

A Theoretical Analysis of Digital Finance Enabling Green Innovation

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Abstract. This paper explores the development of digital finance as a force for promoting green innovation. It discusses how digital finance can be developed in high quality and how it can promote the theoretical mechanism of green innovation. Finally, policy recommendations for the development of digital finance and green innovation are presented. Digital finance primarily supports green innovation in three ways. Firstly, it facilitates the development of green enterprises and promotes high-quality and sustainable economic growth through convenient and efficient financial services. Secondly, it employs digital technology to enhance the coverage of financial services. Finally, it encourages the adoption of sustainable practices through the provision of financial incentives. Secondly, digital finance has facilitated the development of green financial products and services, expanded financing opportunities for enterprises, and lowered the cost of financing green projects. Thirdly, the integration of digital finance and green innovation has contributed to the enhancement and upgrading of industrial structure, as well as the transition towards a greener economy. Therefore, it is imperative to support the advancement of digital finance for green innovation from various perspectives.

Keywords: Digital finance, green innovation, financing constraints, industrial upgrading.

1. Introduction

China's economic development since the reform and opening up has achieved world-renowned success. However, the long-term development mode has resulted in serious environmental pollution, creating unprecedented pressure on China's resources and environment. As China's economy transitions from high-speed to high-quality development, it is essential to follow the laws of economic development and maintain sustained and healthy growth. China has committed to achieving carbon peak by 2030 and carbon neutrality by 2060 during the 14th Five-Year Plan period. Green transformation is crucial in achieving the strategic goal of 'carbon peak and carbon neutrality' in green development, promoting stable economic growth, and building a beautiful China. It is important to note that China is still a developing country. However, it is important to note that China is still a developing country with a relatively low level of economic development and urbanisation. Additionally, China has yet to achieve its goal of a new type of industrialisation. Therefore, it is not feasible for China to solely focus on solving environmental problems. The national development strategy aims to reduce carbon emissions without compromising production capacity and economic growth. Green innovation can help achieve this balance by using less energy and capital investment, resulting in less pollution and greater ecological benefits. It is important to maintain the normal order of supply and demand. "Green" represents the increasing ecological needs of people, while "innovation" is a crucial factor in achieving a high level of self-sufficiency and self-reliance for the country. Green innovation is the effective integration of "green" and "innovation". It is an important measure to balance economic development and environmental protection in the context of "dual-carbon", and a necessary step towards promoting high-quality development. Balancing the relationship between environmental sustainability and economic development is crucial. Green innovation has become a key factor in achieving this balance. The promotion of green innovation policies is currently a pressing issue that requires exploration.

The digital economy is a new mode of production that considers data resources as the key factor. It is considered the main economic form after the agricultural and industrial economies. The modern

information network is the main carrier of the digital economy, and the integration and application of information and communication technologies, along with the digital transformation of all factors, are important driving forces that promote a new economic form that is more unified in terms of equity and efficiency. The proportion and scale of the digital economy in the national GDP have been steadily increasing year by year. Figure 1 below illustrates the development from 2017 to 2022. Digital finance is a new generation of financial services that combines the Internet and information technology with the traditional financial service industry [12]. It includes third-party payment, financing platforms, crowdfunding platforms, wealth management businesses, and the digital transformation of traditional finance. This development makes financial transactions more efficient, convenient, and secure, enhancing the ability of financial services to support the high-quality development of the real economy. Digital finance plays a crucial role in regulating finance facilitating change, deepening services, supporting the integrated development of the digital economy and the real economy, and promoting financial innovation. It has become the main driving force for China's high-quality development in the digital economy. The use of digital finance also addresses the traditional financial sector's insufficient support for the development of green innovation, providing new opportunities for green innovation. This point has been discussed in the context of both financially developed and financially less developed regions. Figure II highlights the development of the digital economy in financially developed and less financially developed regions [14].

