Journal of Applied Economics and Business Research
JAEBR, 15 (1): 22-37 (2025)

Digital Pathways to Sustainability: A Qualitative Review of Finance Tools for Emissions Reduction

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Abstract

This paper explores the relationship between digital finance and environmental sustainability, focusing on the role and challenges of financial developments in reducing carbon emissions. Digital finance has the potential to transform conventional financial systems and move the global economy towards a low-carbon one. Additionally, the body of literature sheds light on how smartphone banking reduces impacts on the environment by limiting the need for physical travel, while blockchain technology enhances the transparency and efficiency of carbon markets. In support of emissions reduction, instruments of green finance include green bonds, which provide financing for clean energy projects.

However, the study sheds light on the negative impact of cryptocurrencies like Bitcoin, due to its energy-intensive proof-of-work system, thereby drastically increasing the global carbon footprint. This paper further discussed technological disparities, which hinder the accessibility of digital finance to developing nations, thereby hampering the full potential of cutting global emissions. The paper concludes by issuing policy recommendations towards energizing blockchain technology for green finance and expansion of digital finance platforms around the world, and undertakes a comprehensive exploration of the ways in which digital finance impacts the environment towards sustainability, documenting strategies to minimize risk and maximize benefits.

Keywords: Sustainability, Green Finance, Carbon Emissions, Digital Finance, China.

JEL Codes: G2; Q54

1. Introduction

Countries around the world face the challenge of balancing economic growth with reduced carbon emissions amid accelerating climate change and environmental damage (Sadorsky, 2010; Shahbaz et al., 2018; Sharif et al., 2019). According to the Intergovernmental Panel on Climate Change (IPCC), achieving the goal of limiting global warming to 1.5°C will require a 43% reduction in greenhouse gas emissions by 2030.

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To achieve this target, considerable investments have been made in renewable energy. During the period from 2010 to 2019, global investment in renewable energy capacity was led by China (US$758B), the United States (US$356B), Japan (US$202B), Germany (US$179B) and the UK (US$122B) (Climate Trade, 2023). These numbers demonstrate that advanced economies are becoming increasingly committed to a sustainable future.

Simultaneously, there is a growing focus on the role of financial systems in both promoting and impeding environmental sustainability. The influence of financial systems on carbon emissions and the environment, once regarded as conducive to economic growth, is today undergoing ever-stricter scrutiny (Elheddad et al., 2021). Digital finance includes online shopping, mobile banking, blockchain technology, cryptocurrency, and online bill payment. The widespread adoption of digital technology by businesses and consumers has given birth to a new financial structure (Zhang et al., 2023). With this shift in the framework, perhaps traditional financial systems can be made more transparent, efficient, and inclusive. At the same time, the specific environmental impacts of this shift in terms of energy use and carbon emissions are unspecified (Saqib & Usman, 2023).

Digital finance can be integrated to upgrade the transition to a less carbon-intensive economy: integrate green financial tools to facilitate the trading of carbon credits, and improve financial support for renewable energy projects (Campiglio, 2016). For example, more people can now launch green bonds on digital platforms and raise funds for renewable energy projects. As such, alternative sources of energy are becoming enhanced (Majumdar & Mitra, 2024 and Mim et al., 2024). In the same vein, the integration of blockchain technology is poised to enable enhanced carbon credit management and to ensure that carbon markets become more transparent (Andoni et al., 2019). In contrast, the widespread adoption of cryptocurrencies like Bitcoin raises concerns about their significant energy consumption (Tamazian et al., 2009). This is primarily attributable to the energy-intensive nature of the proof-of-work computers employed to manage their networks (Belkhir & Elmeligi, 2018). The need to further examine the relationship between digital finance and climate change stems from the opposing features of digital finance and carbon emissions (Cao et al., 2021).

The purpose of this paper is to explore how digital finance can broaden the scope of actions taken to reduce CO2 emissions. Specifically, the paper will discuss the negative environmental effects of financial technology design. The main thrust of this study is that the struggle against global warming can be more easily achieved through appropriate governance of digital finance and its connection to various policy objectives, especially environmental policy. The analysis of this paper involves document analysis, theoretical modelling, and a comprehensive review of the body of literature by synthesising empirical secondary data to integrate cases with policy development. The analysis will focus on how digital finance can improve the functioning of carbon markets, support green financing strategies, and enable economically viable practices.

