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Can Green Finance Development Reduce Carbon Emissions? Empirical Evidence from 30 Chinese Provinces

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Abstract: Dealing with the relationship between environment and economic development is the core issue of China's sustainable development. At present, China's economic transformation is urgent, and green finance is being widely concerned. This paper measured the development level of China's green finance from the perspective of green credit, green securities, green investment, and green insurance. Then, it used a spatial dynamic panel model to empirically test the mechanism of the impact of green finance on carbon emissions with panel data of 30 Chinese provinces from 2005 to 2018. The following can be seen from the results: (1) The development of green finance contributes to carbon emission reduction. (2) The spatial spillover effect of green finance is significant. Specifically, the development of green finance can not only reduce the carbon emissions of the local region but also inhibit that of adjacent areas. (3) The development of green finance indirectly leads to a decrease in carbon emissions by reducing financing constraints and boosting green technology innovation. In order to stimulate the carbon emission reduction effect of green finance to a greater extent, we should further support the development of green finance, reduce the financing constraints of energy-saving and environmental-protection enterprises, and encourage the research and development of green innovative technologies.

Keywords: green finance; carbon emission; spatial spillover effect; mediating effect; China

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1. Introduction

Since the industrial revolution, the economies of all countries in the world have grown rapidly [1]. However, increased environmental problems such as global warming and sea-level rise, caused by economic development, have seriously threatened human health and social development. Based on this, the developed countries earlier in industrialization actively carried out financial innovation to reduce environmental pollution [2]. Meanwhile, they have provided valuable experience for the construction of green financial systems [3]. Since then, scholars have linked resource and environmental issues with economic development. They further explored how to incorporate environmental factors into financial decision making to achieve the sustainable development of economy and environment [4]. In this context, the concept of green finance came into being. Green finance refers to economic activities that could utilize resources efficiently, mitigate climate change, and support environmental improvement [5]. Through the rational allocation of financial resources, green finance aims to guide industrial enterprises to use less resources and energy to achieve more economic and ecological benefits [6]. Thereby, we should promote the development of green finance and guide more capital to flow into green industries to enhance the sustainability of economic growth [7].

For China, serious environmental problems have come simultaneously with rapid economic growth [8]. From Figure 1, we find that China's carbon emissions in 2019 exceeded the total emissions of OCED countries [9]. Therefore, environmental governance is urgent. Then, in 2020, the Chinese government announced during the 75th United

Nations General Assembly that its carbon emissions would reach a peak before 2030, and it would achieve the goal of "carbon neutrality" by 2060 [10]. Compared with the United States, Europe, and other developed countries, China has had a difficult time reaching its peak of carbon emissions and achieving its goal of carbon neutrality. It requires a systematic change involving the R&D of green technologies, the transformation of industries, and a low-carbon lifestyle [11]. Related calculations show that China needs hundreds of billions of yuan of green and low-carbon investment to achieve the "30·60" target [12]. In addition to government funding, most of the funds need to be obtained by market-oriented methods. The development of green finance can encourage more "greener" social capital into the financial system [13]. Therefore, it is particularly essential to limit greenhouse gas emissions through a green financial system, which will provide the investment and financing support needed to transform high-pollution enterprises.

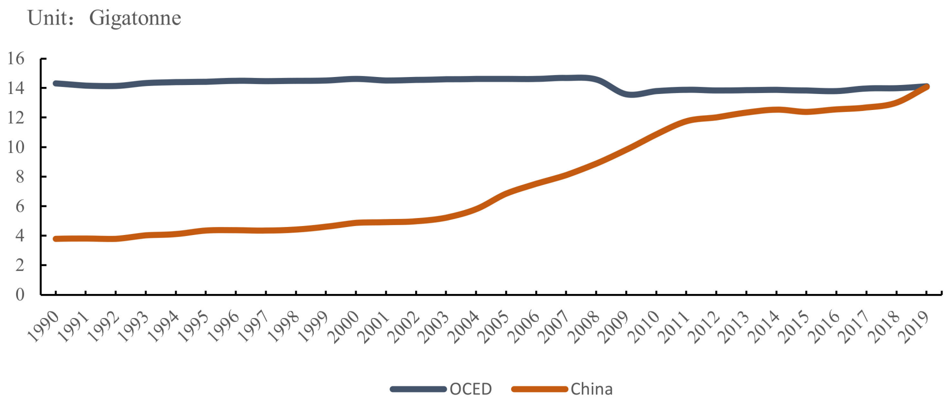

Figure 1. Carbon emissions of China and OCED countries from 1990 to 2019.

Recently, the Chinese government had carried out a series of green financial policies at the national level, which has sent a signal that "the country is taking action to develop green economy vigorously" [14]. So, what impact will the development of green finance have on China's carbon emission intensity? While promoting the return on investment of green projects and improving the availability of financing, can the diversified green financial policies of Chinese government inhibit the investment in polluting projects and reduce carbon emissions?

This paper answered the above questions through basic facts, theoretical analysis, and empirical tests. The marginal contributions are from the following three aspects: (1) We used a comprehensive index system to measure the development level of green finance rather than a single index, since China's green financial system is developing rapidly, involving securities, insurance, credit, and other fields [15]. According to the framework of green finance development in China, green credit, green securities, green investment, and green insurance are taken as the four indicators in this paper to measure the development level of green finance in Chinese 30 provinces. (2) Compared with ordinary panel regression, spatial econometrics can reduce the estimation error caused by ignoring the spatial correlation among variables. It will overcome the assumption that the traditional econometric model ignores spatial correlation among variables [16]. Therefore, we empirically analyzed the impact of green finance development on carbon emissions with a spatial measurement model. (3) This paper used the mediating effect model to examine the transmission mechanism between carbon emissions and green finance. The results obtained herein are helpful for more accurate understanding of the implementation effects of China's green finance policies. Furthermore, it also provided theoretical guidance and policy recommendations for China to realize a low-carbon-recycling economy.

