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Article

Measuring the Development Level and Influencing Factors of Green Finance under the Context of a Low-Carbon Economy

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ABSTRACT

Green finance (GF) is increasingly recognized as a critical instrument for facilitating the low-carbon economic transition. This study utilizes panel data of 30 Chinese provinces from 2015 to 2024, comprising 300 observations. First, an index system for assessing the level of green finance (GF) development is established using the entropy-weighting method. Subsequently, fixed-effects model is applied to examine the direct effects of per capita GDP, industrial structure upgrading, and the intensity of environmental regulation on GF development. To assess the robustness of the findings, a series of robustness checks are conducted. In addition, regional heterogeneity is examined by comparing the effects across eastern, central, and western China. The findings indicate that environmental regulation intensity exerts a substantial and robust positive effect on GF development; the negative impact of industrial structure upgrading aligns with expectations but fails to reach statistical significance; and the effects of openness to foreign trade and the share of fiscal expenditure on environmental protection are not significant. Regional differences present a more complex picture. In the eastern region, GF development is jointly driven by environmental regulation and market forces. In the central region, economic development and R&D investment play a more important role, while environmental regulation remains the dominant driving force in the western region. The study, therefore, after the analysis, suggests policy measures including promoting substantive industrial upgrading, strengthening environmental regulatory frameworks, enhancing interregional cooperation, and improving green financial market mechanisms. The findings provide empirical evidence for advancing high-quality GF development. They also contribute to achieving low-carbon economic goals.

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Research Highlights

- A provincial GF development index is constructed using the entropy method based on green credit, green bonds, and green investment indicators.
- Environmental regulation is identified as the most significant and robust driver of GF development.
- Environmental regulation and market forces jointly drive GF development in eastern China.
- Economic development and R&D investment are key determinants in central China, while environmental regulation dominates in western China.
- Policy recommendations are proposed to strengthen environmental governance, optimize industrial transformation, improve regional coordination, and enhance green financial market mechanisms.

1. Introduction

1.1. Research Background and Significance

Global warming has taken a progressive turn, making the establishment of a low-carbon economy (LCE) an even more pressing issue. China has put forward their strategic targets aiming at carbon peak and carbon neutrality, which actually means that the entire economic development model must shift towards green and low-carbon. Green finance (GF) plays the role of a link between financial capital and those low-carbon industries, which can direct social funds to green fields such as energy conservation and environmental protection or clean energy, and is a key support for achieving low-carbon economic development [1]. The GF market in China has developed rapidly. By the end of 2023, the total balance of green loans in domestic and foreign currencies in China had exceeded 30 trillion yuan, with a year-on-year growth rate of over 36%. The scale ranks first globally. Looking at green bonds, the total amount issued at home and abroad in 2023 exceeded 1.1 trillion yuan, ranking among the top green bond issuers globally for several consecutive years. Meanwhile, emerging segments of green finance, including green funds, green insurance, and carbon finance, have expanded rapidly, contributing to the initial establishment of a multi-tiered green financial system. However, there are some issues. For instance, green credit and green bonds being mainly concentrated in the developed eastern provinces, and the development among regions is actually unbalanced [2]. As for what factors are driving GF and in what direction and to what extent they are functioning. There is no consensus in the relevant research field at present. For example, whether environmental regulations can push GF forward, and whether industrial structure upgrading promotes or restrains it. The mechanisms of these core issues are not clear at present. These problems are all constraining the development of GF towards higher quality. In the context of a LCE, accurately assessing the level of GF development and identifying its key determinants are essential for designing effective and targeted policy interventions. From a theoretical perspective, this study develops a measurement framework for GF development tailored to the requirements of an LCE, thereby enriching and extending the existing literature on GF assessment. Then, through empirical analysis, reveal exactly how the various factors influencing the development of GF work, thereby improving the theoretical framework of the influencing factors. In terms of practical significance, the conclusions may provide some data basis and decision-making references for government departments when formulating relevant development policies in the context of a LCE, thereby helping to promote the coordinated advancement of GF among regions and ultimately exerting a certain driving effect on the overall green transformation of the economy and society. The practical significance of this study lies in its provision of empirical evidence for local governments to design differentiated GF promotion policies. Given the substantial regional heterogeneity we uncover, our results can directly inform the formulation of location-specific policies, thereby enhancing policy precision and effectiveness in promoting high-quality GF development.

1.2. Literature Review

Measuring the level of GF development is a fundamental issue in GF research. Early studies primarily relied on single indicators to measure GF development, such as the outstanding balance of green credit and the scale of green bond issuance, both of which represent absolute measures of GF activity. In recent years, scholars have gradually shifted to constructing multi-dimensional comprehensive evaluation index systems. Qiao et al. constructed the GF development index of the provinces along the Belt and Road Initiative from multiple perspectives including credit, bonds and insurance using the entropy method [3]. Xu et al. followed a similar approach but used principal component analysis to measure the level [4]. Li et al. extended this line of inquiry by focusing on regional disparities in GF development and examining the evolution

of these differences over time [5]. Based on the existing literature, measurement methods have indeed shifted from single-factor to comprehensive approaches, with objective weighting techniques—such as the entropy method—which minimize human subjectivity, being widely adopted [6]. However, regarding the specific selection of indicators, existing studies still vary: some employ macro-level statistics, such as the proportion of green credit in total credit; others tend to seek proxy indicators at the firm level, such as the market capitalization share of environmental protection companies. These differing approaches provide a reference framework for the subsequent construction of an indicator system in this paper.

Regarding the factors influencing the development of GF, the existing literature mainly explores multiple aspects. From an economic perspective, Shi and Shi identified economic development as a crucial determinant of GF development, while emphasizing that the relationship between the two is characterized by considerable complexity rather than a simple linear pattern [7]. Guo, on the other hand, noted that the impact of per capita GDP on GF development exhibits a threshold effect; that is, its direction and intensity vary across regions with different economic conditions [8]. With regard to policy drivers, Xu et al. provided evidence that strengthened environmental regulations significantly promote the development of green credit, highlighting the important role of policy intervention in advancing GF [9]. This validates the applicability of Porter's hypothesis in the field of GF. However, studies have cautioned that the implementation of environmental regulations varies greatly from place to place and cannot be generalized. In terms of industrial structure, Wang et al. found that the relationship between industrial upgrading and GF development is complex. Sometimes they push each other forward, and sometimes they may restrain each other [10]. The key lies in the path and quality of industrial upgrading. In terms of openness, Caetano et al. pointed out that the increase in the degree of openness does help to bring in the international standards and capital of GF, but this effect is not consistent in different regions, being obvious in some places and not so good in others [11]. In terms of fiscal support, the guiding role of government spending on environmental protection has been confirmed by some studies, but its effect has been affected by the structure and efficiency of spending [12]. International studies also corroborate these mechanisms. For instance, Caetano et al. [11] demonstrated that foreign direct investment fosters green growth only when accompanied by stringent energy transition policies, while Li et al. [13] emphasized the moderating role of fiscal decentralization in enhancing the effect of GF on regional innovation. These cross-country findings provide a useful international benchmark for our China-specific analysis.

