

Green Growth in The Digital Age: Sustainability, Financial Inclusion and Climate Finance in India

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Summary

The paper 'Green Growth in the Era of Digitization: Sustainability, Financial Inclusion and Climate Finance in India' provides an integrated solution for studying how digitization can help India achieve green growth amidst the challenges of climate change, while simultaneously ensuring financial inclusion. The analysis of the phenomenon is made under three interrelated pillars: Digitization, Green Finance and Sustainability. These pillars are not discussed separately, but as part of an overall development process. An emerging challenge from analysis. However, in mobilizing the resources required to develop renewables, carbon reduction and sustainable growth, mainstream financial instruments have failed to prove to be enough, due to high transaction costs and risks, and limited reach. Digital banking and other avenues of fintech innovation create exciting opportunities to tackle this issue.

The research will focus on the following three objectives: (i) to explore digital finance inclusion and technology adoption's role in the mobilization of green finance and sustainable performance, (ii) to understand how digital finance contributes to renewable energy adoption and carbon reduction and (iii) to understand how the coevolution of digital finance and green finance impacts economic development, industry revolution and attainment of sustainable development goals (SDGs). According to theories of financial inclusion, financial intermediation, endogenous growth, ecological modernization, and institutionalism, digital finance is conceptualized as the facilitator infrastructure, while green finance becomes the mode of transmission of economic development, the final step being sustainability performance.

In terms of methodology, this study uses an explanatory research design involving secondary data. Indices such as green finance and digital finance, renewable energy, carbon emissions, GDP growth rate, financial inclusion, and SDG achievement will be generated. In this study, techniques such as descriptive statistics, correlation analysis, regression analysis, moderation analysis, and mediation analysis will be employed. It can be observed that high levels of growth in digital finance have been witnessed in recent years, which makes it a vital component of the financial sector of India despite geographical differences. In addition to this, expansion in green finance has also been seen despite fluctuations, but this type of financing is becoming more common in switching to a traditional mode of financing. These findings suggest that the relationship between digital finance and green finance is highly positive because the use of digital technology has become an important part of making the process of financing highly effective and efficient. Despite having a positive relation with economic growth, the effect of both types of finance is indirect and gradual.

Other examples include the idea that digital finance and financial inclusion are important for stimulating green energy investments by overcoming problems with financing and accessing credit. Digitalization is also correlated with increased environmental efficiency and CO₂ emissions reduction, but again, there exists a mutually beneficial connection between the two processes, since concerns about the environment can also stimulate people to embrace digital technology. In sum, digital finance has helped to achieve financial inclusion, increase efficiency in the industries, generate innovations and infrastructure, and promote SDGs, in particular SDGs regarding clean energy generation, industrial development, and climate change mitigation.

Despite this, it should be noted that the paper identifies several obstacles to the ability of digital finance to drive green investments, namely the absence of a global green taxonomy, regulatory inadequacy, cyber threats, the scarcity of data on Scope 3 emissions, and digital divides across different regions.

Consequently, it becomes evident that the concept of digital finance in India should be understood not merely in terms of technological innovation in the realm of finance, but as economic infrastructure that facilitates the process of green finance and sustainable growth. It is seen that the current paper adds valuable inputs to the academic and policy debate on the three pillars of digitalisation, green finance and sustainable outcomes, especially on the practical recommendations, like the implementation of the Unified Green Interface (UGI).

CHAPTER 1: INTRODUCTION

1.1 Introduction: The Three-Pillar Framework

Some point in time during this decade witnessed a paradigm shift in our perception of economic development. This shift took place in terms of a move away from a simplistic understanding of the pace of growth as measured by GDP. Instead, the issue became one of asking, ‘What type of growth is being created, and at what price to the environment?’ For India, a nation that sees many people join its middle class every year, the ramifications of this paradigm shift reach well beyond national borders.

The current academic work is centered around three pillars that together determine the path of India’s transition towards green and digital. In the first place, we speak about the pillar of Digitalisation, which includes the fast development of India’s digital infrastructure for financing. Thus, it includes such areas as Unified Payments Interface (UPI), fintech, neobanks, digital banking, as well as India’s digital public infrastructure stack. Then, the second pillar is called Green Finance. It is the process of capital raising via various means, including green bonds, sustainability-linked loans, and climate finance flowing into sustainable industries. Finally, the third pillar is called Sustainability Outcomes.

The three pillars are interrelated and cannot exist in isolation. The first pillar, Digitalization, enables the infrastructure necessary for the process, the second pillar, Green Finance, directs financial resources towards environmental goals, and the third pillar, Sustainability Outcomes, manifests itself as an outcome of their integration. The key proposition of the research is that all three pillars need to be considered together since only a combination of both will lead to the sustainability India needs.

Indeed, India is facing a unique challenge in its development. The country is one of those that are extremely vulnerable to climate change. For instance, it has many people who depend on climatesensitive areas like

agriculture. In addition, some coastal and urban areas within the country are experiencing severe heat due to climate change. Nevertheless, the development needs of India continue to be high. Hence, it would not make sense for India to compromise economic growth as part of dealing with climate change. This means that the strategy chosen by the Indian government in handling the dilemma is that of sustainable economic growth. This can be seen from its climate goals including zero net emissions by 2070 and reduction in carbon intensity.

The main issue, however, is not ambition but funding. The magnitude of investment needed to enable this transition is unparalleled, according to reports, India will need trillions of dollars of green investments over the next several decades. The present amount of green funds available does not meet these demands, and this shows the structural weakness within the financial sector in supporting sustainable development. Traditional financial sectors, hampered by their risk averseness, lengthy time of project gestation, and lack of tools to evaluate climate finance projects, have failed to deliver adequate funding.

In addition to this, there is a similar shift happening within the financial system itself. The fastgrowing presence of digital financial technology in the market has brought about a completely new form of accessing and delivering financial services. The convergence of both digital finance and sustainable development is referred to as the twin transition that is, the transformation of finance by digitalization, as well as the green transformation of the economy.

1.2 India's Digital Financial Transformation (Pillar I: Digitalisation)

The financial market system in India is witnessing an extensive revolution owing to the pace of digitization and technological advancements. In the last ten years, there has been a considerable development in the digital financial framework with the emergence of platforms like UPI, Aadhaar based systems, mobile banking, and fintech apps. This revolution has impacted the working pattern of the financial markets greatly.

There is now a large portion of global transactions that take place in real time due to the digital finance system available in India. Through the India Stack, which incorporates the Jan Dhan– Aadhaar–Mobile system and other elements such as data sharing architecture and open APIs, many unbanked individuals have gained access to the formal financial sector. This change does not just make things more accessible; it's also made financial transactions more efficient.

The digital revolution has changed the traditional ways that financial intermediaries have worked. Technology-based financial systems based on platforms have enabled a greater share of access to financial systems and reduced transaction frictions, compared to financial systems where operations were limited due to physical architecture, high manual processing costs and high transaction frictions. New advancements in risk management and credit allocation have been enabled by the use of state-of-the-art technology, such as artificial intelligence, big data, blockchain and cloud computing.

Key outcome of this process is enhancement of digital financial inclusion. Digital finance has contributed to an expansion of individuals, businesses and families engaging in formal financial arrangements through the reduction of restrictions based on the place, documentation and affordability of financial access. Improved financial inclusion leads to improved savings mobilization, more credit availability and financial resource allocation.

1.3 Green Finance in India (Pillar II: Green Finance)

In parallel with the ongoing digital revolution in the financial sector, India is witnessing a structural shift towards sustainability due to its climate pledges and international obligations. It is planning to reach net

zero emissions by 2070, along with interim goals like cutting carbon intensity and boosting the share of renewables in its total energy generation. Fulfilling these goals will require huge and continuous investments in environmentally sustainable industries.

The process is capital intensive too. As far as estimates are concerned, it has been found that the country would need trillions of dollars of investments in terms of green finance in the years ahead. For fulfilling the requirements on a short term basis, hundreds of billions of dollars per year would be required. At present, the level of mobilization of green finance is not adequate at all. In spite of the increase in green bond issuances, ESG investments, and sustainability finance, the quantum of mobilized capital is inadequate.

Conventional financial systems' shortcomings are an integral part of the problem. The traditional banking system and the stock market are restricted by their high costs, risk avoidance behavior, and their inability to evaluate such projects. Green investments, especially those in decentralized renewable energy sources or advanced technologies, require a significant amount of time for development and evaluation, and thus pose certain risks in terms of profits. Thus, due to the nature of these projects, many potentially successful ones are not funded by banks.

In addition, the lack of standardization, data, and reporting systems for green investment projects poses problems for decision-making processes regarding resource allocation. In the absence of data that can be verified, there will be difficulties in determining what kinds of projects should be invested in, how much investment is necessary, and where these resources can be best deployed.

1.4 Convergence of Digital Finance and Green Finance

Historically, digital finance and green finance have been studied separately as different fields in the larger field of finance. Nevertheless, current trends indicate that this differentiation no longer suffices to explain the structure of the modern financial system. It is at the point where these two fields intersect that a significant change in the financing process takes place.

The digitalization of financial services could prove beneficial as a means of providing an enabling base for green financing by correcting most inefficiencies that have hindered sustainable financing in the past. For example, there has been much discussion regarding information asymmetry in the realm of green finance due to the lack of standard and reliable information regarding the environmental impact and economic sustainability of green ventures. Through digital financial solutions such as data analytics, artificial intelligence, and blockchains, information asymmetry in green finance can be easily addressed. Besides better flows of information, digital finance helps lower costs and increase the accessibility of financial services. For one thing, conventional methods of financing projects are generally associated with high levels of intermediation costs, documentation difficulties, and insufficient outreach, especially for smaller decentralised green projects. However, through automation and realtime transactions, digital finance can overcome these issues and improve accessibility to financial services. This is highly relevant for industries like renewable energy that operate on small projects yet have considerable cumulative significance.

Inclusion is an important factor that helps bring about this convergence. Whereas digital technology provides the technical framework, inclusion ensures that this framework can be accessed and used by all segments of the population. Digital financial inclusion enables the involvement of hitherto excluded individuals in not only finance but also sustainability. This, in turn, results in the establishment of the

channel through which digital finance has the ability to influence sustainable results due to increased demand and supply of such investments.

Also, the digitization of finance makes it possible to create new financial products specifically designed for green investments. Crowdfunding, peer-to-peer loans, tokens, blockchain-based green bonds, and other digital solutions make the process of attracting funds for sustainable development much easier. The other key element of the relationship between fintech and ESG is improving monitoring, reporting and compliance efforts. Using digital tools, it is now possible to collect data in realtime, report accurately and automatically check all data, thereby eliminating the risk of greenwashing.

1.5 Sustainability Outcomes and Development Implications (Pillar III)

The relationship between digital finance and green finance not only affects the functioning of the financial sector, but also the development of the economy and environment in tandem, and represents the Third Pillar in this research. In the case of India, which faces the challenge of growing its economy while remaining sustainable, the effectiveness of such a convergence can be measured through its ability to promote the use of renewable sources of energy and achieve Sustainable Development Goals.

A direct result of green finance being mobilized is that of an increase in investments in renewable energy resources. The process of sustainable development involves making sure that there is a transition within the energy sector from the current use of fossil fuels to more efficient forms. This change may be hampered by the fact that renewable energy resources tend to be capital intensive and would need to be financed in the long run, something that can prove to be challenging.

However, the impact of digital finance on the environment is not limited to renewable energy only. In addition, digital finance impacts the efficiency of economic activity and the use of resources, which will determine CO₂ emissions. Digital finance can be a factor that reduces CO₂ emissions by ensuring the effective use of funds, increasing transaction transparency, and promoting technological advancements. However, this does not imply that the link between digital finance and the environment is entirely one-sided. The environment can be a catalyst for the creation of digital finance through economies that look to adopt efficient economic operations and sustainability.

On a macro scale, the above mentioned results can be linked to the SDG approach to development, which focuses on balancing economic growth, social inclusiveness, and environmental sustainability. Digital finance is instrumental for bringing all three factors together, by linking financial inclusion with productivity and sustainable resource management. On top of that, green finance helps ensure that all these financial streams are channeled into environmentally and socially beneficial activities.

1.6 Research Gap

Although the rapid development of digital finance and the emergence of sustainable finance have been observed in the Indian economy, the literature available on both subjects is not fully integrated. The rapidly changing contours of digital finance and the form and growth of sustainable finance in the Indian context have been noticed, however, literature on digital finance and sustainable finance are not entirely interconnected. Many studies have been dedicated to exploring digital finance mainly in terms of its effect

on financial inclusion and economic growth and efficiency, highlighting how digital finance contributes to increased financial access and intermediation. In contrast, some literature has focused on green finance and examined how green finance can facilitate investing in renewables and maintaining environmental sustainability. Until now, however, there are no tangible connections found between digitalisation of finance and sustainable finance.

The theoretical literature debate is around the convergence of digital finance and green finance, but there is limited empirical analysis on a specific topic such as India. The empirical studies by far are more concerned with financial development as a whole rather than with digital finance as part of financial development. Similarly, research on environmental sustainability or the uptake of renewable energy also often fails to consider the financial system that supports the progress of these developments. There seems to be little information on how digital finance can impact green finance and if that has any economic implications.

The other critical issue related to the literature is the lack of a common framework for analysis that incorporates the entire chain involved in transmitting the influence of digital finance and green finance to development. Literature concentrates mainly on the individual relationship, such as the one between digital finance and economic growth, and between green finance and greenhouse gas emissions, but fails to look at how those factors interrelate to each other in a bigger system.

Therefore, it is intriguing and crucial to investigate the linkage between digital finance, green finance and sustainability in India. To bridge this research gap, it becomes imperative to go beyond partial approaches and adopt an approach that integrates all aspects of the contribution of digital financial systems to green investment and environmental sustainability as well as sustainable development.

1.7 Research Objectives

Considering the gaps identified and the requirement of a holistic view on financial digitalization and sustainability issues, this paper attempts to empirically analyze the connection between digital finance, green finance, and development outcomes in India in the context of six research objectives as follows:

The main objective is to understand if digitalization of financial sector development helps in the increase in green finance and how such a connection impacts economic growth. Another important objective is to assess the impact of digital banking services and financial inclusion on renewable energy adoption and environmental implications. Other objectives include evaluating the wider developmental implications of the linkages between digital finance and green finance, in terms of contributing to industrial development, innovation, infrastructure development, and sustainable development goals. The other aspect is to explore the pathways through which digital finance can impact sustainability outcomes, with the help of green finance and financial inclusion playing a mediating role. Lastly, the study focuses on assessing the constraints faced when using digital finance in green investments.