2. Literature Review

2.1. Financial Development and Carbon Emission

Existing literature holds that the effect of financial development on environmental pollution has two sides. On one side, it fits the view that financial development will increase carbon emissions. Firstly, the improvement of financial development stimulates investment growth by alleviating the financing constraints of enterprises, thereby expanding the economic scale and energy consumption and further increasing carbon emissions. For example, Sadorsky (2010) [17] found that financial development made it easier to obtain credit, stimulating consumers to purchase energy-intensive products such as cars, air conditioners, and refrigerators, increasing regional carbon emissions. Secondly, financial development can reduce financing constraints and the production costs of enterprises. It also promotes enterprises to purchase large-scale equipment and build new production lines to expand their production scale, which will inevitably increase carbon emissions. However, another side holds the view that financial development will reduce carbon emissions. With the improvement of finance, sufficient R&D funds can provide financial support for researching clean technologies, guiding the transformation of the energy consumption structure of high-consumption enterprises, which will decrease carbon emissions [18]. Meanwhile, Tamazian et al. (2009) [19], Jalil and Feridun (2011) [20], and Gu et al. (2012) [21], based on data from other countries, have found a similar conclusion that carbon emission was inhibited by financial development using different methods.

2.2. Green Financial Development and Carbon Emission

In the early stage, scholars mainly focused on the definition of green finance, including connotation, functional, development paths, and the important role of green finance in bank risk control, pollution treatment, and green economic development in developing countries [22]. Relevant studies have shown that green finance raises the loan threshold for high-emission and high-pollution activities. It also provides low-carbon industries with low-interest rates to meet their financing needs, which is conducive to the rapid growth of low-carbon sectors [23]. For example, Xiu et al. (2015) [24] built a non-linear threshold panel model. They found that green credit policies contribute significantly to emission reduction and energy saving under the constraints of industrial growth. Liu et al. (2017) [25] constructed a financial CGE model and found that green credit policies effectively curb investment in energy-intensive industries. In brief, the improvement of green finance can alleviate the financing constraints of enterprises in environmental protection, new energy, new materials, etc., and help provide more low-carbon products or services to support the development of environment-friendly enterprises [26]. What is more, it will reduce the capital supply to high-pollution and high-emission enterprises, forcing them to carry out technological transformation and upgrading, or reducing the scale of production to reduce carbon emissions [27].

2.3. Summary

To sum up, scholars have carried out many research studies on the relationship between green financial development and environmental pollution. However, there are still some shortcomings: (1) Existing research usually adopted a single green credit measuring green finance. However, according to the connotation of green finance, green credit is the most important part of green finance [28]. Furthermore, green investment, green insurance, and green securities are equally crucial parts of green finance [29]. (2) Existing research has mostly studied the relation between green finance development and environmental pollution in China from a horizontal perspective, thus ignoring the spatial spillover effect [30]. However, whether it is green finance or environmental pollution, the provinces are not independent of each other. Taking carbon emission as an example, due to geographical proximity and the pollution flow between provinces, environmental pollution has spatial spillovers [31]. If the empirical research neglects pollutants outside the provinces through environmental media, the results will be biased. (3) Most research only focused on the direct impact of green finance on carbon emissions, but it did not reveal the internal mechanism of the impact of green finance on carbon emissions, which needs to be further expanded [32].

3. Theoretical Hypotheses

From a theoretical perspective, green finance can penetrate environmental protection into the entire industrial development system through the three mechanisms of funding: orientation, policy guidance, and risk sharing [33].

Funding-oriented mechanism. Banks, acting as depository institutions for social capital, can achieve large-scale capital concentration in a short period. Following the principle of "differentiated treatment", green finance uses financial tools to increase the financing constraints of high-polluting enterprises and guide capital inflow to low-energy, low-emission, and low-polluting industries [34]. Meanwhile, it is also leading more funds into green industries, forcing the transformation and upgrading of high-polluting enterprises, which all have positive impacts on carbon emission reduction [35].

Policy guidance mechanism. "Accelerate the development of green finance" is a national-level fiscal policy of China, which is destined to have broad and strategic prospects [36]. Hence, green finance policies can support the development of green industries through government procurement, financial support, tax reduction, fee reduction, etc. What is more, it will ultimately guide the improvement and attainment of a greener industrial structure. Therefore, the financing cost of the environmental protection industry will be much lower than that of the high-pollution manufacturing industry, thus boosting the profitability and competition of the environment-friendly industries [37]. Furthermore, with the resources from national policies, it will effectively reduce carbon emissions as well as speed up the transformation and improvement of high-pollution industrial structures.

Risk-sharing mechanism. Due to its ecological and environmental benefits, green projects usually have the characteristics of significant capital demand and slow recovery [38]. Therefore, green financial institutions can rely on professional risk identification and control capabilities to conduct comprehensive risk management for supporting green projects. It will force enterprises to consider ecological and environmental factors in production and operation activities, and it can reduce social risks caused by climate change, environmental pollution, and other environmental damage [39].

Accordingly, the development of green finance can lead more funds to flow into low-carbon industries, provide more financing and investment opportunities, and enable the environmental protection industry to have further development. The high-pollution industries will be punished by high interest rates when lending, which may act as a "warning effect" on other high-pollution companies. Therefore, the development of green finance will not only reduce local carbon emissions but also reduce those of the surrounding areas [38].

A flow chart of theoretical analysis is shown in Figure 2. The first hypothesis is put forward here on this basis:

Hypothesis 1. *The development of green finance is conducive to reducing carbon emissions.*

The development of green finance can affect carbon emissions through financing constraints. Firstly, the implementation of green finance provides loan support to environmental-friendly companies with preferential low interest rates. However, it will change the financing costs of pollution enterprises through the restriction of loan amount and the punitive high interest rates, thereby forcing enterprises to cleaner production [40]. Secondly, the development of green finance makes companies invest with low environmental risks to avoid financing constraints brought by environmental regulation. More importantly, it gives more impetus to low-carbon environmental protection industries, thus contributing to the reduction of carbon emission.

