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# The impact of digital finance on green economic development: A literature review

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**Abstract:** Green economic development has become an essential pathway to achieving high-quality economic growth, while digital finance represents a prominent trend in global financial advancement. The rapid expansion of digital finance in China has spurred extensive research in this domain. This study systematically combes the literature on digital finance and green economic development. Initially, it delineates the conceptual definition of digital finance, measurement indices and the conceptual definition of green economic development, identifies the key influencing factors. Subsequently, it synthesizes empirical findings on how digital finance influences the growth of green economy from economic, environmental, and energy perspectives. The economic perspective is divided into macroeconomic impacts, mechanisms of influence, and microeconomic aspects; the environmental perspective focuses on the pollution effects and carbon emission reduction attributable to digital finance, and the energy perspective reviews literature on improvements in energy efficiency and reductions in energy intensity driven by digital finance. Finally, the paper offers a comprehensive summary of current research trends and future directions in the field. It emphasizes the need for enhanced digital finance index systems, robust risk control and regulation, and a balanced approach to fostering a genuine green economy. Additionally, it highlights potential future research avenues, such as the effects of digital finance on government policies, foreign trade, environmental pollution, and energy utilization.

***Keywords:*** *Digital finance, Economic effect, Energy effect, Environmental effect, Green economic development.*

## 1. Introduction

China's economy is undergoing a transition towards high-quality development. However, it still faces structural contradictions in supply and demand, imbalanced regional economic growth, environmental pollution, resource limitations, and other pressures. In order to handle the increasing pressure, overcome challenges, and achieve efficiency in China's high-quality economic development, it is essential to seek opportunities in new businesses, modes, and industries. The green economic development is a crucial step towards realizing the goal of high-quality economic development, it has also become the economic development strategy of most countries. Finance is an essential booster of economic development, and the "Resolution on the Outline of the Fourteenth Five-Year Plan for National Economic and Social Development and the Vision for 2035" (the "Fourteenth Five-Year Plan"), published in 2021, puts forward the following " To improve the modern financial system with a high degree of adaptability, competitiveness, and universality." Digital finance, as an innovative and efficient model for financial transactions and services, offers precise and effective financial solutions that cater to the demands of economic development in the "Internet +" era. Characterized by its universality and inclusiveness, digital finance aligns with contemporary financial development requirements. Numerous scholars have investigated the connection between digital finance and economic development


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across various levels, fields, and perspectives, and their findings consistently show that the two are closely related.

Existing research has clarified the conceptual connotations, indicator measurements, characteristic functions, and development trends of digital finance, thereby promoting its advancement. Additionally, empirical analyses have explored how digital finance contribute to green economic development, uncovering the intricate relationship between the two. However, there remains a gap in systematically synthesizing and summarizing this body of literature. This paper's primary contribution lies in systematically reviewing the literature on digital finance and green economic development since 2011. By adopting a comprehensive literature review approach, it summarizes the research progress and highlights key research trends and hotspots. This synthesis aims to provide valuable references for encouraging the healthy and sustainable development of digital finance and enhancing its contributions to the green economy.

The remainder of this paper is organized as follows: Section 2 provides a brief review of the literature on the concepts of digital finance and green economic development, including measurement indices of digital finance and influencing factors of green economy. Section 3 discusses the impact of digital finance on green economic development, organizing the literature according to economic, environmental, and energy effects. Section 4 concludes the paper and suggests directions for future research.

## 2. Review of Research on Digital Finance and Green Economic Development

### *2.1. Review of Research Related to Digital Finance*

#### *2.1.1. Definition of Digital Finance*

Internet finance is the term used to describe the early stages of fintech development when information technology and finance are combined, such as mobile Internet and cloud computing(Xie & Zou, 2012). It particularly refers to the use of new Internet technologies like big data, cloud computing, and mobile payments. Internet finance is a new financial paradigm where traditional financial institutions and technology companies use information technology to undertake financial activities, according to the People's Bank of China and other ministries and commissions.

Fintech is a collective term for "finance + technology," which is commonly understood as the provision of services to the traditional financial industry through the means of modern technology. The International Financial Stability Board (IFSB) defines FinTech as new business models, technology applications, business processes, and products that have a major impact on financial markets, institutions, and services. FinTech represents financial innovation driven by technological advancements. The Basel Committee on Banking Supervision adopted this definition, as did the Fintech Development Plan (2019-2021) issued by the People's Bank of China.