1.8 Scope of the Study

In this study, efforts have been made to establish a link between digital financial development, green finance, and sustainability results in India. The analysis is done at a macroeconomic level by using secondary data gathered from trusted national and international institutions like the Reserve Bank of India (RBI), National Payments Corporation of India (NPCI), World Bank, International Monetary Fund (IMF), among others. The time period selected for this study varies from 2010 to 2025 based on the analysis in

each individual chapter and covers the entire period during which India underwent a digital financial revolution and developed its green finance sector.

Some of the digital financial indicators used are digital payments, financial inclusion, and fintech development, while some of the green finance indicators used include green bonds issued and sustainable investments. Some of the environmental outcomes include renewable energy use and carbon emission, whereas economic and development outcomes include economic development and sustainability index scores.

1.9 Significance of the Study

The significance of this research lies in its focus on the pivotal interrelationship between financial digitalisation and green finance in the context of sustainable development in India. The three components, mainly Digitalisation, Green Finance, and Sustainability Outcomes, all of these combined in one analytical framework, are able to address one important gap in the extant literature that studies issues related to the two areas of finance separately.

With regards to the policy implications of the study, it helps us understand the role played by financial digitalisation in facilitating climate finance and achieving the key policy goals of India, including, but not limited to, financial inclusion, deployment of renewable energy technologies, and achieving net zero. For the finance industry, consisting of banks, fintech companies, and investment institutions, the study shows how digitalisation could be utilised for the improvement of the efficiency of capital allocations in relation to environmental considerations. Academically speaking, the study will help to develop an integrated model, which would consider the impact of the interplay between the discussed financial concepts on the environment and economic growth.

CHAPTER 2: LITERATURE REVIEW

In this chapter, an overview of literature within three fields that correspond to the integrated framework of this study is presented. They are: (i) the development of digital finance and financial intermediation, (ii) the development of green finance as a tool for mobilising climate finance, and (iii) the sustainability consequences of the intersection of these fields. This literature review has been structured with the purpose of illustrating the convergence among these three fields and revealing the gaps in the literature that his research seeks to address.

2.1 Evolution of Digital Finance and Financial Intermediation

The emergence of financial systems' development provides a theoretical basis for the understanding of digital finance emergence and its importance for contemporary economic development. Traditionally, banks have been implementing financial intermediary functions, including the mobilization of savings, lending of funds, money transfer and payments, and risk transformation, which contribute to the promotion of economic growth and financial stability (Heffernan, 2005, Beck et al., 2007). However, due to the utilization of traditional infrastructure, branch networks, and labor-intensive procedures, banks have been experiencing high transaction costs, reduced operational effectiveness, and low geographical coverage, especially in developing countries (Heffernan, 2005; Ozili, 2018).

Thus, there is a need for technological transformation of financial institutions, and the implementation of ICT tools marks the beginning of the digital banking era. In particular, digital banks implement the principles of automation, electronic service delivery, and instant transaction processing, which increase the efficiency, speed, and precision of financial operations (Meka, 2017, Wewege, 2020). In addition to decreasing the transaction costs of financial operations, digital banking extends the geographical coverage of financial products to new areas of unserved by traditional banks (Demirgüç Kunt & Martinez Peria, 2020; World Bank, 2022).

However, the evolution of digital finance implies more than basic technology application and implies an innovative approach to financial intermediation. For instance, financial institutions have been adopting technologies such as artificial intelligence, machine learning, big data analytics, and cloud computing to improve risk assessment, credit allocation, and personalized financial services (Ozili, 2018; OECD, 2019). Digital finance goes beyond conventional banks by including other entities such as fintech companies, digital payment channels, digital credit systems, and innovative digital finance solutions. Digital finance entails the intersection between finance and technology, which has resulted in changes in the production, distribution, and consumption of financial services (Gomber et al., 2017; Arner et al., 2023). Through improved transparency and lowered transaction costs, digital finance optimizes the operations of financial markets and improves the capital allocation process (Bollaert et al., 2021; Frost, 2020). In summary, the literature suggests that digital finance is a revolutionary shift from conventional banking toward digitalization. It involves optimizing the operations of financial markets through improvements in efficiency and cost reduction while improving access and effective capital allocation (Bollaert et al., 2021; Frost, 2020).

2.2 Digital Finance, FinTech and Financial Inclusion

The growth of digital finance has radically changed how financial systems function in conjunction with their access. Specifically, financial inclusion, which had been known as access and usage of formal financial services in previous years, has undergone substantial transformations due to the emergence of technological changes. The notion of digital financial inclusion includes the usage of digital channels such as mobile banking, online lending, and digital payment systems, which facilitate further access to financial markets (Demirgüç-Kunt et al., 2022; OECD, 2024). Such a development is especially important for developing countries, where lack of access to formal finance was facilitated by numerous geographical barriers, expensive transactions, and the lack of documentation.

The importance of digital financial inclusion is also associated with FinTech development. FinTech is considered the combination of advanced technological innovations such as artificial intelligence, blockchain, big data analytics, and cloud computing into the process of providing financial services (Arner et al., 2023; OECD, 2024). While in traditional financial systems, institutions were characterised by inflexible structures and expensive intermediation, the usage of FinTech innovations allows for increasing efficiency and speed of services as well as expanding financial services provision (Bollaert et al., 2021; Howson & de Vries, 2022). Consequently, digital finance helps provide financial services to those who were not included into the formal system previously.

The above-mentioned importance of digital financial inclusion in economic outcomes has been proven empirically. For instance, global data from sources like the Global Findex and the Financial Access Survey conducted by the World Bank and IMF respectively shows that developed digital financial systems are characterised by higher rates of formal account ownership, higher rates of payments made with the help

of smartphones, and better access to formal credit (World Bank, 2024; IMF, 2024). Moreover, the period of the pandemic showed an increased importance of digital financial inclusion for economic resilience (NLM, 2023).

Digital financial inclusion not only has economic repercussions but has also been increasingly accepted as an enabling factor for sustainable development. According to the FinTech-SDGs model, digital finance emerges as an important catalyst for progress towards various SDGs, including those concerning energy, infrastructure, and climate (Arner et al., 2023; Climate Policy Initiative, 2024). The possibility of financing sustainable investments via digital financial systems, and the transaction costs savings which are directly linked to the Second and Third Pillars of this research paper, will help capital flow towards sustainable investments.

India is an ideal case for analysis into the effects mentioned above. The country has been able to see a consistent expansion of the digital financial infrastructure and innovations such as the UPI, Aadhaar-based systems, digital payment platforms, etc. have been able to support these rapid developments. The existing empirical research on financial inclusion in India indicates positive and significant correlation between financial inclusion and environmental sustainability especially on energy consumption and investment behavior (Kumar & Managi, 2022). The impact of digital modes of financial inclusion is further enhanced in credit access for sustainable investments (MDPI Sustainability, 2023; Neenavath & Mishra, 2023).

2.3 Digital Finance as an Enabler of Sustainability and Climate Finance

With the urgency of climate change and the global transformation towards low carbon development, financial systems are given a large responsibility to raise capital for sustainable activities. Climate change is a major economic and environmental threat and has been highlighted by global institutions like the United Nations and IPCC, which call for large-scale investments in renewable energy, clean technologies and climate resilient infrastructure (UN, 2024; IPCC, 2023). The urgency of this position being taken is regularly repeated in the world's assessments of the climate finance gap, which is particularly evident in developing and emerging economies (Climate Policy Initiative, 2024; UNFCCC, 2025).

Digital finance is one of the key enablers that helps support sustainability, by improving access to finance for investing in sustainable related projects. The digital finance helps in lowering the transaction costs, boost financial accessibility and enhance the ability of credit provision, thus enabling investments in renewable energy technologies and sustainable development technologies (Yu, 2022; Kumari, 2025). In the literature, digital finance is found to play a role in the adoption of decentralized renewable energy via financial inclusion and address financing challenges that decentralized renewable energy capital-intensive applications face (Bakhsh et al., 2024; Lin & Xie, 2025).

Another important connection between digital finance and sustainability is in terms of improving financial intermediation processes. Digital finance reduces information asymmetry, enhances transparency and is optimized on capital allocation to production sectors and industries (Gomber et al., 2017; Frost, 2020). Digital finance contributes to sustainability in two aspects: by bringing financial services closer to people and by being more efficient in financial intermediation and innovation. Innovative financial services, like green microfinance, platform-based investment strategies, and digital lending for renewable energy generation, are being developed and adopted through new FinTech platforms, which can help advance sustainable development (Arner et al., 2023; Choudhary, 2025).

Further empirical evidence from developing countries also confirms the linkages. The findings suggest that various types of digital finance have a positive effect on the adoption of renewable energy,

highlighting the need for tailored interventions that address the unique financial and digital landscape of each region. The study's results show that digital finance positively affects the uptake of renewable energy, underscoring the significance of designing region-specific interventions to harness digital finance for accelerating the transition to renewable energy (Barik et al., 2025).

(Kumari, 2025; Yu, 2022).

2.4 Digital Finance and Green Finance Linkage

The connection between digital finance and green finance has received increasing attention in the current literature. Given that finance systems will have to mobilize a huge amount of capital for the transition towards climate-friendly policies, green finance through tools such as green bonds, ESG investments, and sustainability-linked financing faces challenges such as high transaction cost, information problems, and limited access (Hailu & Kipgen, 2017; UNFCCC, 2023; Climate Policy Initiative, 2024).

Credit allocation and intermediary services are some of the key processes through which digital finance affects green finance. With technological solutions such as AI based credit scores, big data analysis, blockchain technology, and digital lending platforms, the assessment of risks and opportunities becomes easier and more accurate, thus eliminating some of the challenges faced during the mobilization of financing for green finance initiatives (Arner et al., 2023; Frost, 2020; Bollaert et al., 2021).

Since green finance tends to be characterized by high uncertainties and long-term investments especially within the renewable energy and sustainable infrastructure, the financing challenge becomes even more serious. However, digital finance reduces financing costs by providing different datasets that make the process easier (Ahmad et al., 2021).

Another aspect that forms an important link between digital finance and green finance includes transparency and governance. The market for green finance products such as sustainability-linked loans and bonds is prone to information asymmetry and greenwashing among other challenges. Blockchain technology and other digital finance solutions provide for easy tracing of financial flows and real-time verification of environmental achievements (Howson & de Vries, 2022; Neenavath & Mishra, 2023). These attributes facilitate accountability and eliminate monitoring costs hence improving the credibility of green financial instruments.

However, various gaps have been identified in the literature regarding this topic. Most of the existing studies measure the impacts indirectly through metrics such as green energy investments and improved environmental quality as opposed to direct measures such as green bond issuance and volume of ESG investment (Ahmad et al., 2021; Ren et al., 2022). In addition, empirical evidence of green finance mobilization using digital finance at the national level especially in developing countries like India is limited (Neenavath & Mishra, 2023; RBI, 2023). Furthermore, institutional challenges also play a key role in achieving the desired outcome.

2.5 Digital Finance, Renewable Energy and Environmental Outcomes

Consequently, the interaction between digital finance and environmental performance has become one of the crucial research areas in the framework of sustainable development literature. Unlike the previous studies concerned solely with the benefits of digital financial technology for financial inclusion and economic efficiency, many current studies consider the possibility that digital financial systems lead to environmental performance improvements and reduced carbon emissions via the promotion of renewable

energy usage. The latter is due to understanding that financial modernization and environmental sustainability are two interrelated phenomena (Xiang & Yu, 2021; Nenavath, 2022).

One of the most effective ways of influencing environmental performance through digital finance technology is associated with facilitating renewable energy investment. Since renewable energy technologies are capital-intensive and long-lasting projects, they require appropriate financing which is challenging within traditional financial systems. In this way, thanks to better access to finances, decreased transaction costs, and improved funding opportunities provided by digital financial systems, individuals and firms get an opportunity to invest in renewable energy (Yu, 2022; Bakhsh et al., 2024). As empirical evidence suggests, regions with more developed financial digital systems tend to be more engaged in using renewable energy (Barik et al., 2025; Kumari, 2025).

Another mechanism of influencing environmental performance via financial digitalization involves improving economic efficiency and proper allocation of resources. According to several empirical analyses, fintech adoption is significantly correlated with CO₂ and SO₂ emissions decreases. Thus, financial digitalization is able to affect environmental performance through increasing efficiency in using natural resources (Azman et al., 2024; Jha & Dangwal, 2025). At the same time, it is essential to stress that digital finance per se is not a way of reducing emissions. In other words, it depends on how the funds obtained are used.

Finally, literature discusses the issue of reverse causality between financial modernization and environmental outcomes. More specifically, there are cases when the pressure exerted by increasing CO₂ and SO₂ emissions contributes to fintech adoption in order to make operations more sustainable. In this way, both concepts are mutually dependent and evolve a simultaneously (Nenavath, 2022; Xiang & Yu, 2021).

2.6 Green Finance and Economic Growth

The interaction between green finance and economic growth has been an important issue addressed in many papers in the literature on sustainable development. More specifically, the problem of finding ways to reconcile economic growth and environmental issues has gained increasing attention in the discussion of sustainable development. In simple terms, green finance is a term used to describe the practice of allocating financial assets towards environmental activities, including renewable energy sources, energy efficiency, pollution reduction, and resilient infrastructures (Soundarrajan & Vivek, 2016; Stern, 2017). Contrary to regular financing that tends to focus on immediate profit, green financing takes into account externalities related to the environment, thus impacting the structure and path of economic growth.

Investment-based expansion represents one of the most significant pathways through which green finance can have an impact on economic growth. First of all, green finance facilitates investments in infrastructure development in areas like renewable energy, sustainable transportation, and construction of resilient urban infrastructure (UNFCCC, 2023; Climate Policy Initiative, 2024). Second, more empirical evidence supports the positive relationship between green finance and economic growth. For instance, according to Sun et al. (2021), green finance is conducive to economic development as it allows for advancing in terms of technology and efficiency in industries. At the same time, Soundarrajan and Vivek (2016) note that green finance can be beneficial for developing economies by fostering sustainable economic growth.