Moreover, this paper augments the current literature by providing a thorough synthesis of the theoretical and practical connections between digital finance and carbon emissions. It effectively integrates insights from various case studies and regulatory developments across countries, showcasing both the environmental benefits and the potential unintended consequences of digital finance. The paper underscores the substantial impact of technologies such as blockchain, mobile banking, and green financial instruments, while also addressing critical issues like unequal access, regulatory gaps, and cybersecurity risks. By consolidating these perspectives, this study presents a comprehensive conceptual framework and actionable policy directions that will guide future empirical research and policy initiatives in the realm of digital finance and sustainability.

 ISSN 1927-033X

The structure of the paper is as follows: The first section presents an Introduction, while the second offers a comprehensive review of the literature in the corpus of research by synthesising compilations on digital finance, green finance, and carbon emissions. The subsequent section (third) structures a theoretical foundation outlining how digital finance will impact the release of carbon through the use of the Environmental Kuznets Curve (EKC) and its deviations in economics. Moreover, the fourth section elucidates the methodology and the techniques incorporated to consolidate several case studies and findings of various empirical research papers, thereby analysing whether or not there is a connection between digital finance and carbon emissions. Consequently, the fifth section discusses the outcomes and offers recommendations for integrating digital finance into the current environmental regulations. The paper concludes by finally mentioning the research issues and scope in this field.

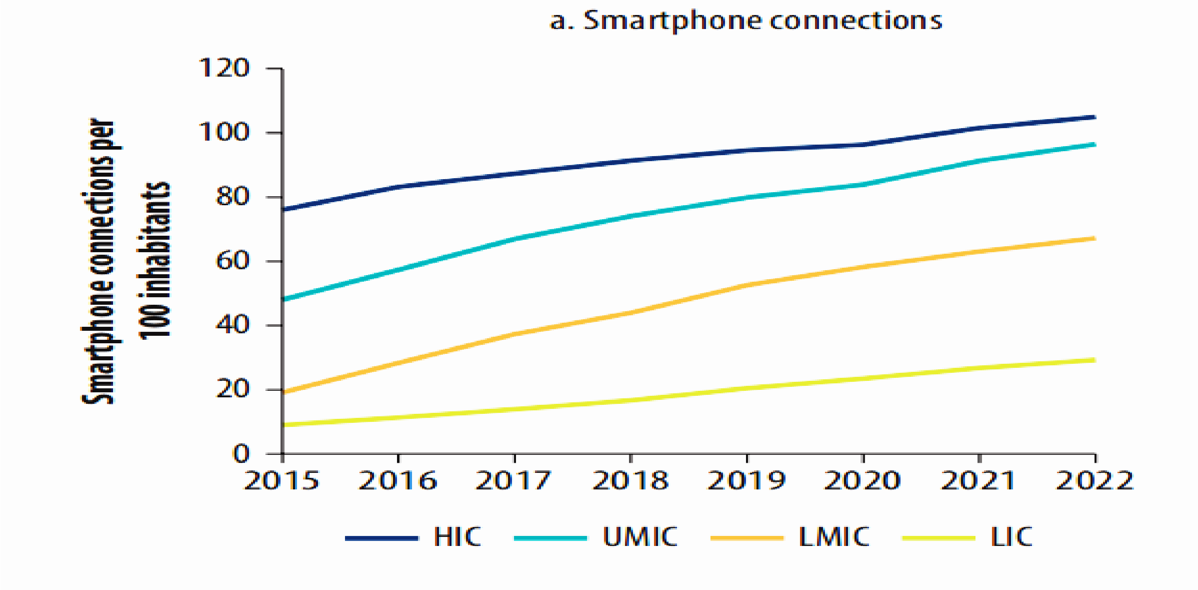
2. Literature Review

In the last two decades, the term "green finance" has gained momentum as environmentally responsive companies and governments began to devise their plans in terms of that jargon (Sharma et al., 2022). It principally concentrates on several financial services and products, that are said to have an environmental impact, such as energy efficiency, renewable energy, and environmental-friendly infrastructural upgrades (Shahbaz et al., 2018). Because green bonds invest in environmentally friendly projects that are financed by public or private entities, and higher focus on renewable energy projects, they have come to represent the most significant part of the green finance landscape (Razzaq & Yang, 2023). Voluntary carbon trading has also emerged simultaneously with integrated carbon markets as a method of pollution control; one of the most significant programs globally is the EU Emission Trading System (Dong et al., 2020). To supplement these traditional aspects of finance, digital finance has become an important economic force by driving policies supportive of preservation (Zhou et al., 2015).