Digital finance. Since the emergence of digital finance, many scholars have defined its concept. Most of the literature believes that digital finance is the use of new generation information technology by traditional financial institutions such as banks and securities and emerging enterprises such as Internet companies to carry out financing and investment, payment and other new financial services. Huang and Huang (2018) believe that digital finance refers to the use of digital technology by financial institutions and Internet platforms to achieve financing, payment, investment and other new financial business models by traditional financial institutions and Internet companies. The combination of digital technologies—such as the Internet (mobile and the internet of Things), big data, distributed technologies (cloud computing and blockchain), artificial intelligence, and information security measures (biometrics and encryption)—with financial services gives rise to digital finance (Tang et al., 2020). Guo et al. (2020a) define digital finance broadly as financial activities conducted by traditional banks and other financial institutions, as well as Internet enterprises using digital technology. Narrowly, it refers specifically to innovative financial models developed by Internet enterprises. Digital finance is still

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fundamentally about finance and how to use science and technology to achieve financial functions. Therefore, it is a product of integrating technological innovation and traditional finance (Tang et al., 2020).

The three concepts and the content they cover are very close to each other, and digital finance, Internet finance and financial technology, is a group of concepts on the financial innovation spectrum (Teng & Ma, 2020). The subtle difference is that Internet finance is more prominent in the monetary business carried out by Internet companies, Fintech accentuates the technological aspects of financial business, while digital finance maintains a neutral stance and covers a wider scope of area (Huang & Huang, 2018). Much of the existing literature does not differentiate between these nuances and often uses these terms interchangeably.

*2.1.2. Measurement of Digital Finance*

Numerous research studies have been conducted on the accuracy and rationality of measurement methods of digital financial indicators. Measuring digital financial indicators in the academic field mainly consists of independently constructing and utilizing other authoritative indicators.

Based on the indicator measurement of financial institution data: some researchers take into account the accessibility of data from the characteristics of the geographical distribution of traditional banks, insurance companies, securities companies, and other institutions to the construction of digital finance as an indicator (Jiao et al., 2015). For example, Wang and Hu (2013) constructed the digital finance index from two main perspectives: financial supply and financial demand. Financial supply was measured by the number of banking institutions and banking employees, while financial demand was assessed through the number of bank deposits and loans. Wu and Xiao (2014) developed Digital Finance Index by evaluating the availability of financial services through the number of regional commercial banking institutions and ATMs. They measured the level of financial use by analyzing adult loans, credit card usage, and bank accounts, and assessed the quality of financial services from the perspectives of information, legal, and credit services.

Fintech Development Index of Research Institutions or Commercial Organizations: Some research institutions regularly publish indices on digital finance or fintech in each province and city. In the China Household Finance Survey (CHFS) data surveyed and regularly released by Southwestern University of Finance and Economics, which aims to collect relevant information about household finance at the micro level, the questionnaire questions for online shopping payment methods will reflect the number of households that choose "online banking, Alipay, credit cards and Tenpay" as their payment method to reflect the Internet finance (Lu & Zhang, 2018; Yin et al., 2023; Yin & Zhang, 2017). Zero2IPO Research Center constructs the Fintech Development Index based on four indicators: policy environment, innovation and entrepreneurship resources, fintech activity, and fintech development results and publishes the "Chinese Cities' Sci-Fech Finance Index" (CCSTFI) once a year.

The Peking University Digital Inclusive Finance Index is developed by the Digital Finance Research Center of Peking University in collaboration with researchers from the Ant Group Research Institute. Initiated in 2011, the index builds on traditional financial inclusion indicators while incorporating the unique characteristics and evolving landscape of digital financial services. It is synthesized from three dimensions, the breadth of coverage, depth of use and digitization of digital finance, with a total of 33 distinct indicators, involving the three tiers of provinces, cities, and counties (Guo et al., 2020b). Scholars have widely used this index to investigate and evaluate how digital finance affects economic development.

