic profile of the responder's points to a well-rounded and varied sample. A good portion of the population is young and working age; 44.36% of those between 25 and 34 years old especially. Following that, 25.19% fall between 18 and 24 and 18.05% fit the 35–44 age range. About education, most of the respondents had postgraduate degrees; some had doctorates and varied academic backgrounds, so reflecting a highly educated group. By helping to spread the gender roles, men and women help to ensure fair

representation. The respondents range in their employment from homemakers, self-employed persons, students, and service professionals, so allowing a complete knowledge of financial activities from many angles. Following those making between INR 50,001–1,00,000 and below INR 25,000, the biggest segment of earners falls in the INR

25,001–50,000 range, so reflecting a varied representation of the middle-income class in India. This group presents a great opportunity to investigate points of view and behavioural intentions about sustainable banking and virtual financial systems especially among those who are educated and technologically sophisticated.

4.0 Data Analysis

The data analysis is conducted by Partial Least Square-Structural Equation Modelling (PLS-SEM) with SmartPLS 4.0 software. PLS-SEM is a bifurcated procedure whereby we first evaluate the measurement model to assess the reliability and validity of the constructs included in the model using several metrics, such as the HTMT ratio and Cronbach's alpha. Subsequently, we evaluate

the Structural Model to examine the proposed link. This statistical analysis facilitates a comprehensive knowledge of the interrelationships among the variables and offers insights into the overall efficacy of the theoretical model. The outcomes of the PLS-SEM analysis will be essential in assessing the relevance of the associations and guiding future research trajectories.

4.1 Measurement Model

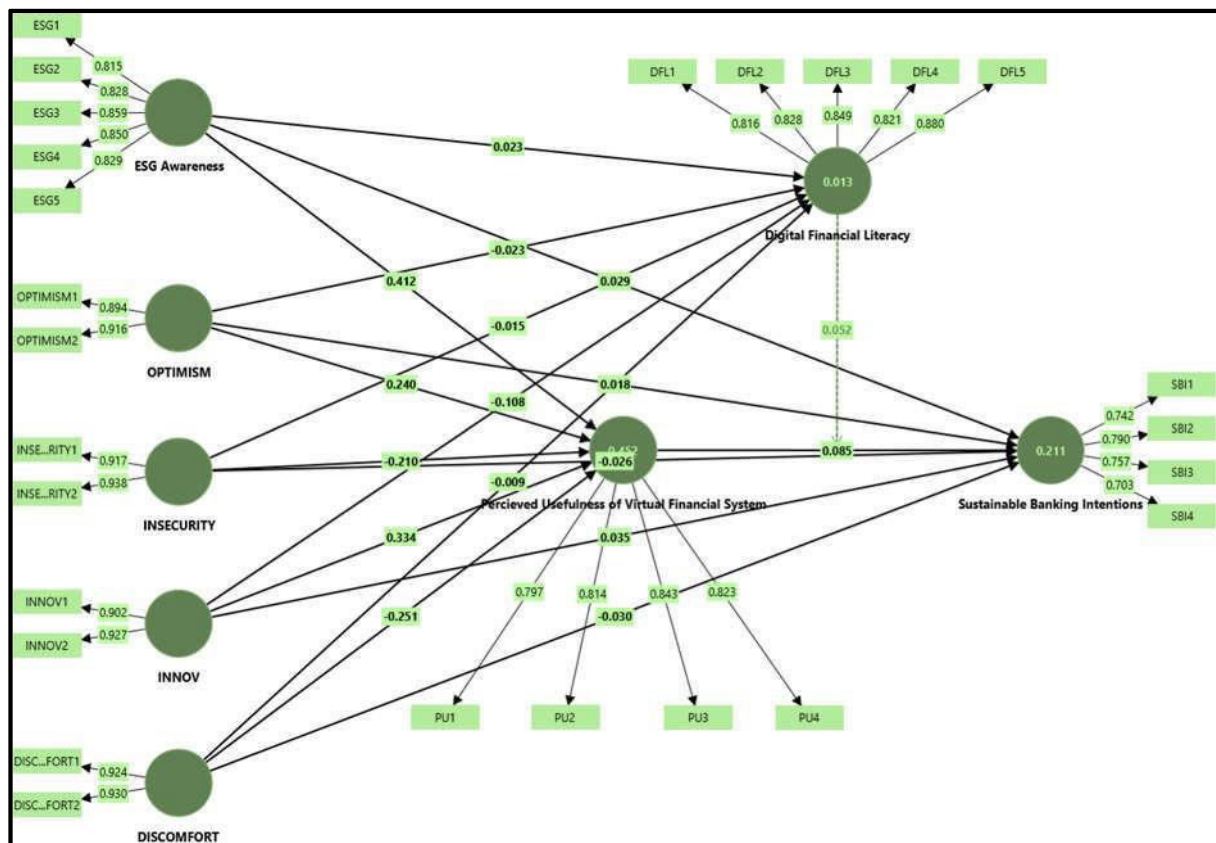


Figure 2: Measurement Model

The figure 2 presented above illustrates the visual representation of the measurement model. Additionally, it is evident from Table 1 that the values of Cronbach alpha, Composite Reliability, and Average Variance Extracted for all the examined constructs exceed the minimum acceptable range which is 0.70 for Cronbach's Alpha (Hair et al., 2019), 0.50 for AVE (Fornell and Larcker, 1981), and 0.70 for Outer Loadings (Hair et al., 2022), demonstrating strong internal consistency and reliability of the measurement model. One of our independent variables in the model is higher order construct (Technological Readiness), which consists of different sub-dimensions, thus we tested reliability and validity of each respective sub-dimension separately. Then we used the latent scores of these sub-dimensions to convert formative construct into reflective construct to test the hypothesize relationships. This indicates that the variables in the theoretical model are precisely measured and are suitable for additional analysis and interpretation.

Table 1: Reliability and Outer Loadings

	Constructs and Related Items	Outer Loadings
<i>ESG Awareness (Reliability and Convergent Reliability: $\alpha = 0.893$; CR = 0.896, AVE =0.699)</i>		
ESG1	I am familiar with the concept of ESG (Environmental, Social, and Governance) criteria in banking.	0.815
ESG2	I know which banks follow ESG criteria.	0.828
ESG3	I look for information about the environmental performance of banks.	0.859
ESG4	I consider a bank's social responsibility before using its services.	0.850
ESG5	I am aware of how a bank's governance affects its ESG performance.	0.829
<i>Technological Readiness: Optimism (Reliability and Convergent Reliability: $\alpha = 0.780$; CR = 0.786, AVE =0.819)</i>		
OPTI1	Technology gives me more freedom of mobility.	0.894
OPTI2	Technology makes me more efficient in my life.	0.916
<i>Technological Readiness: Innovativeness (Reliability and Convergent Reliability: $\alpha = 0.805$; CR = 0.816, AVE =0.836)</i>		
INNOV1	Other people come to me for advice on new technologies.	0.902
INNOV2	I keep up with the latest technological developments.	0.927
<i>Technological Readiness: Discomfort (Reverse-coded) (Reliability and Convergent Reliability: $\alpha = 0.836$; CR = 0.845, AVE =0.859)</i>		
DC1	Technical support lines are not helpful because they don't explain things in terms I understand.	0.902
DC2	Sometimes, I think technology systems are not designed for use by ordinary people.	0.927
<i>Technological Readiness: Insecurity (Reverse-coded) (Reliability and Convergent Reliability: $\alpha = 0.838$; CR = 0.850, AVE =0.860)</i>		
INSEC1	I doubt I can meet the standards of entry to my ideal career.	0.924
INSEC2	People are too dependent on technology to do things for them.	0.930
<i>Perceived Usefulness of Virtual Financial System (Reliability and Convergent Reliability: $\alpha = 0.837$; CR = 0.891, AVE =0.671)</i>		

PU1	Using virtual banking would enable me to accomplish banking activities more quickly.	0.797
PU2	Virtual financial systems enhance my effectiveness in managing finances.	0.814
PU3	I find virtual banking systems useful in my daily life.	0.843
PU4	Using virtual banking increases my productivity.	0.823
<i>Sustainable Banking Intentions (Reliability and Convergent Reliability: $\alpha = 0.741$; CR = 0.748, AVE = 0.560)</i>		
SBI1	I intend to use green banking services in the future.	0.742
SBI2	I will try to use sustainable banking products/services.	0.790
SBI3	I will recommend green banking services to my family and friends.	0.757
SBI4	I would switch to a bank that offers more sustainable options.	0.703
<i>Digital Financial Literacy (Reliability and Convergent Reliability: $\alpha = 0.897$; CR = 0.932, AVE = 0.859)</i>		
DFL1	I know how to protect myself from fraud when using digital financial services.	0.816
DFL2	I can evaluate the security of digital payment platforms.	0.828
DL3	I understand the terms and conditions when using online banking or payment services.	0.849
DFL4	I can compare costs and features of different digital financial products.	0.821
DFL5	I know what to do if I suspect unauthorized access to my digital banking account.	0.880

Note: ESG= ESG Awareness, INNOV= Innovativeness, DC= Discomfort, INSEC= Insecurity, PU= Perceived Usefulness of Virtual Financial System, SBI= Sustainable Banking Intentions, DL= Digital Financial Literacy, OPTI= Optimism

To examine the discriminant validity in PLS-SEM, the investigator has tested the HTMT ratio. The HTMT analysis provided additional confirmation of discriminant validity, with the values for the pairs of primary constructs remaining below the recommended threshold of 0.80. It is evident from Table 2 that all the values of the constructs are below the 0.80 threshold. This indicates that the constructs within the model are separate from one another, reinforcing the notion that they are assessing various facets of the phenomenon under investigation. Overall, these results instill a strong sense of assurance in the measurement model and the validity of the relationships explored in the study.

Table 2: Discriminant Validity-HTMT Ratio

Constructs	DC	DFL	ESG Awareness	INNOV	INSEC	OPTI	PU	SBI	DFL x PU
DC									
DFL	0.045								
ESG Awareness	0.074	0.045							
INNOV	0.07	0.12	0.062						
INSEC	0.073	0.057	0.07	0.1					
OPTI	0.036	0.049	0.056	0.025	0.094				
PU	0.294	0.245	0.517	0.401	0.209	0.294			
SBI	0.19	0.174	0.265	0.231	0.141	0.162	0.508		
DL x PU	0.032	0.051	0.05	0.073	0.036	0.104	0.074	0.143	

Note: ESG= ESG Awareness, INNOV= Innovativeness, DC= Discomfort, INSEC= Insecurity, PU= Perceived Usefulness of Virtual Financial System, SBI= Sustainable Banking Intentions, DL= Digital Financial Literacy, OPTI= Optimism

4.2 Structural Model

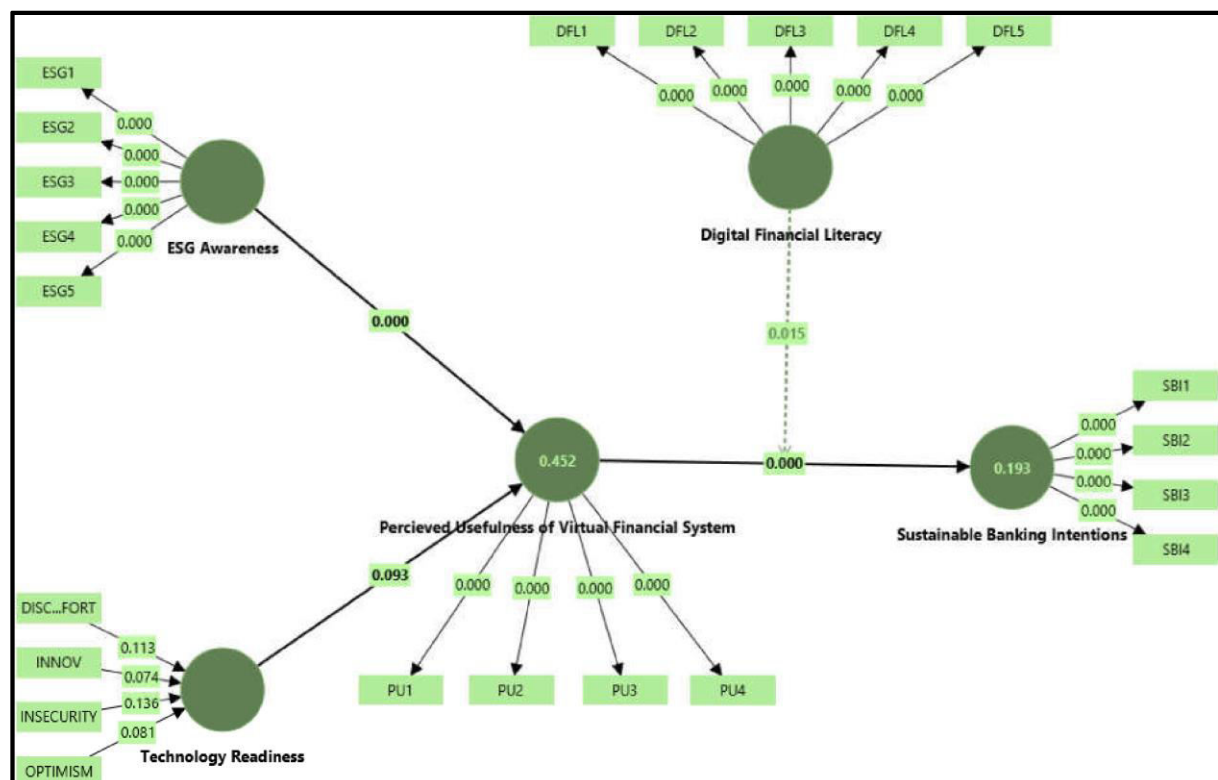


Figure 3: Structural Model

As can be seen in figure 3 above, the hypothesized relationships are tested through examining the structural model. Results of the hypothesis testing are given in Table 3. The

results indicate that the relationship between ESG Awareness and Perceived Usefulness of Virtual Financial System is significant ($\beta=0.412$, $t\text{-value}=10.119$, $p<0.05$), thereby accepting hypothesis 1. Next researcher test the relationship between Perceived Usefulness of Virtual Financial System and Sustainable Banking Intentions and the results

demonstrate significant results ($\beta=0.127$, $t\text{-value}=6.46$, $p<0.05$), thus hypothesis 2 is accepted. Next, the relationship between Technology Readiness and Perceived Usefulness of Virtual Financial System is significantly related ($\beta=0.127$, $t\text{-value}=6.46$, $p<0.10$), however it is significant at 0.10 $p\text{-value}$ level.