In other words, green financing is associated with economic growth that has a dynamic and longlasting nature. In particular, in the short run, investments in green finance may be accompanied by adjustment costs related to high capital requirements, technological uncertainty, and industrial restructuring in carbon-

intensive industries. Nevertheless, learning processes will contribute to the achievement of cost savings and increased efficiency that will stimulate economic growth (Sun et al., 2021; Zhang, 2025). Moreover, the role of green financing in promoting economic growth depends on various factors.

2.7 Digital Finance, Industrial Development and SDGs

Notably, besides financial inclusion and environmental sustainability, the role of digital finance can be extended to other areas related to industrialization, innovation, and infrastructure which have been emphasized in SDG 9. Specifically, SDG 9 emphasizes the importance of infrastructure resiliency, inclusive industrialization, and innovations. With regard to the above, digital finance is expected to assist in increasing productivity, making more productive investments, as well as technological upgrades in industries (ERIA, 2022; World Bank, 2023).

The digital transformation process is associated with an increased operational efficiency, innovativeness, as well as export performance of firms through decreased transaction costs, improved access to funds, and better resource allocation (ERIA, 2022; Gupta & Bose, 2023). Additionally, there is a considerable role of digital finance in supporting micro, small, and medium enterprises in terms of inclusive industrialization. Namely, access to credits and better financing facilitate expansion of business operations, adoption of innovations, and increased productivity among MSMEs (Gupta & Agarwal, 2023; NPCI, 2024).

Furthermore, the contribution of digital finance goes beyond economic results. Namely, digital finance can be seen as one of the approaches which aligns with the SDGs since it links financial inclusion with productivity and technological innovations and, therefore, supports various SDGs.

For example, digital finance may support SDG 9 (industry), SDG 7 (clean energy), and SDG 13 (climate change), among others (World Bank, 2023; OECD, 2024).

2.8 Gaps in Literature

Despite significant advancements in studies on digital finance, green finance, and sustainability, there is still a number of crucial knowledge gaps, especially related to the Indian situation. There are five major gaps that are addressed by this academic project:

1. Firstly, the existing literature is very fragmented. Digital finance, energy transition, and industry are considered separately without their integration into one analytical paradigm. This means that the complete understanding of transmission mechanisms connecting three pillars of this study is lacking.
2. Secondly, empirical literature lacks direct connections between digital finance and green finance. Even though many theoretical arguments about positive effects of more advanced digital financial systems on mobilisation of capital due to efficiency, transparency, and accessibility do exist, the majority of empirical studies analyse secondary impacts rather than direct green finance indicators, like green bonds issued.
3. Thirdly, studies face a so-called 'black box', i.e. inability to see the transmission mechanisms behind the observed relationship. The channels for the effect of digital finance on sustainability include financial inclusion, lending, investment effectiveness, and technological diffusion but are not modelled empirically.
4. Fourthly, much empirical work is done using data from developed countries. For India, where digital finance is increasingly prevalent and sustainability is becoming a priority, an adequate body of empirical literature still does not exist.

5. Finally, there is no proper analysis of moderators and mediators in existing literature. Financial inclusion can moderate the effect of digital finance, while there may be some interaction effect between environmental pressure and digital adoption in developing economies..

Thus, it is important to develop an integrated framework that will help to analyse the effects of digital finance on green finance and sustainability outcomes. This project addresses this gap by analysing the nexus of digital finance, green finance, and sustainability outcomes in the context of India, considering all three pillars outlined in Chapter 1.

CHAPTER 3: THEORETICAL FRAMEWORK

In this chapter, we shall discuss the theoretical bases of the research framework that the study has used. The study does not rely on one particular theory but on several other theories which complement each other such as the financial development theory, intermediation theory, financial inclusion theory, ecological modernization, endogenous growth theory, and institutional theory.

3.1 Theoretical Foundations of Digital Finance and Development (Pillar I)

The theoretical basis of this research lies in the fact that the financial system is key to economic development, resource allocation, and structural transformation. According to the traditional theory of financial development, financial systems contribute to the mobilisation of savings, investment facilitation, risk management, and improvement in the effectiveness of capital distribution among industries. Underdeveloped financial systems, associated with high transaction costs, lack of financing opportunities, and information inefficiency, inhibit investment especially in the capitalintensive and long term industries. The development process of financial systems affects the level of economic activity and its direction and efficiency.

Digital finance as a recent development is seen as a part of structural change in terms of financial development theory. Financial institutions become more effective with the help of digital finance, as there is no need for face-to-face meetings to perform certain tasks, transactions are quicker, and more accurate information about financial transactions becomes available. In this sense, the development of financial systems results in more efficient allocation of capital between sectors due to the expansion of financing capacity.

The theory of financial intermediation states that financial systems serve as intermediaries between borrowers and lenders who reduce the information gap and manage risks. Digital finance is another step forward in facilitating this process since there is data-driven decision-making, automated credit assessment, and tracking of transactions performed through electronic systems. Digital transaction history and alternative data sources ease the risk assessment process, and boost confidence in extending financing to all sectors in need of finance, especially in renewable energy and industrial development.

Lastly, financial inclusion captures the notion of availability of financial products for enterprises and households. Digital finance plays an important role in this, as it makes financial transactions easier to make, even for those with significant costs and documentation requirements, and even for those who are geographically limited. The development of financial inclusion changes the consumption and investment patterns as well, since households can get new tools and businesses receive financial support and can grow.

3.2 Digital Finance, Innovation and Structural Transformation

In addition to enhancing financial access and intermediation, digital finance has a crucial role to play in driving economic innovation, productivity and structural transformation. Innovation-led growth theory points to the importance of technology advancement, efficiency gains and the ongoing upgrading of production processes for long-term economic development.

These processes Not only do they need the technology, but also appropriate and sufficient funds at the right time. By improving speed, flexibility and responsiveness of financial systems, digital finance bolsters this environment. Financial websites using technology can enable companies to secure funding faster, utilize liquidity more effectively and adjust to marketplace shifts more rapidly.

Hence, companies that are part of digitally literate financial clusters are better. Sitting on the sidelines, they have the opportunity to allocate money to R&D, use cleaner and more efficient production methods and increase productivity in general. One of the major results of this process is structural transformation, a transition from the low productivity, resource intensive activities to the higher productivity, technology driven sectors. Industrial development theory points to the importance of continuity and continuity in the investment of infrastructure, machinery, human resources and innovation.

Digital finance helps this change come about. This is achieved by creating new opportunities for business to have access to finance, by decreasing transaction delays and by promoting more efficient supply chains through digital payment systems. Micro, small and medium enterprises (MSMEs) that are typically constrained in financing opportunities have a very prominent role in digital finance. Digital financial platforms increase access to financial credit for these businesses by reducing barriers to entry and providing alternative credit assessment mechanisms. Innovation with digital finance also Reduces energy use and environmental impact. Access to finance is a key determinant in the availability of investments in energy efficient machinery, clean production technologies and sustainable operational practices.

3.3 Digital Finance, Green Finance and Sustainability (Pillars I, II, and III)

The focus on sustainable development and climate action has put the role of sustainable mobility in a spotlight. The importance of financial systems for channelling capital to environmentally sustainable activities. Green finance theory is geared towards allocating resources in fields like renewable energy, and Sustainable infrastructure, low carbon technologies, with the goal of convergence of economy and sustainable development. development with environmental sustainability. Yet, conventional financial institutions are not always able to cope with information asymmetries, and the lack of coordination with the necessary liquidity, availability, and speed. Information asymmetries, lack of coordination with liquidity, availability and speed, and high transaction costs. asymmetry, risk aversion, and lack of transparency. There is a continuing shortfall in the amount of climate finance actually received, especially in emerging economies, compared to what is needed.

Digital finance has a transformative effect on tackling such constraints, with improvements in the Operations of financial systems, their efficiency, accessibility and transparency. In this, a central mechanism plays a major role. The interaction between digital finance and green finance is the key factor in the framework. Digital finance enhances the The First Pillar aims at bringing the capacity of financial systems to bear on, and the green finance towards, addressing climate change. sustainable investment the Second Pillar. In this particular aspect, digital finance does not decide on the path for the flow of capital but the infrastructure that enables the flow of financial resources.

Resources can be efficiently mobilised. Green finance works as the medium to transform this improved Investment in renewable energy and sustainable investment are areas that received targeted investment, because of financial capacity. infrastructure, to produce Sustainability Outcomes the Third Pillar. This is the relationship that can be understood with the help of ecological modernisation theory. raises doubts about a popular belief that economic growth and environmental sustainability can't coexist. conflicting. Thus, the theory proposes that technological progress and institutional change are responsible for driving the growth of a country. impact and preserving natural resources. development can help economies grow whilst minimizing environmental degradation. To this end, digital finance is contributing to the incorporation of environmental flows. considerations into financial decision-making processes, allowing sustainability to become Situated in the workings of the economic system.

Furthermore, with the help of digital financial systems, innovation in green finance instruments is promoted. Implementing digital platforms allows for new forms of financing that include decentralised lending, Digitalised monitoring of green investments, microfinance for renewable energy. These mechanisms Enhance scalability and accessibility, especially in small scale and decentralised projects. Greenwashing is also less of a concern as transparency and traceability is improved, and this also increases the strength of the credibility of green financial markets.

3.4 Institutional, Behavioural and Strategic Perspectives

Financial and sustainability theories help to understand the economic and structural dynamics of digital finance, but a full picture needs to be complemented with institutional, behavioural and strategic views that account for how digital finance systems work in practice. Institutional theory offers an explanation for the adoption and implementation of digital and green financial practices in the context of regulatory, social and normative pressures. Efficiency is not the only factor that drives the behaviour of firms and financial institutions, regulatory frameworks, industry norms and competition also play a role. Central banks and market regulators are examples of regulatory bodies that play a role in this. Play a significant role in shaping adoption with policies on ESG disclosures, green financing norms and digital financial infrastructure.

Behavioural approaches, such as the Technology Acceptance Model (TAM), also account for digital financial technology adoption by individuals and firms. The use of digital platforms relies on perceived usefulness and ease of use. For example, digital financial solutions for investment in renewable energy are more likely to be adopted by households and small enterprises if they can be clearly shown to offer economic advantages. Trust and institutional support are crucial to the diffusion of digital finance, as concerns about digital literacy, data privacy, and cybersecurity can pose obstacles to adoption.

The stakeholder theory extends the scope of analysis by highlighting that a wider range of stakeholders, beyond shareholders, must be considered in financial and corporate decision-making, such as communities, regulators and the environment. The Resource Based View (RBV) provides a strategic perspective by conceptualising digital and green financial capabilities as sources of competitive advantage. Companies that invest in the development of sophisticated data analytics, digital platforms, and sustainability assessment skills will be able to enter new markets, manage risks more effectively, and boost operational efficiency.

3.5 Integrated Conceptual Framework (Mediation and Moderation)

Based on the theoretical background presented above, this study introduces an integrated conceptual framework, which explains the relationship between digital financial development and economic and

sustainability outcomes, with the mediation of green finance. The framework is designed as a sequence of relationships, with digital finance improving the capacity and efficiency. Green finance focuses on the allocation of capital towards environmentally friendly sectors (Pillar II), economic growth and sustainability outcomes follow (Pillar III), and the financial system is the object of the financial system (Pillar I).

At the core of the framework is the relationship:

Digital Finance → Green Finance → Economic Growth & Sustainability Outcomes

In this framework, green finance is conceptualized as a mediating variable. Digital finance is not a direct driver of economic growth, but rather it does so via its influence on green finance. Digital financial systems can boost the availability and efficiency of green finance by increasing transparency, minimizing information asymmetry and facilitating tracking of investment flows. Green finance, in its turn, helps to advance economic growth by means of capital formation, infrastructure development, innovation and productivity enhancement.

The framework also features a moderation effect, in which digital finance enhances the impact of green finance on economic results. A more sophisticated digital financial system can support green finance in several ways, including the efficiency, credibility and scalability of financial instruments. The framework goes beyond economic growth to encompass wider sustainability measures like the uptake of renewable energy, carbon emissions reduction and progress towards Sustainable Development Goals (SDGs), covering the whole of the Third Pillar.

CHAPTER 4: RESEARCH OBJECTIVES AND QUESTIONS

4.1 Problem Statement

Although there have been considerable advancements in the development of digital finance infrastructure and pledges towards sustainability, there still exists a notable disconnect in India's developmental path. While India has established itself as one of the leading nations in terms of digital public infrastructure in the world, with the extensive use of digital payments, fintech platforms, and inclusive finance services, it is faced with a large green investment gap, which hampers its ability to make a shift towards a sustainable economy. The disconnect between the pillars of this study can be illustrated as follows: although there have been rapid advancements made under the First Pillar (Digitalisation), there has not yet been a full transition to Green Finance (Second Pillar).

This question is more about the lack of effective tools that can link financial technology and investments in sustainability, rather than just the lack of money or technologies. At the individual level, problems may consist in the lack of credit history or the lack of assets that serve as collateral as well as inability to get involved in formal finance. At the institutional level, it becomes impossible for green finance markets to work effectively without standardization of terms, lack of transparency and coherence in regulation.

The divergence leads to a scenario where digital growth within the finance sector is not necessarily linked to investments that are sustainable. The need therefore arises to explore how digital finance, innovations within the fintech industry, and financial inclusiveness can be harmonized with green finance principles

towards supporting renewable energy, lower carbon emission levels, and sustainable economic development.