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*2.2. Review of Research Related to Green Economic Development*

*2.2.1. Definition of Green Economic Development*

The term "green development" was formally introduced by the United Nations Economic and Social Council for Asia and the Pacific (UNESCAP) during the Ministerial Conference on Environment and Development in 2005 (Shang et al., 2020). According to the Organization for Economic Co-operation and Development (OECD), the "green growth" concept, refers to the economic expansion that ensure the natural resources and environmental services that are vital to human well-being continue to be available. In addition, in order to achieve this green growth development paradigm, there should be a strong utilization of investment and innovation to foster sustainable growth and create new economic opportunities. This definition clarifies how green economy can be developed among economic development, intergenerational equity, and environmental protection. It also suggests specific practical approaches to achieve these goals (Zhang & Li, 2016). Reilly (2012) explains the triple objectives of green development in terms of "economic growth, job creation and reduced environmental impact" from the perspective of objectives, and Yu et al. (2017) argue that the fundamental connotation of green development lies in maximizing the performance of economic growth with the minimum input of energy resources.

In summary, "green economic development" is defined as an economic growth model that integrates economic advancement, resource conservation, and environmental sustainability. This model, fundamentally driven by innovation and supported by system optimization and organizational backing, is realized through technological advancements, industrial structure enhancement, and optimized factor allocation. This approach aims to achieve sustainable development across economic, societal, and environmental dimensions.

*2.2.2. Factors Affecting the Green Economic Development*

The existing literature on the factors that influence green economic development has been wealthy; a combination of the existing research has found that its influencing factors mainly focus on the following aspects: Technological factors, industrial structure factors, governmental policy factors, and agglomeration factors.

The technological factors affecting green economic development: Technological factors are mainly categorized into technological efficiency and technological progress. Ge et al. (2018) showed that fundamental innovations through technological efficiency and applied innovations through technological progress promote green total factor productivity. Fan and Sun (2020) argued that market-incentivized environmental regulatory policies promote green economic development through stimulating green technological innovation. Wang and Liu (2015) suggested that energy conservation and emission reduction advance green total factor productivity growth via technological improvements. Similarly, Xie and Liu (2019) illustrated that green credit mainly facilitates green economic growth mainly through advancements in technology.

Industrial structure factors affecting green economic development: The transformation and upgrading of industrial structures have redirected resources towards the tertiary and clean industries, thereby fostering green economic development. Nationally, the growth of the tertiary sector significantly enhances green growth (Sun et al., 2014). Wu and Hu (2018) incorporated environmental regulation and industrial restructuring into the analytical framework of stochastic frontier production function to conduct a study. Their findings show that China's green economic growth is significantly aided by industrial structure advancement and rationalization. Li et al. (2021) also discovered that utilizing Internet development to boost the effectiveness of the green economy requires advanced and rationalized industrial structures. Lu and Li (2021) concluded that industrial structure upgrades and technological innovations in China positively impact total green factor productivity, with notable variations between provinces. According to Li and Mao (2018), managing tax competition among local

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governments and strategically guiding the efficient upgrading of local industrial structures have significant policy implications for high-quality regional economic growth and coordinated, green development in different areas.

Government policy factors affecting green economic development mainly include environmental regulation, fiscal decentralization, and foreign direct investment (FDI): Regarding environmental regulation, Reasonable and moderate regulation yields the innovation compensation effect, fostering green economic development. However, excessive regulation results in a crowding-out effect, hindering green economy development. The inverse "U" relationship can be seen between environmental regulation and green total factor productivity (GTFP) (Fan et al., 2020; Li et al., 2020), the current regulatory intensity is on the left side of the inflection point, which is help to favor the technical innovation and growth of GTFP in China's manufacturing sector (Liu et al., 2022). Concerning fiscal decentralization, a policy where certain fiscal powers are devolved to local governments, there remains no consensus on its impact on green economy development. Although local governments with more autonomy can achieve a more rational allocation of resources, it inevitably leads to competition among them, which may reduce the stringency of environmental regulations and be detrimental for developing the green economy. For example, Cheng and Jin (2021) argued that on the one hand, fiscal decentralization promotes green growth through increasing R&D input and infrastructure development, on the other hand, fiscal decentralization leads to regulatory competition and market segmentation, which inhibits green growth. Li et al. (2016) also concluded that increasing fiscal decentralization is generally detrimental to GTFP. In terms of FDI, there is no uniform conclusion regarding how FDI affects GTFP. Generally speaking, most scholars' research results show that FDI positively impacts GTFP. Song and Li (2021) concluded that two-way FDI significantly affects GTFP at the present stage. However, as spending on both independent and imitative innovation rises, the impact of two-way FDI on enhancing green economic efficiency diminishes over time. Zhu et al. (2019) discovered that FDI reverse technology spillovers can boost GTFP within a region. Additionally, they can significantly elevate the GTFP in adjacent provinces through spatial spillover effects, he reached this conclusion by empirically applying the spatial Durbin model (SDM). Fu et al. (2018) investigated the different impacts of FDI from different sources on GTFP. However, they concluded that the overall impact of FDI on GTFP was insignificant.