Overall, existing research has yielded significant findings regarding the measurement of GF development levels and its influencing factors, but there is still room for further exploration. For instance, systematic examinations of these influencing factors remain insufficient; in particular, there is a relative scarcity of empirical studies that integrate multidimensional factors—such as economic, policy, and industrial factors, as well as the degree of openness—within a single analytical framework. Secondly, discussions regarding regional disparities could be further deepened. Building on the existing literature, this study employs panel data from 30 Chinese provinces spanning the period 2015–2024. First, the level of regional coordinated development is quantified using the entropy-weighting method. Subsequently, fixed-effects model is applied to systematically assess the impacts of the selected determinants and to investigate potential regional heterogeneity in their effects.

1.3. Research Content and Methods

This study focuses on the development of GF within the context of a LCE. The specific content comprises three parts: First, based on the entropy method, we construct an index to measure the level of GF development across three dimensions: green credit, green bonds, and green investment. Second, descriptive statistics and correlation analyses were conducted using interprovincial panel data to characterize the variables and examine their preliminary relationships. The fixed-effects model was subsequently employed to estimate the baseline effects. Third, robustness checks were performed by incorporating the first-order lagged terms of the core explanatory variables. Furthermore, heterogeneity analysis was conducted by classifying provinces into eastern, central, and western regions, thereby identifying potential regional variations in the effects of the influencing factors.

The contributions of this article are as follows: First, methodologically, we construct a comprehensive GF development index using the entropy method, which objectively determines indicator weights and avoids subjective bias—an improvement over single-indicator or principal-component approaches used in earlier studies. Second, econometrically, we employ fixed-effects model that simultaneously controls for unobservable provincial heterogeneity and time-specific macroeconomic shocks, yielding more consistent estimates than pooled OLS or random-effects specifications. Third, empirically, we go beyond national-level analysis by systematically examining regional heterogeneity across eastern, central, and western China, an aspect often overlooked in previous studies. This regional decomposition allows us to identify differentiated driving mechanisms and offer more targeted policy recommendations.

This study employs a combined approach of literature review and empirical research:

Literature review: This method involves reviewing relevant theories on the LCE and GF, summarizing measurement methods and influencing factors for GF development levels, thereby laying a theoretical foundation for the study.

Empirical research: Based on inter-provincial panel data, data processing and model regression were con-

ducted using Stata software, and then the research hypotheses were verified through descriptive statistics, correlation analysis, benchmark regression, robustness test and heterogeneity analysis. By identifying region-specific drivers, our findings directly support the achievement of the United Nations Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action), and provide actionable evidence for balancing economic growth with ecological resilience.

2. Theoretical Framework and Research Hypotheses

2.1. Theoretical Foundations

LCE is characterized by reduced energy consumption, pollution, and carbon emissions, while fostering sustainable economic growth through technological innovation, industrial transformation, and policy support [13]. GF serves as a critical financial mechanism for facilitating the transition to an LCE. By directing capital toward low-carbon and environmentally sustainable industries, GF enhances the efficiency of resource allocation, while simultaneously constraining investment in high-energy-consuming and highly polluting sectors. In doing so, it promotes the low-carbon transformation of the broader economy.

According to Porter's hypothesis, appropriate environmental regulations do not necessarily bring additional costs to businesses. Instead, they stimulate green technological innovation, which can offset compliance costs and ultimately enhance corporate competitiveness. In the context of a LCE, as the intensity of environmental regulations increases, the demand for green transformation among enterprises will increase, and this demand will drive the supply of more green financial products, thereby promoting the development of the entire GF [14].

Industrial structure upgrading theory suggests that economic development is typically accompanied by the progressive transformation of the industrial structure, often reflected in a rising share of the tertiary sector. Such transformation is generally expected to enhance resource allocation efficiency and promote sustainable economic growth. However, the effects of industrial upgrading are not necessarily uniform. If the upgrading process relies excessively on the expansion of energy-intensive industries while neglecting the development of green and low-carbon sectors, it may hinder the growth of GF by reinforcing carbon-intensive investment patterns and weakening demand for green financial services [15]. Only when the process of industrial upgrading is truly combined with the goal of low-carbon transformation can the real demand for GF be effectively generated.

At the core of the theory of government intervention lies the emphasis on the government's use of fiscal spending and policy guidance to address the market's own malfunctions. Especially in the context of a LCE, government fiscal spending on environmental protection actually provides the necessary financial support for the development of GF [16]. This kind of support reduces the risks of related businesses and thus stimulates the enthusiasm of market entities to participate.

2.2. Research Hypotheses

To identify the key determinants of GF development in the context of a LCE, this study develops a set of research hypotheses based on the existing literature and relevant theoretical foundations.

The Porter hypothesis can be used to understand the relationship between environmental regulation and green finance. This hypothesis suggests that appropriate environmental regulation can motivate companies to engage in green technology innovation. Such innovation increases the demand for financial resources to support environmentally sustainable activities, thereby fostering the development of GF. However, there are also studies suggesting that if regulation is too strict, the cost pressure on enterprises will rise in the short term, potentially squeezing out investments that should be used in the green sector. Judging from the actual situation in our country in recent years, the constantly improving environmental policy system has actually been sending a very strong signal of green transformation to the market. Therefore, this paper argues that, against the backdrop of a LCE, increased environmental regulation will significantly drive enterprises to increase their financing needs for activities such as green technology upgrades and environmental protection projects, thereby propelling the development of GF.

H1: There is a positive correlation between the strength of environmental regulations and the development of GF. Strict environmental regulations can compel enterprises to undergo green transformation, thereby increasing demand for GF and driving its development.

Regarding the impact of industrial structure upgrading, there are differing viewpoints. Some scholars argue that the upgrading of the industrial structure—which implies an increased share of the high-value-added, low-energy-consumption tertiary sector—will naturally generate greater demand for GF. However, another viewpoint emphasizes that if the so-called upgrade merely remains superficial in terms of statistics—while in reality it continues to expand on a large scale through high-energy-consuming and high-polluting industries, or merely relocates heavy industries to the central and western regions—the result could lead to a carbon lock-in phenomenon, thereby suppressing the genuine demand for GF. Considering the potential for such issues to arise in some regions of China during the early stages of industrial upgrading, this paper leans toward the latter view.