Online banking, through deposits, withdrawals, and payments, has been propagated by the high uptake of mobile phones (Anyasi & Otubu, 2009). According to the World Bank Digital Progress and Trends Report, 2023, the number of smartphones per 100 inhabitants increased between 2015 and 2022 in all countries with different income levels, with slower growth noted in lower-income countries (Fig.1). Smartphone penetration is reaching 100% in upper-middle-income countries; thus, developing countries are rapidly catching up with high-income countries in smartphone usage. Smartphone adoption has also increased significantly in lower-middle-income nations, though at a slow rate since 2020. Yet, development in low-income nations has been too slow to close the gap with higher-income groups. The increasing adoption of smartphones enables the development of financial services that can support the potential of the green economy. This is demonstrated by the growing usage of mobile banking in cities has eliminated the need for numerous physical branches, significantly reducing the carbon footprint related to the conventional banking system (Mhlanga, 2020). Regarding the carbon markets, they have emerged as a powerful instrument to reduce market risks as they grow, particularly those related to the misappropriation of carbon credits on registries (Wang et al., 2023).

 ISSN 1927-033X

Fig.1: Smartphone penetration, by income group, 2015–22



Sources: Digital Progress and Trends Report, 2023, World Bank
Note: HIC = high-income countries; UMIC = upper-middle-income countries; LMIC = lower-middle-income countries; LIC = low-income countries

Although the claims regarding the environmental benefits of digital finance are commendable, they can be challenging on their own (Esty & Winston, 2009). For example, cryptocurrencies have been associated with the yellow vests, particularly when considering the proof of work consensus. This is because the energy footprint of these currencies demonstrate that even a nation like France can use up to 25% less energy than even one individual. (De Vries, 2019). This undermines the legitimacy of the practice, particularly in situations where renewable resources are expensive and in short supply. Furthermore, it has been observed that gender-based regional and global inequalities, specifically the North-South Divide, have further impeded access to digital financing services, which raises questions about the possibility of reducing emissions utilizing the adoption of digital finance (Wang et al., 2024).

This literature review establishes the framework for the current study and goes into great detail about the problems associated with digital finance and carbon emissions.

2.1 Digital Finance and Environmental Sustainability

All facets of financial services that use digital technologies—such as internet payments, mobile banking, digital currencies, and any developments in financial technology, or FinTech—are collectively referred to as digital finance (Gomber et al., 2017). As it has developed, the financial systems that are in place have changed, and new approaches to solving environmental and economic problems are being explored. Digital finance has numerous advantages, one of which is that it promotes environmental sustainability by reducing pollution levels associated with traditional banking sectors and fostering the development of more green financial products (Yu et al., 2022).

Several studies have consistently shown that digital finance contributes to a reduction in carbon emissions from financial transactions conducted over paper by using electric systems, reducing reliance on physical bank branches and facilities, and implementing less energy-intensive financial systems (Shahbaz et al., 2018). For example, the emergence of mobile banking and online payment services has reduced emissions associated with people visiting bank locations, completing paper forms, and using electricity to run office equipment. One notable example is the banking system in India, where institutions are progressively implementing mobile banking to reduce the use of paper as well as the emissions that come with it (Nath et al., 2014). According to an empirical analysis based on data from China, digital finance significantly reduces carbon emissions; for every 1% increase in the digital financial inclusion index, carbon emissions will typically drop by 0.5712% (Zhao et al., 2021). Similarly, a study by Jiang et al. (2024) suggests that digital finance development can mitigate carbon emissions intensity (CEI) by approximately 0.14 %.

