Research on the Collaborative Carbon Reduction Mechanism of Green Finance and Digital Finance

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Abstract. By integrating policy evolution analysis, market size data, and multidimensional empirical evidence, it is revealed that the two form a synergistic effect through three major paths: at the capital guidance layer, digital technology improves the accuracy of green project identification, optimizes the flow of credit and bond funds to low-carbon areas.In terms of innovation capability, the Internet of Things and big data enable full-chain carbon tracking, promoting industrial digitization and significant leaps in energy efficiency. At the risk management level, AI dynamically models and quantifies the potential for emission reduction, thereby reducing climate risk mismatches. Research has found significant spatial heterogeneity in synergistic effects: the eastern region relies on digital infrastructure to form a carbon reduction hub, while green finance contributes more prominently to emissions reduction in the western region, and the overall synergistic effect exhibits an inverted U-shaped nonlinear characteristic, positively regulated by financial regulatory efforts. Finally, policy implications are proposed: it is necessary to establish a green value accounting system, strengthen information disclosure, and specifically address the shortcomings of Digital infrastructure in less-developed regions, to maximize the potential for "Dual Synergy" emission reduction.

1 Introduction

The current global climate crisis is approaching an irreversible tipping point. The latest assessment by the Intergovernmental Panel on Climate Change (IPCC) points out that there are only 400 billion tons of CO_2 remaining in the carbon budget. If the current emission rate is maintained, humanity has only 9 years left to avoid temperature rise exceeding the safe threshold of 1.5 ° C, otherwise it will trigger irreversible melting of the Greenland ice sheet, collapse of the coral reef system and other chain ecological disasters. As the world's largest carbon emitter, China's commitment to carbon neutrality by 2060 faces severe challenges - the transition window from carbon peak to neutrality is only 30 years, and it needs to achieve an average annual emission reduction intensity of 4% -8%, far exceeding the historical average reduction rate of 1.5% for EU countries [1]. This urgency has received a rigid response in national policies: the State Council's Comprehensive Work Plan for Energy Conservation and Emission Reduction mandates that the proportion of non fossil energy reach 25% by 2030, the carbon intensity per unit of GDP be reduced by more than 65%

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compared to 2005, and the responsibility for emission reduction is incorporated into the legal framework through the Draft Carbon Neutrality Promotion Law.

In this context, green finance and digital finance, as dual driving forces, are entrusted with the key mission of solving the emission reduction dilemma. Green finance reshapes capital flows through tools like green bonds and targeted credi. Empirical evidence shows that for every 1% expansion in global green bond size, carbon emission intensity decreases by 0.21% [2]. Lei Tianyi et al. utilized panel data from 256 cities in China from 2011 to 2018 to verify that digital finance significantly reduces regional carbon emission intensity through three channels: promoting industrial progress, fostering green technology innovation, and optimizing labor resource allocation [3]. Xianwei Ling et al. further verified that blockchain technology can reduce the possibility of corporate greenwashing and enhance the impact of government subsidies [4]. Subsequently, research by Weibo Jin et al. also showed that the digital economy significantly reduces carbon emission intensity by restructuring energy consumption and promoting green technology innovation [5]. Yongfei Han's research in 2025 proves that supply chain digitization promotes green innovation through digital transformation, thereby reducing corporate carbon emissions [6]. China's "Dual Synergy" strategy is promoting digital finance as a green governance infrastructure.

This article aims to systematically deconstruct the theoretical framework of collaborative carbon reduction between green finance and digital finance. By analyzing the interaction between capital allocation and incentive mechanisms, technological innovation and industrial upgrading, information disclosure and risk assessment, and other paths, this paper elucidates the impact mechanism of regional development heterogeneity on collaborative efficiency. The research will provide theoretical support for optimizing the technology integration provisions in China's "Green Credit Guidelines" and contribute to the Chinese paradigm of "financial technology collaborative emission reduction" for global climate governance.