H2: Industrial structure upgrading may exert a negative effect on the development of GF when it is not accompanied

by decarbonization. Specifically, an industrial structure characterized by a high concentration of energy-intensive industries may constrain the expansion of GF by reinforcing demand for carbon-intensive investment and reducing incentives for green financial activities.

Regarding government behavior, government intervention theory provides a foundation for understanding the role of fiscal expenditure. Existing research widely confirms that government financial support is a key driver in the early stages of GF development. Fiscal spending on environmental protection can not only directly inject capital into green projects, but also play a leverage role through risk compensation and interest subsidies, thereby guiding social funds to flow into the green sector and reducing the risk expectations of market entities.

H3: The proportion of fiscal environmental spending is positively correlated with the development of GF. Government fiscal spending on environmental protection can guide social capital to flow into the green sector and provide support for the development of GF.

Regarding the impact of opening up to the outside world, existing research conclusions are relatively consistent. Opening up is often seen as a channel to bring in advanced GF concepts, standards and capital from around the world. The entry of foreign capital can intensify market competition, stimulate the innovation vitality of domestic financial institutions, and at the same time, alignment with international standards can help improve the standardization level of China's GF market.

H4: The degree of openness is positively correlated with the development of GF. Opening up to the outside world can introduce advanced international concepts and resources of low-carbon finance and stimulate the vitality of the GF market.

Finally, studies on the influencing factors of GF have pointed out that China has a vast territory, and there are significant differences in economic development levels, industrial structures, and policy implementation among different regions. This difference may lead to the driving effect of the core variable showing very different effects in different regions. For example, market forces may be more effective in the east, while government intervention may be more prominent in the Midwest.

H5: The impact of key determinants on GF development exhibits significant regional heterogeneity. Due to the differences in economic development level, industrial structure, and resource endowment among eastern, central, and western China, the intensity and direction of these impacts are expected to vary in different regions.

The mechanism diagram of this article is shown in Figure 1.

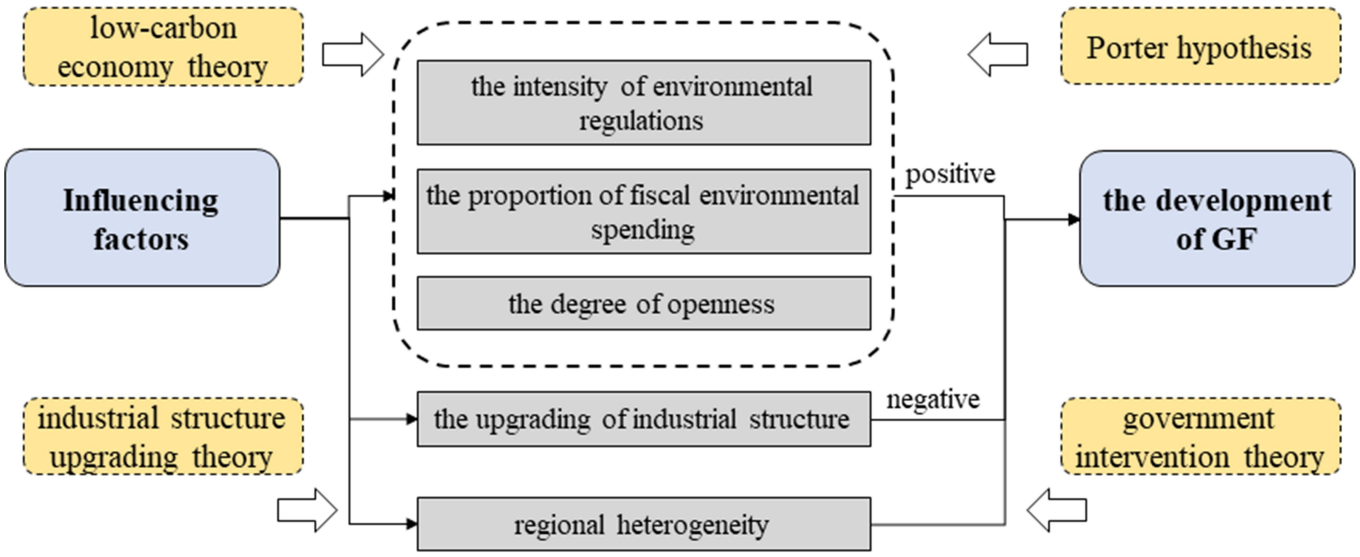

Figure 1. Research mechanism diagram.

3. Research Design

3.1. Data Sources

This study employs an interprovincial panel data from China as its sample. Due to severe data gaps for Tibet, that region was excluded from the analysis. The sample period spans 2015–2024, comprising a total of 300 observations. The data were sourced from the China Statistical Yearbook, the China Science and Technology Statistical Yearbook, the CSMAR database, and the Wind database. Some missing data were filled in using interpolation.

3.2. Variable Selection

3.2.1. Dependent Variable: Level of GF Development (gf)

To capture the level of GF development in the context of a low-carbon economy, this study constructs a composite GF index using the entropy-weighting method. The indicator system is developed from three dimensions: green credit, green bonds, and green investment.

Green credit. This dimension is proxied by the ratio of loans extended to environmental protection enterprises to the total loans of listed companies, reflecting the extent to which financial institutions allocate credit resources to environmentally sustainable industries.

Green bonds. This dimension is represented by the share of the market capitalization of environmental protection enterprises in the total market capitalization of listed companies, capturing the capital market's support for low-carbon and environmentally friendly industries.

Green investment. This dimension is measured by the proportion of industrial pollution control investment to regional GDP, reflecting the investment intensity of environmental protection and energy-saving activities.

All three indicators are positive indicators. First, the original indicators undergo Min–Max standardization to eliminate the influence of units. Then, based on the standardized data from 300 observations, objective weighting is performed using the entropy method. Finally, the standardized indicators are weighted and summed to obtain the GF development level index gf, calculated as follows:

$$gf_{it} = w_1 \times X_{1,it} + w_2 \times X_{2,it} + w_3 \times X_{3,it} \quad (1)$$

where $X_{1,it}$, $X_{2,it}$, and $X_{3,it}$ represent the Min–Max standardized values of the green credit, green bond, and green investment indicators for the ith province in the tth year, respectively. w_1, w_2, and w_3 are the weights, calculated as 0.3175, 0.2939, and 0.3886, respectively.

3.2.2. Explanatory Variables

The definitions of relevant variables and the measurement indicators are shown in Table 1.