At the same time, the development of green finance affects carbon emission by stimulating green technological innovation. On one hand, "green technology" is increasingly demanded when green finance is widely developed [41]. In the carbon emission background in China, most high-polluting and high-emission companies have generated colossal market demand for environmental protection technologies. On the other hand, green financial development can stimulate enterprises' willingness to innovate independently. What is more, it will increase R&D investment in low-energy, high-value-added industries, further forcing polluting companies to adopt cleaner technologies to reduce carbon emissions.

Accordingly, Hypothesis 2 is proposed:

Hypothesis 2. *The development of green finance may affect carbon emissions through transmission channels such as financing constraints and green technology innovation.*

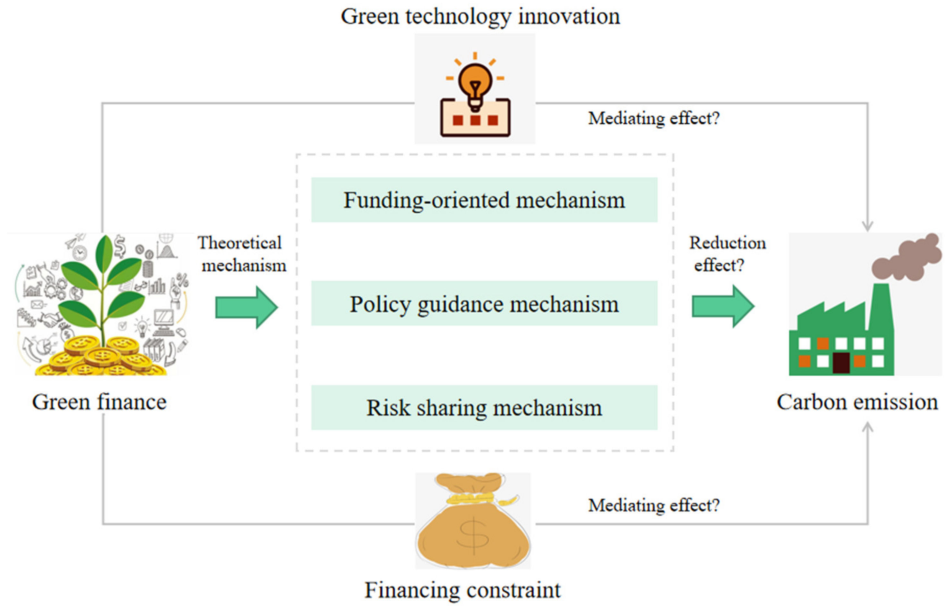

Figure 2. Flow chart of theoretical analysis.

4. Empirical Model and Data Explanation

4.1. Spatial Econometric Model

The spatial econometric model integrates the influence of region, location, and space, and it believes that there will be a spatial dependence relationship between variables in different regions [42]. Under the influence of industrial transfer, atmospheric flow, and other similar natural and economic activities, carbon emissions may have a strong spatial correlation among regions [43]. As shown in $C_{it} = E_{it} + S_{jt} - S_{it}$, there are three parts in the sources of carbon emission in a region. In this equation, C stands for the measurement of carbon emissions; i stands for cross-section unit; t stands for the year; E_i stands for the amount of carbon emission produced in local region i; S_j stands for the amount of carbon emission diffused from surrounding areas to region i; S_i stands for the region's carbon emission diffused to other regions. In accordance with the theory of spatial econometrics, $S_{jt} - S_{it}$ reflects the "contributions" of surrounding areas to the local region's carbon emissions and represents the spatial dependence between regions. It can be expressed as the spatial error characteristic ($S_{jt} - S_{it} = \mu_{it} = \lambda\rho\sum_j w_{ij}\mu_{it} + \varepsilon_{it}$) or the current spatial dependence ($S_{jt} - S_{it} = \rho\sum_j w_{ij}C_{jt}$).

There are three types of spatial econometric models: the spatial lag model (SAR), spatial error model (SEM), and spatial Durbin model (SDM). The SDM integrates the characteristics of the SAR and the SEM, and the intensity of the influence of adjacent spatial units is represented by the spatial weight matrix [44]. Therefore, green finance (*Gfin*) is introduced into the model, where Formula (1) is the spatial lag form (SAR) and Formula (2) is the spatial error form (SEM):

$$C_{it} = \alpha_0 + \alpha_1 Gfin_{it} + \alpha_2 X_{it} + \rho \sum_j w_{ij} C_{jt} + u_{it} \tag{1}$$

$$C_{it} = \beta_0 + \beta_1 Gfin_{it} + \beta_2 X_{it} + \lambda \sum_j w_{ij} \mu_{it} + \phi_{it} \tag{2}$$

where α and β are coefficient vectors; X denotes a series of control variables; $\phi_{it} = \varepsilon_{it} + u_{it}$, ε_{it}, and u_{it} are the perturbation terms with normal distribution; λ is the coefficient of the spatial error term; and ρ is the spatial lag coefficient, respectively. Relatively speaking, the spatial Durbin model (SDM) can comprehensively express the characteristics of the spatial lag model and the spatial error model [45], and its manifestation is as follows:

$$C_{it} = \delta_0 + \delta_1 \text{Gfin}_{it} + \delta_2 X_{it} + \rho_1 \sum_j w_{ij} C_{jt} + \rho_2 \sum_j w_{ij} \text{Gfin}_{jt} + \rho_3 \sum_j w_{ij} X + u_{it}. \tag{3}$$

Among them, δ is the coefficient vector. Since the environmental pollution variables have the characteristic of path dependence [46], the environmental pollution level of the previous period will have a greater impact on the current period. Therefore, this paper introduces the lag phase of carbon emissions into Equation (3), constructing the dynamic SDM model as follows:

$$C_{it} = \delta_0 + \delta_1 \text{Gfin}_{it} + \delta_2 X_{it} + \delta_3 C_{i,t-1} + \rho_1 \sum_j w_{ij} C_{jt} + \rho_2 \sum_j w_{ij} \text{Gfin}_{jt} + \rho_3 \sum_j w_{ij} X + u_{it}. \tag{4}$$

Obviously, the time and space lag effect of carbon emission can be comprehensively reflected by the dynamic spatial panel from the time dimension and the space dimension, thus leading to a more robust estimation result. This paper constructs a geographical distance weight (W1) in accordance with the geographical distance between provinces in China to reveal the impact of geographical factors on carbon emission. In addition, the economic distance weight (W2) in China is constructed by the GDP of each province, and it reflects the impact of economic factors on carbon emission.