Table 3: Hypothesis Testing Results

Relationships	Beta Coefficient	Standard deviation	T statistics	P values	Outcome
ESG Awareness → Perceived Usefulness of Virtual Financial System	0.412	0.041	10.119	0.000	Significant
Perceived Usefulness of Virtual Financial System → Sustainable Banking Intentions	0.127	0.02	6.46	0.000	Significant
Technology Readiness → Perceived Usefulness of Virtual Financial System	0.501	0.298	1.678	0.093	Significant at 0.10 level
Digital Financial Literacy x Perceived Usefulness of Virtual Financial System → Sustainable Banking Intentions	0.058	0.024	2.439	0.015	Significant

Lastly, we test the moderating role of digital financial literacy between Perceived Usefulness of Virtual Financial System and Sustainable Banking Intentions. The results demonstrated the significant role of digital financial literacy between Perceived Usefulness of Virtual Financial System and Sustainable Banking Intentions ($\beta=0.058$, $t\text{-value}=2.439$, $p<0.015$). The visual

representation of the moderate relationship is given in figure 4. This finding indicates that those who possess advanced digital financial literacy tend to view virtual financial systems as beneficial for fostering sustainable banking intentions. Consequently, improving digital financial literacy could play a crucial role in promoting sustainable banking practices.

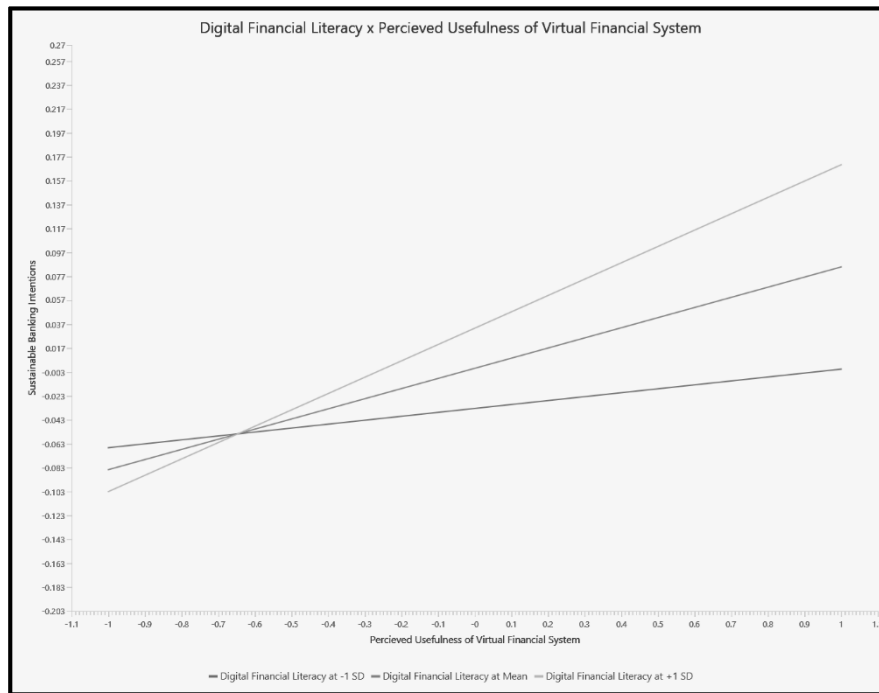


Figure 4: Moderation Effect of Digital Financial Literacy

5.0 Discussion:

This research utilised the PLS-SEM approach to delve into the domain of green finance in virtual banking systems, examining how ESG awareness and technological readiness impact sustainable banking intentions, framed by the Technology Acceptance Model (TAM) (Marangunić & Granić, 2015). Furthermore, it examined the influencing role of digital financial literacy. Initially, it was proposed that ESG Awareness has a notable connection with the perceived usefulness of Virtual Financial Systems. The analysis substantiated this relationship, affirming our initial hypothesis. This suggests that heightened awareness of ESG significantly enhances the perceived utility of virtual financial systems, underscoring a valuable opportunity for promoting sustainable banking practices in the digital era. This finding supports earlier studies (Khalil & Khalil, 2022) indicating that environmental, social, and governance factors significantly influence consumer attitudes towards financial technology. Moreover, it highlights the significance of integrating ESG principles into the creation and execution of virtual financial systems to improve their perceived value and efficiency. Secondly, the research proposed that technological readiness has a significant connection to the perceived usefulness of virtual financial systems. The analysis validated this relationship, thus affirming hypothesis 2. This

discovery underscores the necessity of guaranteeing that users are adequately prepared and equipped to effectively leverage virtual financial systems. This supports earlier studies (Omar et al., 2023) that emphasise the importance of the TAM model in forecasting user acceptance of technology. This highlights the importance for organisations to allocate resources and training to assist users in transitioning to new virtual financial systems. Ultimately, these endeavours can result in enhanced efficiency and greater satisfaction among users. Third, it is asserted that the perceived usefulness of virtual financial systems influences sustainable banking intentions. The analysis confirms that the perceived usefulness of virtual financial systems influences sustainable banking intentions, indicating that users are more inclined to adopt and persist in using these systems when they recognise their benefits in fulfilling banking needs. This highlights the importance for financial institutions to prioritise improving the perceived utility of their virtual systems to promote sustainable banking behaviours among users. Lastly, it is noted that digital financial literacy affects the link between how useful people think virtual financial systems are and their plans to use sustainable banking. This means that helping people understand digital financial tools can make them even more committed to using

sustainable banking practises. Consequently, financial institutions ought to explore the implementation of educational initiatives aimed at enhancing digital literacy within their customer base. By offering resources and training on the effective use of digital financial tools, banks can enable their customers to make more informed decisions regarding sustainable banking. This enhanced comprehension can foster a deeper sense of

trust and assurance in virtual financial systems, ultimately encouraging more individuals to embrace sustainable banking practices. Over time, these educational initiatives can assist financial institutions in attracting a greater number of environmentally conscious customers while also fostering deeper connections with their current clientele.

6.0 Practical and Theoretical Implications

The research utilises the TAM model to investigate green finance in relation to the virtual banking system. Initially, this research enhances the theoretical framework by enriching the understanding of how greater insight can impact consumer behaviour in sustainable banking. By incorporating ESG Awareness and Technological Readiness into the model, the study highlights the significance of integrating environmental, social, and governance factors into financial decision-making processes. A virtual bank could leverage the findings from this study to create intuitive and secure online platforms that encourage their customers to explore

sustainable investment options. Utilising technology and ESG principles, the bank has the potential to build customer trust and loyalty, paving the way for sustained financial success. Furthermore, the study offers practical contributions by outlining a roadmap for financial institutions to synchronise their strategies with sustainable development goals, thereby securing long-term viability in a progressively competitive market. This comprehensive strategy not only enhances the environment and society but also establishes the bank as a responsible and innovative leader in the sector.

7.0 Conclusion

The study explores the impact of ESG awareness and technological readiness on the perceived usefulness of virtual financial systems, as well as how this system influences sustainable banking intentions, while considering the moderating role of digital financial literacy. The analysis conducted using PLS-SEM confirmed the relationships and indicated that ESG awareness and technological readiness significantly enhance the perceived usefulness of virtual financial systems, thereby influencing intentions towards sustainable banking. Furthermore, digital financial literacy significantly enhances these connections and promotes the embrace of sustainable banking practices in today's digital landscape.

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Building a Sustainable Future: Connecting the Dots between Sustainable Practices and Stock Market Performance in India

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Abstract

This research explores the connection between sustainable practices and stock market performance in India. The research investigates the dynamics by analyzing Environmental, Social, and Governance (ESG) scores and their influence on pivotal stock market performance indicators, including earnings per share, price-to-earnings ratio, price-to-book ratio, and book value per share. The methodology applied in the paper includes SHAP dependency plots and the panel linear and nonlinear ARDL model for the period 2010 to 2024. This timeline captures the latest evolutions in sustainable practices, underscoring the intricate dynamics between sustainable practices and stock market prosperity. These findings suggest that ESG scores have varying impacts on different stock market performance indicators, with potential asymmetries between positive and negative shocks.

Keywords: Sustainability, ESG, Stock Market Performance, India, ARDL

Introduction

The finance system in India, including the stock market, plays a crucial role in driving economic growth and development in India as well as globally. India, being a fast-developing country, holds immense growth potential because of its abundant resources, burgeoning population, and increasing technological advancements.

India contributes to the growth and development across the world through its commitment to fostering inclusive and sustainable development, sharing experiences, and building meaningful

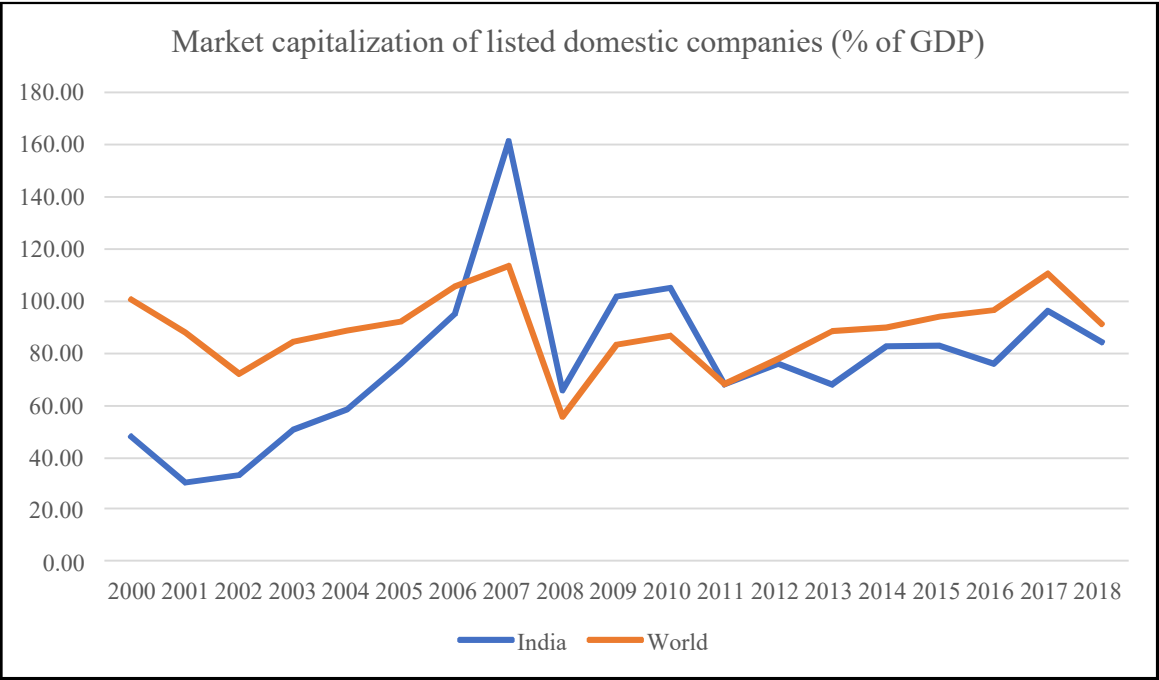
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partnerships with other countries. As a key player in the global economy, India's financial system catalyzes investment opportunities and fosters economic progress. India's financial system comprises diverse financial institutions (Banking, Insurance, Mutual funds, Non-Banking Financial Companies and Others) and financial markets (Stock Markets and Money markets).

The Indian stock market, as a part of the financial system, serves as a key platform for capital mobilization, investment, and wealth creation. India's stock market has witnessed significant growth and transformation over the years. It has emerged as one of the world's largest and most vibrant stock markets. It serves as a mechanism for domestic and international companies to raise capital through public offerings, enabling them to fund their expansion plans, invest in research and development, and create employment opportunities.

Building a Sustainable Future: Connecting the Dots between Sustainable Practices and Stock Market Prosperity in India

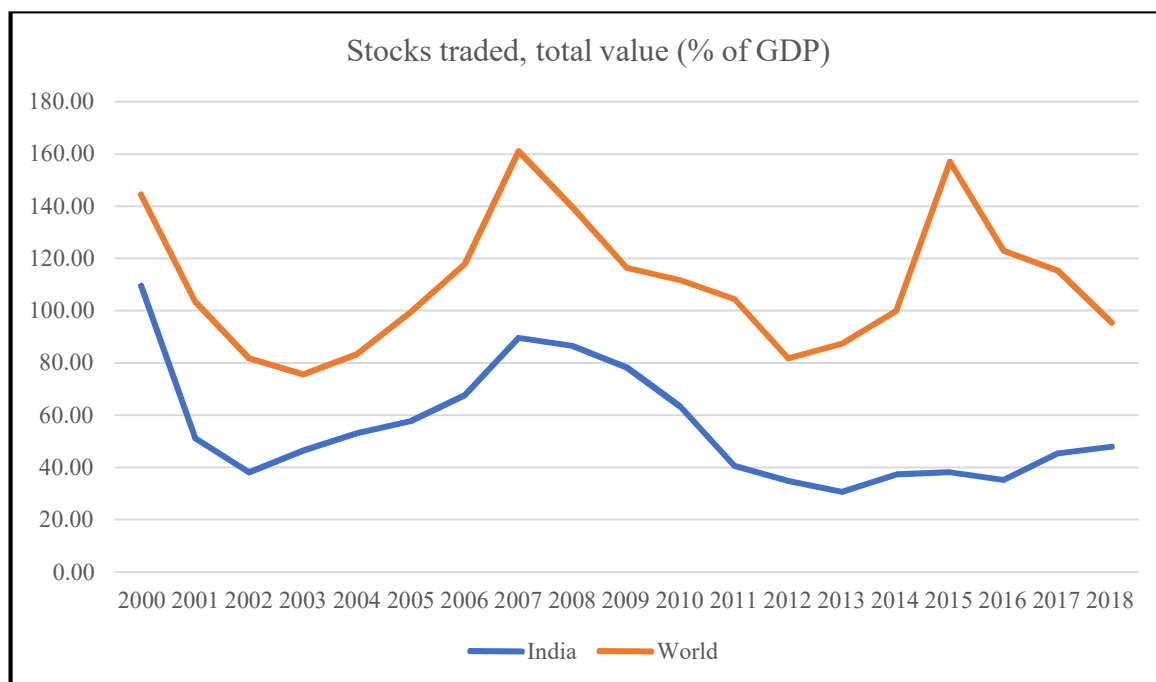
(a) : Market capitalization of listed domestic companies (% of GDP)



Source: World Development Indicators

(b)

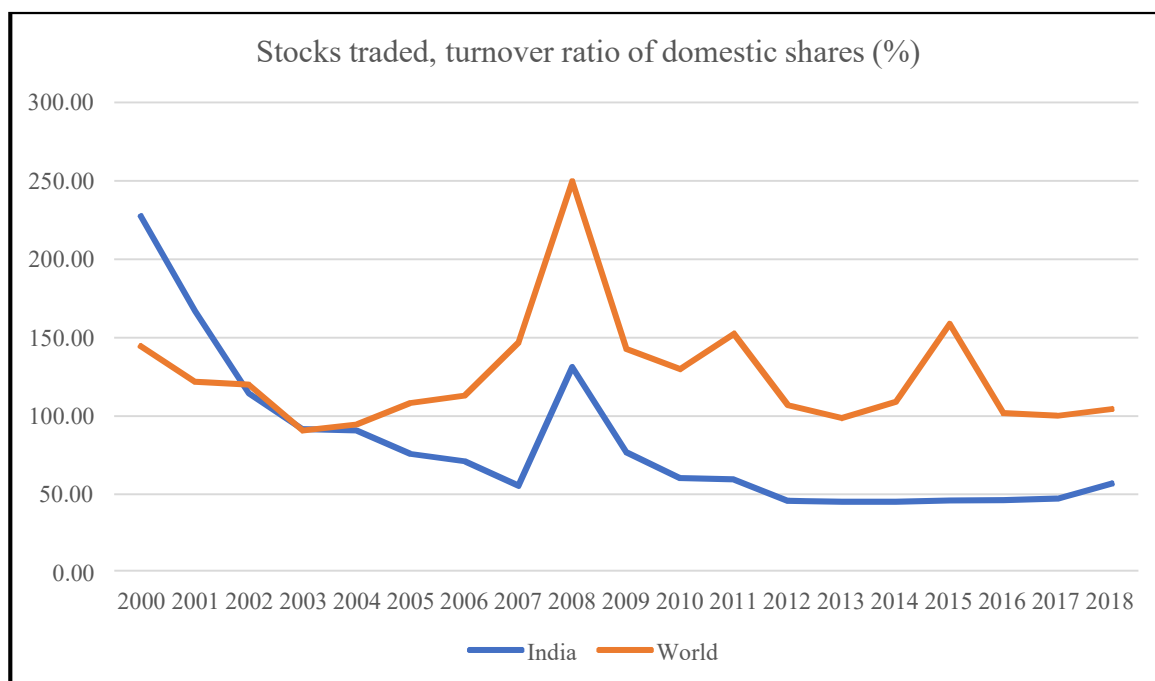
: Stocks traded, total value (% of GDP)



Source: World Development Indicators

(c)

: Stocks traded, turnover ratio of domestic shares (%)



Source: World Development Indicators

Figure 1: (a): Market capitalization of listed domestic companies (% of GDP). (b): Stocks traded, total value (% of GDP). (c): Stocks traded, turnover ratio of domestic shares (%).