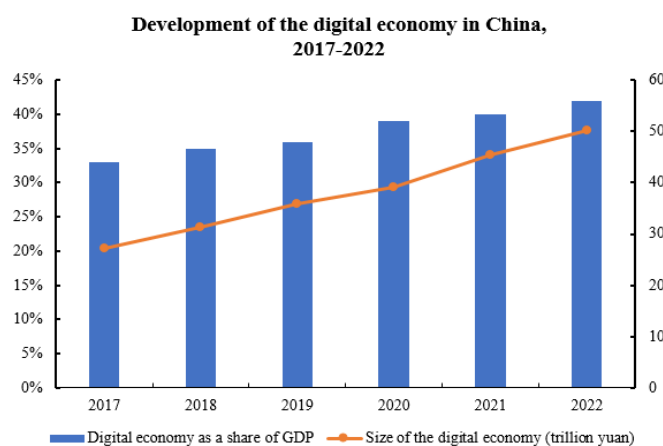


Figure 1. Development of the digital economy in China,2017-2022.

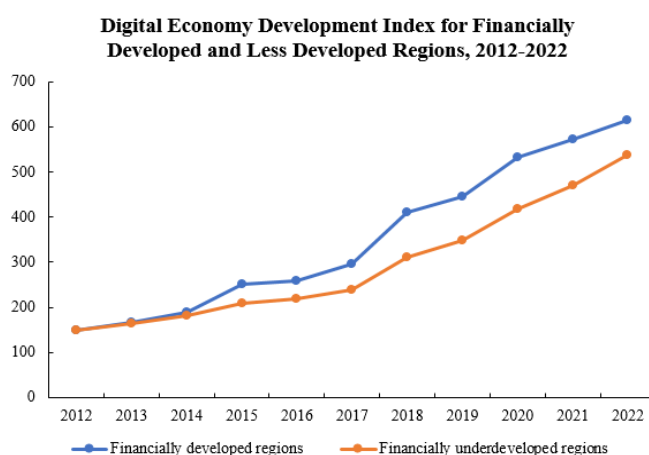


Figure 2. Digital Economy Development Index for Financially Developed and Less Developed Regions, 2012-2022.

Currently, there are limited studies on the relationship between green innovation and digital finance. However, existing literature suggests that digital finance has a positive impact on green innovation efficiency, particularly in the east, centre and west regions [1]. The literature closely related to this study focuses on two aspects: the impact of digital finance on corporate green innovation. Liang Lingling, Li Ye, and Chen Song demonstrated that digital financial inclusion plays

a significant role in promoting corporate green technology innovation. The positive impact of digital financial inclusion is stronger on high environmental governance level enterprises compared to low environmental governance level enterprises. Additionally, the promotional effect of digital financial inclusion is greater on enterprises with CEOs lacking financial background experience compared to those with financial background experience [2]. Secondly, Zhao Jun, Li Yanshan, and Zhu Weili examine the impact of digital finance and green innovation on urban development using a fixed effects model. They explore the correlation effects of digital finance and green innovation on urban high-quality development and conclude that: During the investigation period, the quality of urban development was significantly improved by the cross-multiplication of digital finance and green innovation. Additionally, green innovation played a positive non-linear role in promoting high-quality urban development under different levels of digital finance. Thirdly, the correlation between digital finance, green innovation, and their effects enhances the level of high-quality urban development in the long term, but slows down over time. Fourthly, there is significant variability in the impacts of digital finance and green innovation on the high-quality development of cities, as analysed by heterogeneity [3].

This paper explores the relationship between digital finance and green innovation by incorporating them into the same theoretical framework. It aims to address the shortcomings of existing studies and provide a clear theoretical understanding of the role of digital finance in promoting green innovation. The discussion will focus on three specific aspects while committing to fulfilling this marginal contribution. First, this paper will continue to expand the relevant research on digital finance and green innovation, explore the relationship between digital finance and green innovation from the theoretical level, and provide theoretical guidance for green innovation. Secondly, traditional finance has limited support for green innovation. Digital finance, on the other hand, not only offers the advantages of traditional finance but also compensates for its shortcomings by utilizing its own diverse, multi-level, high-efficiency, and cost-effective features. However, there are fewer theoretical explanations in the literature regarding the impact of digital finance on green innovation. Therefore, this study aims to explain the impact of digital finance on green innovation through the national strategy and theoretical aspects. Thirdly, this paper presents policy recommendations for achieving green transformation, enhancing green innovation, improving green development, and integrating digital finance and green innovation under the context of 'dual-carbon'. This study offers new ideas and perspectives, and serves as a reference for decision-making in the development of digital finance and green innovation in China [13].