2 2 The development status and trends of green finance and digital finance

2.1 Development status of green finance

2.1.1 The policy history of carbon reduction

In 1995, China first proposed the concept of "green credit" in policy documents, requiring financial institutions to include environmental factors in loan approval, but a systematic framework has not yet been formed. At the 2009 UNFCCC meeting in Copenhagen, China pledged a 40-45% decrease in carbon emissions per unit of economic output relative to 2005, and for the first time included emission reduction targets in international obligations. It also clarified carbon reduction targets in the 12th Five Year Plan. From 2011 to 2016, the carbon trading pilot program was launched. The 2011 Twelfth Five-Year Plan marked China's inaugural policy mandate to institutionalize a carbon emissions trading system, with experimental platforms subsequently implemented in seven provincial-level jurisdictions encompassing Beijing and Shanghai. The Shenzhen carbon market was the first to open. Subsequently, the country introduced many relevant policies, and the green finance system was initially formed. In 2020, China announced the goal of "Carbon Peaking and Carbon Neutrality Goals", making carbon reduction the core task about green finance. Subsequently, green finance deepened its internationalization and marketization around the "dual carbon" goal.

In summary, the core of China's green finance policy is to build a framework consisting of key mechanisms involve optimal resource deployment, exposure management, and fair pricing. as well as a standard system, information disclosure, incentive mechanisms, product systems, and international cooperation. It focuses on supporting key areas such as clean energy, industrial carbon reduction, pollution prevention and control, and ecological protection. By unifying standards, strengthening environmental information disclosure, innovating carbon reduction tools, and enriching green financial products, guide funds to accurately invest in pollution reduction and carbon reduction projects. The goal is to establish an internationally leading green finance system by 2029 and achieve policy maturity by 2035, providing systematic financial support for the "dual carbon" goals and forging a Harmonious and Beautiful China

2.1.2 Market size and product types of green finance

The Chinese green finance market has formed a pattern of coordinated development of multiple tools such as green loans and green bonds, as well as ESG investment and carbon markets. The overall scale continues to expand, and the structure is optimized. According to Wind data, the main market areas are: 1. Green loans. As of the end of the first quarter of 2025, the main scale has exceeded 40 trillion yuan, with direct or indirect carbon reduction projects accounting for 67.5%. Green infrastructure upgrading, low-carbon energy transformation, and ecological protection and restoration are the three key areas where green loan funds are invested.2. Green bonds, with a domestic labeled green bond issuance scale of approximately 680 billion yuan in 2024, have a stock scale of 212 trillion yuan. China's green bond issuance scale has ranked first in the world for two consecutive years, accounting for 15% of the global market.3. In terms of ESG investment, public funds had a total of 854 products with a total size of approximately 437.9 billion yuan by the end of 2024, and wealth management products had a size of 188 billion yuan in the second quarter of 2024.4. The national carbon market will have a trading volume of 189 million tons and a turnover of 18.141 billion yuan in 2024, making it the world's largest quota trading market.5. Green insurance and other tools such as sovereign bonds are also rapidly diversifying their product categories.

At present, the total size of China's green finance market has exceeded 45 trillion yuan, showing the characteristics of "loan-led, bond innovation, and regional differentiation". The synergy between policy-driven and market mechanisms aim to establish an internationally leading system by 2029. In the future, still need to pay attention to the expansion of transformational finance, the release of potential in the central and western regions, and the alignment with international standards.

2.2 Development status of digital finance

2.2.1 Main scale of digital finance

In 2024, the scale of China's digital finance market will reach 3.2 trillion US dollars, accounting for 71% of the global total, ranking first in the world for five consecutive years. China's digital finance relies on the world's largest 5G network and cloud computing infrastructure, with a mobile payment penetration rate of 86%, accounting for 60% of the global market share, and a digital RMB transaction volume exceeding 3.2 trillion yuan.

The structure of China's digital finance sector can be divided into three parts: 1. Digital payments: as of 2025, the transaction scale will reach $12.8 trillion, and cross-border payment efficiency has been improved to the minute level;2. Digital credit: balance growth rate of 21%, the proportion of small and micro enterprise loans has increased to 42%, and AI risk control covers 85% of business 3. Digital wealth management and insurance: the scale of intelligent investment advisers exceeds 5 trillion yuan, and the Internet premium accounts for 25% [7].