Table 1. Variable definitions and measurement indicators.

Variable Name	Variable Symbol	Measurement Indicator
Log of GDP per capita	ln*pgdp*	Natural logarithm of per capita regional GDP
Industrial Structure Upgrading	*struc*	Ratio of value added in the tertiary sector to that in the secondary sector
Intensity of environmental regulations	*er*	Proportion of industrial pollution control investment in regional GDP
R&D intensity	*rd*	Share of local government science and technology expenditures in general public budget expenditures
Share of value added by the financial sector	*fin*	Share of Financial Sector Value Added in Regional Gross Domestic Product
Urbanization rate	*urban*	The proportion of the urban permanent resident population in the total population
Degree of openness	*open*	Total imports and exports as a percentage of regional GDP
Share of fiscal spending on environmental protection	*fiscal_env*	Share of local fiscal environmental protection expenditure in general public budget expenditure

3.2.3. Model Construction

The model is specified as follows:

$$\begin{aligned} gf_{it} &= \alpha_0 + \alpha_1 \ln pgdp_{it} + \alpha_2 struc_{it} + \alpha_3 er_{it} + \alpha_4 rd_{it} \\ &\quad + \alpha_5 fin_{it} + \alpha_6 urban_{it} + \alpha_7 open_{it} \\ &\quad + \alpha_8 fiscal\_env_{it} + \mu_i + \lambda_t + \varepsilon_{it} \end{aligned} \tag{2}$$

where:

gf_{it} denotes the GF development index for the ith province in the tth year;

α_0 where is the constant term, and $\alpha_1 - \alpha_8$ are the regression coefficients for each explanatory variable;

μ_i represents the provincial fixed effect, controlling for unobservable factors at the provincial level;

ε_{it} represents the random error term.

λ_t denotes the time fixed effect, controlling for common shocks at the time level;

4. Empirical Analysis

4.1. Descriptive Statistics

To better present the basic characteristics of each variable, this paper conducts descriptive statistics on the level of GF development and the various influencing factors, with the results shown in Table 2.

The mean value of the GF development level (*gf*) is 0.199, with a standard deviation of 0.136. The significant gap between the maximum and minimum values indicates that there are certain differences in the GF development levels among provinces during the sample period, which aligns with the reality of uneven regional development in GF in our country.

The mean value of per capita GDP (ln*pgdp*) is 11.09, with a standard deviation of 0.428. The variable ranges from 10.16 to 12.34, indicating substantial variation in economic development levels across provinces. This range in logarithmic values reflects significant disparities in regional economic development levels across China, which is also a key factor influencing regional disparities in GF development.

The mean value of industrial structure upgrading (*struc*) is 1.526, indicating that the average value-added of the tertiary sector in the sample provinces exceeds that of the secondary sector, suggesting an overall trend toward industrial structure upgrading. The standard deviation of 0.809 suggests substantial variation in the pace of industrial structure upgrading across provinces.

The mean value for environmental regulation intensity (*er*) is 0.0007, with a standard deviation of 0.0008 and a maximum value of 0.0076. This indicates that there are quite significant differences in the level of investment in industrial pollution control among the provinces, with a few provinces having investment intensities far exceeding the average level.

The mean value of R&D intensity (*rd*) is 0.0238, with a maximum of 0.0706 and a minimum of 0.0047. This reflects significant disparities in science and technology investment across provinces; the R&D intensity in the more economically developed eastern provinces is clearly much higher than that in the central and western regions.

The average financial value added as a proportion (*fin*) is 0.0792, and the standard deviation is 0.0355. This indicates that although there are certain differences in the financial sector's share of each province's economy, the overall degree of dispersion is acceptable and not particularly prominent.

The average urban rate is 0.620, indicating that the average urban rate in the sample provinces has exceeded 60%. However, the gap between the minimum of 0.400 and the maximum of 0.912 reveals considerable imbalances in the urbanization process across different regions.

The mean of openness is 0.246 and the standard deviation is 0.232. This indicates significant differences in the degree of dependence on foreign trade among provinces, revealing the fact that coastal provinces are much more open to the outside world than inland provinces.

Table 2. Descriptive statistics.

Variable	Number of Observations	Mean	Standard Deviation	Min	Max
gf	300	0.199	0.136	0.0124	0.639
ln*pgdp*	300	11.09	0.428	10.16	12.34
struc	300	1.526	0.809	0.751	5.881
er	300	0.0007	0.0008	0.0000	0.0076
rd	300	0.0238	0.0165	0.0047	0.0706
fin	300	0.0792	0.0355	0.0359	0.226
urban	300	0.620	0.110	0.400	0.912
open	300	0.246	0.232	0.0076	1.041
fiscal_env	300	0.0075	0.0047	0.0018	0.0361

The mean value of fiscal expenditure on environmental protection (*fiscal_env*) is 0.0075, indicating that, on average, environmental protection expenditure accounts for a relatively small share of total fiscal resources. The overall level is notably low, while the maximum value of 0.0361 indicates a substantial disparity in the level of fiscal investment in environmental protection across different provinces.

4.2. Correlation Analysis

To preliminarily assess the linear relationships among variables and avoid the impact of multicollinearity on the accuracy of regression results, this study conducted a correlation analysis on all variables. The results are shown in Table 3.

Based on the results of the correlation analysis:

Correlations among core variables: The intensity of environmental regulation (*er*) is significantly positively correlated with the level of GF development (*gf*), which preliminarily supports Research Hypothesis 1; the sophistication of industrial structure (*struc*) is significantly negatively correlated with the level of GF development (*gf*), which preliminarily validates the directional expectation of Research Hypothesis 2. The correlation coefficient between the share of fiscal environmental expenditure (*fiscal_env*) and gf is positive but not significant, and requires further testing through regression analysis. Before conducting the empirical analysis section, we first drew box plot scatter plots and presented them in the form of line fitting graphs, as shown in Figures 2 and 3.

Table 3. Correlation matrix.

Variable	*gf*	ln*pgdp*	*struc*	*er*	*rd*	*fin*	*urban*	*open*	*fiscal_env*
gf	1.00								
ln*pgdp*	−0.135**	1.00							
struc	−0.209***	0.437***	1.00						
er	0.279***	−0.325***	−0.230***	1.00					
rd	−0.130**	0.716***	0.407***	−0.252***	1.00				
fin	−0.156***	0.554***	0.728***	−0.079	0.479***	1.00			
urban	−0.094	0.855***	0.546***	−0.204***	0.594***	0.763***	1.00		
open	−0.242***	0.738***	0.542***	−0.215***	0.740***	0.754***	0.837***	1.00	
fiscal_env	0.040	−0.384***	0.057	0.326***	−0.399***	0.087	−0.211***	−0.355***	1.00

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$; controlling for province and time fixed effects.