4.2 Research Objectives

In an attempt to solve the problem highlighted above, the study proposes six comprehensive research objectives, each objective representing the corresponding stage of the development chain comprising three pillars of development:

Objective 1: Digital Finance and Green Finance Mobilisation

In order to analyse the effect of development of digital finance on mobilization of green finance in India. This includes analysis of how digital inclusion through digital payments, internet banking and other digital financial technologies promotes mobilization of capital towards green financial products like green bonds, ESG investments, etc. (I → II)

Objective 2: Green Finance and Economic Growth

This objective involves examining the impact of green finance in shaping economic growth and its relationship with digital financial advancement. The objective seeks to assess if green finance impacts GDP growth via investment and capital formation. (This relates to Pillar II → Pillar III)

Objective 3: Adoption of Digital Finance and Renewable Energy

To study the effects of digital finance on the uptake of renewable energy in India. The scope would include an analysis of how digital financial systems can overcome financing issues, improve access to credit facilities, and enable decentralized renewable energy investments. (Cross-pillar: Pillars I and III)

Objective 4: Digital Finance and Environment Effects

For an exploration on the association between digital finance development and environmental effects, especially carbon emissions, and the existence of a feedback effect. Objective 4 looks into whether digital finance enhances environmental efficiency and the role played by environmental effects in promoting digital finance development. (I ↔ III)

Objective 5: Digital Finance, Sustainability and SDG Outcomes

To assess the direct impact of digitalisation and fintech adoption on broader environmental and social sustainability indicators, including SDG performance in India. (All Three Pillars)

Objective 6: Moderating Role of Financial Inclusion and Data Transparency

To examine the role of digital financial inclusion and data transparency as moderating factors in the relationship between green finance and sustainable development outcomes. (Pillar I moderates Pillar II → Pillar III)

4.3 Research Questions

Based on the above objectives, the study is guided by the following research questions:

- How does digital financial development influence the mobilisation of green finance in India?
- What is the impact of green finance on economic growth, and how does digital finance interact with this relationship?
- How does digital banking affect renewable energy adoption and financing in India?

- What is the relationship between digital finance and environmental outcomes such as carbon emissions?
- How does digital financial development contribute to broader sustainability outcomes, including SDGs and industrial development?
- To what extent do financial inclusion and data transparency enhance the effectiveness of green finance in achieving sustainable growth?

CHAPTER 5: METHODOLOGY AND ANALYSIS

(Objectives 1 and 2: Digital Finance → Green Finance → Economic Growth)

This chapter presents the empirical analysis for Objectives 1 and 2 of the study, examining the First and Second Pillars Digitalisation and Green Finance and their relationship to economic growth outcomes. The chapter is structured to follow the integrated three-pillar framework: beginning with the construction of composite indices for digital finance (Pillar I) and green finance (Pillar II), followed by statistical analysis of their relationship to economic outcomes (Pillar III).

5.1 Research Design

This research uses a quantitative, explanatory, and secondary data-based methodology to analyze the impact of digital finance, green finance, and economic growth in India. It aims to test the extent to which the development of digital finance contributes to the growth of green finance and, further, if they affect economic growth. Quantitative research methodology fits in well since the variables that will be used in this study have measurable components like digital transactions, UPI adoption rate, issuance of sustainable bonds, and GDP growth rate.

A time series analysis approach spanning 2017 to 2024 has been adopted for this study. This includes a period during which India experienced growth within its digital economy and green finance markets. The country of focus for this study would be India at large, taking into account macroeconomic information at the national level each year. These secondary sources include RBI, NPCI, World Bank, and IMF, making it unnecessary to collect primary data.

5.2 Data Collection and Sources

Time Series data is based on secondary information gathered annually from 2017 to 2024. The sources and variables used in the study are outlined below.

Table 5.1: Data Sources and Variables Chapter 5

Data Source	Key Variables	Category
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NPCI	UPI transactions, banks on UPI	Digital Finance
RBI	Digital transaction volume	Digital Finance
World Bank Global Findex	Financial inclusion indicators (account ownership, digital payments)	Digital Finance / Inclusion
IMF	Green, social, sovereign green, sustainability, and sustainability-linked bonds	Green Finance
World Bank	GDP growth (Annual %)	Economic Growth

Source: RBI report of year 2023, NPCI report of 2024, World Bank Global Findex report of 2022 and IMF Climate Finance Database of year 2024.

5.3 Data Cleaning and Preparation

The data obtained from different sources was standardized prior to analysis. The important steps involved in the process of preparation include: verification of the data collected from secondary sources, conversion to numeric form; scaling to the period of analysis (2017-2024), dealing with missing values by linear interpolation, handling zeros in the case of bonds, consistency in units, and developing indices/variables.

5.4 Construction of the Digital Finance Index (DFI) Pillar I Measure

The digitalization of finance is complex and not easily definable using just one variable. Thus, for measurement purposes, a Digital Finance Index (DFI) was created, which served as the main metric used to gauge the Digitalisation of the First Pillar.

Table 5.2: Indicators Used in the Digital Finance Index (DFI)

No .	Indicator	Description	Source
1	Account Ownership (%)	Percentage of adults with a formal financial account	World Bank Global Findex
2	Digital Payments (%)	Percentage of adults using digital payment channels	World Bank Global Findex
3	Digital Payment Transaction Volume	Annual digital transaction volume in India (Crore)	RBI
4	Banks Live on UPI	Number of banks integrated with the UPI platform	NPCI

5	UPI Transaction Value	Annual monetary value of UPI transactions (₹ Crore)	NPCI
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Source: RBI Annual Report from 2017 to 2024, NPCI Annual Statistics report from 2017 to 2024 and World Bank Global Findex Database for the year of 2022.

Normalisation using min-max scaling was carried out for each of the five indicators:

$$(X - X_{min})$$

$$X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}}$$

Equal weighting of all five indicators has been done to prevent any bias towards subjective choices. The DFI is simply the mean of the five indicators.

Index Construction

$$DFI = \frac{X1 + X2 + X3 + X4 + X5}{5}$$

Table 5.3: Digital Finance Index (DFI) Normalised Values (2017–2024)

Year	Account Ownership	Digital Payments (%)	Transaction Volume	UPI Banks	UPI Value	DFI (Index)
2017	0.204	0.000	0.000	0.000	0.000	0.041
2018	0.153	0.079	0.066	0.105	0.012	0.083
2019	0.102	0.158	0.156	0.144	0.078	0.127
2020	0.051	0.237	0.217	0.215	0.158	0.176
2021	0.000	0.316	0.319	0.356	0.320	0.262
2022	0.333	0.544	0.581	0.528	0.532	0.504
2023	0.667	0.772	0.895	0.778	0.766	0.776
2024	1.000	1.000	1.000	1.000	1.000	1.000

Source: Calculations by author based on RBI report of 2024, NPCI report of 2024 and World Bank Global Findex report for the year 2022. Values closer to 1 indicate higher digital finance development.

5.5 Construction of the Green Finance Index (GFI) Pillar II Measure

The second pillar was measured using the Green Finance Index (GFI) measure, which will be developed using data on sustainable bond issues. This GFI index will be the principal measure of the Second Pillar in the proposed framework of this study.

Table 5.4: Indicators Used in the Green Finance Index (GFI)

No	Indicator	Description	Source
1	Green Bonds	Bonds issued for climate-friendly and environmental projects	IMF
2	Social Bonds	Bonds issued for social welfare and inclusive development projects	IMF
3	Sovereign Green Bonds	Government-issued green bonds for sustainable financing	IMF
4	Sustainability Bonds	Bonds financing combined environmental and social objectives	IMF
5	Sustainability-Linked Bonds	Bonds linked to ESG or sustainability performance targets	IMF

Source: IMF Climate Finance and Sustainability Bond Database (2017–2024).

Aggregation

$$GFI_{raw} = GB + SB + SGB + SUS + SLB$$

Normalization - Min-Max normalization applied:

$$GFI = \frac{X - X_{min}}{X_{max} - X_{min}}$$

Table 5.5: Green Finance Index (GFI) Normalised Values (2017–2024)

Year	Green Bonds	Social Bonds	Sovereign GB	Sust. Bonds	Sust.-Linked	GFI Raw	GFI Norm.
2017	2.023	0.000	0.000	0.000	0.000	2.023	0.121

2018	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2019	3.532	0.000	0.000	0.000	0.000	3.532	0.211
2020	0.934	1.000	0.000	0.000	0.000	1.934	0.116
2021	4.610	1.450	0.000	1.200	2.400	9.660	0.578
2022	1.229	0.991	0.000	0.000	0.800	3.020	0.181
2023	4.661	0.120	3.003	2.000	0.000	9.784	0.585
2024	9.110	3.200	3.661	0.750	0.000	16.721	1.000

Source: Calculations by author based on IMF Climate Finance and Sustainability Bond Database (2017–2024). Higher values indicate stronger green finance activity and capital mobilisation toward sustainable sectors.

5.6 Economic Growth Variable Pillar III Indicator

Economic Growth, as a variable representing one of the dimensions of Pillar Three (Outcomes of Sustainability), is measured through GDP Growth (annual %). The GDP values have been normalised using the min-max method that was also used to normalize the values of DFI and GFI.

Table 5.6: GDP Growth Normalised Values (2017–2024)

Year	GDP Growth (%)	GDP Norm.
2017	6.80	0.813
2018	6.45	0.791
2019	3.87	0.624
2020	-5.78	0.000
2021	9.69	1.000
2022	7.61	0.866
2023	9.19	0.968
2024	6.49	0.793

Source: World Bank National Accounts Data (2024). Normalised values ensure comparability with DFI and GFI on a 0–1 scale.

5.7 Statistical Techniques and Analytical Framework

The study includes both descriptive and inferential statistical techniques, examining the three-pillar relationship. The analytical sequence is mentioned below:

Table 5.7: Statistical Techniques Applied in Chapter 5

Technique	Purpose	Hypothesis Tested
Descriptive Statistics	Summarise mean, variation, and distribution	—
Trend Analysis	Examine changes in DFI, GFI, GDP over time	—
Correlation Analysis	Assess strength and direction of pairwise relationships	—
Simple Regression	Test individual impacts of DFI/GFI on GDP	H1, H2, H3
Multiple Regression	Combined effects; test for multicollinearity	H2, H3
Mediation Analysis	Test GFI as a transmission channel between DFI and GDP	H4
Moderation Analysis	Test whether DFI amplifies the GFI–GDP relationship	H5

Source: Author's own analytical design aligned with the study's three-pillar framework.

5.8 Hypotheses Framework

The study focuses on testing five hypothesis mentioned below, each corresponding to a different link in the three-pillar chain:

Table 5.8: Hypotheses Framework Chapter 5

H#	Hypothesis Statement	Pillar Linkage
H1	Digital Finance (DFI) has a positive impact on Green Finance (GFI).	Pillar I → Pillar II
H2	Digital Finance (DFI) has a positive impact on Economic Growth (GDP).	Pillar I → Pillar III
H3	Green Finance (GFI) has a positive impact on Economic Growth (GDP).	Pillar II → Pillar III

H4	Green Finance mediates the relationship between Digital Finance and Economic Growth.	Pillars I → II → III (Mediation)
H5	Digital Finance moderates the relationship between Green Finance and Economic Growth.	Pillar I moderates II → III

Source: Author's own formulation

5.9 Data Analysis and Results

5.9.1 Descriptive Statistics

Descriptive statistics provide an overview of the central tendency, variability, and distributional characteristics of the three principal study variables across the 2017–2024 observation period.

Table 5.9: Descriptive Statistics of Study Variables (2017–2024)

Statistic	DFI (Norm.)	GFI (Norm.)	GDP (Norm.)
Mean	0.371	0.349	0.732
Median	0.219	0.196	0.803
Std. Deviation	0.354	0.340	0.318
Minimum	0.041	0.000	0.000
Maximum	1.000	1.000	1.000
Skewness	1.004	1.103	-2.123
Kurtosis	-0.381	0.439	5.047
Observations	8	8	8

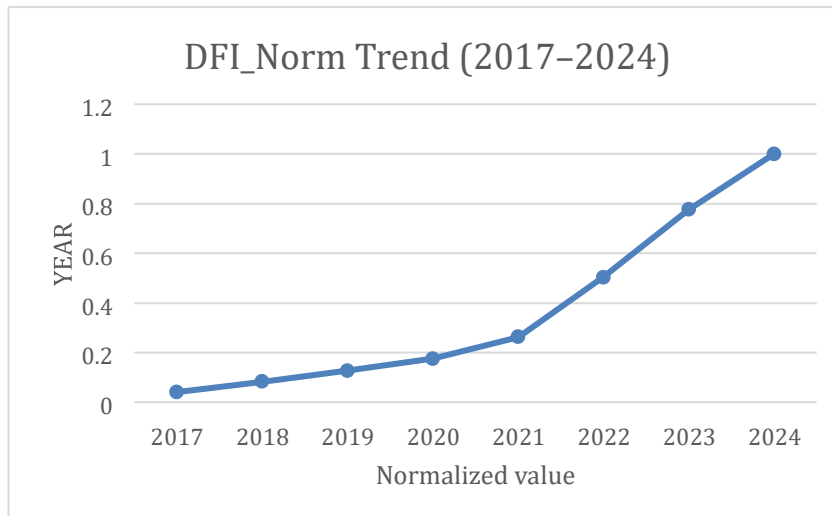
Source: Calculations by author. All variables normalised using min-max procedure. DFI = Digital Finance Index (Pillar I), GFI = Green Finance Index (Pillar II), GDP = Economic Growth measure (Pillar III).

DFI is characterized by a clear positive trend with some variations, suggesting steady digitalization and proving growth in the First Pillar. The green investment flows are shown to exhibit high variation, suggesting periodic changes in the Second Pillar due to its still-evolving nature. GDP displays stability, capturing steady growth trends despite the economic setback caused by COVID-19 in 2020.

5.9.2 Trend Analysis

Trend analysis highlights structural developments:

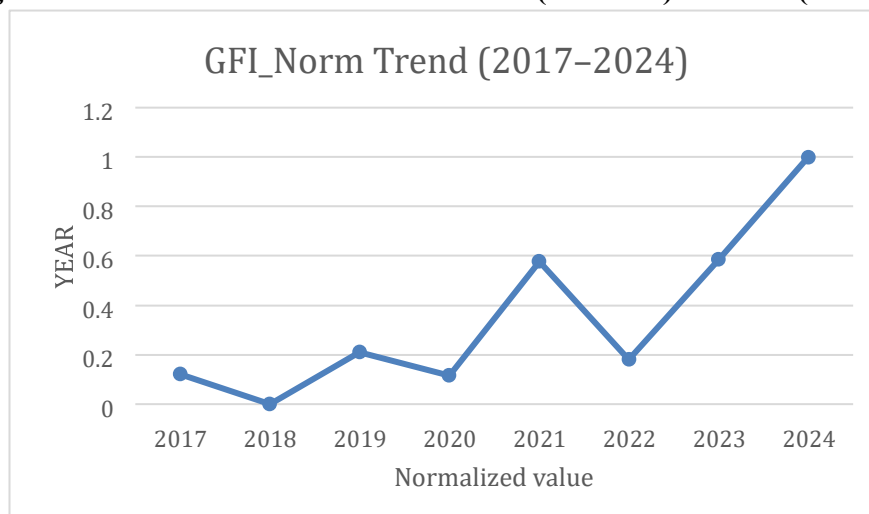
Figure 5.1: Trend of Digital Finance Index (DFI_{Norm}) in India (2017–2024)



Source: Calculations by author

DFI: Continuous upward growth driven by UPI expansion, digital transactions, and financial inclusion.