4.2. Description of Variables

4.2.1. Explained Variable: Carbon Emission (C)

The method of IPCC (2006) [47] is adopted to measure the amount of carbon emission of Chinese 30 provinces, which is an internationally recognized carbon emission calculation method. The data of energy comes from the "China Energy Statistical Yearbook", and the amount of carbon emission is calculated according to the following formula:

$$C_{it} = \sum_i E_i \times CF_i \times CC_i \times COF_i \times \frac{44}{12}. \tag{5}$$

Among them, E_i represents fossil energy consumption, CF_i is the low calorific value, CC_i is the carbon content per unit of heat, COF_i is the oxidation rate of energy, and 44/12 is the mass ratio of carbon dioxide molecules to carbon atoms.

We use acrgis software to draw the 2005 and 2018 distribution maps of carbon emission in China (Figure 3). It can be found that carbon emissions were increasing from 2005 to 2018 in various Chinese regions, and there was an obvious spatial correlation between provinces. Compared with the central and western regions, the eastern region has a much higher level of carbon emission. Therefore, a spatial econometric model can be used to measure the impact of green finance on carbon emission.

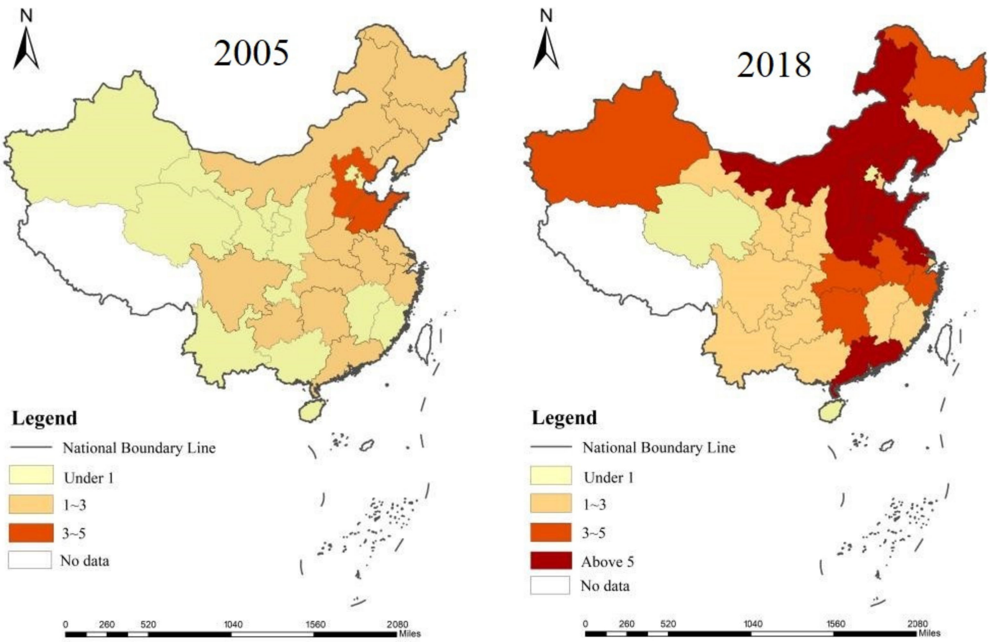

Figure 3. Carbon emission distribution map 2005 and 2018.

4.2.2. Core Explanatory Variable: Green Finance Development (GFin)

The Chinese Green Finance Professional Committee proposed four dimensions of green finance: green credit, green securities, green investment, and green insurance. As a typical bank-dominated country, China is mainly driven by commercial banks, where green credit is the core content of green finance. This paper used the available data of six high energy-consuming industries and the ratio of interest expenditure to total industrial interest expenditure as a reverse index to measure green credit [48]. Green investment promotes the treatment of environmental pollution. This paper applied the ratio of expenditure on environmental pollution to GDP to measure green investment. Compared with bank loans, insurance funds are long-term capital, which is in line with the long-term financing and investment needs of green projects. However, agricultural production is a major source of carbon emissions [49]. Therefore, this paper used agricultural insurance scale and loss ratio to measure the depth of green insurance. The scale of environmentally friendly companies can be measured by green securities to some extent, so the market value of environmentally friendly companies is used to measure green securities in this paper [50]. In summary, this paper gave weight by the entropy method, and the index system of green finance development is shown in Table 1.

Table 1. Green finance development index system.

	Index	Index Description
Green credit	Proportion of interest expense of high-energy consumption industry	Interest expense of six high-energy consuming industries/total industrial interest expense
Green securities	Proportion of market value of environmental protection enterprises	Market value of environmental protection enterprises/total market value of listed companies
Green investment	Proportion of investment in environmental pollution control in GDP	Investment in environmental pollution control/GDP
Green insurance	Proportion of agricultural insurance scale	Agricultural insurance expenditure/total insurance expenditure
	Agricultural insurance loss ratio	Agricultural insurance expenditure/agricultural insurance income

4.2.3. Control Variables

As a serious environmental problem, carbon emission results from many aspects of economic and social development. Therefore, this paper introduced the economic development level, energy structure, industrial structure, openness, and urbanization level into the model to control their impacts on carbon emission. The reasons for the selection of control variables are as follows:

(1) Economic development level (Pgdp): In terms of per-capita GDP, its primary and secondary terms are introduced into the model in accordance with the EKC hypothesis to explore whether economic growth and carbon emissions have an inverted U-shaped relationship [51]. (2) Energy structure (Estru): The burning of fossil energy is a major source of carbon emissions. Obviously, the higher the proportion of fossil energy, the less conducive it is to carbon emission reduction [52]. (3) Industrial structure (Indu): Industrial production is another primary source of carbon emissions. The higher level of industrial structure, the less conducive it is to reducing carbon emissions [53]. (4) Opening up (Open): Developed countries usually have more serious environmental pollution control policies, which will correspondingly increase the production costs of polluting enterprises. On the contrary, developing countries usually have more relaxed environmental regulations, and they are more inclined to absorb the transfer of high-polluting industries from developed countries, which is not conducive to environmental governance [54]. (5) Urbanization level (City): The development of urbanization may also cause more energy consumption and environmental pollution, which is not conducive to carbon emission reduction.