Innovative technologies have profoundly transformed India's traditional banking system (Barik and Sharma, 2019). The country's regulatory framework, led by the Reserve Bank of India (RBI), has been instrumental in fostering sustainable growth in digital finance. Key regulations include the Payment Aggregators and Payment Gateways Regulations (2020), which address registrations, capital requirements, and dispute resolution (Reserve Bank of India, 2020). Additionally, the RBI has introduced the Master Directions on Peer-to-Peer Lending Platforms (2017) and established a regulatory sandbox to facilitate controlled Fintech innovation (Reserve Bank of India, 2024). The 2016 demonetization and COVID-19 pandemic accelerated digital finance adoption, cementing its role in India's financial ecosystem (Zou et al., 2023).

In contrast, the United States (US) incorporates a decentralised regulatory framework involving agencies such as the Office of the Comptroller of the Currency (OCC), Consumer Financial Protection Bureau (CFBP) and the Securities and Exchange Commission (SEC). While this approach fosters innovation through initiatives, it also creates complexity and compliance burden for digital finance corporations like Fintech firms (Vijayagopal et al., 2024). Conversely, the United Kingdom (UK) adheres to the centralised and proactive regulatory model led by the Financial Conduct Authority (FCA), utilising strategies like regulatory sandboxes and open banking to facilitate innovation, thereby positioning the UK as a leading Fintech hub and promotes environmental sustainability through secure digital transactions and reducing reliance on paper (Vijayagopal et al., 2024).

Simultaneously, the corpus of extant literature highlights and deliberates upon an additional issue, a plausible albeit relatively inadvertent fallout from the proliferation of digital finance: the environmental impact of blockchain technologies, and cryptocurrencies specifically (Sestino et al., 2024; Lemma, 2020). The main cause is the extremely high electricity used to create digital currencies such as bitcoin and other coins that are mined employing the proof of work algorithm. According to another study by de Vries (2019), the evaluation indicates that the entire grid network fueled by Bitcoin mining consumes roughly the same amount of energy as certain medium-sized nations, resulting in massive carbon emissions. This in turn prompted conversations about whether the environmental effects of cryptocurrencies, such as Bitcoin, are justified considering the financial inclusion and transaction facilitation these currencies enhance that alternative methods do not (Belkhir & Elmeligi, 2018).

2.2 Green Finance and Carbon Reduction

Green finance is a part of digital finance which includes financial services and products that are aimed at the sustainability of environment. It comprises of a range of activities such as investing in energy-efficient infrastructural projects, financing the adoption of alternative renewable energy source, and promoting the development of sustainable technologies. Green financing, through various instruments such as carbon credits, climate bonds and sustainability-linked loans, minimizes carbon footprints. The report by the Climate Bonds Initiative (CBI) states around $5.5 trillion in green bonds had been issued cumulatively by the end of 2023, denoting the rise in demand for climate-linked investments.

The relation between green finance and carbon reduction is based on the Environmental Kuznets Curve (EKC) theory which propounds that initially, when the economies are in the developing stage, their carbon emissions increase leading to the deterioration of the environment. However, as the economies grow, with increase in their income levels, their carbon emissions decrease as they begin to concern more about the sustainability of environment (Grossman & Krueger, 1995). This hypothesis of EKC theory has been supported by various empirical studies, demonstrating the impact of green financing in the shift towards renewable sources of energy and reduction of carbon foot prints (Nawaz et al., 2021; Tu et al., 2021; Zhang et al., 2022).

With the incorporation of technologies like blockchain and artificial intelligence (AI) into the green financing platforms, the transparency and efficacy in carbon trading markets has improved (Jiang et al., 2023; Marchant et al., 2022). The immutable ledger tracking transactions offered by blockchain guarantees the reliability of carbon credits and prevents the fraudulent activities in carbon trading, while artificial intelligence (AI) systems forecast the trends in the market and assist in the efficient allocation of resources to attain the maximum positive environmental outcomes (Boumaiza & Maher, 2024; Greif et al., 2024; Khanna & Maheshwari, 2023).