The agglomeration factors affecting green economic development are mainly economic, industrial, and financial agglomeration: Lin and Tan (2019) found that green economic efficiency is positively impacted by reasonable economic agglomeration. The effect of economic agglomeration on green economic efficiency is first facilitated and then inhibited mainly through infrastructure, labor market sophistication, and environmental regulation. Chen and Tang (2018) discovered a pattern of "first promotion and then suppression" between manufacturing agglomeration and urban green total factor productivity. They also noted that the synergistic agglomeration of manufacturing, services, and different components of the two industries shows the same 'U' relationship on urban green total factor productivity. Hu et al. (2018) determined that high-tech sector agglomeration's influence on green economic efficiency also follows the "U" curve, primarily affecting pure green technical efficiency. Furthermore, specialized agglomeration was found to hinder green economic efficiency improvements, while diversified agglomeration was found to promote it. B. Wang et al. (2022) found that while financial agglomeration enhances the green economic efficiency in the region, it depresses green economic efficiency in neighboring region. Moreover, they discovered the inverted "U-shaped" between financial clustering and green economic efficiency.

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## 3. Review of Research on the Impact of Digital Finance on Green Economic Development

### *3.1. Economic Effects of Digital Finance*

#### *3.1.1. The Macroeconomic Effects of Digital Finance*

Existing research has identified that digital finance influences macroeconomic development by promoting inclusive economic growth, fostering high-quality economic progress, and ensuring balanced regional economic development.

Digital finance and inclusive economic growth: Several scholars have found digital finance fosters economic inclusive growth. Zhang et al. (2019) revealed that in China, digital finance enhances inclusive growth by encouraging entrepreneurial activities among rural inhabitants. Tang and Zhao (2022) showed that digital inclusive finance significantly enhances inclusive economic growth, the advanced and rationalized industrial structure can reinforce inclusive growth through digital finance. Ren and Yin (2022) showed that China's inclusive economic growth is significantly impacted by digital inclusive finance and its three sub-dimensions. This effect is especially notable in areas with greater local government efficiency, robust market development, and high levels of urban innovation. Digital finance can realize inclusive economic growth by easing the financing barriers that small and medium-sized enterprises (SMEs) must overcome and encouraging entrepreneurship among low-income households.

The relationship between digital finance and high-quality development has been gradually confirmed: Zhang and Yang (2022) using the systematic GMM method, they found the non-linear relationship, characterized by an inverted "U" shape, among digital finance, government fiscal expenditure, and high-quality economic development. They also discovered that, at its current stage, the digital finance fostered economy's high-quality growth under government fiscal expenditure. Jiang and Zhou (2021) found that digital inclusive finance currently promotes the high-quality economic development. However, with a certain degree of structural contradiction. Shangguan and Ge (2021) argued that digital finance can significantly and directly enhance high-quality economic development and has positive spatial spillover effects. They also suggested that environmental regulation directly promote high-quality economic development but has negative spatial spillover effects. Additionally, they found a significant moderating influence of environmental regulation on the high-quality economic development by digital finance.

Digital finance and balanced regional economic development: Digital inclusive finance significantly reduces intra-provincial, inter-city, and intra-municipal economic imbalances through innovation, industrial structure transformation, and industrial structure upgrading (Li & Shen, 2022). Xiao (2021) believes that the central and western areas see higher levels of economic growth stimulation from digital inclusive finance than the eastern region. Moreover, it has the potential to diminish the economic development disparities among these regions and within each region.

#### *3.1.2. The Economic Mechanism Effects of Digital Finance*

Digital Finance and the Mechanisms Affecting the Effects of Economic Development: Most research has determined that digital finance improves industrial structures, promoting technological innovation and entrepreneurship.

There can be a linear or non-linear link between industrial structure and digital finance: Mu et al. (2022) showed that there is a considerable positive correlation between digital finance and industrial structures upgrading, with the degree of economic development serving as a partial mediator. Li and Ran (2021) empirically examined the fact that digital finance promotes industrial structure upgrading by improving capital allocation efficiency. Conversely, Tang et al. (2019) believed through empirical analysis that it is a nonlinear between digital finance and industrial structure upgrading, with a threshold effect.