4.2.4. Mediating Variable

Financing constraints (Fcon): Companies with poor financing channels will be subject to financing constraints. Most of these companies show insufficient internal funds, debt financing, equity financing, etc., which is not conducive to obtaining more "green" capital support. Furthermore, it will adverse to carbon emission reduction. Thus, this paper refers to the cash flow sensitivity model [55] to calculate the degree of financing constraints on companies. We used the regional level to match the corporate data of listed companies.

Green technology innovation (Gtech): The number of green patent applications in each province is adopted to express the level of green technology innovation. The development of green finance will support the enterprise to make more effort to explore environmental protection technologies, which help reduce an enterprise's innovation risk and thereby reduce carbon emissions.

4.3. Data Source

Table 2 gives the description of each variable and its data source.

Table 2. Data selection and description.

Variable	Index Selection	Sign	Description	Data Source
Dependent variable	Carbon emission	C	Calculated based on Formula (1)	China Energy Statistics Yearbook (2006–2019) China Financial Statistics Yearbook (2006–2019)
Core independent variable	Green finance	Gfin	The index system is constructed from the four dimensions of green credit, green insurance, green investment and green securities, and the weight is given by the entropy method	China Statistical Yearbook (2006–2019) China Insurance Statistical Yearbook (2006–2019) Wind database CSMAR database Flush Ifind database

Table 2. *Cont.*

Variable	Index Selection	Sign	Description	Data Source
Control variable	Economic development	Pgdp	Per-capita GDP	China Energy Statistics Yearbook (2006–2019) China Statistical Yearbook (2006–2019)
	Energy resource structure	Estru	Proportion of coal consumption in energy consumption	
	Openness	Open	Total import and export/GDP	
	Industrial structure	Instu	Industrial added value/GDP	
	Urbanization	City	Urban population/total population	
Mediating variable	Financing constraints	Fcon	Calculated by cash flow sensitivity model	Wind database
	Green technology innovation	Gtech	Number of green patent applications	Wind database

5. Empirical Regression

5.1. Impact of Green Finance Development on Carbon Emission

5.1.1. Selection of Spatial Econometric Model

The LM test and LR test are applied to identify the form of the spatial econometric model. According to Elhorst (2014) [45], if LM-lag and LR-lag are both significant at 1%, as well as the LR-error and LR-error test, we should choose spatial Durbin model (SDM) for empirical analysis.

Table 3 presents the LR and LM test results based on W1 and W2. It can be found that the LM and LR test results of both static and dynamic spatial models pass the significance test. Hence, this paper chose the SDM model to explore the impact of green finance on carbon emissions.

Table 3. LR test and LM test in spatial model.

Model	Static Spatial Model		Dynamic Spatial Model	
W	W1	W2	W1	W2
LR-lag	132.78 ***	135.40 ***	110.59 ***	112.49 ***
LR-error	101.35 ***	98.56 ***	82.23 ***	78.90 ***
LM-lag	167.87 ***	168.45 ***	231.25 ***	227.82 ***
LM-error	186.12 ***	194.62 ***	276.77 ***	287.90 ***

Note: *** represent the significance levels of 1%.

5.1.2. Benchmark Regression Test

In this paper, a panel regression model (OLS) and dynamic panel regression model (GMM) without considering spatial factors are firstly used to test the impact of green finance development on carbon emission, respectively. Then, the static SDM and dynamic SDM model, considering spatial factors, are also used for empirical analysis. Table 4 gives the results of benchmark regression tests. Firstly, the development of green finance can significantly reduce the carbon emissions under the four types of models. Secondly, from the significance of variables, the dynamic spatial Durbin model shows better statistical characteristics. This is because the carbon emissions of the local region are also affected by the surrounding areas. It also indicates that carbon emission, energy consumption, and economic activities between regions show obvious spatial autocorrelation. Hence, ignoring the spatial proximity effect in research may lead to estimation errors. In addition, due to human activities and economic behaviors occurring simultaneously in a certain space–time, we should consider the space–time dimension when conducting economic and social research. Therefore, the dynamic SDM model is the focus of the following discussion.

Table 4. Benchmark regression test.

Variable	OLS M1	GMM M2	Static SDM M3	Dynamic SDM M4
L.C		0.7456 ***		0.5591 ***
		(12.59)		(13.60)
Gfin	−1.3757 *	−1.0190 **	−1.7991 **	−0.9857 ***
	(−1.70)	(2.02)	(−1.98)	(−3.05)
Pgdp	0.4232	0.0421 **	1.1007 ***	0.2503 ***
	(1.10)	(2.13)	(2.83)	(5.66)
sPgdp	−0.0512 ***	−0.0142 *	−0.06975 ***	−0.0160 ***
	(−2.62)	(−1.93)	(−3.43)	(−3.82)
Estru	0.1539 **	0.3405 *	0.1001 **	0.0490 ***
	(2.68)	(1.65)	(2.23)	(6.30)
Indu	0.0527	0.0663 **	0.0337	0.0369 **
	(0.85)	(2.21)	(0.43)	(2.02)
Open	−0.0617 **	−0.0563 *	−0.0094	−0.0404 **
	(−2.23)	(−1.82)	(−0.39)	(−2.25)
City	0.0784	0.0238	0.1384 *	0.0813 ***
	(1.28)	(1.48)	(1.84)	(4.63)
Log			389.8303	834.7580
Rho			0.8819 ***	0.7625 ***
			(3.88)	(3.49)
R2	0.8527	0.8902	0.6103	0.9407
AR(2)		2.0232		
[P]		(0.3341)		
Sargan		156.38		
[P]		(0.9331)		
Obs	420	390	420	420

Note: ***, **, and * represent the significance levels of 1%, 5%, and 10% respectively.