2.3 Challenges of Digital Finance for Carbon Emissions Reduction

Digital finance although has potential to minimize carbon footprints, there are some obstacles that restricts its effectiveness. One of the core concern is proof-of-work mechanisms in digital currencies as well as their mining, which require considerable amount of electricity, prominently generated from conventional sources of energy. For instance, mining of renowned cryptocurrency, Bitcoin, consumes a substantial amount of total worldwide electricity usage, thereby placing a strain on energy resources and substantially adding to the global carbon footprints (de Vries, 2019; Roeck & Drennen, 2022; McCook, 2022).

Furthermore, there is a digital divide that often exists between developed and developing nations, meaning that the advantages of digital finance are not distributed equally. In low-income and rural areas, especially in Sub-Saharan Africa and parts of Asia, mostly in developing countries, poor internet infrastructure and limited smartphone penetration remain major obstacles in adopting digital financial tools such as Mobile Banking or Digital wallets (Enfuse Solutions, 2024; Lythreatis et al., 2022; Ragnedda, 2017). Gender disparities further compounded this issue; women are significantly less likely than men to own mobile phones or utilise mobile internet services, particularly in regions with elevated poverty levels (Faton et al., 2025).

Additionally, digital illiteracy and lack of trust in online systems act as a deterrent to adoption, especially among older adults and individuals with minimal formal education (Global Banking & Finance Review, 2024). Regulatory inconsistencies and the lack of supportive digital finance policies also create uncertainties, reducing incentives for providers to serve undeserved markets (World Bank, 2023). In addition, digital finance presents another challenge concerning the data privacy and cybersecurity. Adoption of digital finance brings susceptibility to cyberattacks and data breaches, as embracing new technologies like cloud computing, Artificial Intelligence, and mobile banking endangers sensitive client data and their financial stability (Farayola, 2024; Wang et al., 2024). Therefore, barriers to digital finance reduce its potential to mitigate global warming, especially by making innovations like internet banking, mobile payment systems, and the blockchain-based carbon markets more accessible (Hussain et al., 2023)

The review of the literature explores the twofold nature; the role of digital finance in contributing to the reduction of carbon emissions and the opportunities like green bonds, mobile banking, and challenges associated with the energy consumption of the cryptocurrencies. This creates the basis for the theoretical framework explored in the subsequent section of the paper.

3) Theoretical Framework

In order to explore the connections between digital financial structures, carbon emissions, and the environment, a theoretical model is developed in this section. The Environmental Kuznets Curve (EKC) principle, financial development theories, and modern digital and green financing strategies serve as the model's foundations.

3.1 The Environmental Kuznets Curve (EKC) and Digital Finance

According to Grossman and Krueger's (1995) EKC hypothesis, there exists an inverted U-shaped relationship between the degree of economic development and the degree of environmental degradation. Environmental deterioration is increasing during the early stages of development as a result of urbanization, industrialization, and energy use. But as economies mature, cleaner technologies emerge, regulations tighten, and public awareness of environmental issues grows, all of which contribute to a decline in pollution and carbon emissions.

A crucial component of the late evolution that makes it possible to transition from high-carbon to low-carbon economies is digital finance. Particularly in light of national economic advancements, digital financial services like mobile banking and digital payments help reduce paper transactions and, consequently, the carbon emissions of the conventional banking system (Nath et al., 2014). Furthermore, digital finance systems offer a variety of green finance instruments, including carbon credits and green bonds, which promote the financing of renewable and clean energy projects and sources, hastening the EKC's decline phase (Ouyang et al., 2023).

However, there is a complicated relationship between carbon emissions and digital financial services. The EKC hypothesis is in conflict with the phenomenon of digital currencies, particularly those that operate through proof-of-work procedures. On the one hand, the growth of cryptocurrencies expands prospects and encourages widespread access to financial systems. However, in areas where fossil fuels are used as a source of electricity, these same activities often result in higher energy demand and, consequently, higher carbon dioxide emissions (de Vries, 2019).

3.2 Financial Development and Carbon Emissions

It has long been known that economic growth and financial development are causally related, and that this relationship has favorable demand effects on the environment as clean technologies are adopted as the economy grows (Kirikkaleli & Adebayo, 2021; Li et al., 2015). The utilisation of digital finance enhances the efficacy of financial development by providing greater access to financial services, thereby facilitating financial inclusion and green investments. For example, the use of online payment methods and mobile banking reduces the need for physical bank branches, saving energy and lessening the carbon footprint of banking operations (Kumar et al., 2023; Minoli, 2010).