Figure 1a illustrates the market capitalization of listed domestic companies as a percentage of GDP for India and the world. From 2000 to 2007, India's values exhibited steady growth, with a remarkable surge in 2007, reaching 161.24. However, a significant drop occurred in 2008, possibly indicating an economic downturn or specific event. Subsequently, the values recovered and continued to fluctuate, showing relative stability. In contrast, world values displayed a more consistent pattern, steadily increasing from 2000 to 2007, with a slight dip in 2008, possibly reflecting the impact of the global financial crisis. Like India, the world values also rebounded and continued to rise, experiencing relatively smaller fluctuations.

Figure 1b presents the Stocks traded and total value as a percentage of GDP, showcasing similar trends to Figure 1a with comparable growth and decline patterns for India and the world over the specified years.

Figure 1c depicts the Stocks traded turnover ratio of domestic shares. The data reveals fluctuating trends for both India and the world. India's values started at 227.28 in 2000 and experienced a declining trend, reaching a low point in 2012 at 45.85. However, there was a slight upturn in 2013 to 45.14, followed by relative stability in subsequent years and a gradual upward trend. The world values, on the other hand, demonstrated a different trajectory. After a steady increase from 2000 to 2007, reaching a peak of 146.93, a notable spike to 249.60 occurred in 2008. Subsequently, the world values declined and fluctuated, maintaining a generally lower trajectory compared to the peak in 2008. By 2018, India and the world experienced a recovery, with India's value reaching 56.77 and the world value rising to 104.38, indicating some recovery from the effects of the global financial crisis.

The data presented in Figure 1a-1c shows that the Indian stock market is closely connected to the global economy, and its performance is influenced by global events, particularly during periods of economic upheaval. The resilience and recovery observed in the Indian market demonstrate its importance and potential impact on the global financial landscape. As one of the largest emerging markets, understanding the dynamics of the Indian stock market is vital for investors and policymakers worldwide to make informed decisions and anticipate potential risks and opportunities in the global financial system. This study contributed significantly to the literature on the connection between sustainable practices (SP) and India's stock market performance (SMP). First, this study employed XAI modelling with a nonlinear panel ARDL model, providing a holistic approach to understanding and quantifying relationships in panel data. The visual insights from the shape dependency plot guide the formulation of the model (Vilone and Longo, 2021), and the ARDL model's results validate and provide quantifiable information about the relationship. Second, the study focuses on the Indian market, which has experienced significant growth in sustainable business practices and is known for its rapid economic development. Understanding the connection between sustainability and stock market performance in India is crucial for investors and policymakers interested in promoting sustainable development. Third, this research uses a comprehensive dataset comprising sustainability metrics and stock market data of 75 NSE-listed firms in India from 2010 to 2024. This span effectively captures the evolutionary trajectory of the relationship between SP and SMP. It covers a substantial period during which sustainable practices gained prominence across industries, enabling a comprehensive analysis of their

impact on stock market indicators. The research seeks insights into how businesses' sustainable actions translate into financial outcomes by spanning this era of heightened sustainability focus. Fourth, this research used performance and valuation measures to represent the SMP of firms, such as Earnings Per Share (EPS), Price to Earnings Ratio (P/E), Price to Book Ratio (P/B) and Book Value per Share (BVPS). The environment, Social and Governance (ESG) score represents the sustainable practices of firms. The data for the study is collected from the Bloomberg database.

The subsequent sections of this paper are structured as follows: the "Theoretical Background" section encompasses the literature review, identifies research gaps, and elucidates the motivation behind this study. The "Data and Research Methodology" section outlines the sample, variables, study models, and the estimation methods applied in the analysis. Subsequently, the "Estimation Results and Discussions" section encapsulates the principal empirical discoveries of the research. Finally, the paper culminates with a "Conclusion" section, encapsulating the key insights and implications drawn from the study.

Theoretical Background

Literature Review

The connection between sustainable practices and firm performance has been well explored in panel and individual contexts across various nations. Broadstock et al. (2021) examined whether ESG performance could signal future stock performance and risk management for investors during a market-wide financial crisis triggered by the COVID-19 pandemic and proved that portfolios with higher ESG scores tend to outperform lower-scoring ones. Additionally, ESG performance was found to help mitigate financial risk during crises, emphasizing its importance in turbulent times. Chetty et al. (2015) examined the CSR announcements' impact on firms' performance within or outside the Johannesburg Securities Exchange's Socially Responsible Investment Index. The findings revealed occasional investor rewards during index entry years and penalties during exit; however, CSR activities did not significantly alter long-term financial performance despite several short-term fluctuations. Eccles et al.

(2014) studied how corporate sustainability impacts US companies' performance. Analyzing 180 matched firms, they found that those adopting sustainability policies by 1993 (High Sustainability) had distinct organizational processes compared to those with minimal adoption (Low Sustainability) by 2009. Sustainability companies displayed formal board responsibility for sustainability, linked executive compensation to sustainability metrics, engaged stakeholders, prioritized long-term goals, and outperformed counterparts in the stock market and accounting performance over the long term. Lachuer and Ben Jabeur (2022) also investigated the correlation between corporate social responsibility (CSR) and financial performance in the United States. Their findings revealed an adverse relationship between CSR and financial performance during favourable market conditions.

In the Indian context, Maji and Lohia (2023) studied how ESG performance influences the performance of Indian firms, using CRISIL ESG scores and ACE Equity data for 222 companies. They found positive links between ESG and firm performance, particularly emphasizing governance and social aspects. The research is notable for being the first in India to analyze the ESG-firm performance relationship using CRISIL scores and exploring ESG's impact across different levels of firm performance through quantile regression. Khandelwal, Sharma, and Chotia (2023) investigated voluntary ESG disclosure's impact on firm performance in India, utilizing S&P BSE 500 data from 2014 to 2023. Their research yielded unconventional results, challenging established beliefs by revealing a negative association between high ESG disclosure and returns, contradicting prior studies.

In a study exploring the between ESG practices and economic performance in Malaysia and Singapore, Tarmuji, Maelah, and Tarmuji (2016) underscored the significant influence of social and governance practices on economic performance. Their work provided valuable insights into the broader implications of ESG practices. Beddewela and Fairbrass (2015) focused on multinational enterprises (MNEs) and their CSR practices. This study explored how MNEs strategically engage with host institutions in Sri Lanka. The research shed light on the intricate dynamics between external institutional pressures, CSR activities, and stakeholder relationships, offering insights into CSR's instrumental and political aspects in a developing country. Nurim, Harjanto, Prabawati, and Wijaya (2022) examined the foundational role of financial performance in driving ESG activities and its subsequent positive influence on firm value in Indonesia. The

research emphasized the interplay between financial and ESG dimensions, contributing to stakeholder theory, CSR practices, and governance understanding.

Several multinational studies prove the favourable connection between ESG scores and corporate financial performance. Hirigoyen and Rehm (2015) researched the United States, Europe, and the Asia-Pacific region, shedding light on the positive correlation between ESG performance and firm financial performance.

In a comprehensive study, Bhaskaran et al. (2020) examined the financial performance of 4,887 firms, revealing that superior performance across ESG dimensions correlates with heightened market value. Likewise, De Lucia et al. (2020) observed a constructive relationship between ESG variables and financial performance among 1,038 European publicly traded companies. Naeem et al. (2022) delved into the financial performance of 1,042 companies from emerging economies, unearthing a positive association between ESG performance, firm value, and profitability. Meanwhile, Chairani and Siregar (2021) explored the intricate interplay of ESG, enterprise risk management (ERM), firm value, and profitability across ASEAN countries. Their research underscored the synergistic impact of ESG on ERM and firm value while demonstrating a positive correlation between ERM and firm value and profitability.

Furthermore, Waworuntu, Wantah, and Rusmanto (2014) investigated stakeholder commitment, financial outcomes, and corporate disclosure in ASEAN countries. Their findings illuminated a constructive relationship between stakeholder commitment and financial results, contributing to the growing recognition of Corporate Social Responsibility (CSR)

disclosure practices among leading firms listed in ASEAN markets.

Research Gaps

Measuring the impact of sustainability on firm performance is a very complex task that requires robust methodologies. While numerous studies have employed quantitative techniques like linear regression analysis and event studies to identify the connection between sustainable practices and firm performance (Al-Hiyari and Kolsi, 2021; Eccles et al., 2014), the nonlinear properties of stock performance data emphasize the need for innovative techniques, such as artificial intelligence and machine learning-based methods or nonlinear regression models (Lachuer and Ben Jabeur, 2022; Ahmad, Mobarek, Roni and Tan 2021; Deng and Cheng 2019).

Rationale for the study

The impetus for conducting this study originates from the global embrace of sustainable practices spanning business operations, processes, and financial markets. The profound ramifications of this widespread adoption resonate deeply with a spectrum of stakeholders, including investors, financial analysts, policymakers, and corporate decision-makers.

The meticulous analysis of specific ESG variables vis-à-vis key market indicators equips investors with nuanced decision-making tools, aligning financial objectives with sustainability imperatives. Financial analysts, on their part, stand to gain an enriched analytical repertoire. Deploying innovative methodologies further amplifies analytical precision and enables financial analysts to decode the intricate nonlinear and

Moreover, most existing studies rely on cross-sectional data or short-term time series or panel analyses, which may not fully capture the cumulative effects of sustainability initiatives over time. Hence, there is a need for a longitudinal analysis that captures the temporal dynamics of sustainable practices and their impact on organizational performance. A comprehensive longitudinal analysis covering an extended period can provide a more robust understanding of how sustainable practices influence stock market performance (Panda and Ray, 2023; Gavrilakis and Floros, 2023).

asymmetric dimensions of ESG-market interactions, fostering sophisticated advisories for clients seeking to harmonize financial aspirations with sustainable principles.

This study's ramifications transcend geopolitical boundaries, reverberating within the context of economies confronting analogous sustainability imperatives. The insights from the Indian experience resonate as a strategic paradigm, offering transferrable lessons for nations grappling with comparable developmental trajectories. By contextualizing the Indian encounter, this study offers a prescriptive blueprint for nations aspiring to harmonize growth imperatives with sustainable progress, fostering positive financial outcomes.

Data and Research Methodology

Sample Description

The study sample comprises 75 National Stock Exchange (NSE) listed mid-large capitalized firms for which annual data is available from 2010 to 2024. Since small-cap firms don't issue sustainability information, it is not available on the Bloomberg terminal, so they were not chosen in the study. All the relevant financial and non-financial data was collected from the Bloomberg terminal and CMIE prowest database.

Study Variables

This study explores the connection between sustainable practices and the market performance of mid-large capitalized firms listed on the NSE. To gauge the stock market performance of these firms, we employed key financial metrics, including Earnings Per Share (EPS), Price to Earnings Ratio (P/E), Price to Book Ratio (P/B), and Book Value per Share (BVPS). EPS is a fundamental indicator offering insights into a firm's performance and profitability within the stock market. In contrast, P/E, P/B, and BVPS are valuation metrics that provide valuable perspectives on how investors perceive the intrinsic value of these companies. To quantify sustainability, we utilized the ESG score, which encompasses three vital components: the Environment Score (ES), Social Score (SS), and Governance Score (GS). A comprehensive outline of these variables is presented in Table 1 for reference and clarity.

Table 1. Description of Variables.

Category	Variable	Description
Performance	Earnings Per Share (EPS)	EPS is the portion of a company's profit allocated to each share of its stock. Higher earnings per Share indicates greater profitability of the company's stock.
Valuation	Price to Earnings Ratio (P/E)	P/E is the ratio of a stock's share price to its earnings per share. It provides insight into whether a stock is priced expensively or inexpensively at its current market value. A low P/E ratio may suggest an undervalued stock,

		whereas a high P/E ratio might imply a stock with high growth expectations.
	Price to Book Ratio (P/B)	P/B compares a stock's price to its book value, reflecting its assets' value. P/B below 1.0 suggests that the market may undervalue the stock relative to its asset value.
	Book Value per Share (BVPS)	BVPS is calculated by dividing the equity available to common shareholders by the total number of outstanding shares. It quantifies a company's book value per share and is a fundamental measure of its equity.
Sustainable performance	Environment Score (ES)	The score reflects a firm's environmental sustainability level.
	Social Score (SS)	The social score indicates the degree of social sustainability of a firm.
	Governance Score (GS)	The governance score measures a firm's governance sustainability level.

Study Models and Preliminary Analysis

The study is based on two different estimation techniques examining linear and nonlinear connections in the variables under study: XAI modelling and Panel ARDL models.

XAI Modelling:

In this study, XAI modelling has been employed to investigate the relationship between SP and SMP. To facilitate a better grasp of XAI techniques, we provide a graphical elucidation of one of the widely recognized methods, namely SHapley Additive exPlanations (SHAP), as introduced by Lundberg and Lee (2017). The SHAP dependency plot primarily serves the purpose of elucidating individual predictions made by a machine learning model. It helps to

understand how changes in specific features impact the model's output on a case-by-case basis. The plot shows the relationship between a single feature and the model's predictions, indicating whether the impact is positive or negative. This method is also considered efficient in handling the nonlinear relationship in variables by exploring relations at different threshold levels (Amato, Ecclesia and Levantesi, 2023; Lachuer and Ben Jabeur, 2022).