Firstly, the spatial lag coefficient is at a 1% significance level under the setting of spatial weight (W1), which proves that China's provincial carbon emissions have significant spatial correlation. That is, regions with relatively high carbon emissions will gather together as will the regions with low carbon emissions. For example, in Figure 2, we can find that the carbon emissions in China's eastern regions are higher than those in China's central and western regions. This is because under the multiple factors of atmospheric circulation, industrial transfer, population migration, and other economic and natural factors, the carbon emissions of local area are inevitably affected by the surrounding regions. The time lag term of carbon emission (L.C) elasticity coefficient is 0.5591, which is significant at a 1% level. If the carbon emissions in the current period are at a high level, the amount of carbon emissions might continue to rise in the next period. It reveals the path dependence characteristics of carbon emissions for a specific region.

From the core explanatory variables (Gfin), −0.9857 is the value of the elasticity coefficient of green finance to carbon emission, which is significantly negative at a 1% level. It indicates that the development of green finance is conducive to reducing carbon emission. Thus, Hypothesis 1 is verified. As we know, the most basic function of the financial system is to gather and distribute funds. Therefore, green finance mainly forms the financial capital necessary for the development of green industry by collecting funds and guiding funds to industries with cleaner structures. It effectively reduces the cost of raising capital and makes it easier for green industry to have further development, thereby decreasing the proportion of high-polluting industries and carbon emissions. Meanwhile, green finance enables investors to take the potential environmental impacts into account when making investing and financing decisions. Capital can be ceaselessly poured into environment-friendly industries. Furthermore, green finance not only has an impact on producers, but it also enhance the consumption willingness of consumers to purchase more low-carbon products. In addition to the above theoretical analysis, the relevant data also prove that the development of green finance contributes to carbon emission reduction. According to relevant data, as of June 2017, China's green credit has reduced its emissions by 490 million tons of carbon dioxide. Therefore, China should further accelerate the development of green finance, improve China's green financial system, and strive to achieve China's 2030 carbon peak and 2060 carbon neutralization goals.

From the perspective of control variables, (1) the elastic coefficient of Pgdp is positive and the coefficient of the Pgdp is negative. That is, economic development and carbon emission have a significant inverted U-curve relationship. We have the same conclusion as Ke et al. (2021) [56] and Chen et al. (2021) [57]. It shows that economic development first promotes carbon emission and then suppresses it. (2) The elasticity coefficient of energy consumption structure is 0.0490, which is significant at a 5% level. This is because coal-based fossil fuel combustion is still one of the main sources of carbon emissions in China. (3) Industrial structure also can promote the increase in carbon emission, and its elasticity coefficient is 0.0369, which is significant at the level of 1%. It indicates that China's current industrial structure will still aggravate carbon emissions. Therefore, the transformation of the industrial structure is imminent. (4) There is a significant negative correlation between opening up and carbon emissions, which is at a 5% significance level. In the initial stage of economic development, China's coastal areas have absorbed a large number of high-pollution industries from abroad. However, with the improvement of economic development, their environmental regulation has become strict, and the high-polluting industries in coastal areas have transferred to inland areas. Therefore, regions with high levels of openness are more inclined to absorb green investment and acquire advanced management experience and green innovative technology so as to achieve the goal of carbon emission reductions. (5) Urbanization can significantly increase the amount of carbon emissions. With the acceleration of China's urbanization, a large amount of urban construction will increase the combustion of fossil energy, resulting in an increase in carbon emission.

5.1.3. Robustness Test

This paper mainly used three methods: replacement spatial weight matrix, replacement index, and replacement spatial model for testing the robustness of the benchmark regression. First of all, W2 is used to replace W1 in the previous regression for the robustness test, considering whether the differences of regional economic development would affect the regression results. Secondly, the index system of green finance is re-weighted using subjective and objective weighting methods. We used the reconstructed green financial development index to re-estimate the model. Finally, the model is re-estimated based on W1 by using the third-order spatial lag term of carbon emission as the instrumental variable in the generalized spatial least squares (GS2SLS) model. Meanwhile, the endogeneity of the benchmark model is also tested.

Table 5 describes the regression results of the robustness test. The global Moran index reported by the GS2SLS model is still significant, the spatial lag term of carbon emission intensity is still significant, and the core explanatory variable is still significantly negative to carbon emission. It could be inferred that the benchmark regression results have strong robustness.

Table 5. Robustness check.

Variable	Replace Weight	Replace Index	Replace Model
L.C	0.5449 *** (13.31)	0.8403 *** (14.58)	1.0434 *** (6.38)
Gfin	−0.4912 * (−1.83)	−0.2776 *** (−2.95)	−1.0453 *** (−5.61)
Pgdp	0.7351 ** (2.09)	0.3342 * (1.69)	0.5430 *** (4.07)
sPgdp	−0.0292 ** (−1.69)	−0.0850 *** (−7.98)	−0.0057 ** (−2.26)

Table 5. *Cont.*

Variable	Replace Weight	Replace Index	Replace Model
Estru	0.0475 *** (2.91)	0.2245 *** (5.84)	0.0308 * (1.80)
Indu	0.0617 ** (1.99)	0.0127 *** (4.07)	0.0023 * (1.72)
Open	−0.0938 *** (−4.35)	0.0077 *** (3.70)	0.0053 ** (2.36)
City	0.1267 *** (2.06)	0.0075 * (1.83)	0.0036 *** (6.09)
Log	177.7073	889.9060	1867.2806
Global Moran's I [P]			0.1034 *** (0.000)
Rho	0.1890 *** (2.61)	0.7002 *** (6.90)	
R2	0.9462	0.9506	0.8052
Obs	420	420	420

Note: ***, **, and * represent the significance levels of 1%, 5%, and 10%, respectively.