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Most scholars have confirmed the positive effect of digital finance on technological innovation, by reducing financial barriers and optimizing industrial structure, digital finance dramatically boosts technological innovation at the regional level (Nie et al., 2021). From the supply and demand perspective, digital finance may both directly and indirectly support regional innovation, this can be directly achieved from the supply side by easing financing limitations, and indirectly from the demand side by promoting consumer demand (Liu & Li, 2021). Du and Zhang (2020) also found that digital finance development can both directly and indirectly improve regional innovation, and the indirect impact is mainly achieved by improving the innovation effect of bank credit and increasing residents' consumption levels. Zheng and Zhao (2021) found that digital financial development can indirectly foster the regional technological innovation convergence by reducing the distortion of capital factors, upgrading labor force skills, and stimulating market demand.

Several scholars have also confirmed that digital finance has an entrepreneurial effect. The development of digital finance has a substantial impact on promoting entrepreneurship, especially in provinces with lower urbanization rates and for microenterprises with limited registered capital with more substantial incentives (Xie et al., 2018). Digital financial inclusion increases entrepreneurial activity and can have spatial spillover effects (Huang & Zeng, 2021). By decreasing credit restrictions and enhancing technical innovation, the development of digital finance can influence the degree of entrepreneurship (Feng & Cai, 2020). Li and Li (2020), through a survey study, found that financial education moderates the way that digital finance promoting entrepreneurship.

*3.1.3. The Microeconomic Effects of Digital Finance*

*3.1.3.1. The Impact of Digital Finance on Enterprises Economic Activities*

The major areas of concern for the effects of digital finance on enterprise economic activities include financing constraints, technological innovation, and enterprise business performance. Financing constraints: Digital finance effectively alleviates enterprise financing constraints by reducing financial expenses and lowering financing costs; for example, Ren (2020) found that digital inclusive finance reduces enterprise financing constraints through expanding the enterprise's cash flow and reducing its financial expenses and leverage level. Yuan and Zeng (2020) showed that the synergistic development of digital finance in breadth of coverage, depth of use, and degree of digitization effectively alleviated corporate financing constraints and could be partially attributed to the development, reducing corporate debt financing costs.

Technological innovation: Digital finance can effectively alleviate financing constraints; digital finance, by alleviating the degree of enterprise financial mismatch, address the enterprise "financing difficulties, financing expensive" problem on the micro subject of technological innovation. There is a "structural" driving effect (Tang et al., 2020; Wan et al., 2020; Zhao et al., 2021). Liu and Yang (2022) found that digital finance promotes SMEs' innovation in science and technology by easing financing constraints, and the effect is especially noticeable in China's economically less developed central and western areas. Nie and Wu (2021) showed that digital finance can significantly reduce the financial barriers that small and medium-sized enterprises face in order to realize its "incentive" effect on the level of technological innovation. Moreover, even more important is the "incentive effect" on the degree of technical innovation in high-tech SMEs. Yu and Dou (2020) found that the digital finance development on the innovation promotion of micro, small, and medium-sized enterprises (MSMEs) is mainly concentrated on the poorer quality of internal governance, higher information asymmetry, and better institutional environment of the region.

Digital finance is also notably linked to enterprise performance: Wang and Liu (2021) show that the digital finance overcome the financing challenges and reduce high financing costs for enterprises, thereby enhancing their total factor productivity. Meanwhile, digital finance has a heterogeneous impact on enterprise total factor productivity, which is affected by the size and nature of enterprises (Jiang &

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Jiang, 2021), while Zhang and Wang (2021) argued that digital finance boosts operational efficiency in small-scale and manufacturing enterprises more strongly. Additionally, Li et al. (2022) suggested that regional digital finance development can improve the financial sustainability of SMEs by addressing financing constraints.

*3.1.3.2. The Impact of Digital Finance on Banks*

The primary ways that digital finance affects banks are in terms of bank risk and overall performance. Digital finance has become a crucial factor affecting the credit risk of commercial banks, especially given the significant changes in financial and economic fundamentals.