Panel ARDL Estimation:

The linear panel ARDL model examines the short-run and long-run relationship between two variables but does not consider potential nonlinearities and cross-sectional dependencies. The nonlinear panel ARDL model, on the other hand, is a statistical technique used to analyze the relationship between variables over time, accounting for potential nonlinearities and cross-sectional dependencies. Hence, this study used a nonlinear (asymmetric) Panel Autoregressive Distributed Lag (ARDL) model to understand the SHAP dependency plots better. The shape dependency plot offers an initial visual cue of the relationship's nature, while the nonlinear (asymmetric) Panel (ARDL) model quantifies the relationship and provides statistical significance. Comparing the two can provide a more comprehensive understanding of how the variables interact. The combined approach allows for more informed decision-making. Suppose the shape dependency plot suggests a nonlinear relationship, and the panel nonlinear ARDL model confirms it. In that case, one can confidently make decisions based on the understanding that the relationship is visually apparent and statistically valid. Shape dependency plot analysis and the panel nonlinear ARDL model are complementary techniques that provide a

holistic approach to understanding and quantifying relationships in panel data. The visual insights from the shape dependency plot guide the formulation of the model, and the model's results validate and provide quantifiable information about the relationship.

Furthermore, we have opted for ARDL models over GMM models for several compelling reasons. First, ARDL models enable us to capture nonlinear relationships in our analysis. Second, they effectively account for the inherent heterogeneity in our dataset, as indicated by Pesaran's (2007) CD test, which suggests the presence of heterogeneity in the stock price performance indicators (refer to Table 2). Third, ARDL models are particularly suitable when our study reveals a mixed order of integration, as evident in Table 2. Fourth, they are well-suited for handling large datasets with substantial time series (T) and cross-sectional (N) dimensions. Notably, Blackburne and Frank (2007) emphasize that the asymptotic properties of large N, large T dynamic panels differ from those of traditional large N, small T dynamic panels. Small T panel estimation typically relies on fixed- or random-effects estimators, along with the Arellano and Bond (1991)

generalized method-of-moments estimator. Given the nature of our dataset, characterized by mixed order integration, heterogeneity, and cross-sectional dependence, the dynamic heterogeneous panel data model is the most appropriate choice for our study, rendering the GMM estimator unsuitable.

Our analysis explores two prominent techniques for estimating the dynamic heterogeneous panel data model: the Pooled Mean Group (PMG) estimator and the Mean Group (MG) estimator. These estimators apply to both symmetric and asymmetric panel ARDL models. The MG estimator entails the estimation of N time-series regressions, followed by the averaging of coefficients. Conversely, the PMG estimator combines the pooling of data and the averaging of coefficients, as detailed by

Blackburne and Frank (2007). To ascertain the most suitable estimator, we conduct a Hausman test to assess whether any systematic differences exist between the two approaches.

Our analysis commences by assuming a symmetric response of stock market performance to changes in ESG, employing the symmetric panel ARDL model (see Table 3). The symmetric panel ARDL model treats all individual entities (cross-sectional units) in the panel equally. Subsequently, we employ the asymmetric panel ARDL model, which accommodates the possibility that the impact of changes in an independent variable on the dependent variable may vary depending on the direction of the change. The results of the panel nonlinear ARDL model are presented in Table 4.

Preliminary Test:

Unit Root Test

In the context of our study, which involves a panel with a substantial number of observations (large T) and entities (large N), we thoroughly examined relevant variables through panel unit root tests. The dynamic heterogeneous panel data model, which we have chosen as the most suitable for our

analysis, is typically applied when the underlying variables exhibit different degrees of cointegration, ranging from level $I(0)$ to first difference $I(1)$ or a mixture of integration levels with extended periods (Shin et al., 2014).

Table 2. Panel Unit root and Cross-Sectional Dependence Test.

Null hypothesis	Unit root within common process			Unit root with individual unit root process		Unit root in the presence of cross-section dependence	Unit root with common unit root process	No or weakly cross-sectional dependence
	Levin, Lin & Chu t	Breitung t-Stat.	Harris-Tzavalis rho	Im, Pesaran & Shin W Stat	ADF Fisher Chi-square	Pesaran CIPS test	Hadri Z-Stat.	Pesaran CD test
EPS	-1.34*** b	-1.85**b	0.14***b	-7.22*** b	372.10** *b	-2.24***b	16.35*** b	-1.281 (0.100)
P/E	1.83**b	-3.72*** b	-0.002*** b	-1.27**b	441.77** *b	-2.38***b	5.91***b	-4.-67 (0.000)
P/B	-5.54*** b	-8.55**b	0.45***b	-2.09**b	466.95** *b	-2.91**b	15.15*** b	1.414 (0.921)
BVPS	9.11**b	-6.20***a	-0.05***b	-1.56**b	389.27** *a	-2.20**b	28.32*** b	6.868 (1.000)
ES	-6.64***a	-13.04** *a	-0.16***a	-3.21*** a	571.63** *a	-2.49**a	28.87*** a	
SS	-12.63** *a	-11.50** *a	0.67***a	-3.11*** a	199.09** *a	-2.90**a	28.55*** a	
GS	-28.71** *a	-10.04** *a	-0.18***a	2.91*** b	585.44** *a	-2.24**a	28.15*** a	

Source: Calculated using STATA 17

Note: a and b denote stationarity at level and at first difference respectively, while ***, **, * indicate statistical significance at 1%, 5% and 10% respectively. Note that the Pesaran CD test is not conducted for the ESG series since it is considered to be homogenous as it is cross-section invariant.

We have conducted four distinct types of panel unit root tests to assess the integration characteristics of our variables. As presented in Table 2, the first type involves panel unit root tests with the null hypothesis positing a unit root with a common process (Breitung, 2000; Levin et al., 2002; Harris and Tzavali, 1999), where homogeneity is assumed. In contrast, the second type assumes a unit root with individual unit root processes (Im et al., 2003), allowing for heterogeneity among entities. The third type also assumes a unit root in the null hypothesis but incorporates

cross-sectional dependence (Pesaran, 2007). The fourth category tests the null hypothesis of no unit root with a common unit root process (Hadri Lagrange Multiplier test, 2000). The Pesaran (2007) unit root test is of particular significance in our study, which not only assesses unit roots but also examines the homogeneity or heterogeneity of cross-sections within each group. The null hypothesis for this test posits homogeneous non-stationarity, while the alternative hypothesis considers possible heterogeneous alternatives.

Our findings indicate that SMP indicators exhibit integration with order zero $I(0)$, whereas ESG scores display integration with order one $I(1)$, as observed in most of the tests. Furthermore, the Pesaran CIPS test outcomes suggest that stock price indexes exhibit heterogeneous stationarity of order $I(1)$, signifying that cross-sections display heterogeneity based on stock price indexes.

Cross-Sectional Dependence Test

We also conducted a Cross-Sectional Dependence (CD) test, as Pesaran (2015) recommended, to account for potential cross-sectional dependence within the data. Panel data analysis typically assumes that disturbances are independent across different cross-sectional units. However, cross-sectional dependence can arise due to various factors, such as geographic proximity or shared political and economic influences (Gaibullov et al., 2014). To assess the presence of cross-sectional dependence, we

Consequently, our paper's chosen framework for estimation, which accounts for inherent heterogeneity and non-stationarity in the panel data series, remains valid for our analytical purposes. In essence, the results of the unit root tests affirm the appropriateness of our selection of the panel ARDL model as the preferred estimation framework within the context of this study.

applied the Cross-Sectional Independence Pesaran Statistic (CIPS) and the CD tests, examining the characteristics of the residuals (as detailed in Table 2). The results of the CD test indicate a substantial level of cross-sectional dependence within the error term, leading to the rejection of the null hypothesis of weak cross-sectional dependence. Consequently, this supports the suitability of the nonlinear panel ARDL model for our estimation, given the presence of cross-sectional dependence.

Hausman Test

We also employed the Hausman test as a critical step in selecting between the Pooled Mean Group (PMG) and Mean Group (MG) estimators (as indicated in Table 6 and Table 7). The null hypothesis for this test assumes that the PMG estimator is the efficient choice, while the alternative hypothesis suggests that

the MG estimator is more efficient. Our study's findings, as determined by the Hausman test results, indicate the efficiency of the PMG estimator for both symmetric and asymmetric panel ARDL models. This outcome supports the use of the PMG estimator in our analysis.

Wald Test of Asymmetric Link

We utilized the Wald test to investigate whether there exists an asymmetric response in both the short and long run to changes in ESG scores affecting SMP. The null hypothesis for this test posits an asymmetric

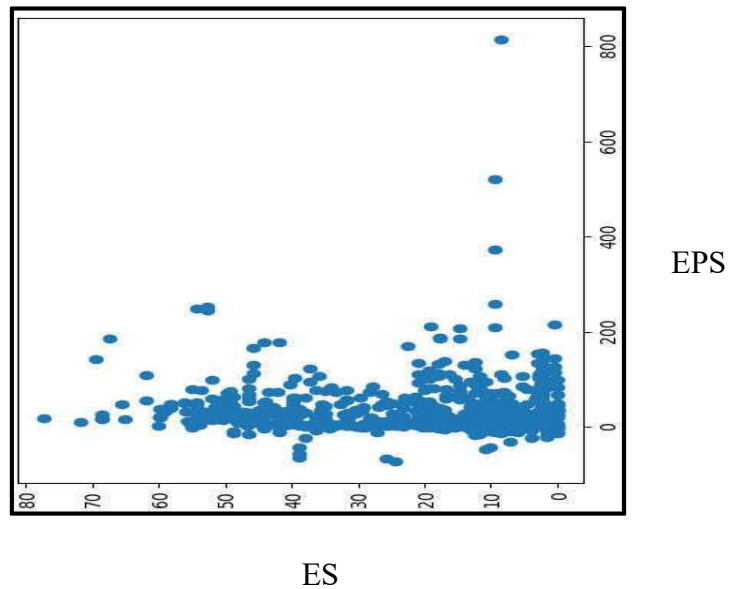
link in both the short and long run. If the p-values associated with the Wald long-run (WLR) and Wald short-run (WSR) tests exceed 0.05, we cannot reject the null hypothesis of an asymmetric link.

Estimation Results and Discussion

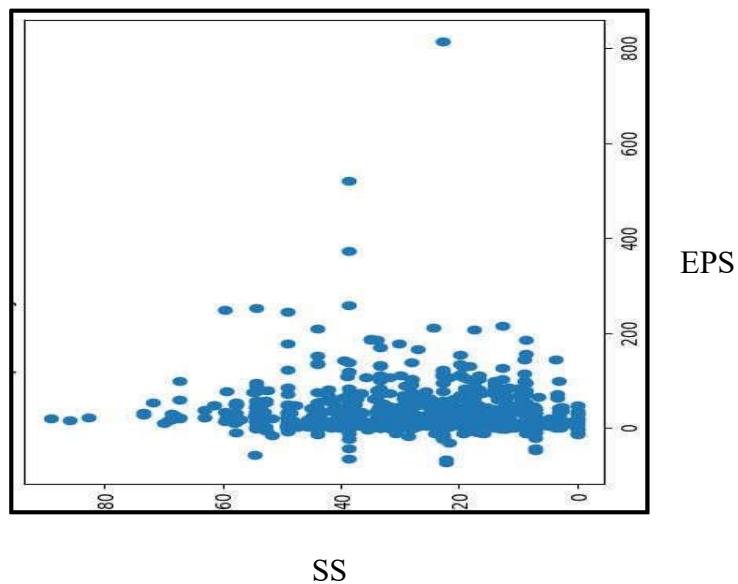
SHAP Dependency Plots

SHAP dependency plots are used in this study to examine the connection between ESG scores and various SMP indicators.

(a) : Dependency plot: Effect of ES on EPS.



(b) : Dependency plot: Effect of SS on EPS.



(c)

: Dependency plot: Effect of GS on EPS.

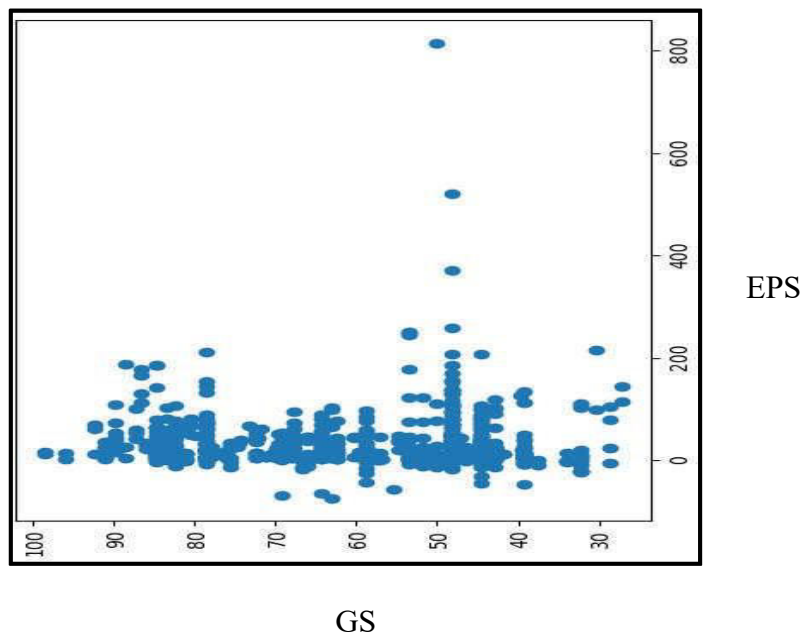
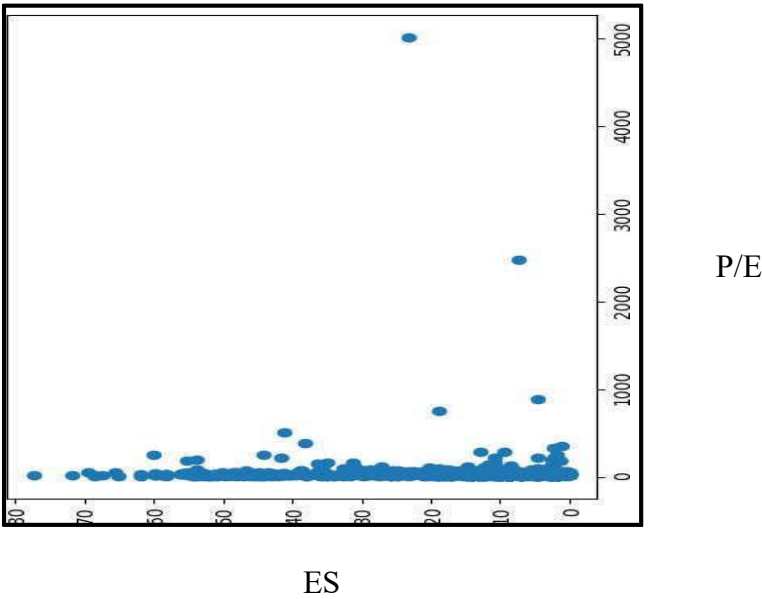


Figure 2. (a) Dependency plot: Effect of ES on EPS. (b) Dependency plot: Effect of SS on EPS. (c) Dependency plot: Effect of ESG on EPS.