2. Connotation of digital finance and its mechanism of action

The digital economy is a new mode of production that relies on data resources as the primary production factors. It has become the main economic form after the agricultural and industrial economies. The digital economy has gradually emerged as a new engine leading the world's economic growth and a new driving force for development. Digital finance is the integration of finance and technology, promoting financial innovation and subverting traditional financial operations. It is a crucial financial model in the digital economy, playing a decisive and driving role in its development. Digital finance is a new financial model that integrates traditional financial institutions and enterprises with the internet and information technology to provide financial services such as financing, payment, and lending. It is a revolutionary product of the deep integration of finance and science and technology. The language used is clear, objective, and value-neutral, avoiding biased, emotional, figurative, or ornamental language. The text adheres to conventional structure and maintains regular author and institution formatting. Technical term abbreviations are explained when first used. The text is grammatically correct and free from spelling and punctuation errors. No changes in content have been made. Secondly, digital finance refers to the development derived from third-party payments, financing platforms, crowdfunding platforms, wealth management businesses and the digital transformation of traditional finance. This makes financial transactions more efficient,

convenient and secure. Thirdly, digital finance provides a range of financial services through mobile terminals, personal computers, and the internet to meet the needs of individuals and enterprises. Simultaneously, the implementation of cutting-edge technologies, such as blockchain, artificial intelligence, and big data, provides robust technical support for the advancement of digital finance. This not only enhances the efficiency of financial services but also renders them more intelligent and personalised. Digital finance follows the development principles of openness, speed, security, and efficiency. Its purpose is to address the challenges faced by innovative enterprises, such as difficulties in obtaining financing, expensive financing, and insufficient support. Digital finance provides a reliable foundation for the development of green innovation [15]. However, it also has its limitations. Digital finance is heavily reliant on internet technology, which in turn is supported by data. However, this dependence on technology also makes it vulnerable to system failures, which can result in issues such as data leakage and fund theft. These problems can cause harm to financial security and hinder enterprise innovation. Secondly, the popularity of digital finance has led to the collection and processing of a large amount of personal and financial data. If not properly protected, this may result in privacy breaches, causing harm to personal rights and interests. Additionally, enterprises may not obtain the expected benefits due to data leakage, reducing the incentive to innovate. Thirdly, the development of digital finance may exacerbate the problem of the digital divide, making it impossible for some groups lacking digital skills to access digital financial services. Additionally, funding for innovation in small and micro-enterprises is not guaranteed, which can hinder enterprise development [16].

Currently, China's digital finance is still in the developmental stage. Although it has addressed some of the limitations of the traditional financial model, its prevalence rate remains low. To promote the high-quality development of digital finance, it is necessary to focus on the following three aspects. Firstly, digital finance should leverage the advantages of traditional finance and technological innovation to promote economic development in an organic manner. Secondly, digital finance still retains the fundamental attributes of traditional finance. It utilises digital technology to integrate information and solve the problem of enterprise financing. Thirdly, digital finance addresses the issue of factor mismatch and empowers high-quality economic development. Therefore, in the future, the state should provide policy support from these three aspects to enhance the popularity of digital finance and facilitate the integration of financial forms with digital technology.

2.1. Digital finance for economic development

Economic development is primarily a process of currency circulation. Digital finance acts as a financial accelerator in the era of the digital economy. It accelerates the process of currency circulation, promoting the speed of monetary value-added acceleration. This, in turn, further promotes the circulation of capital and factors. The faster the capital circulation, the faster the speed of commodity production, and the faster the economic development. The main body of digital finance comprises traditional financial institutions, internet enterprises, and financial technology companies. It is a combination of these entities. Digital finance has transformed the monetary system by creating digital currencies and promoting the development of money. It has expanded from electronic and information-based business management of financial institutions to online and mobile financial transactions. Additionally, it has digitised the entire process of financial services and broadened the scope of digital finance. Digital finance's inclusive nature can accelerate high-quality, synergistic economic development in different regions. Digital financial inclusion reduces the fixed costs associated with traditional financial inclusion physical outlets. Additionally, digital finance enables payment behaviour to become paperless digital payments, reducing the time cost of consumption. Digital financial services have a low-cost advantage that enables them to cover areas that traditional financial services find hard to reach. This promotes economic growth in these areas and meets the demand for innovation in high-quality development, making it a core driving force of high-quality economic development. Advanced digital technologies such as big data, blockchain, and artificial intelligence have enabled digital finance to exhibit characteristics of lower cost, wider coverage, and