The theoretical model that establishes a connection between financial development and carbon emissions could be extended to incorporate the role that digital finance plays in reducing carbon emissions. Digital finance platforms assist in lowering the entry barriers for investing in green technologies. As a result, an increasing number of investors are able to fund the development of carbon-friendly technologies and renewable energy sources, decreasing carbon emissions as a result of hastening the transition to a greener economy (Lin et al., 2022).

3.3 Blockchain and Carbon Markets

The development of digital finance has given rise to several innovations, one of which is "blockchain technology." This technology has applications in the carbon markets, where it can improve accountability and transparency in a number of domains. The registration, tracking, and verification of carbon credits in the current carbon markets are frequently susceptible to fraud management. Because all transactions are recorded on a shared and distributed system through the use of Blockchain, carbon credits will not only be tracked but also shielded from being double-counted (Ashley et al., 2018).

Additionally, people and businesses can easily create and use their own "decentralised" carbon markets, enabling them to acquire and trade carbon emission credits directly to one another, thanks to blockchain technology, which eliminates the need for them to depend on the standard carbon market and its intermediary services. This encourages companies and consumers to buy carbon offsets and creates an efficient market with lower transaction costs. Blockchain-enabled carbon markets can be expanded internationally, improving the efficacy of the tactics utilized to reduce carbon emissions (Parhamfar et al., 2024).

Energy consumption in relation to cryptocurrencies, however, is still a problem because of blockchain technology. As previously stated, the energy-intensive "proof-of-work" requirement exhibited by digital currencies such as Bitcoin and several others results in carbon emissions into the atmosphere. This places the sustainability of blockchain technology in its current form in skepticism and advocates for the creation of sustainable solutions like the use of less energy-intensive proof of stake mechanisms (Belkhir & Elmeligi, 2018).

4. Methodology

This paper incorporates a qualitative approach featuring Document analysis and Secondary empirical data synthesis. The document analysis was conducted by extracting content related to digital finance tools (mobile banking, blockchain), carbon emission trends and regulatory measures promoting or hindering sustainability. The second technique (secondary empirical data synthesis) is constructed from case synthesis, utilising secondary data from published studies. The study doesn’t incorporate primary data; rather, all empirical findings are derived from peer-reviewed or government-validated sources.

We review research from both developed and developing nations, concentrating on the methods of cutting emissions by using blockchain, green finance, and mobile banking, respectively. This methodology facilitates the conceptual-empirical integration, where theoretical insights are aligned with real-world cases and policy developments.

5. Document Analysis and Secondary Data Empirical Synthesis

5.1 Mobile Banking and Carbon Emissions

One particular area of interest for determining the carbon footprint of digital finance is mobile banking, which is expanding dramatically both in developed and developing nations. According to research, as mobile banking technology becomes more widely used, the amount of physical bank buildings and paper transactions decrease, resulting in a reduction in carbon emissions from the conventional banking system. In a case study conducted over 256 cities in China by Lei et al., (2023), digital financial transactions through mobile banking have been found to minimize carbon emissions over a period of eight years. The study asserts that digital finance can lower carbon emissions by supporting advanced industries and green technologies and increasing utilisation efficiency through better match of labour. This effect is more

 ISSN 1927-033X

significant in low-carbon pilot cities and the lower urbanization rate where it further improves the efficiency of energy saving and emission reductions. The extent and depth of digital finance positively influence the reduction of regional carbon emission intensity due to its extensive coverage.

In the same way, in Sub-Saharan Africa, there has been rise in financial inclusion due to the introduction of digital platforms such as M-pesa, and these platforms have, at the same contributed to the minimization of carbon footprints associated with conventional banking system (Mhlanga, 2022). An empirical study by Aron and Muellbauer (2019) reveals that the adoption of digital banking in Kenya has resulted in reduced carbon emissions on account of reduced reliance on in-person banking services. The results from these studies substantiates the assertion of association of digital banking with the reduction in carbon footprints related to financial services, particularly in the nations where the conventional banking infrastructure is poor.