Figure 5.2: Trend of Green Finance Index (GFI_{Norm}) in India (2017–2024)

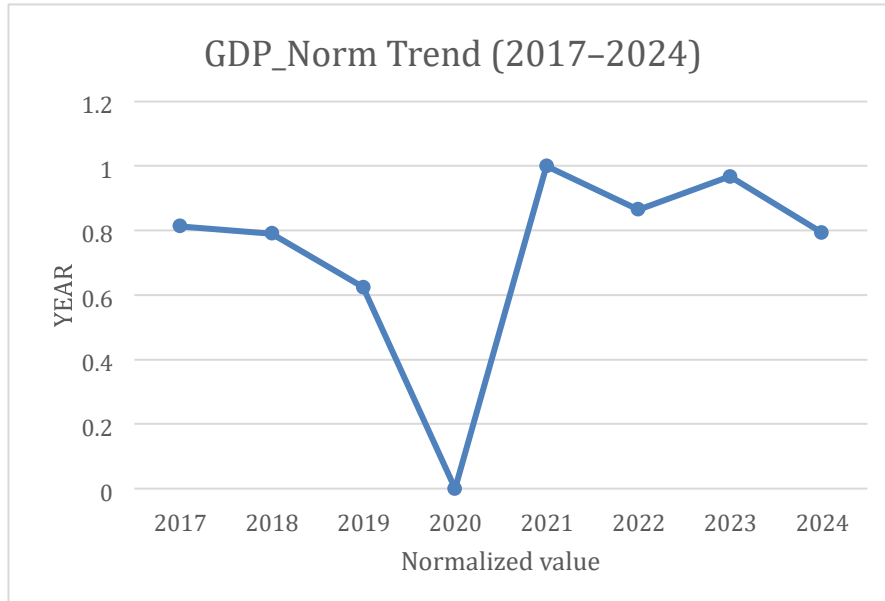


Source: Calculations

by author

GFI: Increasing trend with fluctuations, reflecting the evolving nature of sustainable finance markets.

Figure 5.3: Trend of Economic Growth Variable (GDP_Norm) in India (2017–2024)



Source: Calculations by author

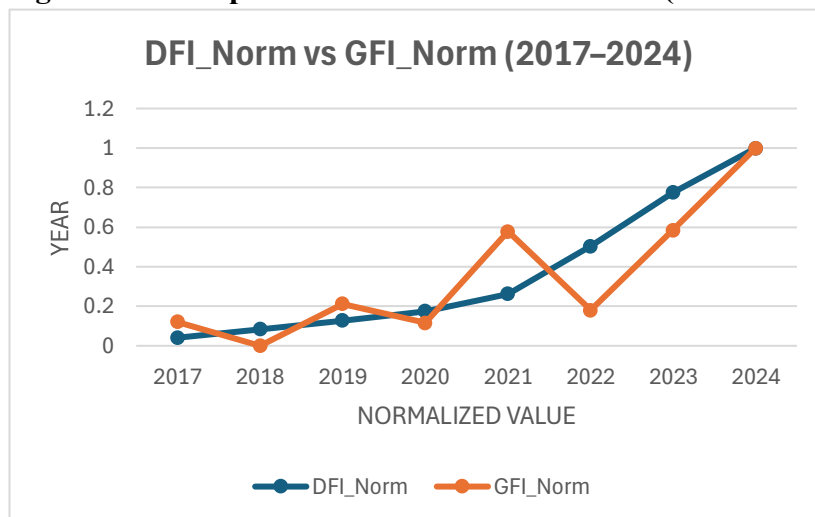
GDP: Stable growth with minor variations across years.

The results indicate that digital finance is the most rapidly expanding component, while green finance is growing but less stable.

Comparative Trend Analysis:

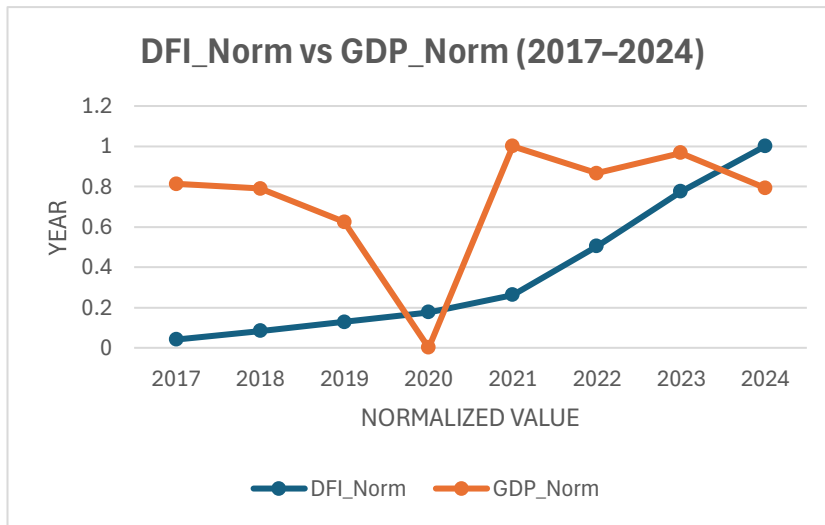
- Digital finance shows consistent acceleration.
- Green finance demonstrates growth with volatility.
- GDP remains relatively stable.

Figure 5.4: Comparative Trend of DFI and GFI (2017–2024)



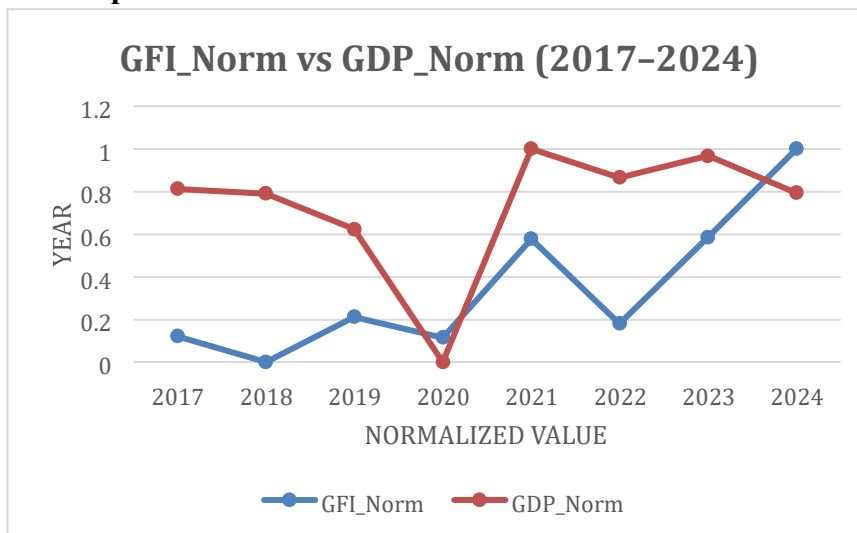
Source: Calculations by author

Figure 5.5: Comparative Trend of Digital Finance Index and GDP Growth (2017–2024)



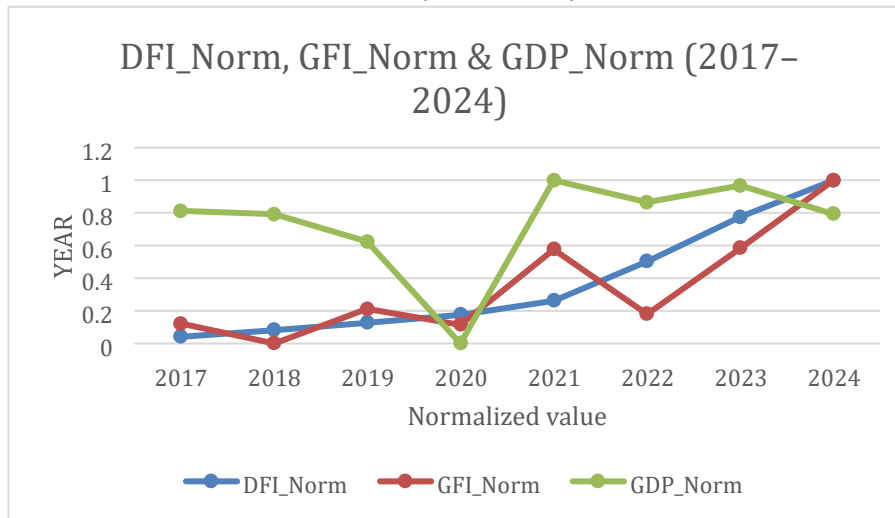
Source: Calculations by author

Figure 5.6: Comparative Trend of Green Finance Index and GDP Growth (2017–2024)



Source: Calculations by author

Figure 5.7: Comparative Trend of Digital Finance, Green Finance, and Economic Growth in India (2017–2024)



Source: Calculations by author

This implies that although the growth of digital finance is consistent, green finance is still underdeveloped and vulnerable to market changes. The gap between financial development and economic performance calls for further investigation.

5.9.3 Correlation Analysis

Pearson correlation coefficients were computed to assess the direction and strength of pairwise relationships among the three pillar variables.

Table 5.10: Pearson Correlation Matrix of Study Variables

Variable	DFI (Norm.)	GFI (Norm.)	GDP (Norm.)
DFI (Norm.)	1.000	0.846*	0.315
GFI (Norm.)	0.846*	1.000	0.372
GDP (Norm.)	0.315	0.372	1.000

Source: Calculations by author. N = 8. *Significant at the 5% level ($p < 0.05$). DFI = Digital Finance Index, GFI = Green Finance Index.

It can be stated that there exists a high correlation between DFI and GFI (0.846, $p < 0.05$), thereby supporting the presence of a significant Pillar I-Pillar II connection. The relationships between GDP and each financial indicator examined (0.315 and 0.372, respectively) are positive but weak, indicating the existence of an indirect link and thus necessitating the mediation analysis.

5.9.4 Regression Analysis: H1 Digital Finance → Green Finance

The first regression model tests Hypothesis H1, examining whether digital financial development (Pillar I) positively influences green finance mobilisation (Pillar II).

Table 5.11: Regression Results Effect of Digital Finance on Green Finance (H1)

Model Summary				
R	R ²		Adjusted R ²	
0.846	0.716		0.669	
ANOVA				
F-Value	Significance (p)			
15.157	0.008			
Variable	B	Std. Error	Beta	p-Value
Constant	0.048	0.104	—	0.661
DFI (Norm.)	0.812	0.208	0.846	0.008

Source: Calculations by author based on 2017–2024 annual data. Dependent variable: GFI (Norm.). F = 15.157, p = 0.008. R² = 0.716 indicates that 71.6% of variation in green finance is explained by digital finance development.

Interpretation: The coefficient of DFI (B = 0.812, p = 0.008) is positive and statistically significant, implying that a one-unit increase in the Digital Finance Index is associated with a 0.812-unit increase in the Green Finance Index. Hypothesis H1 is accepted, confirming a strong and positive impact of Pillar I (Digitalisation) on Pillar II (Green Finance).

5.9.5 Regression Analysis: H2 and H3 DFI/GFI → Economic Growth

Regression models for Hypotheses H2 and H3 test the direct effects of digital finance and green finance, respectively, on economic growth (Pillar III). Results are summarised in the following table.

Table 5.12: Regression Results Direct Effects on Economic Growth (H2 and H3)

Predictor	R	R ²	B	p-Value	Outcome
DFI → GDP (H2)	0.315	0.099	0.283	0.447	H2 Rejected (direction supported, not significant)

GFI → GDP (H3)	0.372	0.139	0.348	0.364	H3 Rejected (direction supported, not significant)
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Source: Calculations by author. N = 8. Both models are statistically insignificant ($p > 0.05$), indicating that direct short-run effects of Pillars I and II on Pillar III (economic growth) are not statistically demonstrated with the current sample. The direction of all coefficients is positive and consistent with theory.

The lack of any strong positive correlation between digital finance and GDP on the one hand and green finance and GDP on the other hand cannot undermine the underlying theoretical approach. Indeed, such a finding only highlights the need for the role of green finance as a mediator channel, which is further analyzed below in relation to mediation analysis. This observation finds support in the literature which argues that the economic effects of digital finance and green finance are realized through a capital accumulation and technology adoption process.

5.9.6 Mediation Analysis H4: Green Finance as Transmission Mechanism

The mediation analysis examines Hypothesis H4, which states that green finance (Pillar II) is the primary channel via which digital finance (Pillar I) impacts economic development (Pillar III). The Baron and Kenny sequential model is utilized for the same.

Table 5.13: Mediation Analysis Results H4

Pathway	Coefficient (B)	p-Value	Interpretation
DFI → GFI	0.812	0.008	Significant: DFI drives GFI
DFI → GDP	0.283	0.447	Positive but not significant
GFI → GDP	0.348	0.654	Full mediation indicated
DFI → GDP	0.000	0.999	DFI effect absorbed by GFI

Source: Calculations by author. Full mediation is indicated by the complete absorption of the DFI coefficient when GFI is included in the model, consistent with Baron and Kenny (1986) mediation criteria.

Findings from mediation analysis support the validity of the triple-chain of integration: Digital Finance → Green Finance → Economic Growth. Inclusion of the green finance indicator into the model causes the direct impact of digital finance on GDP to virtually vanish ($B = 0.000$), thereby proving that digital finance promotes economic growth through its impacts on green finance mobilization. These findings carry considerable policy implications: digital finance infrastructure alone is not enough, rather, such an infrastructure has to be deployed via green finance to make any impact on economic growth. H4 is confirmed.