higher efficiency. This can greatly impact the technological innovation of small enterprises, as well as the entrepreneurial vitality, innovation efficiency, and technological innovation level of the region, making it a source of innovative power for high-quality economic development. Digital finance is a source of innovative power for high-quality economic development. It reduces transaction costs, expands the coverage and transaction forms of financial services, improves the accessibility of financial services, and promotes enterprise innovation and industrial upgrading, thereby promoting the development of the overall economy.

2.2. Digital finance enhances the economic vitality of enterprises

The financing structure of enterprises has a significant impact on their business activities. Banks and financial institutions are the primary sources of financing for enterprises and play a crucial role in solving their financing problems. However, traditional financial institutions often face issues with paper-based material review and approval, which increases the time and cost required for enterprise innovation. The funding problem cannot be solved in a timely manner. Additionally, traditional financial institutions are unable to synchronize credit and qualification information of enterprises or individuals in a timely manner. Digital finance utilises innovative technologies to organise and analyse information, effectively addressing the issue of information asymmetry. This strengthens the exchange and processing of information for both enterprises and investors, resolves financing constraints for innovation, enables efficient allocation of resources, and alleviates the distortion of resource allocation. Digital finance covers the management of electronic and information technology in financial institutions, as well as online and mobile financial transactions. It also encompasses the digitisation of the entire financial services process. Digital finance enables enterprises to compare financing products from different financial institutions through the internet and mobile devices, and choose suitable financing solutions. Financial institutions can also cooperate through supply chain platforms to provide more financing options for enterprises, breaking down geographical restrictions. The language used is clear, objective, and value-neutral, with a formal register and precise word choice. The text follows conventional structure and adheres to formatting guidelines, with no grammatical errors or spelling mistakes. The content remains unchanged. The development and popularisation of digital technology has enabled digital finance to optimise enterprise operation systems and improve efficiency. Enterprises can also enhance their operation modes through innovation and development of digital finance, along with government policy support. This can incentivise them to seek broader development opportunities and bring benefits to themselves and the market [17].

2.3. Digital finance eases capital factor mismatch

The government and the market are the main bodies responsible for factor allocation. The government guides the rational flow and allocation of factors through the formulation of planning and policies, investment in infrastructure construction, and the provision of public services. It also maintains the fairness and efficiency of factor allocation by strengthening market supervision. The market promotes the development of a multi-level capital market to meet the financing needs of different types of enterprises, improve market inclusiveness and resilience, and provide more capital support for enterprise innovation. Digital finance can utilise big data, blockchain and other technologies to enhance the transparency of financial transactions and reduce information asymmetry. This can aid the government in gaining a better understanding of the market situation and enterprise demand, allowing for more accurate allocation of factors and a reduction in the problem of factor mismatch. Digital finance can strengthen risk control and management through big data analysis, risk assessment, and other technical means. This can reduce the impact of financial risks on factor allocation, enabling the government to maintain economic stability and security more efficiently and guarantee the effectiveness of factor allocation. Enterprises should consider resource allocation and process optimization when allocating factors to achieve sustainable development. Digital finance, using cloud computing and other technical means, allows for real-time understanding of business

situations and financing needs, leading to more accurate capital allocation. Digital finance can offer enterprises a personalised and diversified financial service model, enabling them to manage their assets more effectively and enhance their market competitiveness. The development of digital finance encourages enterprises to accelerate their digital transformation, improving productivity and core competitiveness. Digital finance can alleviate the problem of factor mismatch and achieve factor Pareto improvement by promoting technological progress and upgrading the industrial structure. This can empower and enable high-quality economic development [18].