The existing studies on the connection between digital finance and bank risk-taking can be categorized into two types. The first type investigates the linear between the digital finance and bank risk. Wei and Li (2024) demonstrated that digital finance heightens the credit risk of commercial banks by weakening their intermediation. However, it will weaken as commercial banks' digital transformation increases. He et al. (2022) found that advancements in fintech reduces commercial bank risk-taking, with the risk reduction effect being more significant for larger banks. Gu and Bian (2022) conducted an empirical analysis on how digital finance influences the systemic risk of banks and explored the underlying mechanisms. Their findings indicated that digital finance contributes to increased systemic risk within banks, especially affecting the non-state banking sector more significantly. The second type explores the non-linear between digital finance and bank risk. Wei and Qiu (2022) found that there was a "U"-shaped trend in the impact of digital finance on commercial banks' risk-taking behavior—it started off declining, increased, and then reversed. Fu et al. (2023) conducted an empirical investigation into how digital finance affects the commercial banks' credit risk. Their findings revealed a non-linear "inverted U-shaped" pattern between digital financial development and credit risk. Additionally, they identified that the cost of liabilities and the structure of these liabilities serve as mediating factors. At present, the index value of digital financial development is located to the right of the inflection point.

There are three different views in existing research on how digital finance influences bank performance. The first view is that advancements in digital finance enhance bank performance. Du and Liu (2022) argued that digital finance is essentially an act of financial innovation, and their study found that digital finance helps to improve the operating efficiency of commercial banks by strengthening bank's credit risk prevention and control capabilities. Zhang et al. (2024) used an "Evolutionary Game Theory" model to derive the three-stage characteristics of "competition-cooperation-competition" between county agricultural and commercial banks and digital financial institutions, and their results showed that digital finance is advantageous to the development of county agricultural and commercial banks throughout the period. Guo and Zhu (2021) concluded that banks could improve business efficiency, reduce risk-taking, and expand profitability by leveraging fintech, thus promoting the sound operation of banks. The second view is that digital financial development is detrimental to enhancing bank performance. Feng and Guo (2019) used the Tobit model and generalized moment estimation to investigate the impact of digital finance on bank competition and bank efficiency, the findings show that the digital finance development improves the bank's cost efficiency but reduces the bank's profit efficiency. The third view is that digital financial development has both facilitating and inhibiting effects on bank performance. Zhang and Liu (2022) found that digital financial development improves rural commercial banks' operational efficiency by enhancing e-enablement. However, digital financial development inhibits the improvement of rural commercial banks' operational efficiency by increasing the risk they take. Chen and Ling (2023) matched digital finance with the loan data from Chinese commercial banks' city branches at the prefecture level. According to the study, the digital finance breadth index has a "spillover effect" on commercial bank credit, and the digital finance depth index has a "crowding out effect" on commercial bank credit.

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*3.2. Environment Effects of Digital Finance*

*3.2.1. The Environmental Pollution Effects of Digital Finance*

The literatures refer to the environmental effect of digital finance primarily concentrate on its influence on environmental pollution improvement and carbon emission reduction. According to the study, they found the advancement of digital finance indirectly addresses environmental pollution and enhances environmental conditions by fostering economic growth, upgrading industrial structures, innovating green technologies, and reducing the green financing costs (Li et al., 2023; Zheng & Zhao, 2021).Xu et al. (2021) found that digital finance contributes to pollution mitigation, stimulates entrepreneurship, fosters innovation, and facilitates industrial upgrading, which are essential mechanisms. They observed s a double threshold effect based on the level of digital finance development, in the "N" shape. Zhu and Zhang (2022) noticed while the digital finance development reduces pollution emissions by facilitating economic structure transformation and technological progress, it can also exacerbate pollution emissions by promoting economic scale expansion.

*3.2.2. The Carbon Emissions Effects of Digital Finance*

The first view is that digital financial development is helpful in lowering carbon emissions: On The development of digital finance enhances the overall carbon emission performance. Furthermore, it reduces intensity of carbon emission through maximizing the benefits of economic growth, industrial structure, technological innovation, and energy structure adjustment.(Deng & Zhang, 2021; Feng et al., 2023; Wang & Fan, 2022). Sun et al. (2022) argued that digital finance reduces regional carbon emission through two paths, namely rural revitalization and increasing the diffusion intensity of information and communication technology (ICT). They noted a favorable spatial autocorrelation, whereby the progress of digital finance within a locality positively influences neighboring regions in reducing carbon emission.