5.2 Blockchain Technology and Carbon Markets

The application of blockchain technology has been envisaged in enhancing the credibility of transparency related to carbon markets. Thanks to blockchain, carbon credits cannot be faked, and even if some auditor tried to double count the carbon credits that had been traded, the blockchain would expose this. This has led to the emergence of blockchain-powered carbon trading platforms that can enhance effective carbon credits trading which ultimately lead to tangible emission cutting impacts.

Research done in China by Zhang et al., (2023) and Dong et al., (2024) offers understanding into the effects of blockchain technology on carbon markets. Blockchain carbon trading platforms boost trading efficiency by enhancing emissions tracking and accountability among the market players. It also facilitates increased number of organizations to join carbon offset programs to further contribute to emission cuts. Further, through the use of Internet of Things (IoT) sensors for gathering real-time data along with Artificial Intelligence for optimization and decision making, business can make well-informed decisions that reduce their environmental impact (Gupta & Singh, 2024). A study based on the analysis of 195 studies to examine the role of blockchain technology in achieving environmentally sustainable goals revealed that blockchain technology contributes in a number of areas such as sustainable supply chain, energy efficiency, and development of safe and reliable smart cities (Parmentola et al., 2022). However, the efficiency of the blockchain in the management of the environment faces the issue of high energy consumption, especially when regarding cryptocurrencies like the Bitcoin. In the current literature, it has been established that the proof-of-work consensus model adopted by Bitcoin and other similar cryptocurrencies is computationally expensive, in terms of energy consumption; such that globally, mining consumes more energy than countries like Hungary and Switzerland (de Vries, 2019). This presents a significant obstacle to the adoption of blockchain technology in the carbon market since the technological advancements are very energy-intensive, which negates their ability to promote environmental protection.

5.3 The Role of Green Finance in the Promotion of Renewable Energy Development

The shift to a green economy and investments undertaken in renewable energy markets have been made possible by green finance, which is made possible by digital finance systems. Stated differently, the financing of clean energy initiatives like the establishment of wind and solar farms has been facilitated by the issuance of green bonds. Global green bond issuance cumulatively reached to $5.5 trillion by the end of 2023, with both developed and developing nations taking an active part (Climate Bonds Initiative report, 2023).

According to Leitao et al. (2021), green bonds are purportedly used to finance beneficial renewable projects in the European Union that aim to reduce carbon emissions by 2030, in compliance with the EU's climate targets. In China, green debt instruments have been used to finance renewable energy generation capacity, which has contributed to the reduction in the country's carbon emissions (Yu et al., 2022).

6. Policy Recommendations

It is obvious that regulations enacted by the government will be necessary to prevent the beneficial aspects of this developing market from being outweighed by its negative ones, given that digital finance has the potential to both mitigate and increase carbon emissions. The framework for accomplishing these goals is provided by the policy recommendations that follow.

6.1 Integrate Green Finance Instruments

The appropriate authorities should actively research, produce, and market off-the-shelf products such as green bonds, carbon credits, sustainability linked loans, and other instruments that can be referred to as green finance derivatives. These tools will facilitate the transition to a low-carbon economy by helping allocate funds to environmentally friendly initiatives. Policy makers should motivate the companies to undertake green bonds by providing them provisions of tax exemptions or subsidies for funding renewable energy programs and energy-efficient capital investments (Ouyang et al., 2023).

Moreover, regulators ought to be more precise in defining what green finance entails in order to avoid situation where such funds will be used to finance projects with little or no actual positive impact on the environment. This include developing codes for green bond standards, the adoption of carbon standards, and increasing transparency of carbon markets through online financial technologies such as blockchain (Boumaiza & Maher, 2024).

6.2 Implement Energy-Efficient Blockchain Solutions

Optimal use of blockchain technology, especially for bitcoin-like cryptocurrencies, depends on how it resolves some environmental factors like cost of proof of work. Policymakers should help foster the shift from proof-of-work algorithm consensus to more sustainable ones like the proof of stake and take other actions. They can accomplish this by providing funding to blockchain technology developers for the creation of less power-hungry blockchains or by enacting laws requiring cryptocurrency operators to employ eco-friendly technologies (Parhamfar et al., 2024).