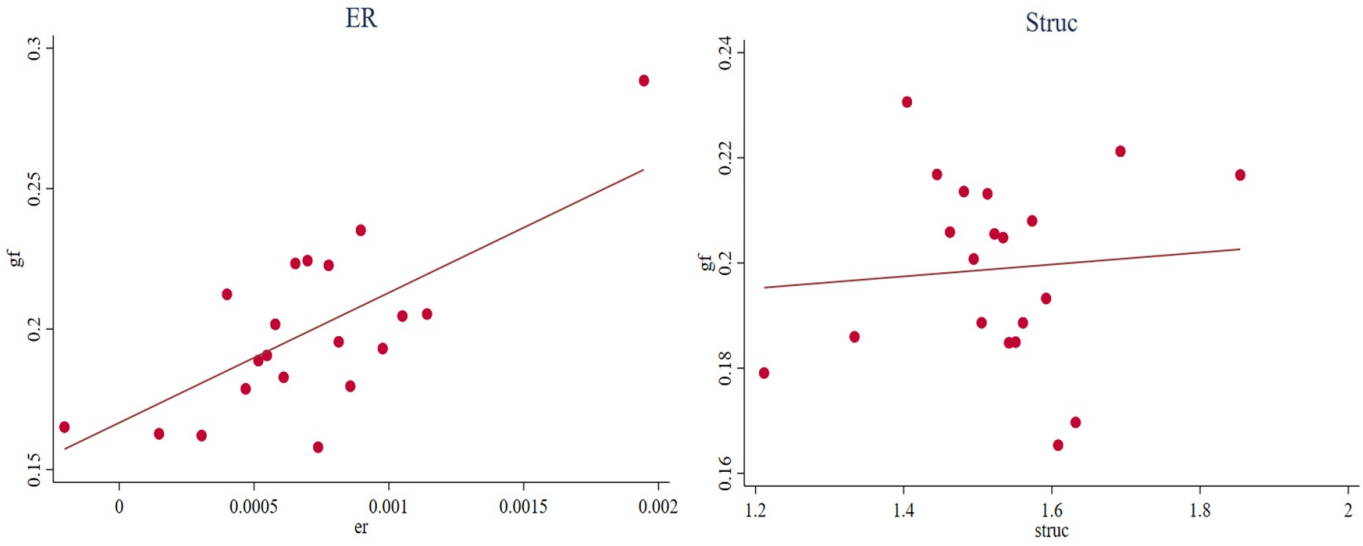

Figure 2. *Struc* and *gf*, *er* and *gf* linear fitting graphs.

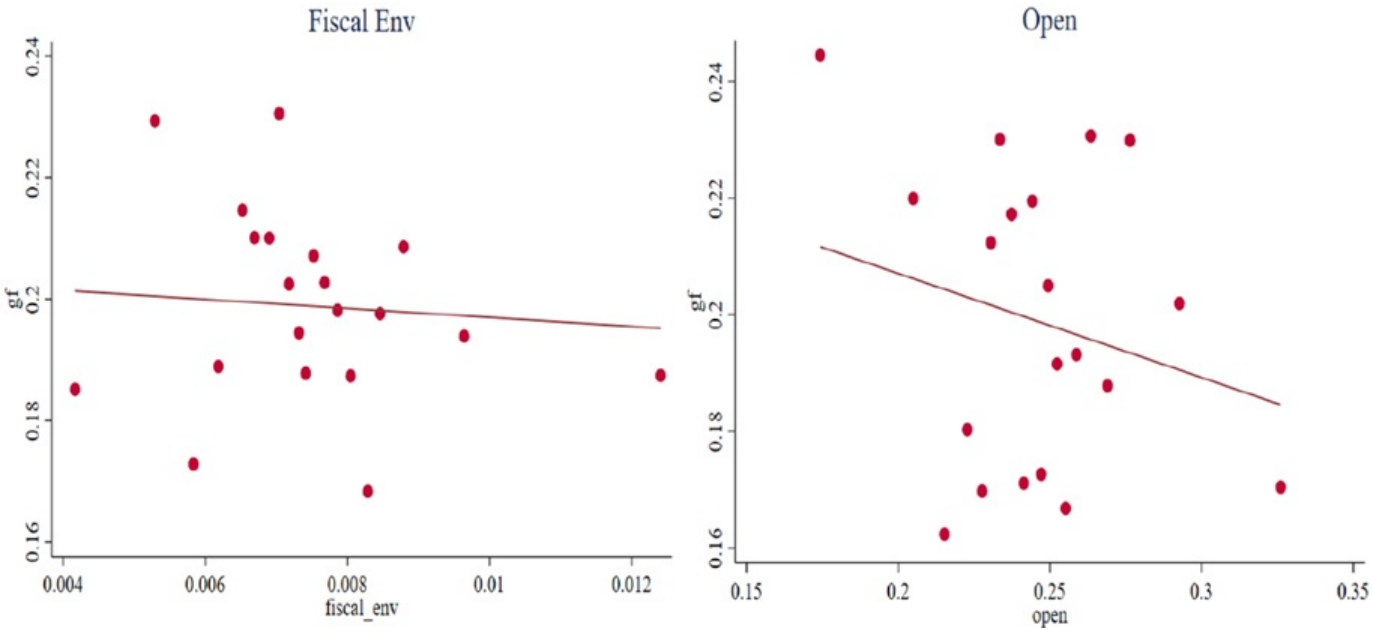

Figure 3. *Fiscal_env* and *gf*, *open* and *gf* linear fitting graphs.

Multicollinearity Test: There is a high degree of correlation among some explanatory variables. For example, the correlation coefficient between the ln*pgdp* and the *urban* is 0.855, while the correlation coefficient between the degree of openness (*open*) and the urbanization rate (*urban*) is 0.837.

4.3. Baseline Regression Analysis

This study employs a fixed-effects model to conduct a benchmark regression analysis to examine the impact of various factors on GF development in the context of a LCE. The regression results are shown in Table 4.

The baseline regression results indicate:

The coefficient for environmental regulatory intensity is significantly positive at the 1% level, confirming Research Hypothesis 1. This result is consistent with the Porter hypothesis. Appropriate environmental regulation creates innovation incentives for enterprises. This prompts them to increase investment in green technology R&D and environmental protection facilities. The resulting demand for green transition directly drives demand for green financial products such as green credit and green bonds. Thus, environmental regulation promotes the entire GF development process. In terms of economic magnitude, environmental regulation exhibits the strongest effect among all explanatory variables. Specifically, for every one-unit increase in the intensity of environmental regulation, the GF Development Index increases by approximately 0.464 units. This indicates that in the context of a LCE, environmental regulation has become the most core force driving the development of GF.