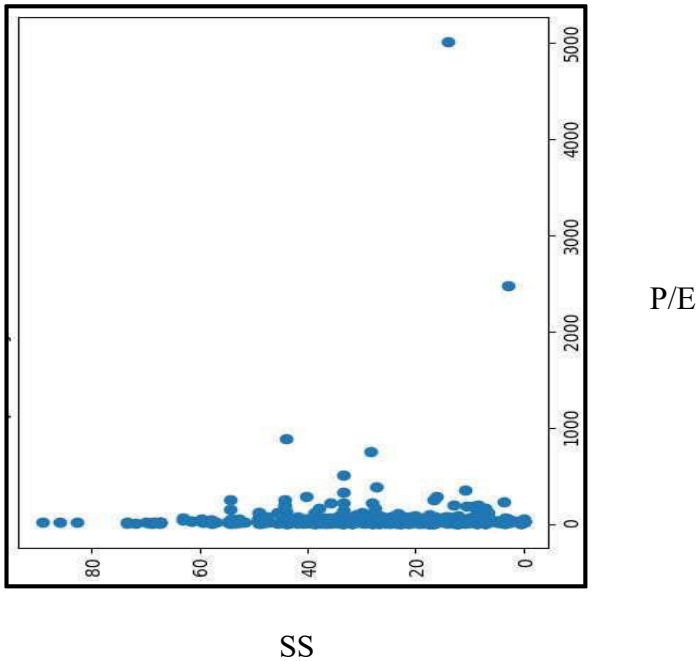
Sources: Author's Calculation (Python)

Figure 2a-c demonstrates that ES, SS, and GS have a significant positive impact on EPS, but in some cases at specific threshold levels, such as ES between 10-20 with minimal effect, SS between 20-60 a bigger range, and GS between 40-60. This implies that certain ranges of ESG scores can influence EPS positively, but the overall effect is limited. ESG factors may not directly and immediately impact EPS because the influence of sustainability practices on stock performance can be complex and multifaceted. Various factors influence earnings, including revenue growth, cost management, competitive dynamics, and market conditions. While ESG practices can contribute to long-term business sustainability and resilience, their effects on short-term stock performance, such as EPS, may be less pronounced.

(a) : Dependency plot: Effect of ES on P/E.



(b) : Dependency plot: Effect of SS on P/E.



(c)

: Dependency plot: Effect of GS on P/E.

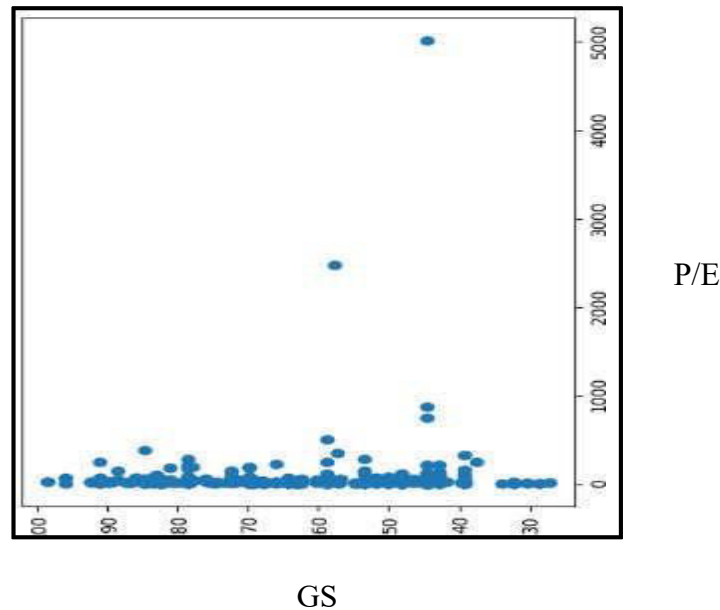
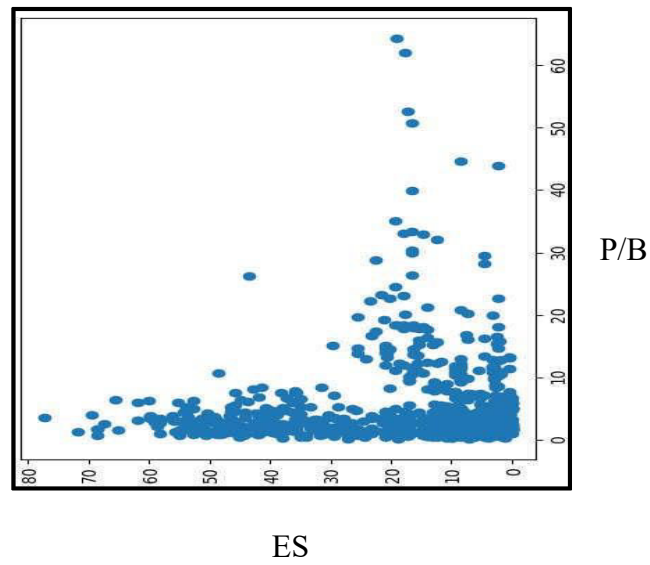


Figure 3. (a): Dependency plot: Effect of ES on P/E. (b): Dependency plot: Effect of SS on P/E. (c): Dependency plot: Effect of GS on P/E.

Sources: Author's Calculation (Python)

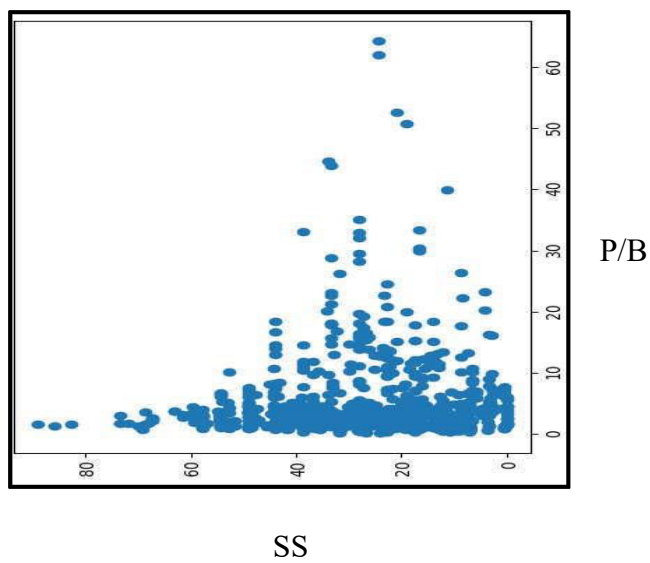
Figure 3a-c indicates that ES, SS, and GS have no substantial impact on P/E ratios. This suggests that ESG scores do not play a significant role in determining the P/E ratios of firms. This finding suggests that market valuation, as reflected in P/E ratios, is driven by factors other than ESG performance in the context of the Indian firms studied. P/E ratios are widely used to measure market expectations and investor sentiment regarding a company's future earnings growth potential. Various factors influence these expectations, including macroeconomic conditions, industry dynamics, competitive position, growth prospects, financial performance, and management quality. While ESG factors are important considerations for long-term sustainability and risk management, they may not be the primary drivers of market valuation in the context of the studied Indian firms.

a): Dependency plot: Effect of ES on P/B.



(b)

: Dependency plot: Effect of SS on P/B.



(c)

: Dependency plot: Effect of GS on P/B.

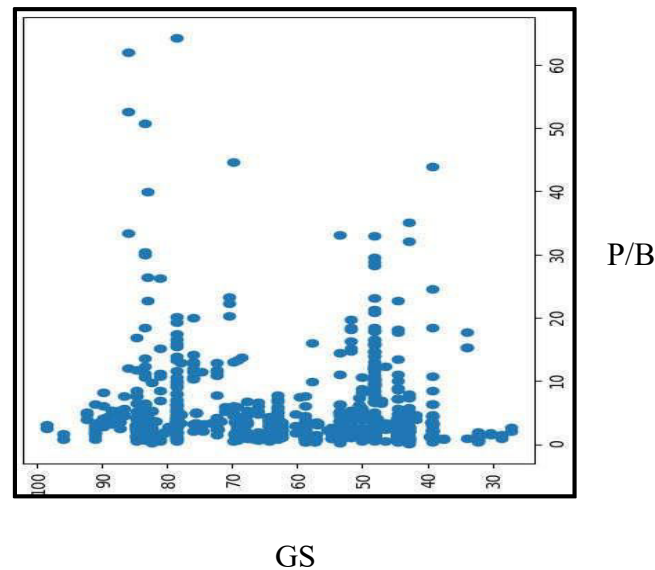


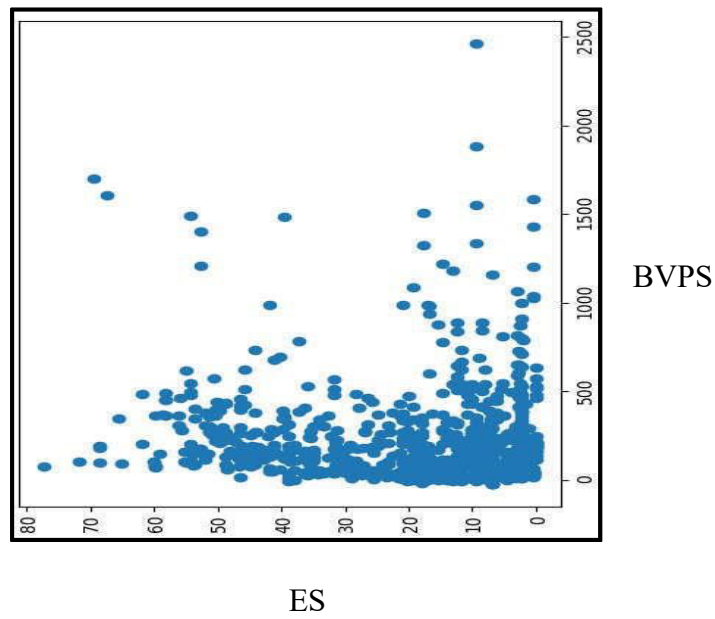
Figure 4. (a) Dependency plot: Effect of ES on P/B. (b) Dependency plot: Effect of SS on P/B. (c) Dependency plot: Effect of GS on P/B.

Sources: Author's Calculation (Python)

Figure 4a demonstrates a positive relationship between ES and P/B ratios up to a threshold of 25. However, beyond that threshold, the relationship becomes insignificant. The positive relationship between ES and P/B ratios up to a certain threshold level suggests that companies with higher environmental performance, as measured by their ES, may command higher valuations than their book values. This finding indicates that investors and the market value firms with stronger environmental practices, such as sustainable resource management, emissions reduction, and ecological stewardship. These practices indicate long-term viability, risk management, and adaptability to changing environmental regulations and consumer preferences. However, beyond the identified threshold level of 25, the relationship becomes insignificant, suggesting that the impact of ES on P/B ratios diminishes or reaches a plateau. Similarly, Figure 4b shows a mixed relation between SS and P/B ratios. This suggests that the influence of social factors on market valuations is less consistent than environmental and governance factors. Social factors encompass labour practices, community relations, customer satisfaction, and product safety. The mixed relationship implies that the impact of social factors on market valuations may vary across different firms or industries. As depicted in Figure 4c, GS has a significant positive relationship with P/B ratios. This finding highlights the importance of governance factors in determining market valuations. This finding highlights the importance of robust governance practices in determining market valuations. Governance factors include board independence, executive compensation, transparency, and ethics. Firms with higher GS scores, indicating stronger governance practices, are perceived as having better management quality, reduced agency costs, and improved accountability, leading to higher market valuations.

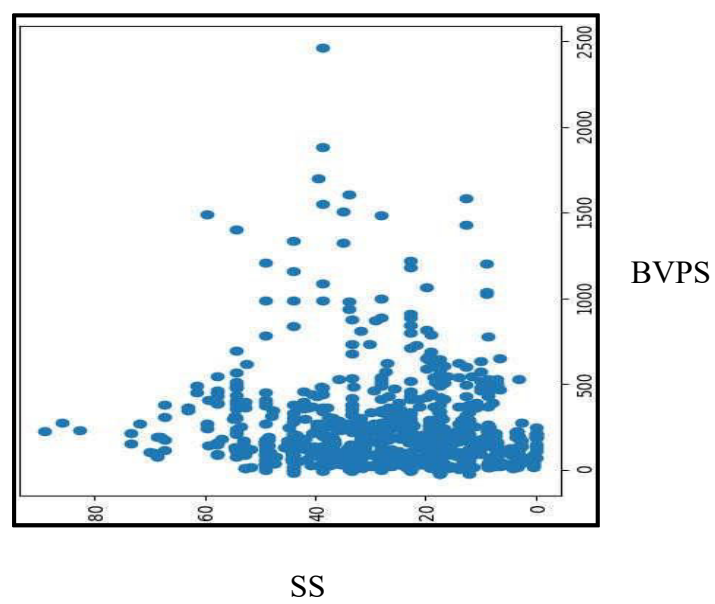
(a)

: Dependency plot: Effect of ES on BVPS.



(b)

: Dependency plot: Effect of SS on BVPS.



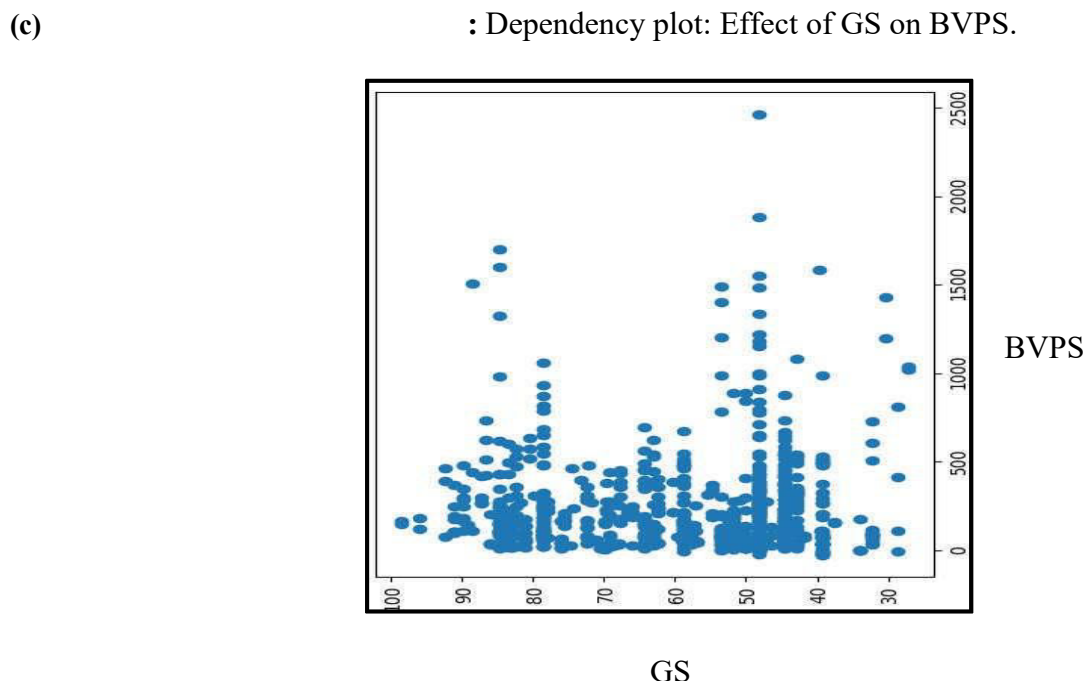


Figure 5. (a): Dependency plot: Effect of ES on BVPS. (b): Dependency plot: Effect of SS on BVPS. (c): Dependency plot: Effect of GS on BVPS.