6.3 Digital Finance Infrastructure Development in Developing Countries

Primarily, it is important to close the gap between digital finance in developed and developing nations in order to optimize the ecological potential that digital finance can provide. Policymakers in developing countries should focus on increasing internet and mobile banking capacity in the area. This will help the uptake of digital payments and mobile banking, which will lower carbon emissions from the area's antiquated banking systems (Mhlanga, 2022).

A number of international institutions, including the World Bank and International Monetary Fund (IMF), ought to provide funding and technical assistance to developing nations in order to aid in the expansion of the digital financial system. Increasing the people’s understanding of digital finance will also help the objective since it will enable users to use these tools productively and accomplish more good for the environment.

6.4 Manage the Amount of Energy Used up by Cryptocurrencies

The increasing energy consumption linked to cryptocurrencies poses a significant threat to the environmentally sustainable nature of digital finance. Lawmakers should consider enacting regulations that would restrict the amount of energy used in cryptocurrency mining operations and/or require miners to use green or renewable energy sources. Governments can also implement carbon pricing schemes, whereby miners of cryptocurrencies are taxed for their carbon footprints, thereby incentivizing them to use less damaging energies, in all areas where people have adopted the use of cryptocurrencies (de Vries, 2019; Hebous & Vernon-Lin, 2024).

7. Conclusion

This study examines the intricate role of digital finance by analysing the benefits and drawbacks of carbon emissions in relation to these innovations, and provides a balanced assessment of their outcomes. Theoretically, the analysis builds on the Environmental Kuznets Curve to show how digital finance can support the transition towards greener economies. Digital finance, specifically blockchain technology, mobile banks, and green finance, has made these kinds of activities very promising for both economic growth and carbon mitigation, by its ability to enhance access to capital, improve efficiency, and foster transparency, all of which are essential to advancing environmental sustainability.

The empirical data synthesis reinforces this conceptual framework.Mobile banking has been effective in reducing the energy demands of conventional banking systems, while blockchain technology has increased the accuracy and trust in carbon trading. In nations like India, China and Sub-Saharan Africa where virtual banking has reduced reliance on brick-and-mortar stores and a lot of paperwork, financing through mobile banking has been demonstrated to lower the carbon emission levels of conventional banks (Lei et al., 2023; Mhlanga, 2022; Nath et al., 2014). The ability to trade carbon credits and the enhancement of the trading system are made possible by blockchain technology, particularly in relation to carbon markets. The shift to a carbon-free economy has also benefited immensely from green bonds and related financial products (Leitao et al., 2021; Ouyang et al., 2023).

However, the study highlights the significant environmental impact of cryptocurrencies that rely on energy-intensive proof-of-work algorithms, like Bitcoin. These problems necessitate the implementation of more energy-efficient operational procedures in blockchain technology as well as regulations aimed at preventing the extensive conventional energy consumption associated with digital finance technologies (Hebous & Vernon-Lin, 2024). This paper also sheds light on the issue of the digital divide, which has an impact on the environmental benefits made possible by digital finance in some developing nations where inadequate infrastructure development has resulted in low adoption of digital solutions (Lythreatis et al., 2022; Ragnedda, 2017).

The study offers policy recommendations in response to these issues, including expanding the use of green finance instruments, deploying energy-efficient blockchain technology, expanding the digital finance base in underdeveloped areas, and regulating cryptocurrency energy expenditure. These steps will make it possible for digital finance to effectively contribute to the sustainable development agenda by ensuring that its positive environmental effects outweigh its negative ones.

Thus, this paper explores the potential of digital finance within the framework of carbon neutrality and offers strategies for mitigating environmental risks. Digital finance has the potential to play a significant role in facilitating the global shift towards a sustainable economy under the low-carbon regime, given the implementation of the suggested policy measures and encouraging technological innovations.

In conclusion, digital finance has the potential to significantly contribute to a low-carbon future – but this requires strategic governance, equitable infrastructure development, and environmentally responsible innovation. With the right policies in place, digital finance can become a powerful force in the global movement toward sustainability.

Funding: This research has not been funded by any agency.

Conflict of interest: The authors declared no potential conflicts of interest concerning this article's research, authorship and/or publication.

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