The coefficient on the logarithm of per capita GDP (ln*pgdp*) is positive and statistically significant at the 10% level, with an estimated value of 0.129. This implies that there is some positive boost to GF from the level of economic development. Where the economy is more developed, residents tend to have higher expectations for environmental quality, enterprises are more likely to have awareness of green transformation, and financial markets themselves are more capable of supporting those green projects. However, the significance of this variable is not high, having only passed the 10% significance threshold; therefore, the promotional effect of economic development on GF should be viewed with caution from a statistical perspective, as there may be a more complex nonlinear relationship between the two.

The coefficient for industrial structure upgrading is negative, consistent with the directional expectation of Research Hypothesis 2 but failing to pass the significance test. This result warrants further consideration: In terms of direction, the upgrading of industrial structure exhibits a certain inhibitory tendency on current GF development. Although the coefficient of industrial structure upgrading is negative, it does not reach conventional levels of statistical significance. One possible explanation is that industrial upgrading, when reflected primarily in an increased share of the tertiary sector, does not necessarily imply a transition toward low-carbon industries. If growth in the service sector is driven largely by energy-intensive activities or real-estate-related industries, rather than by green and low-carbon sectors, the resulting structural transformation may fail to generate effective demand for GF and could even divert resources away from sustainable investment. Nevertheless, the lack of statistical significance suggests that this inhibitory effect is not robust within the current sample period. Another plausible explanation is that the influence of industrial structure upgrading on GF is subject to time lags, with its effects emerging only over a longer

horizon. Furthermore, significant differences in the quality and specific pathways of industrial upgrading across provinces may have diluted the overall effect; another factor is that there is structural differentiation within the tertiary sector itself, as the energy consumption characteristics and financing needs of traditional service industries differ sharply from those of modern green service industries.

The coefficient for the proportion of fiscal environmental protection expenditure is negative and not significant, and Hypothesis 3 was not validated. This result is inconsistent with the general expectations of government intervention theory but aligns with the findings of some empirical studies. A possible explanation is that current relevant expenditures by local governments are directed more toward public environmental governance rather than directly guiding the allocation of financial resources to green industries, making it difficult to generate a direct driving effect on GF; Another factor is that the transmission mechanism for such expenditures is inherently lengthy, and their effects likely exhibit significant lags, preventing the immediate manifestation of current investments in the development of GF; simultaneously, against the backdrop of continuously growing total environmental protection expenditures, there are shortcomings in the efficiency and precision of their utilization, leading to a situation where funds are spent but the results are limited. This finding indicates that merely expanding the scale of environmental protection spending is insufficient to drive the advancement of GF; optimizing the expenditure structure and improving utilization efficiency are equally critical aspects that cannot be overlooked.

The coefficient of openness is negative and not significant, and hypothesis 4 of the study fails to pass the verification. Although the *p*-value was close to the 10% significance level, it was in the opposite direction of theoretical expectations. This reflects the phased characteristics of the development of China's GF market: at present, domestic GF is still mainly supported by policy-driven and domestic financing, the threshold for foreign capital entry is relatively high, the introduction of internationally accepted GF concepts and related standards is still at early stage, and the induced effects of opening up to the outside world have not been fully released. It is also worth noting that international trade frictions in recent years and the uncertainties facing the global economy may have, to some extent, dampened the enthusiasm of foreign capital to participate in the construction of domestic green financial markets.

The coefficients for the intensity of R&D investment, the proportion of added value of the financial industry, and the urbanization rate have not passed the significance test. This suggests that, after controlling for fixed effects by province and time, the explanatory power of these factors on their own is actually very weak, and their impact on GF may not be direct, perhaps only manifested through interaction with other variables. This shows that the driving mechanism of GF development itself is systematic and complex. Economic growth or financial deepening alone is not enough to bring prosperity, and the role of policy guidance and institutional design is difficult to be replaced.

Overall, within the context of a LCE, the intensity of environmental regulations has become the most critical factor driving the development of GF. In contrast, the roles of industrial restructuring, fiscal expenditure, and openness to the outside world have not yet been fully demonstrated. The model's intra-group R^2 is 0.135, which is an acceptable level for provincial panel data, indicating that, after controlling for two-way fixed effects, the explanatory variables possess basic explanatory power for the dependent variable. However, the development of GF is likely also influenced by other macroeconomic factors and regional characteristics not included in the model, which provides a direction for subsequent heterogeneity analysis.

Table 4. Results of the two-way fixed-effects baseline regression.

Variable	Coefficient (Coef.)	Standard Error (Std. Err.)	*t*-Value	$P > \|t\|$
ln*pgdp*	0.129*	0.0684	1.89	0.060
struc	−0.0373	0.0539	−0.69	0.490
er	46.41***	9.870	4.70	0.000
rd	1.320	1.489	0.89	0.376
fin	−0.700	1.035	−0.68	0.500
urban	−0.660	0.431	−1.53	0.128
open	−0.211	0.155	−1.36	0.174
fiscal_env	−1.287	2.273	−0.57	0.572
_cons	−0.708	0.543	−1.30	0.194

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$; provincial and time fixed effects controlled; sample size = 300, R^2 within = 0.135, number of provinces = 30.

4.4. Robustness Tests

To ensure the reliability of the baseline regression results, this study conducted robustness tests by incorporating one-period lags of the core explanatory variables. The use of one-period lagged variables effectively mitigates potential endogeneity issues and prevents reverse causality from interfering with the regression results. The regression results are shown in Table 5.

The significance of the core variables was largely consistent: the environmental regulation intensity lagged one period variable *(L_er)* remained significantly positive at the 5% level, with a coefficient value of 20.84, verifying that the positive driving effect of environmental regulation on the development of GF has strong robustness.

The coefficient of the industrial structure upgrading lagging phase variable *(L_struc)* turned positive, but still failed the significance test, consistent with the conclusion of insignificance in the benchmark regression, indicating that the impact of industrial structure upgrading on GF development is statistically unstable.

The proportion of *fiscal_env* was not significant in the robustness test, consistent with the conclusion of the benchmark regression.

In summary, the benchmark regression results remain robust across a range of robustness checks. In particular, the positive association between environmental regulation intensity and GF development is consistently supported, further strengthening the reliability of the research findings.