Sources: Author's Calculation (Python)

Figure 5a shows positive relationships between ES and BVPS at low ES levels (around 20) and 40-70 ES levels. This finding implies that higher ESG scores, particularly in the environmental aspect, are associated with higher BVPS. The positive relationship at low ES levels suggests that companies with some environmental performance, even if not exceptionally high, tend to have higher book values per Share. Figure 5b indicates a positive relationship between SS and BVPS up to 50, beyond which the relationship is not explicitly identified. This finding suggests that higher ESG scores, particularly in the social aspect, are associated with higher book values per Share. Still, the influence may diminish or become less pronounced beyond a certain threshold level. Figure 5c does not indicate a clear relationship between GS and BVPS. This finding suggests that in the context of the Indian firms studied, governance performance may not directly impact book values per Share. However, it is important to note that effective governance practices are still crucial for long-term business success and investor confidence. Governance factors, such as transparency, accountability, and board independence, play a vital role in shaping investor perceptions and overall firm performance, even if their direct influence on BVPS may not be apparent in this specific analysis.

Panel Data Estimation

The SHAP dependency plot shows the connection between the two variables under study. This connection can be studied in more detail using the panel ARDL model, which

decomposes connection in the short and long run and nonlinear ARDL further enhance understanding by decomposing them in positive and negative asymmetries.

The findings from the symmetric panel linear ARDL model, as shown in Table 3, reveal that the Environmental Score (ES) has a positive and significant long-term influence on Earnings Per Share (EPS), Price-to-Earnings ratio (P/E), and Book Value Per Share (BVPS). Conversely, ES negatively and significantly impacts the Price-to-Book ratio (P/B). The Social Score (SS) and Governance Score (GS) also demonstrate noteworthy long-term effects: they positively and significantly impact EPS and BVPS while exerting a negative and significant influence on P/E and P/B. Notably, the short-run analysis suggests that ESG scores do not have a significant immediate impact on Stock Market Performance (SMP). A significantly negative Error Correction Term indicates a convergence to a long-term relationship, emphasizing the enduring nature of these associations. Table 3 presents the Panel Linear ARDL PMG model results.

In contrast to the symmetrical case, the nonlinear panel ARDL version adopted in this analysis (see Table 4) introduces the possibility of an asymmetric response of ESG scores to SMP indicators. This approach acknowledges that positive and negative changes may not yield identical effects on the stock market's performance. The subsequent findings in Table 4 reveal distinct dynamics in both the long-run and short-run contexts.

In the long-run estimation, it becomes evident that both positive changes in the Environmental Score (ES) negatively impact Earnings Per Share (EPS), and the reverse is true for negative changes. Still, significance is observed for the positive change. The negative impact of positive ES changes on long-term EPS could be due to the short-term costs associated with adopting and implementing environmentally sustainable practices. These upfront investments may temporarily affect a firm's profitability and,

consequently, its EPS. The market might also interpret these changes as potential indicators of shifts in a firm's operational strategy, which can affect earnings. Investors may prioritize short-term financial results over the longer-term benefits of sustainability (Gavrilakis and Floros, 2023; Asterious, Pilbeam and Pouliot, 2023).

Findings for the Price-to-Earnings ratio (P/E), Price-to-Book ratio (P/B), and Book Value Per Share (BVPS) revealed that both positive and negative ES changes yield significant positive impacts. However, the magnitude is notably higher for positive changes. The positive impact of changes in ES on the valuation of firms' shares signifies that investors perceive improved sustainability practices as indicative of future growth potential (Maji and Lohia, 2023). This suggests that investors attach a premium to firms committed to environmental improvement (Zhou, Liu and Luo, 2022; Al-Hiyari and Kolsi, 2021).

Moving to the short run, both positive and negative changes in ES contribute positively to all SMP indicators but without statistical significance. The lack of short-term statistical significance could be due to the relatively transient nature of short-term market movements, which might be driven by various factors unrelated to ESG considerations. The significant and negative Error Correction Term (ECT) highlights the tendency of the model to converge to a long-term relationship, suggesting that while short-term noise may be present, the underlying equilibrium relationship between ES and SMP indicators is persistent.

As indicated by the Wald test, an asymmetric connection implies that the market perceives positive and negative changes in ES differently. This could reflect investor optimism when a firm enhances its environmental performance or investor

caution when it experiences deterioration. Asymmetric reactions may also result from varying investor scepticism regarding the motivations behind positive ES changes.

The long-run analysis for the Social Score (SS) demonstrates substantial and significant positive impacts on almost all SMP indicators, except for P/B, which has not shown a significant impact. However, the magnitude of impact is higher for negative changes in SS.

The substantial and significant positive impacts of SS on all SMP indicators highlight the market's recognition of socially responsible practices, as shown by the research of Asterious, Pilbeam and Pouliot (2023) and Broadstock et al. (2021). Positive SS changes could enhance public image, customer loyalty, and operational efficiencies, improving earnings over the long run (Ahmad, Mobarek, Roni and Tan, 2021; Deng and Cheng, 2019). The positive impact is likely stronger for negative SS changes due to the strong trust of the heightened sensitivity investors in the organization about social performance and stock performance, which does not adversely impact SMP even during the negative change in SS. Another factor showing that SMP is elastic in the long run regardless of whether SS is positive or negative change is SMP determined by the number of factors apart from SS.

The mixed findings concerning P/B suggest that while SS changes might influence certain valuation aspects, they may not consistently impact the perceived intrinsic value of the firm's assets. Positive SS changes could signal improved governance and ethical practices, potentially leading to higher P/B ratios. However, the lack of significance for P/B might indicate that investors primarily assess social factors as less directly tied to the firm's book value than other valuation metrics.

In the short run, the impact of SS changes is statistically insignificant. The statistically insignificant impact of SS changes in the short run could be attributed to the lag between adopting socially responsible practices and their recognition by the market. Short-term market fluctuations, macroeconomic conditions, and other external factors might overshadow the immediate influence of SS changes on SMP indicators.

The significant and negative Error Correction Term underlines the model's inclination to converge towards a long-term relationship. This observation aligns with the implications of the Wald test, which indicates an asymmetric connection between SS and SMP. The observed asymmetry in the connection between SS and SMP could reflect India's particular cultural and market context. Investors may have varying sensitivities and preferences when evaluating social considerations in their investment decisions. The results may also highlight a greater focus on long-term sustainability in India, where socially responsible practices may be crucial for maintaining business longevity and success (Panda and Ray, 2023).

The finding of the Governance Score (GS) in the long run reveals a positive impact on both Earnings Per Share (EPS) and Book Value Per Share (BVPS) for both positive and negative changes in GS where the magnitude of impact is more pronounced in the case of negative changes. In contrast, for the Price-to-Book ratio (P/B), positive and negative GS changes result in significant negative impact, with the magnitude of the negative impact being higher. The scenario differs for the Price-to-Earnings ratio (P/E), wherein both positive change in GS leads to negative impact and negative GS changes yield positive impacts in the long run. Still, the significance is absent in both cases. In the short run, positive GS changes induce significant positive impacts

on EPS and P/B and insignificant negative impacts on P/E and BVPS. Negative changes in GS lead to a positive impact on EPS and P/B and a negative impact on P/E and BVPS. The significant and negative Error Correction Term reaffirms the model's inclination towards a long-term relationship. Correspondingly, the outcomes of the Wald test highlight the presence of an asymmetric connection between GS and SMP.

The positive impact of both positive and negative changes in GS on EPS and BVPS can be linked to the market's recognition of effective corporate governance practices. Positive changes might signal improved transparency, accountability, and risk management, enhancing investor confidence in the firm's ability to generate sustainable earnings and preserve asset quality (Ye, Song and Liang, 2022; Yin, Li and Su, 2023). Negative GS changes might prompt investors to perceive governance weaknesses, which could lead to concerns about earnings stability and asset preservation, thereby impacting EPS and BVPS.

The significant negative impact of positive and negative GS changes on P/B highlights the market's perception of governance as a critical factor influencing a firm's intrinsic value relative to its market price. Positive GS changes may lead to concerns of potential overvaluation, where investors believe that governance improvements may not be adequately reflected in the firm's tangible assets. Negative GS changes might indicate

governance-related risks, which could lead to a lower perceived value relative to book value.

The absence of significance for P/E concerning positive and negative changes in GS could indicate that governance practices might not be the primary driver of perceived future earnings potential in the Indian market. Investors may prioritize other factors, such as financial performance and growth prospects, when assessing a firm's valuation in terms of its earnings capacity.

The significant positive impacts of positive GS changes on EPS and P/B and the insignificant negative impact on P/E and BVPS in the short run highlight the potential for immediate positive contributions to these indicators. Conversely, the negative impacts of negative GS changes on P/E and BVPS suggest that investors might react more sensitively to governance-related concerns in the short term. The significant and negative Error Correction Term emphasizes the tendency for the model to converge to a long-term relationship, underlining the enduring nature of the relationship between GS and SMP.

The presence of an asymmetric connection, as indicated by the outcomes of the Wald test, suggests that positive and negative GS changes may have varying effects on SMP indicators. This could reflect investor caution when negative governance changes are observed and a higher optimism when positive governance changes occur.

Table 3. Panel Linear ARDL: PMG.

	EPS	P/E	P/B	BVPS
Environment Score				
EScore (Long Run)	0.079*** (0.000)	0.063*** (0.002)	-0.019*** (0.000)	0.314*** (0.001)
EScore (Short Run)	0.429 (0.336)	0.475 (0.670)	0.012 (0.698)	3.310 (0.275)
Error Correction Term (EScore)	-0.382*** (0.000)	-0.595* (0.000)	-0.563*** (0.000)	-0.341*** (0.000)
Hausman Test (EScore)				
Chi2	0.19	2.06	0.77	0.46
P value	(0.962)	(0.151)	(0.381)	(0.496)
Social Score				
SScore (Long Run)	0.155*** (0.000)	0.347*** (0.000)	-0.002 (0.396)	0.225** (0.040)
SScore (Short Run)	-0.235 (0.307)	1.048 (0.207)	0.030 (0.460)	-0.301 (0.738)
Error Correction Term (SScore)	-0.396*** (0.000)	-0.661*** (0.000)	-0.597*** (0.000)	-0.356*** (0.000)
Hausman Test (SScore)				
Chi2	0.11	0.56	1.87	0.00
P value	(0.923)	(0.453)	(0.171)	(0.948)
Governance Score				
GScore (Long Run)	0.404*** (0.000)	-0.011 (0.567)	-0.020*** (0.000)	0.464*** (0.000)
GScore (Short Run)	0.216 (0.587)	-0.110 (0.700)	0.056*** (0.000)	-0.446 (0.772)
Error Correction Term (GScore)	-0.402*** (0.000)	-0.579*** (0.000)	-0.545*** (0.000)	-0.354*** (0.000)
Hausman Test (GScore)				
Chi2	0.39	0.65	0.04	0.12
P value	(0.531)	(0.419)	(0.841)	(0.724)

Source: Calculated using STATA 17

Note: Number in parentheses is the p value and ***, **, * shows 1%, 5% and 10% of significance level

Table 4. Panel Nonlinear ARDL: PMG.

	EPS	P/E	P/B	BVPS
Environment Score				
Long Run				
EScore (+)	-0.085*** (0.000)	0.081*** (0.000)	0.004** (0.015)	0.501*** (0.000)
EScore (-)	0.0198 (0.806)	0.183* (0.051)	0.029 (0.113)	2.170* (0.302)
Short Run				
EScore (+)	0.655 (0.147)	0.484 (0.665)	0.018 (0.577)	3.441 (0.246)
EScore (-)	0.361 (0.441)	0.980 (0.307)	0.084 (0.118)	-1857 (0.363)
Error Correction Term (EScore)	-0.364*** (0.001)	-0.604*** (0.000)	-0.505*** (0.000)	-0.321*** (0.000)
Hausman Test (EScore)				
Chi2	0.80	2.65	1.79	1.25
P value	(0.671)	(0.266)	(0.000)	(0.535)
WLR (EScore)				
Chi2	1.87	3.79	34.47	40.88
P value	(0.171)	(0.051)	(0.000)	(0.000)
WSR (EScore)				
Chi2	0.41	0.12	1.69	3.22
P value	(0.521)	(0.730)	(0.193)	(0.072)
Social Score				
Long Run				
SScore (+)	0.181*** (0.000)	0.586*** (0.000)	0.002 (0.458)	5.423*** (0.000)
SScore (-)	0.206*** (0.000)	0.983*** (0.000)	0.065*** (0.000)	7.559*** (0.000)
Short Run				
SScore (+)	-0.122 (0.525)	1.139 (0.170)	0.043 (0.254)	-0.638 (0.495)
SScore (-)	0.355 (0.489)	-0.044 (0.899)	0.015 (0.694)	-0.275 (0.777)
Error Correction Term (SScore)	-0.427*** (0.000)	-0.603*** (0.000)	-0.505*** (0.000)	-0.268*** (0.000)
Hausman Test (SScore)				
Chi2	0.31	1.75	1.67	1.76
P value	(0.857)	(0.416)	(0.432)	(0.657)
WLR (SScore)				
Chi2	0.88	27.44	108.54	108.89
P value	(0.347)	(0.120)	(0.090)	(0.145)

WSR (SScore)				
Chi2	0.85	1.95	3.03	0.18
P value	(0.357)	(0.162)	(0.081)	(0.667)
Governance Score				
Long Run				
GScore (+)	0.390*** (0.000)	-0.033 (0.187)	-0.019*** (0.000)	1.817*** (0.000)
GScore (-)	0.393*** (0.000)	0.059 (0.110)	-0.023*** (0.000)	2.259*** (0.000)
Short Run				
GScore (+)	0.937*** (0.000)	-0.227 (0.482)	0.082** (0.013)	-1.256 (0.470)
GScore (-)	0.137 (0.321)	-0.110 (0.725)	0.063* (0.074)	-2.083* (0.062)
Error Correction Term (GScore)	-0.362*** (0.000)	-0.544*** (0.000)	-0.495*** (0.000)	-0.302*** (0.000)
Hausman Test (GScore)				
Chi2	0.47	0.03	0.67	1.90
P value	(0.790)	(0.986)	(0.716)	(0.387)
WLR (GScore)				
Chi2	0.01	0.00	0.07	24.10
P value	(0.925)	(0.991)	(0.785)	(0.310)
WSR (GScore)				
Chi2	0.01	0.01	0.21	0.33
P value	(0.941)	(0.914)	(0.645)	(0.563)

Source: Calculated using STATA 17

Note: Number in parentheses is the p value and ***, **, * shows 1%, 5% and 10% of significance level

Conclusion

This study delved into the complex relationship between ESG scores and Indian firms' stock market performance. The result of SHAP dependency plots revealed that ESG scores have limited immediate effects on metrics like EPS, P/E, and specific P/B levels. However, they do show positive correlations with BVPS at specific thresholds. These findings highlight the multifaceted nature of ESG's influence on short-term stock performance, impacted by sector dynamics, market conditions, and corporate practices. The study underscores the challenge of directly translating ESG practices into immediate financial indicators, emphasizing sustainability considerations' broader and enduring value in shaping investor perceptions and resilient business strategies. The study also employed a panel nonlinear ARDL model, uncovering that positive changes in ESG scores often result in significant positive effects on various Stock Market Performance (SMP) indicators. Notably, the Social Score (SS) exerts a lasting positive impact on SMP, especially in the long run. Meanwhile, the Governance Score (GS) significantly affects metrics like EPS and BVPS, emphasizing its role in valuation. These

findings emphasize the importance of understanding ESG's impact on India's financial performance and market valuation.