5.1.4. Spatial Spillover Effect

According to Lesage (2009) [58], the total effect represents the impact of green financial development on the carbon emissions of all provinces; the direct effect refers to the impact that the green financial development that the local region receives has on carbon emissions; and the indirect effect is equivalent to the mean of the impact that green financial development has on the carbon emissions of the surrounding regions. The dynamic SDM model is still used in this paper to explore the spatial spillover effect of green financial development on carbon emission. Table 6 gives the details of the regression results.

Table 6. Spatial spillover effect test.

Variable	Direct Effect		Indirect Effect		Total Effect	
	W1	W2	W1	W2	W1	W2
Gfin	−0.9857 *** (−3.05)	−0.4912 * (−1.83)	−0.0436 * (−1.89)	−0.0042 ** (−1.97)	−1.0293 ** (−2.01)	−0.4954 ** (−2.12)
Pgdp	0.2503 *** (5.66)	0.7351 ** (2.09)	0.0158 ** (2.02)	0.0075 ** (2.32)	0.2261 * (1.79)	−07426 *** (−4.70)
sPgdp	−0.0160 *** (−3.82)	−0.0292 ** (−1.69)	0.0139 * (1.89)	0.0280 * (1.69)	−0.0021 * (−1.68)	−0.0012 (1.57)
Estru	0.0490 *** (6.30)	0.0475 *** (2.91)	0.0139 (0.73)	0.0528 (1.01)	0.1880 (0.76)	0.1003 *** (4.48)
Indu	0.0369 ** (2.02)	0.0617 ** (1.99)	0.0560 * (1.69)	0.1827 (1.01)	0.0929 * (1.71)	0.2444 *** (8.04)
Open	−0.0404 ** (−2.25)	−0.0938 *** (−4.35)	0.1693 * (1.71)	0.1561 *** (3.25)	0.1289 *** (4.40)	0.0623 *** (3.56)
City	0.0813 *** (4.63)	0.1267 *** (2.06)	0.3385 (1.22)	0.1240 (0.98)	0.5011 * (1.80)	0.2507 (0.57)
Log	834.7580	177.7073	834.7580	177.7073	834.7580	177.7073
Rho	0.7625 *** (3.49)	0.1890 *** (2.61)	0.7625 *** (3.49)	0.1890 *** (2.61)	0.7625 *** (3.49)	0.1890 *** (2.61)
R2	0.9407	0.9462	0.9407	0.9462	0.9407	0.9462
Obs	420	420	420	420	420	420

Note: *** means significant at 1%, ** means significant at 5%, and * means significant at 10%.

To be specific, Table 6 shows the calculation results of the decomposition effect based on model 4 in Table 4. It can be found that under the setting of geographical distance spatial weight and economic distance spatial weight that the development of green finance contributes to carbon emission reduction, whether it is a direct effect, indirect effect, or total effect. This paper took the result of geographical distance spatial weight (W1) as an example. As shown in the results, the effect of green finance development on the carbon emissions of a local region is negative, that on the surrounding regions is still negative, and its elastic coefficients are −0.9857 and −0.0436, respectively, which are significantly negative at a 1% and 10% level. From these figures, it can be seen that the development of green finance reduces the carbon emissions of the local region, and it also reduces the carbon emissions of adjacent areas. Furthermore, whether it is the elasticity coefficient or significance degree, the carbon reduction effect of local regions is larger than that of the surrounding areas.

First of all, the initial stage of green finance development needs to be led by the government, and there is a competitive effect between regional governments, so the environmental regulation behavior of the local province will "infect" surrounding areas. Secondly, due to the financing constraints of green finance, the enterprises with high pollution in the region have increased loan interest rates, which forces the transformation and development of those enterprises to reduce their carbon emissions. Additionally, high-carbon enterprises in other areas will also reduce their carbon emissions due to this "warning effect". Therefore, the improvement of green finance in the local region will also affect the surrounding areas and then reduce the carbon emissions of adjacent areas.

5.2. Analysis on the Intermediary Effect of Green Finance on Carbon Emission

According to the dynamic SDM model, this part used the stepwise regression method to set the following intermediary effect test steps.

$$M_{it} = \pi_0 + \pi_1 \mathrm{Gfin}_{it} + \pi_2 X_{it} + \pi_3 M_{i,t-1} + \rho_1 \sum_j w_{ij} M_{jt} + \rho_2 \sum_j w_{ij} \mathrm{Gfin}_{jt} + \rho_3 \sum_j w_{ij} X + u_{it} \quad (6)$$

$$C_{it} = \omega_0 + \omega_1 \mathrm{Gfin}_{it} + \omega_2 X_{it} + \omega_3 M_{i,t} + \omega_4 C_{i,t-1} + \rho_1 \sum_j w_{ij} M_{jt} + \rho_2 \sum_j w_{ij} \mathrm{Gfin}_{jt} + \rho_3 \sum_j w_{ij} X + \rho_4 \sum_j w_{ij} M + u_{it} \quad (7)$$

Among them, M is the mediating variable, and Formulas (4), (6) and (7) constitute the intermediary effect test equation [59]. If the coefficients of ω_1 and π_1 are significant, compared with δ_1, the coefficient of ω_1 decreases or decreases significantly, indicating that M is an intermediary variable.

The estimation results of the mediating effect are given in Table 7. The coefficient of green finance is significant in either Equation (4) or Equation (6), and it is higher in Equation (4) than in Equation (7) with a reduced degree of significance when financing constraints are considered to be the mediating variable. Therefore, it can be determined that financing constraints are one of the mediating variables between green finance and carbon emission. That is, green finance development can significantly reduce financing constraints and then contribute to carbon emission reduction. This is because the development of green finance indirectly increases the cost of high pollution projects and then restrains polluting investment by reducing the costs of green investment and financing, making environmental risks explicit. The development of green finance makes environmental risks explicit, reduces green investment and financing costs, and increases the expenditure for high-pollution projects indirectly, thus restraining polluting investment.