The second view suggests a non-linear correlation between digital finance development and carbon emissions. Some researchers have shown that there is an inverted "U"-shaped between digital finance development and carbon emissions. Theoretical examination indicates that digital finance affects enterprises' production activities and innovation efficiency, as well as the concepts and behaviors of residents' consumption. Consequently, carbon emissions are affected. The empirical results verify that the impact of digital finance on carbon emissions is the rising effect of carbon emissions during the early stage of output value expansion and the innovation and emission reduction effect brought by energy-saving technologies in the later stage, respectively (Fan & Feng, 2022). Liao and Ru (2022) also found that the superposition effect of increased carbon dioxide emissions from economic scale expansion and the reduction of carbon dioxide emissions caused by green technological innovations, shows a pattern of increasing first and then decreasing later. J. Wang et al. (2022) focused on digital finance and the manufacturing industry. They found that the digital finance development also yields a non-linear effect on carbon emission intensity of the manufacturing sector through the combined effect of the "scale effect" and "technology effect." which promotes the increase of the carbon intensity of the manufacturing industry first and suppresses it later. According to Wang and Yin (2022), the digital finance development usually helps reduce carbon emissions, while the effects are first inhibited, then facilitated, and finally turned inhibited when digital finance and urbanization are used as the threshold variables respectively.

*3.3. Energy Effects of Digital Finance*

Some researchers have conducted empirical tests and analyses on the energy effect of digital finance. According to Wang and Zhao (2021), digital finance-a product of the new scientific and technological revolution and industrial transformations, holds the capability to enhance regional innovation level. Subsequently, it significantly influences energy efficiency during economic development, and ultimately

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contributes to the improvement of the ecological environment. Zhang and Li (2022) examined the total, mediating, and threshold effects of digital finance on energy efficiency, they discovered that innovation and entrepreneurship can successfully increase energy efficiency. Wei and Chen (2022) employed a two-way fixed effects model to empirically examine the effect between digital finance and energy intensity. Their findings indicated that digital finance can decrease energy intensity by fostering technological advancements. Sun and Tan (2023) investigated the digital finance and energy productivity inequality, their analysis revealed that digital finance reduces energy productivity inequality by addressing financing constraints and promoting technological innovation.

## 4. Summary and Future Research Directions

Presently, a substantial amount of academic literature examines on digital finance and green economic development, respectively. Initially, numerous studies explore the definition and metrics for measuring the development of digital finance. Subsequently, scholars have extensively documented the effects of digital finance on economy, employing a range of research levels, perspectives, and methodologies. These findings offer a robust theoretical foundation and diverse research approaches for further investigating digital finance and green economic development. Overall, the scholarly community increasingly emphasizes digital finance, with research output on the rise. Based on this overview, the following section outlines some conclusions and recommendations for the digital finance and green economic development in China:

Firstly, measurement indicators of digital finance still need further improvement. The most representative Peking University Digital Financial Inclusion Index measures digital finance development mainly from the demand side, which has certain limitations (Guo et al., 2020a). The primary data originates from the Alipay ecosystem, which is a single data source, and there will be improper matching problems when matching data with enterprises above the scale. To make digital finance better serve the real and green economy, it is essential to continuously refining the measurement index system for digital finance.

Secondly, the digital finance development needs to balance the financial risk prevention and promotion of the real green economy development. The majority of studies have established the beneficial impact of digital finance on economic development, including green economic growth. However, these studies often overlook the associated risks. While some scholars have highlighted the risks inherent in digital finance, their focus has primarily been on banking risks, neglecting credit and market risks. Digital finance's low access threshold makes it susceptible to risks. Additionally, when risks materialize within the financial models of Internet platforms, they can spread rapidly and be difficult to manage. There is a pressing need to accelerate reforms in financial system regulation and enhance oversight of digital finance. Therefore, this study suggests that future research focus more on the impact of digital financial risks, it aims to prevent and resolve financial risks under the premise of better-injecting vitality into the development of green economy.

Finally, this paper argues that there are several other areas where there is a need for continued research. First, from the government's perspective, does digital finance impact the government's investment and financing mode? Digital finance can provide specific financial support for the government so that it may impact the government's investment and financing activities. Additionally, what effect does digital finance have on foreign trade? Digital finance is increasingly crucial for reorganizing global factor resources, transforming the international economic structure, and altering world competitive dynamics. From the perspective of international trade, will digital finance reduce exchange rate risks? Can it promote the green development of foreign trade? Finally, the energy and environmental impacts of digital finance, along with their underlying mechanisms, require further investigation. This paper suggests that there is still more potential for research in these areas.

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