The implications drawn from this study are manifold. Firstly, it advances our comprehension of the intricate interplay between sustainability and stock market performance, particularly within the Indian business landscape. The results indicate that while sustainability practices exert varying degrees of influence on diverse stock metrics, they play a pivotal role in shaping market perceptions, bolstering investor confidence, and facilitating enduring business sustainability. Investors and decision-makers can employ these insights to assess the significance of ESG factors in their strategic choices. Secondly, the study elucidates the divergent impact of distinct ESG dimensions on stock market performance. Social factors exhibit a robust influence on earnings per share and price-to-earnings ratios. In contrast, environmental and governance factors wield a more pronounced effect on price-to-book ratios and book values per share. This underscores the necessity of a comprehensive evaluation of multiple ESG facets to unravel their intricate effects on stock performance. Lastly, the research underscores the significance of specific threshold levels in analyzing the interrelation between ESG scores and stock metrics. The findings highlight that the impact of ESG scores on stock performance may fluctuate across various ranges or thresholds. This implies that particular levels of sustainability performance could wield a more potent effect on stock indicators than others. Subsequent research could pinpoint these threshold levels and explore their implications for decision-making.

While acknowledging limitations tied to sample selection and the sole reliance on ESG scores as the sustainability measure, this research underscores the merit of considering alternative sustainability indicators and expanding the sample to encompass firms from other regions in future studies. The findings have tangible implications for investors and decision-makers, offering a deeper understanding of the significance of ESG factors in investment strategies and decision-making processes. By integrating sustainability considerations, stakeholders can refine their investment approaches and contribute to the sustainable development of the financial sector.

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INDIA'S RESEARCH ON FINTECH AND FINANCIAL INCLUSION: A REVIEW

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Abstract

This article presents a concise review of the existing financial inclusion research in India. We use a thematic literature review methodology. We demonstrate that the Reserve Bank of India (RBI) has been a pioneer in the field of financial inclusion in India and has collaborated with other institutions to broaden financial inclusion. Income, age, gender, education, employment, ICT, the network of bank branches, and proximity to a bank are the primary factors that determine financial inclusion in India, according to a review of the existing literature. The common theories used to analyse financial inclusion in India are the finance-growth theory, the diffusion of innovations theory, development economics and modernization theory, the vulnerable group theory of financial inclusion and the dissatisfaction theory of financial inclusion. In the literature, surveys, questionnaires, the financial inclusion index, regression estimations, and causality tests are frequently employed methods. Financial inclusion also has an impact on poverty, human development, financial stability, monetary policy, and income levels in India, according to previous research. Poor geographical access, excessive transaction costs, inappropriate banking products, financial illiteracy, and a large digital divide between tech-savvy and non-tech-savvy individuals are among the criticisms leveled against India's efforts to promote financial inclusion. We also suggest some areas for future research. ‘

Keywords: *ICT, the Internet, financial inclusion, a literature review, access to finance, regression, causality tests, India, index, theory.*

1. Introduction

The purpose of this article is to present a concise review of the existing financial inclusion research in India. Financial inclusion is the provision of basic and affordable formal financial services to all segments of the population so that everyone can have access to basic and affordable formal financial services (Markose et al, 2022; Ozili, 2018). Financial inclusion is desirable because it affects every segment of society positively; it improves access to financial services and gives banked customers an opportunity to access and use the financial services they need to meet their needs and improve their welfare (Demirgüç-Kunt and Klapper, 2012; Ozili, 2021).

To increase financial inclusion, a country must develop a strategy that will be used to meet its financial inclusion objectives, and the selected financial inclusion strategy must be designed and adapted to reflect the peculiarities of the country (Chandran, 2011; Arun and Kamath, 2015). Due to its distinctive approach to financial inclusion, India has recently been at the center of Asian financial inclusion debates. In India, financial inclusion has been a top priority for the past ten years. The Indian government and the Reserve Bank of India (RBI) introduced several financial inclusion initiatives aimed at providing easy access to financial services to

a large section of the Indian population who remain unbanked (Srinivasan et al, 2024).

The Khan Commission was established in 2004 by the RBI to investigate financial inclusion. The recommendations of the commission were incorporated into the national financial inclusion strategy between 2005-2006, and banks were urged to review their existing banking practices to align them with the objective of financial inclusion. The Indian government also launched the Pradhan Mantri Jan Dhan Yojana (PMJDY) scheme in 2014 to further deepen financial inclusion in India by providing universal access to banking facilities to every member of the population.

The progress made in financial inclusion in India has stimulated much interest in financial inclusion among academics and researchers (e.g., Khan, 2011; Subramanian, 2013; Swamy, 2014; Sharma, 2016; Rastogi et al, 2017; Inoue, 2019; Churchill and Marisetty, 2020; Singh and Yadava, 2022; Pal et al, 2022; Lenka, 2022; Nayak et al, 2024 etc.). Understanding the factors that influence and obstacles to financial inclusion in India has sparked a great deal of research interest. But there has been very little review of the existing financial inclusion research in India. We are aware of no review articles that provide a concise summary of the existing research on India's financial inclusion. As a result, the purpose of this research is to provide a brief summary of the state of financial inclusion in India. Regarding the review methodology, we used a thematic literature review methodology to conduct the review. The relevant research articles on financial inclusion in India were found using the Google Scholar search engine. We inserted two keywords, e.g., “financial inclusion” and “India” into the widely used

research search engine ‘Google Scholar’ and we select a sample period from 2010 to 2022. The literature review was carried out with the help of the articles that were found in the Google Scholar search results. We included journal articles, policy articles, working papers and academic conference papers to increase the sample size and to ensure that our article selection takes into account the research that exists in published and non-published formats. The final sample of research articles used in the review, after sorting, was less than 320. We divided the review according to major themes in the literature, focusing on the (i) RBI financial inclusion policy initiatives, (ii) the determinants of financial inclusion in India, (iii) common theories and methodologies, (iv) general effect of financial inclusion, and (v) the criticisms or challenges of the financial inclusion efforts in India. We also present a bibliometric analysis to identify the (i) financial inclusion policy initiatives timeline, (ii) quantity of financial inclusion research, (iii) journal citations, and (iv) interest in internet information about financial inclusion. In conclusion, we discuss a few pertinent areas for future research to advance the body of knowledge. There are a number of ways this review article adds to previous research. First, by providing a review of existing research on the connection between access to finance and development outcomes, our review article adds to the development literature. The reader of our review article can gain an understanding of the current state of research in this field. Second, by providing a succinct overview of India-specific financial inclusion research, our review article adds to the body of knowledge on the subject. Thirdly, our research contributes to ongoing discussions regarding the significance of financial inclusion in enhancing people's well-being in India. The following is the

structure of the remainder of this review article: Section 2 presents the thematic review of literature. Section 3 presents a bibliometric

analysis. The fourth section offers suggestions for future research. The study is completed in Section 5.

2. Thematic review

In this section, we review the India financial inclusion literature according to major themes that have dominated the literature over a decade. The themes are the financial inclusion determinants, the effect of financial inclusion, financial inclusion theories and methodologies, and the criticisms or challenges of financial inclusion in India.

2.1 RBI financial inclusion policy initiatives

We cannot discuss financial inclusion research in India without discussing the efforts of the RBI in promoting financial inclusion in India. This is because a large number of financial inclusion research in India have been anchored on RBI's financial inclusion policy initiatives (e.g., Gupte et al, 2012; Garg and Agarwal, 2014; Aggarwal, 2014; Iqbal and Sami, 2017). The Reserve Bank of India (RBI), India's central bank, is in charge of putting India's financial inclusion strategy into action. The RBI worked collaboratively with the National Payments Corporation of India (NPCI), the Ministry of Finance, the Telecom Regulatory Authority of India (TRAI) and the Unique Identity Authority of India (UIDAI). The RBI adopted a bank-led model for achieving financial inclusion. Below are some of the initiatives led by the RBI in accelerating financial inclusion in India as documented in Chakrabarty (2011).

- (i) The RBI created a conducive regulatory environment and provided

institutional support for banks to accelerate their financial inclusion efforts.

- (ii) The RBI eliminated all regulatory roadblocks that prevent Indian banks from expanding financial inclusion.
- (iii) The RBI required banks to open Basic Saving Bank Deposit (BSBD) accounts with zero minimum balances.
- (iv) In order to facilitate an easy account opening process, the RBI relaxed the requirements for knowing your customer.
- (v) A simplified policy on branch authorization to address the issue of uneven branch distribution.
- (vi) Compulsory requirement of opening branches in un-banked villages.
- (vii) Introduced an effective approach for cash management, customer complaints and the regulation of bank correspondents.
- (viii) Require public and private banks to submit a three-year Financial Inclusion Plan (FIP) that has been approved by the board.
- (ix) To expand financial literacy efforts, carry out monthly outdoor financial literacy outreach.
- (x) Increased licensing of new banks

2.2. Determinants of financial inclusion in India

According to the literature, a variety of socioeconomic factors influence India's level

of financial inclusion. Existing studies show that the level of income is the most significant determinant of financial inclusion in India (e.g., Bhanot et al, 2012; Raichoudhury, 2020; Dar and Ahmed, 2021). Other determinants of financial inclusion have been documented in the literature. For instance, Simon (2020) and Dar and Ahmed (2021) show that age, education, employment and income are significant determinants of financial inclusion, while Govindapuram et al (2022) find that wealth and gender of the household head and their rural-urban location are crucial determinants of women financial inclusion in India. Pandey et al (2022), Bansal (2014) and Tikku and Singh (2023) identify modern information and communication technology (ICT), Fintech, digitalisation and mobile banking as important determinants of financial inclusion because it can help to extend the provision of financial services to people living in remote areas, while Kumar and Pathak (2022) and Ghosh and Vinod (2017) show that gender and financial awareness are important factors influencing the level of financial inclusion. In contrast, Rastogi and Ragabiruntha (2018), Kumar (2013), and Raichoudhury (2020) demonstrate that online banking, financial literacy, the infrastructure of bank branches, employment opportunities, and income are significant factors in financial inclusion. Bhanot et al (2012) and Sathiyar and Panda (2016) identify nearness to post office banks, number of bank branches, population dependency per branch and industry concentration as significant determinants of financial inclusion in India. In conclusion, the income, age, gender, education, employment, income, wealth, ICT, bank branch network, and proximity to a bank have been identified as determinants of financial inclusion in India.

2.3. Fintech in India

The fintech market in India is one of the fastest growing markets in Asia. India's Fintech industry market size reached US\$50bn in 2021 and is expected to exceed US\$100bn by 2025. Some of the largest Fintech companies in India are Paytm, MobiKwik, ItzCash and InCred. Despite the market growth of Fintech, academic research into Fintech in India is surprisingly limited. There aren't many studies out there that agree that Fintech can make payments faster and cheaper in India (Vijai, 2019; Kandpal and Mehrotra, 2019; Rajeswari and Vijai, 2021). Existing studies also show that Fintech can deepen financial services, improve the quality of financial services, and develop innovative models to assess risks in India (Singh, 2020; Raj and Upadhyay, 2020). However, some challenges of Fintech in India have been identified namely, lack of trust, cybersecurity risks, fierce competition, infrastructure deficits and unfavourable economic fluctuations (Priya and Anusha, 2019; Baporikar, 2021).

2.4. Common theories and methodologies

The common theories used in the literature to explain financial inclusion in India are the financegrowth theory (e.g. Sharma, 2016; Sethi and Acharya 2018), the diffusion of innovations theory (e.g. Singh and Prasad, 2021), the development economics and modernization theory (e.g. Pal et al, 2022), the vulnerable group theory of financial inclusion (e.g. Sharma and Mathur, 2022), and the dissatisfaction theory of financial inclusion (e.g. Gupta and Kanungo, 2022). In terms of research data, most financial inclusion research has been conducted using both primary data and secondary data. Studies based on primary data often use surveys, questionnaires and case studies such

as Chattopadhyay (2011), Bhanot et al (2012), Kaur and Kapuria (2020), Churchill and Marisetty (2020), Govindapuram et al (2022), Yadav and Shaaikh (2023) and Tikku and Singh (2023). Other studies use secondary data that are archived with external data providers such as the Reserve Bank of India, the World Bank and other external sources (see, for example, Sharma, 2016; Churchill and Marisetty, 2020). In terms of research methodology, the most common research methodologies used in the Indian financial inclusion literature are the literature review methodology (Goel, 2023), questionnaires (Chattopadhyay, 2011; Bhanot et al, 2012), surveys (Kaur and Kapuria, 2020; Churchill and Marisetty, 2020; Govindapuram et al, 2022; Yadav and Shaikh, 2023), regression estimation methodology (Kumar, 2013; Sathiyam and Panda, 2016; Inoue, 2019; Raichoudhury, 2020), financial index methodology (Laha et al, 2011; Singh et al, 2011; Gupte et al, 2012; Kaur and Kapuria, 2020), causality tests (Sharma, 2016), and data envelopment analysis (Singh and Yadava, 2022).

2.5. General effect of financial inclusion

In this section, we explore the effect of financial inclusion as documented in the literature. Regarding the effect of financial inclusion on development outcomes, Inoue (2019) investigates the effect of financial inclusion on the level of poverty and finds that financial inclusion that is achieved through public sector banks reduces the poverty ratio compared to financial inclusion that is achieved through private sector banks in India. Churchill and Marisetty (2020), using survey data of 45,000 Indian households, examine the effect of financial inclusion on poverty. They find that financial inclusion has a strong poverty-reducing effect in India.

Subramanian (2013) shows that bank branch expansion and card-based banking services in India needs to be supported with financial literacy programs and marketing campaigns to ensure that these services are used by the adult population to improve their welfare and lead to better development outcomes. Singh and Yadava (2022) examine how financial inclusion programs relate to development in 28 Indian states. They find that Indian states that have better human development index have better financial inclusion index.