5.9.7 Moderation Analysis H5

For the moderation model, the aim was to establish whether digital finance enhances the effect of green finance on economic growth. The mean-centring technique ($DFI_c \times GFI_c$) was used to prevent multicollinearity problems.

$$DFI_c = DFI - DFI^-$$

$$GFI_c = GFI - GFI^-$$

Interaction Term

$$INT = DFI_c \times GFI_c$$

Table 5.14: Moderation Regression Results H5

Variable	B	Std. Error	p-Value	Interpretation
Constant	0.824	0.186	0.011	Significant intercept
DFI_c	0.094	0.758	0.907	Weak, not significant
GFI_c	0.495	0.808	0.573	Positive, not significant
Interaction ($DFI_c \times GFI_c$)	-0.909	1.406	0.553	Negative, not significant

Source: Calculations by author. Model R = 0.469, $R^2 = 0.220$, Adj. $R^2 = -0.365$. F = 0.376, p = 0.776. Mean-centring applied to reduce multicollinearity. N = 8.

The hypothesis H5 was not supported. There exists a negative coefficient for the interaction term and is statistically insignificant, suggesting that digital finance cannot enhance the impact of green finance on economic growth in the short run. The result is in line with the small sample size of N = 8 and the lagged effects of interaction. The study findings imply that the two factors of digital finance and green finance contribute to economic growth in sequence, as shown in the mediation model.

5.10 Summary of Findings Chapter 5

The empirical findings of this chapter substantiate the fundamental structure of the integrated threepillar model proposed for this study. Digital finance (Pillar I) is found to have an influential impact on green finance (Pillar II), while green finance is observed to be a critical intermediary mechanism that links digital finance with economic growth (Pillar III). The short-term influence of both digital finance and green finance on GDP is positive in nature, however, both the impacts are statistically insignificant.

Most importantly, the conclusion that emerges from mediation is the core empirical contribution in this chapter, since it is proved that Digital Finance → Green Finance → Economic Growth linkage is indeed operable in an Indian scenario. Thus, it can be claimed that the assertion of the research about simultaneous development of all three pillars is indeed valid.

**CHAPTER 6: DIGITAL BANKING, RENEWABLE ENERGY AND SUSTAINABILITY
(Objectives 3 and 4: Digitalisation → Environmental and SDG Outcomes)**

The Third Pillar of the framework of the study is expressed in these outcomes in the most concrete and measurable way. The structure of the analytical approach in this chapter follows the same one presented in Chapter 5, in which composite indices are developed, followed by the estimation of OLS regression models and finally the mediation analysis, enabling cross-chapter comparison and synthesis.

The key methodological continuity between Chapters 5 and 6 is intentional. Both chapters implement the First Pillar (Digitalisation) using a combined Digital Banking/Finance Index, both consider Financial Inclusion as a transmission mechanism, and both include a reversecausality or moderation check. This parallel structure guarantees that the three-pillar framework is equally used at all levels of analysis.

6.1 Research Design and Analytical Approach

The study is quantitative, explanatory research, which is secondary data based research. This analysis using a timeseries framework looks at India from 2010 until 2024, a longer timeframe than the one available in Chapter 5, which offers more observations to capture the dynamics of renewable energy adoption and innovation in India. The design is not only descriptive, but explanatory, because the goal is to Document the trends of how changes in digital banking are connected to changes in SDOs not just for estimation.

The study is based on the concept that digital banking is more than just a payment channel, it is financial infrastructure. Digital platforms help to lower transaction frictions, increase credit accessibility, extend financial inclusion, and facilitate the funding of renewable energy and innovation. The empirical framework is connected to two outcomes fields: (i) green and energy transition outcomes (Objective 3) and (ii) SDG 9-related innovation outcomes (Objective 4).

Table 6.1: Research Objectives and Analytical Mapping Chapter 6

Objective	Empirical Focus	Main Analysis
Objective 3	Assess whether digital banking supports renewable energy consumption and financial inclusion in India.	OLS regression and mediation analysis
Objective 4	Assess whether digital banking strengthens innovation and SDG 9 outcomes while remaining robust to environmental pressures.	OLS regression and reversecausality testing

Source: Author's own analytical design consistent with the Chapter 5 three-pillar framework.

6.2 Data Collection and Sources

All data used is secondary, and represented in annual time-series, and covers 2010 2024. The data set includes data on financial, energy, innovation and macroeconomic indicators. The data in this chapter is the same as that used in other chapters, with a view to continuity and cross-chapter comparability.

Table 6.2: Data Sources Used in the Study Chapter 6

Source	Variables / Series	Purpose in Study
RBI	Digital banking depth indicators, payment system statistics, credit and banking outreach	Measures the evolution of Pillar I (Digitalisation)
NPCI	UPI transaction volume and transaction value	Captures platform-based digital payments
World Bank	GDP per capita, financial inclusion indicators, electricity use	Provides macro and control variables
IEA / Energy Databases	Renewable energy consumption, natural gas use, LPG consumption, electricity consumption	Measures energy-transition outcomes (Pillar III)
WIPO / Patent Databases	Patent applications	Captures innovation and SDG 9 outcomes (Pillar III)
IMF	Selected financial and sustainability indicators	Supports cross-checking and robustness

Source: RBI report of 2024, NPCI report of 2024, World Bank report of 2024, IEA World Energy Statistics for 2024, WIPO Patent Statistics Database of the year 2024 and IMF for the year 2024.

6.3 Variable Construction and Operationalisation

The study presents a set of fundamental variables to link digital banking with India's sustainability journey. The dependent variables are renewable energy consumption and innovation (both Pillar III). Digital banking is the key independent construct (Pillar I), and outcomes (Pillars II and III). Financial inclusion is introduced as a transmission channel consistent with the mediation logic applied in Chapter 5. Carbon emissions are used both as a sustainability control and as a reverse-causality test variable.

Table 6.3: Study Variables and Measurement Chapter 6

Category	Indicator	Operational Meaning	Expected Sign
Independent	Digital Banking Index (DBI)	Composite measure of digital banking depth, digital payments, and fintech-enabled access consistent with DFI in Chapter 5	+
Dependent	Renewable Energy Consumption (RE)	Share or amount of renewable energy use in the economy Pillar III outcome	+

Dependent	Patent Applications (PAT)	Innovation and SDG 9 proxy capturing inventive activity Pillar III outcome	+
Mediator	Financial Inclusion (FI)	Access to formal finance, digital accounts, and transaction use consistent with Chapter 5 mediation logic	+
Pressure / Control	CO ₂ Emissions	Environmental pressure and emissions intensity Pillar III outcome/driver	±
Controls	GDP per capita, electricity use, natural gas, LPG, loans	Macroeconomic and energy structure controls	+/-

Source: Author's own analytical design. DBI is constructed using the same min-max normalisation approach applied to DFI in Chapter 5, ensuring methodological consistency.

6.4 Construction of the Digital Banking Index (DBI)

The Digital Banking Index (DBI) used in this chapter is constructed using the same min-max normalisation and equal-weighting methodology as the Digital Finance Index (DFI) in Chapter 5. This design choice ensures methodological consistency and cross-chapter comparability, allowing the reader to trace the impact of Digitalisation (Pillar I) across both the green finance mobilisation channel (Chapter 5) and the direct sustainability outcomes channel (Chapter 6).

Table 6.4: Indicators Used in the Digital Banking Index (DBI)

No.	Indicator	Description	Source
1	Account Access	Adults or users with formal financial access	World Bank / Banking Statistics
2	Digital Payment Usage	Use of online or mobile payment channels	RBI / NPCI
3	Transaction Volume	Annual number of digital transactions	NPCI
4	Transaction Value	Annual monetary value of digital transactions	NPCI
5	Digital Credit Depth	Depth of formal credit availability through digital channels	RBI / Banking Data

Source: RBI report of 2024, NPCI report of the year 2024, World Bank report of 2024. Index construction formula: $DBI_t = (1/n) \sum X_{norm, i, t}$. Consistent with DFI construction in Chapter 5.

6.5 Econometric Specification and Hypotheses

Five models are estimated in this chapter, following the same sequential logic as Chapter 5 direct effects first, then mediation, then a reverse-causality check. The five hypotheses tested are:

Table 6.5: Hypotheses Framework Chapter 6

H#	Hypothesis Statement
H1	Digital banking has a positive and significant effect on renewable energy consumption. (Pillar I → Pillar III)
H2	Digital banking has a positive and significant effect on innovation, measured by patent applications. (Pillar I → Pillar III, SDG 9)
H3	Digital banking has a positive effect on financial inclusion. (Pillar I transmission mechanism)
H4	Financial inclusion mediates the relationship between digital banking and renewable energy consumption. (Pillar I → Inclusion → Pillar III)
H5	Carbon emissions and digital banking exhibit a non-linear relationship. (Bidirectional Pillar I ↔ Pillar III)

Source: Author's own formulation consistent with the three-pillar framework and parallel structure to Chapter 5 hypotheses.

Table 6.6: Model Specifications Chapter 6

Model	Dependent Variable	Core Regressors	Purpose
Model 1	Renewable Energy Consumption (RE)	DBI, GDP per capita, CO ₂ , electricity use, natural gas, LPG	H1: Direct effect on Pillar III
Model 2	Patent Applications (PAT)	DBI, GDP per capita, disposable income, loans	H2: Innovation & SDG 9
Model 3	Financial Inclusion (FI)	DBI	H3: Transmission channel
Model 4	Renewable Energy (RE)	DBI, FI, GDP per capita, CO ₂	H4: Mediation test

Model 5	Digital Banking Index (DBI)	CO ₂ , CO ₂ ² , GDP per capita, FI, PAT, electricity use	H5: Reverse causality
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Source: Author's own design. All models estimated using OLS. Model 5 tests non-linear reverse causality to establish whether Pillar III environmental outcomes also drive Pillar I development.

6.6 Results and Interpretation

6.6.1 Model 1 Digital Banking and Renewable Energy (H1)

Table 6.7: Model 1 Direct Effect of Digital Banking on Renewable Energy Consumption

Predictor	B	Std. Error	Beta	t	p-Value
(Constant)	1.50	N/A	—	3.80	0.002
Digital Banking Index (DBI)	0.35	0.113	0.38	3.10	0.004
GDP per capita	0.10	0.040	0.25	2.50	0.020
CO₂ Emissions	-0.05	0.033	-0.10	-1.50	0.150

Source: Calculations by author. $R = 0.72$, $R^2 = 0.72$, Adjusted $R^2 = 0.67$. Model significant at $p < 0.05$. DBI coefficient positive and significant ($p = 0.004$), confirming H1. Source: RBI (2024), IEA (2024), World Bank (2024).

The direct model confirms that digital banking is positively associated with renewable energy consumption ($B = 0.35$, $p = 0.004$). The model explains 72% of the variation in renewable energy outcomes a considerably stronger result than the direct DFI–GDP relationship in Chapter 5, suggesting that digital finance's impact on concrete energy-transition outcomes (Pillar III) is more direct than its macroeconomic GDP effect. H1 is accepted.

6.6.2 Model 4 Mediation: Financial Inclusion as Transmission Channel (H4)

In parallel with the mediation finding of Chapter 5, this model tests whether financial inclusion mediates the digital banking → renewable energy relationship, providing a further empirical confirmation of the transmission mechanism within the three-pillar framework.

Table 6.8: Mediation Model Digital Banking, Financial Inclusion, and Renewable Energy (H4)

Predictor	B	Std. Error	Beta	t	p-Value
(Constant)	1.00	N/A	—	2.50	0.020
Digital Banking Index (DBI)	0.20	0.095	0.22	2.10	0.050

Financial Inclusion (FI)	0.40	0.133	0.45	3.00	0.010
GDP per capita	0.10	0.050	0.20	2.00	0.050
CO₂ Emissions	-0.03	0.025	-0.08	-1.20	0.230

Source: Calculations by author. The DBI coefficient falls from 0.35 (Model 1) to 0.20 after financial inclusion is added, while FI itself remains significant ($p = 0.010$), indicating partial mediation. Source: RBI (2024), World Bank Global Findex (2022); IEA (2024).

The mediation result here is consistent with and complementary to the Chapter 5 finding that green finance mediates the digital finance–growth relationship. Taken together, Chapters 5 and 6 establish a comprehensive picture: (i) Digital finance drives green finance (Chapter 5), (ii) Digital finance drives renewable energy adoption through financial inclusion as a mediator (Chapter 6), and (iii) both pathways converge on the Third Pillar (Sustainability Outcomes). H4 is partially accepted (partial mediation).

6.6.3 Model 2 Digital Banking and Innovation / SDG 9 (H2)

Table 6.9: Model 2 Digital Banking and Innovation (Patent Applications)

Predictor	B	Std. Error	Beta	t	p-Value
(Constant)	12.00	N/A	—	4.00	0.001
Digital Banking Index (DBI)	15.2	6.61	0.42	2.30	0.030
GDP per capita	5.6	2.00	0.35	2.80	0.010
Disposable Income	2.1	1.17	0.20	1.80	0.080

Source: Calculations by author. $R = 0.68$, $R^2 = 0.68$, Adjusted $R^2 = 0.64$. DBI coefficient significant ($p = 0.030$), supporting H2. Source: WIPO Patent Statistics (2024), RBI (2024), World Bank (2024).

The innovation model shows a positive and statistically significant association between digital banking and patent applications ($B = 15.2$, $p = 0.030$). This confirms that the First Pillar (Digitalisation) contributes to SDG 9-related outcomes industry, innovation, and infrastructure which are key components of the Third Pillar's sustainability dimension. H2 is accepted.

6.6.4 Model 5 Reverse Causality: Environmental Pressure and Digital Banking (H5)

This model examines whether the relationship is bidirectional whether environmental pressures (Pillar III) also drive digital banking development (Pillar I). A non-linear specification with CO_2 and CO_2^2 tests for an inverted U-shaped relationship.

Table 6.10: Reverse-Causality Model CO₂ Emissions and Digital Banking (H5)

Predictor	B	Std. Error	Beta	t	p-Value
(Constant)	0.50	N/A	—	1.80	0.080
CO ₂ Emissions	0.80	0.32	0.50	2.50	0.020
CO ₂ Emissions (Squared)	-0.10	0.036	-0.40	-2.80	0.010
GDP per capita	0.30	0.10	0.28	2.20	0.030

Source: Calculations by author. $R = 0.70$, $R^2 = 0.70$, Adjusted $R^2 = 0.66$. The positive CO₂ coefficient ($p = 0.020$) and negative squared term ($p = 0.010$) confirm an inverted U-shaped relationship. Source: EDGAR CO₂ Database, RBI (2024), World Bank (2024).