The national strategy positions digital finance as one of the "five major articles" in finance, and the regulatory framework continues to improve. However, at present, the development of digital finance in China still faces challenges such as data security risks, regional imbalances, and core technological shortcomings [8]. In the future, China will promote high-quality development through technological depth, cross-border finance, and green finance innovation, with the goal of surpassing a market size of $20 trillion by 2030.

2.2.2 Innovative applications of digital finance

The innovative application of China's digital finance has been deeply integrated into five major areas: inclusive services, payment settlement, risk control supervision, technological foundation, and policy coordination. In inclusive services, digital finance can empower the high-quality development of small and medium-sized enterprises through the breadth of digital inclusive finance coverage. Financial institutions and small and medium-sized enterprises also need to spontaneously choose to implement digital inclusive finance strategies to jointly promote the development of digital inclusive finance [9,10]. Digital finance has also brought about innovation in payment methods. The exclusive product of China's digital finance development, the application scenario of digital RMB, has expanded from the public service field to the daily consumption scenario of residents, and has promoted the development of Digital China due to its high efficiency, low cost, safety, and convenience [11]. The most important innovation of digital finance lies in its policy synergy, promoting the digitization of green finance, such as carbon accounts and ESG scoring, driving product innovation, using blockchain to track carbon footprints, and improving the accuracy of green project identification. In addition, digital technology empowers the issuance of green bonds, which can more accurately quantify environmental benefits and standardize disclosure.

The innovative application of digital finance is driving the reconstruction of the financial value chain through technology, achieving inclusive and efficient financial services, controllable risks, and intelligent scenarios through technologies such as artificial intelligence, blockchain, and big data, and deeply empowering the development of the real economy and new quality productivity.

3 3 Analysis of the internal mechanism of collaborative carbon reduction between green finance and digital finance

3.1 Financial guidance and incentive mechanism

At the level of capital allocation, green digital finance enables financial institutions to direct capital more precisely toward environmentally compliant projects and businesses, boosting green investment and green bond issuance [12]. Firstly, green financial mechanisms facilitate capital allocation to low-carbon industries, including renewable power generation, energy efficiency, and environmental preservation, promoting the development of these industries with new quality productivity and low-carbon footprint characteristics [13]. Through data-driven methods, fine data analysis and management are used to improve efficiency, reduce waste, and better identify and evaluate GHG mitigation prospects and ecological persistence, promoting optimal funding allocation models [14-16].Under this funding allocation model, social and economic resources are guided to develop towards low-carbon and environmental protection, and heavy industrial enterprises are encouraged to integrate and transform towards green and low-carbon aspects. In addition, digital finance can also help enterprises achieve green transformation by promoting the digitization, intelligence, and environmental protection of infrastructure. By promoting the growth of industrial digitization and digital industries, it can promote industrial upgrading and reduce the proportion of traditional high carbon enterprises [17,18].

3.2 Technological innovation and industrial upgrading

The theory of technological empowerment emphasizes that digital technology can break through the limitations of traditional tools through data integration and process optimization. In terms of operational processes, the deep integration of digital technologies such as blockchain, Internet of Things, and big data with enterprises can achieve full chain tracking and reliable measurement of carbon emissions, providing an accurate environmental data foundation for green finance and enabling product transformation and industrial upgrading. Therefore, from the supply side of green finance, digital finance can achieve diversification and expansion of green products and provide rich and diverse service choices for the market. In addition, innovation for green technologies can improve energy and resource utilization efficiency and reduce unit carbon emissions.

3.3 Information disclosure and risk assessment

Firstly, information disclosure， based on distributed ledger technology of blockchain, a cross-subject carbon data trusted network is constructed to achieve traceability and tamper proof of the entire chain of carbon emissions data from enterprise production and supply chain flow to terminal consumption, and to solve the problems of "data silos" and information asymmetry [19]. Next, digital sustainability tools facilitate comprehensive assessment of stranded asset risks and carbon pricing exposures. Relying on the dynamic modeling capability of artificial intelligence, intelligent analysis of multidimensional sustainability metrics, specifically power usage, emission intensity, and project technology types is carried out to accurately quantify the actual emission reduction potential and "greenwashing" risks of green projects. These outputs are incorporated into loan pricing and actuarial models. Through integration with large-scale data analysis, they permit enhanced quantification of climate vulnerability for business entities and initiatives, resulting in optimized risk control measures.