4.5. Heterogeneity Analysis

Given the imbalance in regional economic development in our country, the influencing factors of GF development may vary in different regions. This paper divided the samples into three major regions—eastern, central, and western—for grouped regression analysis, and the results are shown in Table 6.

Heterogeneity analysis results showed significant regional differences in the effects of each influencing factor on GF development, verifying study Hypothesis 5 specifically:

Eastern Region: Environmental regulation intensity (*er*) is positive at the 1% level, *rd* is negative at the 5% level, urbanization rate (*urban*) is negative at the 5% level, and logarithm of GDP per capita (ln*pgdp*) is positive at the 1% level.

These findings indicate that the development of GF in the eastern region is characterized by an interplay between policy drivers and market factors; however, R&D investment may exhibit a certain crowding-out effect, and the rapid urbanization process also exerts a degree of restraint on GF.

Central Region: The ln*pgdp* is significantly positive at the 5% level; R&D intensity (*rd*) is significantly positive at the 5% level; and the urbanization rate (*urban*) is significantly negative at the 5% level. This implies that in the central region, improvements in economic levels and investments in scientific and technological R&D jointly constitute the key drivers of GF development, while the rapid advancement of urbanization may currently exert a certain inhibitory effect on the development of GF.

The coefficient of *er* is positive and statistically significant at the 5% level, whereas the remaining explanatory variables are not statistically significant. This finding suggests that environmental regulation plays a particularly important role in promoting GF development in the western region, highlighting the importance of policy-driven mechanisms in areas where market-based drivers may be relatively underdeveloped.

Table 5. Robustness test (one-period lags) regression results.

Variable	Coefficient (Coef.)	Standard Error (Std. Err.)	*t*-Value	$P > \|t\|$
*L_*ln*pgdp*	0.0760	0.0729	1.04	0.298
L_struc	0.0116	0.0612	0.19	0.849
L_er	24.84**	9.441	2.63	0.009
rd	0.820	1.513	0.54	0.588
fin	−1.536	1.151	−1.33	0.184
urban	−0.667	0.595	−1.12	0.263
open	−0.240	0.176	−1.36	0.175
fiscal_env	−3.883	2.452	−1.58	0.116
_cons	−0.0706	0.519	−0.14	0.892

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$; *L_* denotes the variable lagged by one period; provincial and time fixed effects have been controlled; sample size = 270, R^2 within the model = 0.066, number of provinces = 30.

Table 6. Heterogeneity regression results for eastern, central, and western regions.

Variable	Eastern Region	Central Region	Western Region
ln*pgdp*	0.216***	0.424**	0.00145
	(0.001)	(0.017)	(0.991)
struc	0.0385	0.00787	−0.0534
	(0.161)	(0.925)	(0.692)
er	55.44***	20.32	48.47**
	(0.000)	(0.536)	(0.011)
rd	−3.308**	4.100**	9.353
	(0.015)	(0.015)	(0.156)
fin	−1.423	1.929	−0.103
	(0.101)	(0.389)	(0.966)
urban	−1.629***	−4.445**	−0.00152
	(0.005)	(0.015)	(0.998)
open	−0.104	0.178	0.115
	(0.336)	(0.701)	(0.870)
fiscal_env	−2.453	−5.792	−1.883
	(0.247)	(0.310)	(0.614)
_cons	−0.919**	−2.071	0.108
	(0.040)	(0.138)	(0.929)
Sample size	110	80	110
Intra-group R^2	0.607	0.201	0.210
Number of provinces	11	8	11

Note: *P*-values are shown in parentheses; *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$; fixed effects for province and time have been controlled.

This paper systematically examines the actual impact of factors on the GF within the specific context of a LCE through a series of empirical methods, including descriptive statistics, correlation analysis, benchmark regression, and robustness and heterogeneity tests. The results indicate that environmental regulation intensity exerts a significant and robust positive effect on GF development, providing empirical support for the theoretical predictions of the Porter Hypothesis. Although the estimated coefficient for industrial structure upgrading is consistent with the expected direction, its effect does not reach conventional levels of statistical significance. Similarly, the roles of the proportion of fiscal environmental protection expenditure and the degree of openness were also not statistically significant. From the heterogeneity analysis, the three regions exhibit distinct divergences in the key factors driving GF development. The Eastern region is more influenced by the interplay of policy and market forces, while the Central region relies primarily on sustained R&D investment. For the Western region, environmental regulatory policies remain the most critical driving force at present. The results obtained through the empirical analysis in this chapter provide a solid data foundation for formulating more targeted policy recommendations in the future.

5. Research Conclusions and Policy Recommendations

5.1. Research Conclusions

Based on panel data covering 30 provinces across the country over the decade from 2015 to 2024, this paper first constructs a set of comprehensive indicators to measure the level of GF development using the entropy method, and then empirically tests the actual effects of each potential influencing factor with the aid of the bidirectional fixed effects model, from which several key findings are obtained.

The intensity of environmental regulation has been proven to be the most critical force driving the development of GF at the current stage. The results of the benchmark regression clearly show that the coefficient remains posi-

tive at the one percent significance level, reaching 46.41. Even with the introduction of a one-period lag variable in the robustness test, the positive push for the intensity of environmental regulation is still significant at the 5% level, which to some extent echoes the theoretical inferences of the Porter hypothesis, suggesting that strict and well-designed environmental regulatory measures at this stage can indeed form a reverse push mechanism that forces enterprises to shift to greener production models, thereby sustaining it continues to give rise to real demand for green financial products and services.

Regarding industrial structure upgrading, the estimated coefficient is negative, which aligns with our directional expectation, but it is statistically insignificant at conventional levels. Therefore, we cannot draw a robust conclusion that industrial upgrading suppresses GF development. This null finding may stem from measurement issues—using the tertiary-to-secondary ratio may obscure intra-sectoral heterogeneity—or from lagged effects that require longer observation periods. We thus interpret this result with caution and suggest that future research use more disaggregated sectoral data to further investigate this relationship.

The increase in the proportion of fiscal spending for environmental protection should theoretically give a positive boost to the development of GF, but our empirical results do not support this assumption, and the impact has not passed the significance test. It shows that at the current stage of development, relying solely on expanding the overall scale of fiscal spending on environmental protection to boost GF has limited effects. In contrast, how to optimize the specific usage structure of these funds and improve their utilization efficiency may be a more urgent issue.

The effect of openness is also found to be statistically insignificant. This result may reflect the current stage of development of China's GF market, which remains largely policy-driven and continues to rely predominantly on domestic financing channels. In addition, the logarithmic form of per capita GDP shows a positive boost to GF at the 10% level, but its statistical significance is relatively weak. This reflects from the side the considerable systematicity and complexity of the internal mechanisms that drive GF development, which cannot be determined by a single factor.