3. Theoretical mechanisms of digital finance for green innovation

Digital finance is a crucial financial model in the era of the digital economy. It is a new generation of financial services that combines traditional financial services with internet and information technology means. This is achieved through third-party payment, financing platforms, crowdfunding platforms, wealth management business, and the digital transformation of traditional finance. These developments make financial transactions more efficient, convenient, and secure, and enhance the financial services of the real economy, improving its ability to develop at a high quality [4]. Digital finance can reduce information barriers and asymmetry between the supply and demand sides of funds. It can also optimize the credit-granting process, enabling financial institutions to handle transactions faster and improve financing efficiency. This can reduce the financing cost of enterprises and alleviate financing constraints. Secondly, the development of digital finance increases financing support for innovative enterprises by broadening channels of capital supply, enriching means of social financing, and perfecting financing platforms. This eases financing pressure on enterprises and provides financing guarantees for enterprise innovation, thus improving economic efficiency and achieving optimal resource allocation. Finally, digital finance can provide more accurate assessments and predictions of future enterprise development through technical means such as big data and artificial intelligence. This can help enterprises better understand market trends and demands, enabling them to formulate strategies and decisions that align with market demand. Additionally, digital finance can provide more precise data support for enterprise risk management, helping enterprises avoid risks and promote industry stability. Digital finance reduces transaction costs, improves financing efficiency, empowers green finance, and provides a solid financial foundation for the development of enterprise green innovation [5].

3.1. Digital finance promotes green innovation by easing financing constraints

Innovative financial products can enhance the accessibility of financial services, broaden the scope of services offered by financial institutions, and create a scale effect. This can improve the financial service environment for enterprises, lower the threshold of innovative financing, enhance the stability of capital supply, and provide financial security for green innovation. Digital finance can address the structural mismatch between the demand and supply of enterprise innovation financing, reduce the cost of innovation financing, improve the information asymmetry between enterprises and investors, and enhance the efficiency of financial services and innovation financing. Digital finance can promote independent innovation in enterprises, encouraging them to conduct research and development of green technologies in their production processes. This can lead to the adoption of low-consumption and environmentally friendly production methods, promoting green innovation and contributing to China's high-quality development. Additionally, digital finance can accelerate the transmission of data and information related to financial products and factor markets, reducing the negative impact of production processes on the environment and providing a favourable external environment for the green innovation and development of enterprises. Digital finance addresses the limitations of traditional finance in supporting innovative enterprises with financing difficulties, high financing costs, and inadequate support. It also helps to alleviate the constraints of personal financing. Digital finance enables quick access to designated users through mobile internet technology. With the help of cloud computing, big data, blockchain, and other digital technologies, lending and borrowing

operations are automated, reducing transaction costs and risks while improving efficiency. It also allows individuals to obtain funds for green innovation-related projects, promoting their development [19].

3.2. Digital finance promotes green innovation by optimising resource allocation

Digital finance utilises big data and cloud computing to analyse enterprise data, allocating capital elements directly to the user's capital needs. This helps to reduce information costs for both the supply and demand sides of capital, guiding the flow of production factors into the required enterprises to prevent resource mismatch. Digital finance can optimize the resource allocation of each enterprise and individual, and drive the innovation of enterprises themselves as well as enterprises upstream and downstream of the industrial chain. It also promotes the government's use of fiscal policies to alleviate the difficulties of enterprise financing and make up for the efficiency loss caused by market failure. Digital finance can optimize the allocation of production and data factors, promote the symmetrical matching of resources to achieve information symmetry, and provide financial support for the development of the green industry. The emergence of digital finance can expand the financing channels of financing subjects, reduce financing costs, improve the financing platform, and make it easier for small and micro enterprises to obtain financial services. It can also broaden the scope of capital allocation, optimize the allocation of resources, reduce the contradiction between the supply and demand of production and data factors in green production, improve the efficiency of the allocation of financial products and services, and promote the development of enterprises in green innovation [6].