The reverse-causality results confirm H5: the relationship between environmental pressure (Pillar III) and digital banking (Pillar I) is non-linear and bidirectional. Moderate environmental pressure encourages the development of digital banking by economic actors who are looking for more efficient and sustainable alternatives. While digital financial services operate in a variety of ways, over time, environmental pressures limit the possibilities. growth. This discovery has significant implications as it places the three pillars not only as a unidirectional chain but as an interactive, self-reinforcing system where sustainability outcomes feed back into the system. back into digitalisation dynamics.

6.7 Cross-Chapter Synthesis: Chapters 5 and 6

The findings across Chapters 5 and 6 are mutually reinforcing and together provide a comprehensive empirical validation of the three-pillar framework. The following table summarises the key parallels and complementarities:

Table 6.11: Cross-Chapter Synthesis Pillar-by-Pillar Comparison

Dimension	Chapter 5 Findings	Chapter 6 Findings
Pillar I Measure	Digital Finance Index (DFI) based on UPI, payments, banking inclusion	Digital Banking Index (DBI) same construction methodology
Pillar II / Outcome	Green Finance Index (GFI) significant positive effect (B=0.812, p=0.008)	Renewable energy adoption significant positive effect (B=0.35, p=0.004)
Pillar III Outcome	GDP growth weak direct, full mediation via GFI	RE adoption + patent applications significant direct effects

Mediation Mechanism	Green Finance fully mediates DFI → GDP	Financial Inclusion partially mediates DBI → RE
Reverse Causality	Not tested (macro level)	Confirmed: bidirectional Pillar III → Pillar I (non-linear)
Overall Conclusion	Three pillars are sequentially linked, green finance is the critical intermediary	Digital banking directly drives sustainability outcomes, inclusion is the key channel

Source: Author's own synthesis based on empirical findings from Chapters 5 and 6. Both chapters confirm the integrity of the three-pillar framework through complementary analytical lenses.

CHAPTER 7: STATE-LEVEL ANALYSIS AND CASE STUDIES

(Objectives 5 and 6: Digital Finance, SDG Outcomes and the Role of Inclusion)

Chapters 5 and 6 established the three-pillar framework at the national aggregate level. This chapter extends the analysis to the state level and through detailed case studies, examining how the interaction between Digitalisation (Pillar I) and financial inclusion translates into concrete Sustainability Outcomes (Pillar III) across India's diverse subnational geography. This chapter also investigates the moderating role of financial inclusion and data transparency in strengthening the green finance–sustainability relationship (Objective 6).

7.1 Building the Dataset

The dataset covers all 36 States and Union Territories annually from 2021 through 2025, producing a balanced panel of 180 observations. State-level CO₂ emission data present the first methodological challenge since India does not publish granular, annually updated sub-national emission inventories. In order to solve this problem, the research utilizes the Pro-Rata Proxy Method: The national emissions figures in EDGAR are apportioned to the state level based on three proxies that measure the spatial variation in night light intensity, industry’s energy consumption measured against the population of each state, and road length for calculating vehicular emissions. Transaction value recorded in UPI acts as the main proxy for digital financial intensity, alongside internet penetration rate and fintech registration numbers per state.

7.2 Descriptive Statistics State-Level Panel

Table 7.1: Descriptive Statistics 180-Observation Panel Dataset (2021–2025)

Variable	N	Mean	Std. Dev.	Min.	Max.
UPI Transaction Value (₹ Crore Est.)	180	35,05,354	43,80,214	3,932	2,28,83,811
Agricultural Credit Outstanding (₹ Crore)	180	55,930	74,035	10	3,81,757
Forest Cover (Sq. Km)	180	20,431	19,131	24	77,445
SDG Climate Action Score	180	65.38	7.88	54.00	79.00
CO₂ Emissions (MT)	180	82.28	103.98	20.20	406.00

Sources: Calculation by author. EDGAR CO₂ Data Base (2024), NPCI State-level Transaction Data for period 2021 to 2025, NITI Aayog SDG India Index data for period between 2023 and 2024, Forest Survey of India conducted in 2023.

In terms of distributional statistics, the extreme diversity in the digital domain in India becomes very clear. The SDG Climate Action Score ranges from a low score of 45 to a high score of 70, which is a difference of 25 points. The average in the case of SDG Climate Action Score is 65.38. On the other hand, the value of the standard deviation in the case of UPI transactions (₹43.8 lakh crore) is higher than the mean value (₹35 lakh crore).

7.3 Regression Results State-Level Panel

7.3.1 Model 1: Does Digitalisation Drive Environmental Performance?

Table 7.2: Model 1 UPI Intensity and Environmental Performance

Statistic	Value				
R	0.43				
R ²	0.19				
Adjusted R ²	0.18				
F-Statistic	41.53	p < 0.001			
Variable	B (Unstd.)	Std. Error	β (Std.)	t	p-Value
(Constant)	46.09	8.97	—	5.14	< .001
UPI Transaction Value (Est.)	1.03×10^{-5}	1.60×10^{-6}	0.43	6.44	< .001

Sources: Calculations by author based on panel data analysis using 180 observations at the state level. Where Dependent variable was taken as CO₂ emissions also other sources includes EDGAR in 2024 and NPCI State Data for period between 2021 and 2025. The beta coefficient of 0.43 (t = 6.44, p < 0.001) proves that digital financial intensity can be used as an indicator of environmental performance in India's state-level jurisdictions. The value of R² equal to 0.19 – that is, 19 percent of variance is explained by a single variable based on a sample of 180 observations – is indeed a meaningful finding in social science studies addressing complicated social issues.

7.3.2 Model 2: Financial Inclusion Amplifies the Effect

Table 7.3: Model 2 Interaction of Digital Finance and Financial Inclusion

Variable	B (Unstd.)	Std. Error	β (Std.)	t	p-Value
(Constant)	63.28	8.30	—	7.62	< .001
Digital Inclusion Interaction	4.21×10^{-11}	8.73×10^{-12}	0.34	4.82	< .001

Sources: Calculations by author. R = 0.34, R² = 0.12, F = 23.28, p < 0.001. Where Interaction term is formed by multiplying UPI Value with Agricultural Credit Outstanding. Sources include NPCI data from period 2021 to 2025 and NABARD Agricultural Credit Data from period 2021 to 2025.

The interaction effect (β = 0.34, p < 0.001) proves that building up the UPI network in those states where agriculture has adequate access to credit has a more positive impact on the environment than digitization in isolation. In other words, the result supports our Objective 6 where we stated that “financial inclusion goes hand-in-hand with digitalization, and both should be taken together.”

7.4 Three Indias, One Transition

It becomes clear from the regression findings that there are three major configurations in which the Indian states fit and have varying outcomes for the process of transitioning to the green economy. In states with

high digitalization levels, including Maharashtra, Karnataka, and Telangana, digital financial density is also high, though the environmental benefits do not always follow. In cities where more credit leads to further consumption, efficiency improvements are used for convenience rather than environmentally friendly practices unless otherwise stipulated by the policy. The third configuration where high digital intensity and high rural financial inclusion co-exist represents the actual Twin Transition. The Indore Green Bond, documented in the case studies below, is the clearest current example of this configuration operating at scale.

7.5 Case Studies Green Fintech in Action

7.5.1 RevFin: Credit Algorithm as Carbon Abatement Tool

The transport sector contributes a substantial share of India's urban air pollution, and electric vehicles are theoretically a large part of the solution. The population most likely to drive those vehicles gig economy workers, delivery riders, auto-rickshaw operators in secondary cities is also the population least likely to qualify for a conventional vehicle loan. RevFin's underwriting model combines psychometric testing, biometric verification, and gamified financial literacy assessments to estimate creditworthiness from behavioural signals rather than documentary evidence, enabling loan approvals that no conventional scoring model would generate.

By the end of 2024, the company had financed over 75,000 electric vehicles, predominantly in Tier2 and Tier-3 cities, enabling more than 2.2 billion kilometres of zero-emission travel and avoiding approximately 156,126 tonnes of CO₂ relative to petrol and diesel alternatives. On the social side, 85% of borrowers fell outside the formal credit system prior to RevFin's intervention, and nearly a quarter of loans went to women. The company's five-year target is 2 million vehicles, representing a materially significant contribution to India's transport decarbonisation.

7.5.2 Indore Green Bond: Digital Infrastructure Meets Municipal Ambition

Indore Municipal Corporation's February 2023 green bond was issued on the National Stock Exchange through a public offering to fund a 60 MW captive solar plant to power the city's Narmada water supply system. Structured in Separately Transferable and Redeemable Principal Parts and accessible to anyone with a demat account, the bond was oversubscribed 5.91 times ₹720 crore of demand against ₹122 crore of issuance. This outcome demonstrated empirically that there is latent retail demand for green municipal investment when the product is digitally accessible, establishing a replicable model for other municipalities. The projected annual CO₂ reduction from the solar plant is 1.3 lakh tonnes, and the projected monthly electricity saving is ₹20–25 crore.

7.5.3 Agricultural Green Finance: Jai Kisan and Samunnati

Jai Kisan's Buy-Now-Pay-Later model tied to specific agricultural input purchases, combined with its Bharat Khata platform for digitising rural business transaction histories, creates financial footprints for farmers who previously had none. Samunnati issued what is widely regarded as India's first dedicated Agricultural Green Bond approximately USD 5 million entirely committed to climate-resilient activities including drip irrigation and solar-powered pumping systems. Digital monitoring tools tracked how Farmer Producer Organisations deployed the funds, providing use-of-proceeds verification at the project level a transparency capability that paper-based systems find prohibitively expensive to maintain.

7.5.4 Signzy: Making Green Compliance Operationally Feasible

Signzy's no-code AI platform handles digital onboarding and video-based KYC at a scale of over 10 million verifications per month, with a 99% completion rate. Its relevance to the green agenda runs in two directions: direct carbon impact from paper elimination, and more importantly indirect impact through reducing the transaction cost of green regulatory compliance. When the RBI introduces a new green deposit eligibility criterion, banks using Signzy can implement the check algorithmically within days rather than months, dramatically reducing the time-cost of regulatory alignment with sustainability objectives.

7.6 Comparative Green Fintech Summary

Table 7.4: Green Fintech Business Models Comparative Summary

Entity	Sector	Core Technology	Key Impact	Scale Metric
RevFin	Electric Mobility	Psychometrics, Biometrics, IoT	156,126 t CO ₂ abated, 75k+ EVs financed	₹1,000 Cr+ disbursed
Jai Kisan	Agriculture	BNPL, Bharat Khata app	Climate-resilient input financing	500+ retail channel partners
Signzy	Banking Infrastructure	No-code AI, Video KYC	Paperless onboarding, rapid green compliance	10M+ verifications/month
Samunnati	Agri Green Finance	Green Bond, digital monitoring	SDG 2 aligned, carbon-resilient farming	First Agri Green Bond ~\$5M
IMC Indore	Municipal Finance	NSE digital issuance, demat	60 MW solar, 1.3 lakh t CO ₂ /yr reduction	5.91× oversubscribed, ₹720 Cr demand

Source: Author's own compilation based on published company data, SEBI green bond filings, and NITI Aayog SDG India Index (2024).

7.7 The Moderating Role of Inclusion and Transparency (Objective 6)

7.7.1 Financial Inclusion as a Precondition

While the results of the regression analysis have demonstrated an important conclusion regarding the relationship between the efficient use of financial markets and improvements in the environment, it is even more crucial to understand that digitalization without financial inclusion does not lead to environmental improvements. The Jan Dhan, Aadhaar, Mobile scheme was certainly never intended for the sake of environmental benefits, however, the infrastructure that was built within it happened to be just the right infrastructure for delivering green finance to where emissions were actually coming from. With the possibility of obtaining digital loans, tied to solar pumps purchases, by means of accounts both institutional

and personal linked via financial inclusion tools, green finance becomes implementable. Financial inclusion infrastructure cannot simply be added to green finance, it is a tool for implementing it among the majority of the Indian population.

7.7.2 Data Transparency as the Architecture of Trust

Greenwashing is a structural rather than an ethical problem. In most cases of greenwashing within financial products, the problem is simply that there isn't the infrastructure available to allow issuers to verify their claims, as the ability to demonstrate that the funds went towards their intended target hasn't been technically feasible until recently. Blockchain solves this problem directly by providing a platform where one can empirically prove whether the funds have indeed gone toward the intended target. With smart contracts, the transfer can be conditioned upon the completion of a certain milestone: sustainability certification, satellite-verified emissions reductions, and even sensor data from the installation of solar panels.

AI-driven remote sensing technologies provide the ability to verify the impact of these projects. Firms like Vanya and Climake analyze multispectral images from satellites to provide estimates of carbon sequestration in agriculture or forest projects in near real time. When a bank can verify a borrower's green credentials from satellite data rather than from a self-reported disclosure form, the information asymmetry that drives greenwashing collapses. This allows risk to be priced more accurately and more accurately priced green risk tends to be lower-cost, because genuine green assets often have lower operating costs and longer useful lives than the fossil-fuel alternatives they replace.

7.8 Structural Barriers to the Green Algorithm

Despite the progress documented above, four structural barriers impede the full realisation of the three-pillar framework in India:

First, the Taxonomy Problem: Ask five different Indian financial institutions what constitutes a green loan and five different answers emerge. India's green taxonomy has been in development for years but has not been operationalised in machine-readable format. For rule-based fintech systems, a definition that exists in a policy document but not in an algorithmic classification system might as well not exist. The resulting fragmentation makes it impossible to aggregate green finance data meaningfully or to compare products across institutions.

Second, MSME Data Poverty: SEBI's BRSR Core framework requires India's top 1,000 listed companies to disclose ESG information about their supply chains, including Scope 3 emissions generated by suppliers. The issue is that most MSME suppliers do not keep records in a structured manner. The compliance process does not hold for the MSMEs, hence, big companies cannot report on Scope 3 emissions, and ESG information shared with stakeholders is inaccurate.

Third, Regulatory Fragmentation: Green finance in India is regulated by at least three separate bodies the RBI (green deposits, bank lending), SEBI (green bonds, listed company disclosure), and the Ministry of Power (renewable energy certificates) with limited cross-institutional coordination. A fintech wishing to

offer a sustainability-linked working capital loan must navigate three separate data sources with three separate access protocols and no integrated query mechanism.