According to Khan (2011), financial inclusion helps to provide a more stable deposit base, which could improve bank funding rather than relying on borrowed funds, and the deposits can increase the soundness and resilience of financial institutions. This is one of the effects that financial inclusion has on economic and financial systems. Sharma (2016) assesses the relationship between several dimensions of financial inclusion and economic development in India and finds a positive association between economic growth and several dimensions of financial inclusion. Rastogi et al (2017) show that financial inclusion helped to achieve India's demonetisation objectives as a part of the monetary policy of the Reserve Bank of India. Swamy (2014) demonstrates that poor individuals who participate in financial inclusion programs see an increase in their income. Pal et al (2022) find that financial inclusion increases women's earning status, their participation in financial decision-making in their household and their likelihood to benefit from social welfare schemes which increases women empowerment. Lenka (2022) shows that financial inclusion is an essential element for financial sector development especially in India because financial inclusion increases financial access

and financial depth in India. In contrast, financial inclusion also has some negative effects. Notably, Ghosh (2013) shows that microfinance alone cannot solve the development problems of India; in fact, profit-oriented microfinance institutions have been problematic; therefore, microfinance institutions should be regulated and subsidised, and other strategies for viable financial inclusion of the poor should be more

actively pursued. Maity and Sahu (2022) show that it is not enough to open a bank account for excluded people, banks also need to look at flexibility and timeliness in delivery financial services to the banked population. Markose et al (2022) examine the supply side funding gaps inherent in India's financial inclusion schemes especially the PMJDY scheme which started in 2014.

3. Bibliometric analysis

We did a bibliometric analysis in this section to look at patterns in the financial inclusion policy timeline, the number of articles, the number of journal citations, and interest in financial inclusion information on the Internet. 3.1. Financial inclusion policy

timeline The timeline in table 1 below shows that RBI rolled out more financial inclusion policies in 2005, 2006, 2015 and 2016. Meanwhile, no financial inclusion initiatives were introduced in 2007, 2008, 2009, 2013 and from 2017 to 2022

Table 1. Some financial inclusion policy initiatives introduced in India	
Year	Financial inclusion policy initiatives
2005	Relaxation on Know Your Customer (KYC) Norms:
2005	No-Frills Account
2006	Liberalization of Business Correspondents Model
2006	Business Facilitators
2007	None
2008	None
2009	None
2010	Financial Inclusion Plan for Banks
2011	Opening of Branches in Unbanked Rural Centers
2012	Basic Savings Bank Deposit Account (BSBDA)
2013	None
2014	Pradhan Mantri Jan Dhan Yojana (PMJDY) PMJDY scheme
2015	Pradhan Mantri Mudra Yojana (PMMY) scheme
2015	Pradhan Mantri Suraksha Bima Yojana scheme
2016	Stand up India Loan Scheme
2016	Unified Payments Interface (UPI)
2017	None
2018	None
2019	None
2020	None
2021	None
2022	None

3.2. Quantity of research on India's financial inclusion.

We analyzed the quantity of existing financial inclusion research in India, based on the existing literature that are indexed in the Google Scholar database to allow us focus strictly on academic research papers and avoid counting non-academic articles. During our search in Google Scholar, we insert the keyword ‘financial inclusion India’ into the search box and obtain results

for the post-2010 studies. The results revealed that significant research on financial inclusion in India emerged in the post-2014 period. Academic researchers were particularly interested in India's progress in financial inclusion after 2014, which contributed to the growing interest in financial inclusion as a research topic.

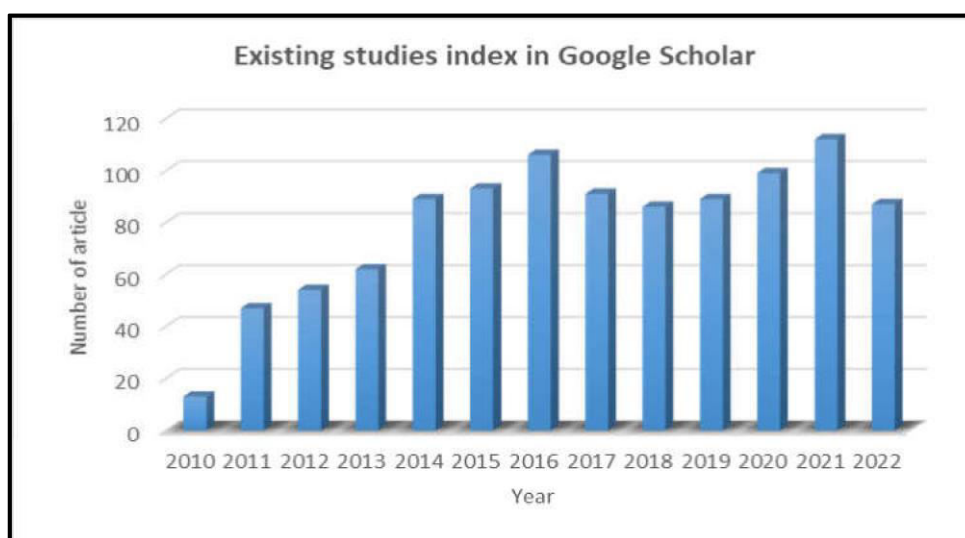
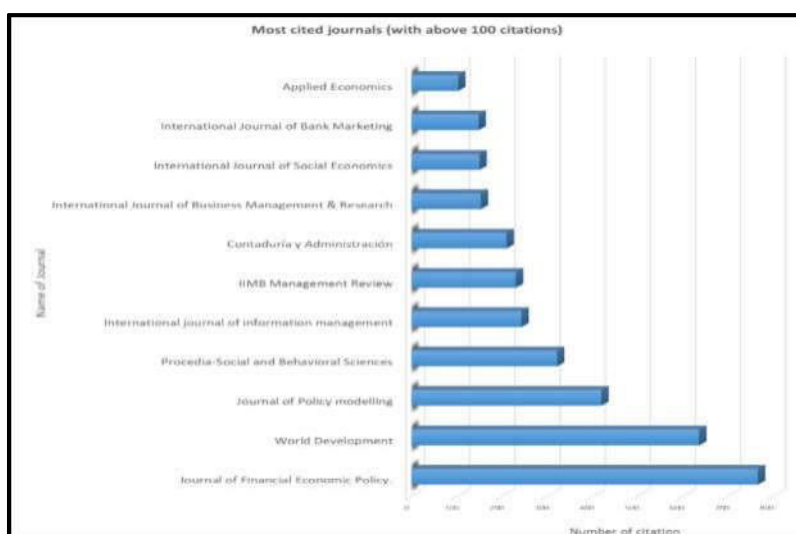


Figure 1: Existing studies indexed in Google Scholar

3.3. Top citations from journals Figure 2 depicts the journals with the highest number of citations (more than 100), indicating their quality in the field of financial inclusion. The journal



with the highest citations is the Journal of Financial Economic Policy. The journal with the second highest citations is the World Development Journal, while the journal with the third highest citations is the Journal of Policy Modelling.

Figure 2: Most cited journals

3.4. Interest in internet information about financial inclusion

Figure 3 presents the data for internet search for information about financial inclusion. According to Figure 3, there was a lot of interest in online information about financial inclusion in some parts of India. In some parts of India, such as Odisha, Jharkhand, Delhi, Kerala, Maharashtra, Jammu and Kashmir, Haryana, and Assam, internet searches for information about financial inclusion exceeded the 50-point threshold. The high interest in Internet information about financial

inclusion in these regions was because many people in these regions were seeking to gain more online information about financial inclusion. They wanted to learn about how financial inclusion can improve their lives. Meanwhile, interest in financial inclusion information was extremely low in regions such as Gujarat, Tamil Nadu, Rajasthan and Uttar Pradesh. The general lack of interest in financial inclusion in these parts of India is the reason for this.

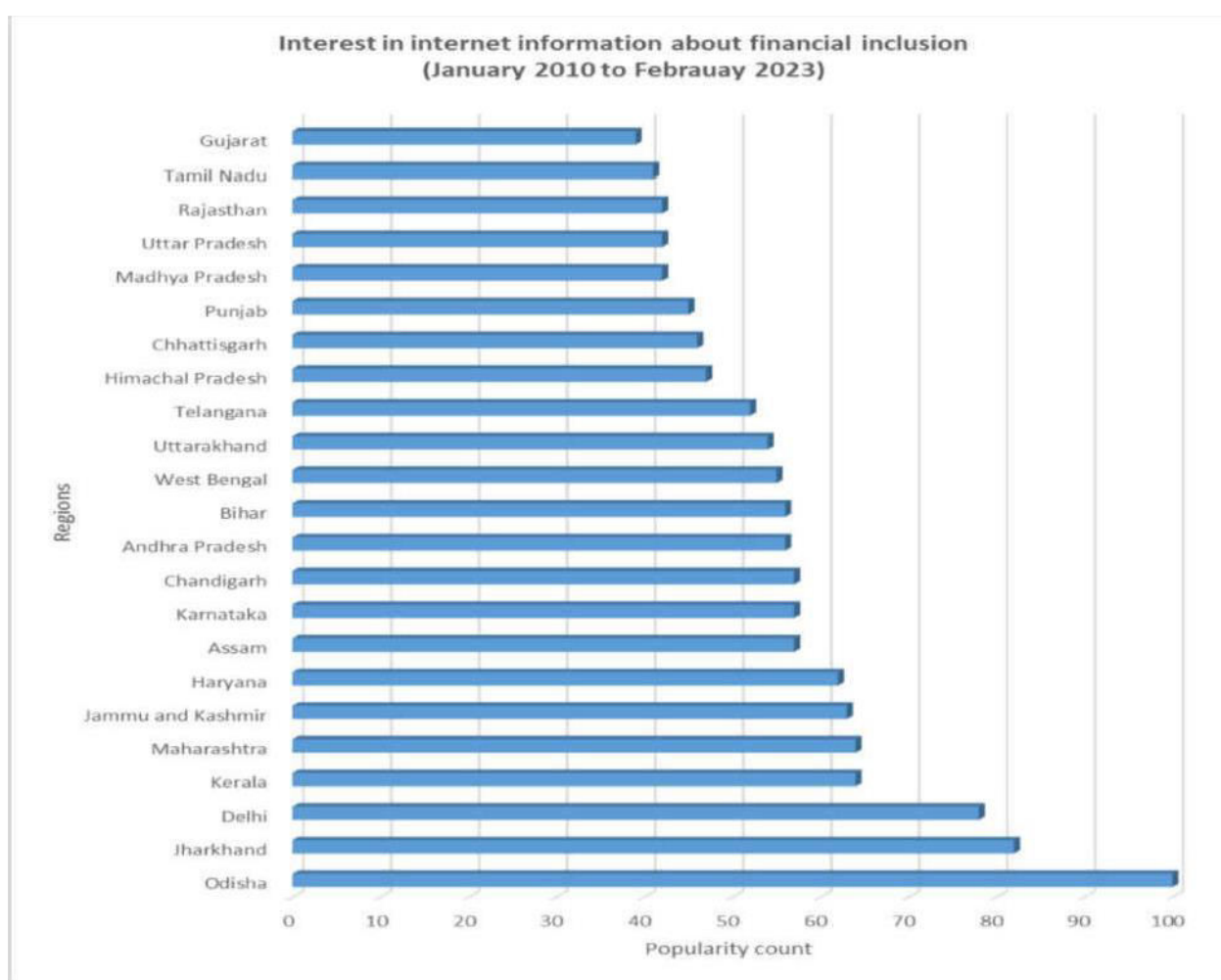


Figure 3: Internet Search for Information about Financial Inclusion in India

4. Areas for future research

In this section, we identify areas for future research in financial inclusion in India – the areas that we consider to be significant to advance the literature. First, there is no mention of cultural factors influencing India's financial inclusion rate in Indian literature. Cultural factors, such as pre-existing norms, traditions and religion, may discourage citizens from using formal financial services and can lead to low levels of financial inclusion (Ozili, 2023b), and this is particularly true in India where there are strong cultural norms and religious beliefs. There is a need to investigate the moderating influence of cultural factors on the level of financial inclusion in India. Future studies should investigate the influence of cultural factors on the level financial inclusion in India. Two, the literature is silent about what can be done to help those who are left behind by India's progress in financial inclusion. Some groups of people are voluntarily excluded from the banking system in India. They prefer to be outside the formal financial system for reasons best known to them. Yet, there are no debates about what can be done to cater for the needs of these group of people. They can benefit from an alternative financial

system or an informal financial system, that is fair and non-exploitative. People who are voluntarily excluded from the formal financial system should be considered for alternative financial systems in future studies. Three, there is a need for more research on how the quality of formal institutions affect financial inclusion in India. Understanding whether financial inclusion in India is influenced by good or bad institutions is essential. According to Ozili et al. (2023a), good institutions provide the necessary protection and accountability mechanisms to guarantee that adults who are banked receive full financial inclusion benefits and are treated fairly by users of financial services in the formal financial sector. Therefore, future studies should examine the influence of institutions on the level of financial inclusion in India. Finally, the PMJDY financial inclusion scheme has helped to increase financial inclusion for women. Most women in India now have a bank account but the challenge is how to get women to use the accounts. Future studies should suggest demand-based strategies to increase the bank account usage among Indian women.

5. Remarks at the end

We examined the existing literature on financial inclusion in India from 2010 to 2022 in this article. Based on the amount of existing research, a timeline of the RBI's financial inclusion policy initiatives, top journal citations, and interest in online information about financial inclusion in India, the articles were analyzed using a thematic literature review methodology.

There are a number of conclusions that can be drawn from our review of the existing literature. First, the RBI has worked together to expand financial inclusion in India and has been at the forefront of this movement. Second, income, age, gender, education, employment, ICT, the network of bank branches, and proximity to a bank are the primary factors that influence financial inclusion in India. Three, the common

theories used in the literature to analyze financial inclusion in India are the finance growth theory, the diffusion of innovations theory, the development economics and modernization theory, the vulnerable group theory of financial inclusion and the dissatisfaction theory of financial inclusion.

Four of the most widely used methods in the literature are regression estimations, questionnaires, surveys, the financial inclusion index, and causality tests. Five. The level of poverty, human development, financial stability, monetary policy, and income in India are all affected by financial inclusion. Sixth, financial inclusion efforts in India have been criticized for their inability to

The policy implication of the findings is that the findings of this review article confirm policymakers' intuition that many factors affect the level of financial inclusion in India. Consequently, policymakers in India should increase their financial inclusion efforts while mitigating the factors that hinder progress in financial inclusion. The success of financial inclusion in India will depend on collaborative efforts and a supportive policy environment in terms of policy relevance. The findings have a positive social impact because they show that financial inclusion has a positive impact on India. This is because high levels of financial inclusion would make money accessible to all members of society, regardless of their income level. This would give Indian citizens a chance to use financial services to improve their welfare and increase social inclusion in India. The findings suggest that academic research into financial inclusion in India continues to be fruitful. Future research in this area can provide new insights if it broadens our understanding of the positive impact and issues regarding financial inclusion in India. This study has one limitation. Despite our efforts to ensure that the review was comprehensive, it is possible that some research studies were omitted by accident. However, we believe that the research on financial inclusion in India published during the examined time period is accurately and succinctly represented in this review.

meet the specific needs of the poor, poor geographic access, high costs, inappropriate banking products, financial illiteracy, and a significant digital divide between people who are tech savvy and those who are not. Last but not least, we offered some suggestions for future research. The contribution of this review article is twofold. One, it presents a concise review that provides a guide to both policymakers and researchers on the state of financial inclusion research in India, and it highlights the main themes and approaches that researchers have taken on this topic. Two, the article identifies some important research areas for future investigation into financial inclusion in India.

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