3.3. Digital finance promotes green innovation by upgrading industrial structure

The government's pursuit of rationalising the industrial structure is a long-term goal. Supporting the development of green innovation can aid in achieving this goal. Therefore, the government has implemented policies to direct financial capital towards green innovation enterprises. This aligns with the needs of industrial development. Enterprises are actively engaged in technological innovation, research and development, and the introduction of new technologies and products to promote the upgrading of the industrial structure [7]. Both the government and the market favour more secure, efficient, and convenient digital finance, making it an ideal tool to assist the development of green innovation. The promotion of industrial structure upgrading through digital finance is a key consideration, taking into account the perspectives of both the government and enterprises. The development of digital finance can improve productivity by integrating data, information, and production factors. This can empower both internet finance companies and traditional financial institutions, improve financing mechanisms, and create innovative financial tools for industrial transformation and upgrading. It can also drive the advancement of the industrial structure. Digital finance's diverse range of financial products can meet various consumer demands, facilitate enterprise industrial chain upgrades, promote internal industry structure upgrades, and lead to industrial structure rationalisation. Digital finance can support the development of green industries, facilitate the transformation and reconstruction of traditional industries, and accelerate the ecological upgrading of industrial structures. The development of digital finance has the potential to improve the coefficient of industrial structure level and labour productivity, reduce the degree of industrial structure irrationality, and accelerate the dual process of industrial structure advancement and rationalization. As the industrial structure upgrades, emerging industries are expanding in scale, and the cluster effect is becoming more prominent. This can lead to the scale effect of green production for enterprises, laying a solid foundation for the development of green innovation [8].

4. Conclusions and policy recommendations

Amidst China's shift towards high-quality development, digital finance can positively contribute to promoting green innovation by providing modern financial support. Innovative financial products

and services offered by digital finance cater to people's diverse financial needs, while also reducing the time and financing costs, and enhancing the quality and efficiency of financial services. Green innovation can promote sustainable development, industrial upgrading, and optimized resource allocation by utilizing its own characteristics. Improving the coverage of financial services, digital finance reduces the financing cost of green projects, improves the efficiency of capital utilization, and promotes the research, development, and application of green technologies. The development of digital finance can optimise the allocation of financial resources, guide the flow of funds to green industries, and promote sustainable economic and social development [20]. To better promote green innovation through digital finance, joint efforts from the government, enterprises, and all members of society are necessary. The government ought to implement appropriate policies to reinforce regulation and guidance. Enterprises should proactively explore innovative models and increase their awareness of social responsibility. All sectors of society should enhance their environmental awareness and participation. By collaborating, all parties can better achieve synergistic development of digital finance and green innovation, promoting sustainable economic and social development [11].

On this basis, this paper has policy implications for giving full play to the advantages of digital finance for the development of green innovation.

First, governments should promote digital finance for green innovation by introducing appropriate policies and promoting digital financial and technological innovation. They should also strengthen regulation and risk prevention. The government should introduce policies to provide financial subsidies, tax incentives, and other relevant measures to reduce the financing costs of green innovation projects. Digital financial enterprises should be encouraged and supported to participate in and promote green innovation. Secondly, the government should enhance supervision of digital financial enterprises, regulate their business conduct, and prevent financial risks. Additionally, a robust risk prevention mechanism should be established to ensure that the risks associated with digital finance supporting green innovation are manageable. Thirdly, the government should encourage and support digital financial enterprises to increase investment in scientific and technological innovation. This can be achieved through the establishment of special funds for scientific and technological innovation. Additionally, more financial products and services should be researched and developed to meet the needs of green innovation.

Second, enterprises should make digital finance promote the development of green innovation by increasing investment in scientific and technological innovation, strengthening information disclosure and transparency, and training and introducing professionals. Enterprises should increase investment in digital financial science and technology innovation to improve risk assessment capabilities and reduce the risk and cost of green innovation projects. Additionally, enterprises should research and develop more financial products and services adapted to the needs of green innovation to promote its development. Secondly, enterprises should cultivate and introduce talented individuals with knowledge and skills in digital finance. They can attract outstanding individuals by establishing talent cultivation programmes and providing training and development opportunities. This will provide a talent guarantee for promoting green innovation. By implementing the aforementioned policy recommendations, enterprises can effectively utilise digital finance to promote green innovation and sustainable economic and social development. This approach can also enhance the competitiveness and social influence of the enterprises themselves [9].

Thirdly, governments and enterprises should play their respective roles in jointly promoting the development of digital finance for green innovation. The government should establish a cooperation mechanism, formulate relevant policies, and build a public service platform. Enterprises should actively participate in green innovation, strengthen cooperation with the government and organizations, raise awareness of social responsibility, and actively participate in international cooperation and exchanges. The sustainable development of digital finance for green innovation can be achieved through the joint efforts of the government and enterprises [10].

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