The coefficient of green finance is significant in either Equation (4) or Equation (6), and it is higher in Equation (4) than in Equation (7) with a reduced degree of significance when green technological innovation is considered to be the intermediary variable. Therefore, it can be determined that the relation between green finance and carbon emission is mediated by green technological innovation. That is, green finance development reduces the amount of carbon emissions through improving the ability of green innovation. This is because with the improvement of the green finance, more funds can provide green innovation capital for the new energy industry and environmental protection industry. It will help to reduce the innovation risk of enterprises and stimulate the green innovation behavior of enterprises. Under the constraints of China's policies aiming to reduce emissions and save energy, high-energy consumption and high-pollution industrial enterprises tend to encounter more and more obstacles in the pursuit of development. On the contrary, the green industries that actively adopt cleaner production and emission reduction technologies get the support of green finance policies and enjoy higher development prospects.

Table 7. Mediating effect test.

Variable	M = Fcon			Variable	M = Gteh		
	(4)	(6)	(7)		(4)	(6)	(7)
L.Fcon		0.0423 ** (5.38)		L.Gteh		0.6054 *** (5.78)	
L.C	0.5591 *** (13.60)		0.4514 *** (13.80)	L.C	0.5591 *** (13.60)		0.6374 *** (12.50)
Fcon			0.0890 *** (3.09)	Gteh			0.3643 *** (5.74)
Gfin	−0.9857 *** (−3.05)	−0.0347 ** (2.10)	−0.6709 ** (−2.20)	Gfin	−0.9857 *** (−3.05)	0.0147 *** (2.80)	−0.0466 ** (2.03)
Control	Yes	Yes	Yes	Control	Yes	Yes	Yes
Log	834.7580	653.0568	853.6860	Log	834.7580	645.5168	850.156
Rho	0.7625 *** (3.49)	0.2891 * (1.69)	2.1709 *** (17.70)	Rho	0.7625 *** (3.49)	0.3451 *** (2.67)	1.4570 *** (17.08)
R2	0.9407	0.6670	0.9691	R2	0.9407	0.7593	0.9451
Obs	420	420	420	Obs	420	420	420

Note: *** means significant at 1%, ** means significant at 5%, and * means significant at 10%.

6. Conclusions, Suggestions, and Discussion

To improve the ecological environment substantially, we should not only rely on powerful pollution treatment measures but also use financial means to change the incentive mechanism of resource allocation. Therefore, in order to decrease carbon emission and achieve the goal of eco-environmental governance, green finance is indispensable. Therefore, this paper used the dynamic spatial econometric model to explore the impact mechanism, transmission mechanism, and the spatial spillover effect of green financial development on carbon emission, and we obtained the following conclusions and policy enlightenments.

6.1. Conclusions

Through the analysis of the spatial econometric model, it can be found that carbon emission has a strong space–time dependence effect. In the spatial dimension, the carbon emissions between regions show a significant spatial positive correlation, which indicates that the current implementation of China's carbon emission reduction must form a synergistic linkage effect among regions. From the time dimension, the carbon emission may continue to rise in the next period if it is at a high level in the previous period.

Under the setting of geographical and economic distance spatial weight, green financial development can significantly reduce carbon emission. Furthermore, it is still valid, under three robustness tests, including spatial weight matrix, replacement explanatory variable index, and replacement spatial econometric model. In addition, whether the impact of green finance on carbon emissions is a direct effect, indirect effect, or total effect, the development of green finance contributes to the reduction of carbon emissions. Furthermore, the development of green finance, due to its significant spatial spillover effect, inhibits the growth of carbon emissions in the local region, and it also reduces the carbon emissions of adjacent regions. Moreover, the carbon emission in the local region receives a much higher inhibitory effect from green financial development than that in adjacent regions in terms of elasticity coefficient and significance.

The improvement of green finance has an indirect impact on carbon emissions by increasing green technology innovation and cutting down financing constraints. That is, financing constraints and green technology innovation both constitute the transmission path of green finance to carbon emissions.

6.2. Suggestions

Firstly, commercial banks should further increase the proportion of green credit, gradually tighten the funds flowing to high-emission industries, and increase the investment in credit funds for environmental protection and green industries. In addition, it is pressing to expand participants in the green financial market and give more impetus to the growth of green insurance business. For example, we can push the mandatory environmental pollution liability insurance system and develop other innovative types of green insurance, such as green vehicle insurance, green construction insurance, etc.

Secondly, we should invest more in the research and development of technologies for preventing pollution, reducing emissions, and saving energy, and motivate companies to take more active participation in the activities targeting green technology innovation through tax reduction from appropriate fiscal support.

Finally, it is essential to constantly reduce the share of oil, coal, and other traditional sources in energy consumption, fiercely advocate promoting the application of new energy, strictly implement the total control of regional coal consumption, speed up the construction of market-oriented energy pricing mechanism, and rely on the market-oriented mechanism to realize the gradual substitution of green and clean energy for traditional energy.

6.3. Discussion

In the context of the global pandemic of new crown pneumonia, whether the social living environment is green and healthy is of vital importance. A green revolution to reduce carbon emissions would also reduce the destruction of mineral resources, force countries to accelerate research and the use of renewable and green energy, and then promote the transformation of the world economy toward a green and sustainable direction. However, these processes cannot be realized without the support of green finance, so the importance of green finance is self-evident. As the world's largest carbon emitter in recent years, the Chinese government has promised the world a carbon peak by 2030 and carbon neutrality by 2060. How will China fulfill this promise? The key point of the primary consideration is how to effectively use green finance to promote the transformation of economic development mode and reduce the total amount of fossil energy combustion and industrial pollution emission. Considering the temporal and spatial diffusion of carbon emissions in different regions, this paper mainly adopted a dynamic measurement model to explore the relationship between the development of green finance and carbon emission, and it obtained the main conclusion that the development of green finance can help reduce carbon emission. At the same time, a variety of methods are used to verify the validity of the conclusions of this paper. In future studies, if the data can be more segmented and precise, more accurate and time-sensitive conclusions and relevant policy recommendations will be obtained. For example, further questions include how to rank the carbon emission reduction effects of different types of green financial instruments and how to break the space and administrative barriers to better promote the development of green finance in different regions.

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