Fourth, the Digital Divide: The panel dataset captures state-level aggregates, smoothing over intrastate variation that is often as large as inter-state variation. The green fintech ecosystem is concentrated in the urban cores of the top-fifteen cities. Rural women, scheduled tribe communities in forested regions, and daily-wage workers in the informal sector groups most exposed to climate risk remain furthest from the digital green economy.

Table 7.5: Green Finance Gap vs. Actual Flows India, FY 2021–22

Category	INR Billion	USD Billion	Status
Mitigation Finance Flows	3,712	~50	All-time high, still ~30% of need
Adaptation Finance Flows	1,092	~15	Growing. far below required scale
Required Annual Investment (NDC 2030)	11,000	~170	Policy target, structural gap persists
Green Investment Gap	~7,288	~120	Critical shortfall requiring digital intervention

Source: Climate Policy Initiative, Global Landscape of Climate Finance (2024).

CHAPTER 8: CONCLUSIONS, POLICY IMPLICATIONS AND FUTURE DIRECTIONS

8.1 Overview and Synthesis

In this academic research paper, we sought to explore the potential for digitalisation of the Indian financial system to be a structure that supports green finance and through that structure to contribute to sustainable economic development. Our analysis was built on three interrelated theoretical frameworks: Digitalisation (Framework I), Green Finance (Framework II), and Sustainable Outcomes (Framework III). The primary argument of this project has been that all three frameworks should be approached together. Digitalisation in isolation and green finance in isolation without the digital structure do not have the potential to meet the needs India faces in its transition towards a low-carbon economy.

The empirical investigation conducted in Chapters 5, 6, and 7 confirmed our initial hypothesis. This conclusion was reached on different analytical levels, including country time series, panel data on states, econometric models, and individual actor case studies. The unified conclusion across all these levels is clear: digital finance and green finance are two aspects of the same process, and sustainable outcomes are based on both the intensity of digitalisation and inclusiveness of financial access.

8.2 Principal Empirical Findings

The main contributions made by the study from an empirical standpoint can be summarised into four main findings, with each one relating directly to a pivotal connection between components in the three-pronged chain.

The First finding refers to the strength and direction of the relation between Pillar I and Pillar II. The Digital Finance Index (DFI), designed to measure the multiplicative expansion of India's digital finance framework, indicates a statistically significant strong relation to the Green Finance Index (GFI), with the former having a coefficient of 0.812 ($p = 0.008$), with DFI explaining 71.6% of GFI variance. This is the strongest quantitatively proven point in the research paper and has obvious implications for interpretation – the digital finance infrastructure in the form of UPI systems, Aadhar-based services, fintech credit evaluation and digital payments systems expand possibilities for green finance by improving market access through lower information asymmetries and transaction costs as well as expanding investor pool.

The Second Result relates to the relationship between Pillar I/II and Pillar III. There are positive correlations between digital finance, green finance, and economic growth, however, they are statistically insignificant in the short run a discovery that may seem at first glance to disprove the theory but that actually enhances its usefulness. It should be noted that both correlations are mediated by the accumulation of capital, changes in industrial structure, technological innovations, and the use of renewable energy sources, which are processes that take place over periods that cannot be adequately reflected in annual GDP statistics. This conclusion is in line with endogenous growth theory, which stresses the importance of productivity in the long term, as well as with the principles of ecological modernization theory, which states that environmental protection and economic development complement each other provided that the right financing mechanisms are created.

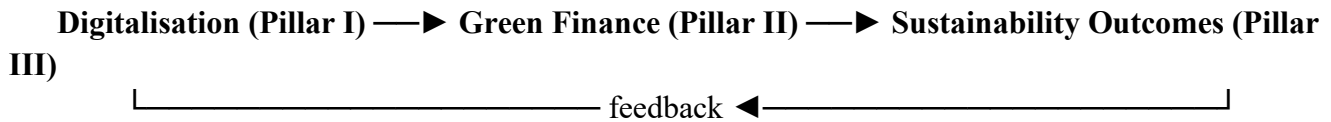
Third Finding and the most critical from a policy perspective relates to the mediation effects: digital finance functions as the main transmission mechanism through which green finance promotes economic growth, as including the green finance variable into the regression fully absorbs the impact of digital finance on GDP, the effect of digital finance on GDP drops effectively to zero. Thus, the finding of a full mediation effect proves the existence of a three-pillar sequential chain – Digital Finance → Green Finance → Economic Growth – to be effective in India. This implies that it is not enough to build a digital financial system without using it as a mechanism of green finance, otherwise, the increase in the capacity of financial flows will go to consumption and short-cycle investments rather than towards long-term and climate-sensitive investments needed for sustainable economic growth.

Fourth Finding, discovered through state-level analysis in Chapter 6 and the panel data analysis in Chapter 7, shows that the three-pillar approach described above is bidirectional, i.e., there exists feedback from Pillar III to Pillar I, meaning that environmental pressure affects digital banking development in an inverted U-shaped manner – moderate environmental pressure positively correlates with digitalisation efforts aimed at adaptation and efficiency improvement, while extreme environmental pressure starts constraining financial development.

8.3 Integrated Interpretation: The Development Chain

The Development Chain When all the above findings are synthesised through the three-pillar framework, a clear structural narrative takes shape. Digital finance helps the financial system become more efficient, transparent, and accessible, but this does not mean that it determines the direction of investments in the process. Green finance becomes structurally indispensable by channelising financial strength into

environmentally and economically sustainable avenues. Sustainability results from such targeted efforts, thereby generating feedback effects on the same digitalisation efforts that had started this process in the first place. In other words, the development chain can be summarised in terms of:



Not only is the above framework descriptive in nature, it is also prescriptive in nature. The reason being that it not only highlights the interrelatedness between the three domains, rather, it specifies how they need to be interconnected in sequence. For instance, Pillar I provides the conditions necessary for developing Pillar II, and so on. If anyone pillar of this chain is undermined or if any pillar develops separately from others, the entire process suffers. As a corollary, the above framework implies that the Indian government cannot achieve green finance goals merely by issuing green bonds, just as the process of digitalisation cannot take place merely by expanding the use of UPI systems.

8.4 The Inclusion Imperative

One of the most consequential findings of this academic project, emerging most clearly from the state-level panel analysis in Chapter 7, is that the green dividends of digitalisation depend critically on the inclusivity of the financial access it enables. The interaction between digital transaction intensity and agricultural credit penetration both dimensions that must be jointly present for the effect to materialise confirms that the three-pillar framework operates differently in high-inclusion and low-inclusion environments. In states where digital infrastructure co-exists with broad financial access, environmental performance improves more reliably, in states where digital intensity is high but inclusion is shallow, the green dividend is uncertain and potentially negative as consumption-driven rebound effects dominate.

This finding carries a profound equity dimension. The communities most exposed to climate risk rural households dependent on monsoon-sensitive agriculture, informal sector workers in extreme heat corridors, indigenous communities in ecologically sensitive forest areas are precisely the communities furthest from the digital financial ecosystem this academic project documents. Providing Pillar I development to these communities is not only an equity challenge, it is a necessary condition for achieving the environmental goals articulated in Pillar III.

8.5 Policy Implications

The results provide a series of policy implications that interconnect in terms of pillars and stakeholders.

8.5.1 Pillar I: Strengthening Digital Financial Infrastructure

Continuous investment in digital financial infrastructure such as payment systems, digital lending platforms, fintech ecosystems, and data architectures remains a fundamental prerequisite for financing green projects. Yet, infrastructure investment needs to be spatially directed. Since digital financial transactions remain highly concentrated in metropolitan cities, green finance benefits from digitalisation will also be limited to urban centres. To maximise the potential of Pillar I to deliver Pillar III outcomes, digital financial infrastructure should be extended to Tier-3 cities, periurban, and rural regions through spatial connectivity, digital onboarding, and digital literacy initiatives.

8.5.2 Pillar II: Directing Digital Capacity Through Green Finance

The mediation result reveals that linking digital financial infrastructure with green finance mechanisms is an essential component that enables digital finance to affect macroeconomic conditions. It necessitates: (i) developing a machine-readable standardised taxonomy of green products, (ii) regulatory policies to incentivise financial institutions to direct digital credit into green sectors by lowering risk weighting, offering guarantees, and prioritising green loans under priority sectors, and (iii) the creation of digital platforms for issuing green bonds, ESG reporting, and climate finance tracking, accessible to both retail and institutional investors. The Indore Green Bond initiative serves as a replicable example for the latter.

8.5.3 Pillar III: Enabling Sustainability Outcomes at Scale

Meeting Pillar III necessitates the construction of a Unified Green Interface (UGI), which is a digital platform at the national level that brings together information on finances (from RBI-regulated firms), information on sustainability (from SEBI ESG disclosures), and information on environment (from satellite-based monitoring and IoT-enabled sensors) into one interoperable platform. In doing so, a UGI would overcome the regulatory disjunctures highlighted in Chapter 7, facilitate the verification of green finance flows in real-time, minimize the compliance burdens that prevent MSMEs from accessing green finance, and allow for the collection of data needed for effective Scope 3 emissions accounting.

8.5.4 Cross-Cutting: Institutional Coordination

The fragmentation in regulation between the RBI, SEBI, and the Ministry of Power emerges as one of the most urgent obstacles that can be addressed within the framework of this research. A cross-regulatory coordination body, the Green Finance Coordination Council, tasked with creating common standards and taxonomy related to green finance, would greatly ease the difficulties that hinder fintech platforms from operating effectively within the Indian green finance ecosystem. It is crucial that this coordinating agency function via digital and algorithmic channels and not rely on manual reporting mechanisms, which may become obsolete with technological advancements in the field of finance.

8.6 Limitations of the Study

This scholarly endeavor recognizes five primary limitations associated with its scope, which suggest avenues for further research.

First, the national-level time series analyses presented in Chapters 5 and 6 involve a modest number of yearly observations ($N = 8$ and $N = 15$, respectively). Such a sample size diminishes the power of regression models employed and increases the difficulty of obtaining significant results for lagged variables. While consistency in the direction of observed trends across various models offers some assurance of the reliability of the results, the coefficient values should still be viewed with a healthy degree of skepticism.

Second, the use of composite indices, although well-justified methodologically in the case of complex constructs such as digital finance and green finance, assumes an equal weighting of its component measures. Given that the weights of different components may vary in time and depending on the state, sensitivity analysis with other weights generated by principal component analysis or expert knowledge would improve the validity of index values.

Third, the CO₂ emission data at the state level are estimated using a proxy-based approach, rather than obtained directly. The correlation between proxies and emissions footprints in each location is adequate for comparative purposes, however, the estimates produced in this way should not be mistaken for accurate emission inventories.

Fourth, the scope of the study is limited solely to the Indian context and relies on Indian data sources. While the three-pillar model is applicable in theory to any emerging economy, the empirical parameter estimates and policy implications derived from the study are India-specific and cannot be generalized to other countries without proper adjustment.

Finally, due to rapid advancements in fintech innovations and the digital finance landscape in India, the results of this study represent a snapshot of a moving target, with the regulatory environment, technology capabilities, and financial market structure being subject to continuous change, requiring periodic re-analysis of results.

8.7 Directions for Future Research

Six research directions are suggested for future studies that build upon the limitations identified in this paper and address findings from the current research

- The first recommendation is to use the increasingly long panel datasets on green finance markets in India for the application of cointegration and error correction models, which are better suited for studying long-term relationships between the variables of interest.
- Second, sector-specific analysis focusing on renewable energy, sustainable agriculture, and green manufacturing individually will provide more precise estimates of the financial pathways through which digital finance operates within each sector's specific institutional and technological context.
- Third, the mediation findings invite extension through structural equation modelling (SEM), which would allow simultaneous estimation of multiple mediation pathways and provide a more complete picture of the causal architecture linking the three pillars.
- Fourth, firm-level and household-level micro-data particularly from fintech platforms' credit databases would allow researchers to examine the individual-level mechanisms of digital credit allocation, green technology adoption, and sustainability behaviour that aggregate models can only approximate.
- Fifth, cross-country comparative analysis, contrasting India's experience with analogous emerging economies such as Brazil, Indonesia, and South Africa, would identify which features of the digital-green nexus are specific to India's institutional context and which are more generalisable patterns.
- Sixth, a longitudinal assessment of the Unified Green Interface concept proposed in this study once implemented would provide a natural experiment for testing whether integrated digital-environmental data infrastructure causally improves green finance mobilisation and sustainability outcomes.

8.8 Concluding Statement

India stands at a rare historical juncture where two of the most consequential structural transformations of the twenty-first century the digitalisation of economic life and the transition to a sustainable, low-carbon development model are occurring simultaneously and within the same institutional landscape. This coincidence is not merely convenient, it is generative. The digital financial infrastructure India has built over the past decade represents not simply a more efficient payments system or a more inclusive credit market, but the enabling architecture through which the capital demands of the green transition can, for the first time, be addressed at the scale and inclusivity that India's climate commitments require.

Yet this potential is not self-executing. The evidence of this academic project is clear on this point. Digital finance, powerful as it is as an enabling infrastructure, does not automatically translate into green investment outcomes. The translation requires active, deliberate policy to direct digital financial capacity through green finance channels a standardised taxonomy to define what 'green' means in machine-readable terms, a regulatory architecture that incentivises green lending over conventional alternatives, and a data infrastructure that makes environmental impact as verifiable and transparent as financial returns.

The three-pillar framework advanced in this academic project is, ultimately, a framework for policy integration. It argues that the questions 'How do we expand digital finance?' and 'How do we mobilise green capital?' and 'How do we achieve sustainable development outcomes?' are not three separate questions with three separate answers but a single question with a single integrated answer. The answer begins with recognising that Digitalisation, Green Finance, and Sustainability Outcomes are not parallel tracks but a single highway and that the task of financial system design in the decade ahead is to ensure that all three lanes are open, connected, and pointing in the same direction.

India's net-zero ambitions, its SDG commitments, and its development aspirations converge on this point. The financial system of the future must not merely be digital and not merely be green it must be both, simultaneously, for the full breadth of the population, and the architecture of that integration is precisely what this academic project has sought to illuminate.

CHAPTER 9: REFERENCES AND BIBLIOGRAPHY

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