Furthermore, the findings reveal substantial regional heterogeneity in the effects of the examined determinants, indicating that the drivers of GF development differ across regions. Specifically, the development of GF in the eastern region is driven by both environmental regulatory forces and market forces; in the central region, research and development investment is the main driving force; and in the western region, the direct driving effect of environmental regulatory policies themselves is more prominent and crucial.

5.2. Policy Recommendations

Drawing on both the theoretical analysis and empirical evidence, and taking into account the pronounced regional disparities in China's economic development, this study proposes a series of policy recommendations aimed at promoting the high-quality development of GF. These recommendations focus on accelerating low-carbon industrial transformation, strengthening environmental policy guidance, enhancing interregional coordination, and further improving market-based mechanisms for green finance.

To optimize the industrial structure and remove barriers to green development, we propose two coordinated actions. First, incorporate green criteria such as carbon intensity and energy efficiency into the industry al upgrading evaluation system, and enforce stricter technological renovation requirements for energy-intensive sectors. Second, formulate differentiated regional industrial policies: eastern regions should focus on high-end green manufacturing and green services; central regions should prioritize the green transformation of traditional industries; and western regions should develop distinctive green industries based on local resource endowments, such as clean energy or eco-tourism, while avoiding the relocation of highly polluting industries.

To strengthen the guiding role of policy, it is necessary to solidify the foundation for GF development. The empirical results of this paper indicate that the intensity of environmental regulations exerts a significant and robust positive driving effect on GF development, making it the most critical policy tool for promoting GF at present. This finding provides a relatively clear direction for policymakers: against the backdrop of a LCE, the guiding function of environmental regulations should be further strengthened.

First, a differentiated system of environmental regulation needs to be established. For instance, stricter environmental access standards could be set in the eastern region; This would force companies to meet compliance requirements through green technological innovation and environmental investment, thereby generating a sustained demand for GF. The central and western regions may be able to moderately ease the intensity of regulation in the short term, but it needs to be accompanied by incentive policies such as subsidies and tax breaks to guide business owners to shift towards green production models. Secondly, it is necessary to establish a dynamic adjustment mechanism for environmental standards to revise and raise emission standards in a timely manner in accordance with the actual situation of industrial upgrading and technological progress in environmental protection, in order to maintain the continuous driving force of regulation. Finally, in terms of fiscal spending on environmental protection, although its positive effect did not pass the significance test in the benchmark regression, this does not mean that fiscal input is unimportant, but rather that the expenditure structure and usage efficiency need to be optimized. It is suggested that environmental protection funds be allocated more precisely to green financial infrastructure, such as green project libraries and environmental information platforms. Risk compensation mechanisms. The goal is to leverage more social capital into the green sector through fiscal funds, rather than simply expanding spend-

ing itself. The results of the heterogeneity analysis show that there are quite obvious differences in the key factors driving GF development among the eastern, central and western regions: For the eastern region, environmental regulations and market forces together constitute the main driving force; The central region is more dependent on research and development investment; In the west, the role of environmental regulatory policies is particularly prominent. This region-specific pattern actually provides a relatively clear entry point for promoting coordinated development among regions.

On the one hand, greater emphasis should be placed on strengthening interregional collaboration to reduce disparities in GF development. A coordinated partnership mechanism linking the eastern, central, and western regions could facilitate the transfer of capital, technology, and managerial expertise. In particular, financial institutions and established green enterprises in the eastern region could expand cooperation with their counterparts in the central and western regions through investment, technology diffusion, and talent exchange, thereby supporting the development of local green industries and enhancing regional GF capacity. Such collaboration would not only promote the diffusion of advanced green financial practices but also accelerate the formation of regionally integrated green industrial value chains. On the other hand, efforts should be made to strengthen the institutional and informational infrastructure underpinning GF development in the central and western regions. Policy support for existing GF reform and innovation pilot zones should be enhanced, while regional green project databases, environmental credit evaluation systems, and environmental information disclosure platforms should be further developed. Given the relatively limited availability and quality of environmental data in some western provinces, improving cross-regional data sharing and harmonizing statistical standards are particularly important. These measures would enhance information transparency, reduce financing frictions, and provide a more robust foundation for both policy design and academic research.

Empirical results indicate that, during the current sample period, the positive impact of openness on GF's development is not significant; however, this does not mean that openness is unimportant. It reflects that the domestic GF market is mainly driven by policies, while the influence from the international level will take a longer time to gradually emerge. In the long term, continuing to expand opening up and introducing mature international experience and rules remains an unavoidable direction for improving the entire market mechanism.

As for the domestic market itself, financial institutions should be encouraged to constantly try to introduce new green financial products. In addition to the more common basic types such as green credit and green bonds, there is a need to vigorously promote the development of more innovative products like green asset securitization, such as green REITs, and various carbon financial derivatives, so as to meet the diverse financing needs of different market participants. For example, in response to the need of high energy-consuming enterprises to reduce carbon emissions, financial tools closely related to the carbon market such as carbon quota pledge loans or carbon insurance can be promoted.

In terms of international cooperation, we need to be more actively involved in the discussion and formulation of global GF standards, and strive to align domestic green bond standards and environmental information disclosure standards with international common practices. At the same time, we need to attract foreign institutions to invest and trade in our domestic GF market and support our own financial institutions and enterprises to issue green bonds on the international market. This will gradually enhance China's influence and say in the global GF system.

5.3. Research Gaps and Outlook

This study still has some shortcomings:

Data: The time span of the sample is relatively short, which prevents the inclusion of data covering a longer period of GF development. Additionally, the measurement of some variables could be improved. For example, when assessing the level of GF development, it would be beneficial to incorporate more multidimensional elements such as green insurance and carbon finance.

Model Level: When analyzing the development of GF, neglecting spatial spillover effects may lead to the omission of potential mutual influences between regions. Future research could consider incorporating spatial econometric models to explore this issue in greater depth.

Future research could be conducted in the following directions:

Expanding Research Perspectives: Against the broader backdrop of the digital economy and rural revitalization, examine how emerging trends influence GF. Concurrently, attention should be paid to the interactive relationship between GF and the LCE; specifically, analyzing the role GF plays in reducing carbon emissions and driving industrial upgrading.

Refining Research Methods: When constructing metrics to measure the development level of GF, emerging methods could be considered. To enhance the reliability of research conclusions and further mitigate endogeneity issues, econometric methods such as the difference-in-differences approach or instrumental variables could be introduced.

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Conflicts of Interest

The authors declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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