3.4 Threshold effect and regional heterogeneity

The impact of green finance on regional carbon reduction has a threshold effect and exhibits different patterns with the size of the regional population. In areas with high population density and frequent daily and production activities, green finance has better carbon reduction effects. However, when the population density reaches a certain threshold, green finance is limited by other factors in the region such as economic development level, technological innovation ability, etc., and reaches a turning point, after which the carbon reduction effect of green finance no longer significantly improves, and even shows a marginal decreasing trend.

The overall carbon emission efficiency in China shows a gradient decreasing trend from east to west [20]. The collaborative carbon reduction mechanism between green finance and digital finance also exhibits significant spatial heterogeneity, but there are opposite differences in the spatial heterogeneity of the carbon reduction effects of green finance and digital finance [21]. The impact of green finance on carbon reduction varies regionally, with the western region contributing the most, followed by the central region, and the eastern region relatively smaller. Similarly, there are regional differences in the impact of digital finance on reducing carbon emissions. In the eastern region, digital finance has developed rapidly, relying on digital infrastructure to form a "green financial technology cluster" and leveraging its first mover advantage to form a stronger collaborative network hub position. However, in the central and western regions, due to insufficient industrial chain support and the loss of digital talents, the foundation of digital finance is weak. Therefore, digital finance has significantly promoted carbon reduction in the eastern region, but not in the central and western regions.

In addition, the synergistic carbon emission reduction mechanism of green finance and digital finance in the region is not simply a linear impact but exhibits an inverted "U" relationship of first increasing and then decreasing, and financial regulatory strength plays a certain role in it. In regions with higher financial regulatory strength, the synergistic relationship between the two can more significantly reduce carbon emission intensity.

In summary, the collaborative carbon reduction mechanism between green finance and digital finance has a nonlinear impact. In regions and industries with developed digital economies and more advanced and complete digital infrastructure, green finance can better promote the application of digital technologies such as blockchain and big data in reducing carbon emissions. Therefore, the collaborative carbon reduction mechanism between green finance and digital finance will be better integrated in the more developed eastern regions and high-tech industrial areas, which can significantly reduce carbon emissions and put the new quality productivity of these regions in a leading position [22].

4 Conclusion

This study summarizes the policy development history, market size, and product types of green finance, as well as the main scale and innovative applications of digital finance. It then delves into the three internal mechanisms of collaborative carbon reduction between green finance and digital finance, and explains the threshold effect of green finance on regional carbon reduction, along with spatial heterogeneity of green finance and digital finance in their respective collaborative carbon reduction efforts.

This study can provide valuable advice for policymakers and practitioners, aiming to use the "two-way empowerment" mechanism of green finance and digital finance to reduce carbon emissions and achieve China's "dual carbon" goal of low-carbon sustainable development. In order to maximize the potential of both, it is crucial to create a favorable policy environment that encourages innovation in green technology and the integration and application of digital technology in low-carbon aspects. Therefore, policymakers can consider the following policy recommendations: firstly, further promote green concepts and digital development concepts, and enhance the willingness of investors and consumers to pay for green premiums. Secondly, incorporating green value into the financial accounting system of enterprises and strengthening their information disclosure requirements, encouraging enterprises to actively promote the internalization of external environmental costs and reducing information asymmetry. Finally, strengthening the use of financial technology can enhance the precision of green and digital finance services and broaden their connotations.

Although this study summarizes the collaborative carbon reduction mechanisms of green finance and digital finance in China, the perspective still focuses solely on the domestic market, without considering the impact of international capital flows on the development of green finance and digital finance in China. The global climate crisis is an international focal point, and in the future, this study should consider how to strengthen international cooperation, break down green trade barriers, and promote the construction of a cooperative and win-win global climate governance system.

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