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Study on the Carbon Emission Reduction Effect of Green Finance Development in the Dontext of "Double Carbon"

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Abstract

Based on the inherent mechanism that green financial development drives green technological innovation and the ecological transformation of industrial structure, thereby reducing carbon emissions, this paper uses a combination of qualitative and quantitative analysis methods to empirically test the impact of green financial development on carbon emissions using 30 inter-provincial panel data from 2010 to 2020 in China, using spatial panel and threshold panel models, focusing on the relationship between green financial development and carbon emissions, the study shows that: green financial development can promote the reduction of regional carbon emission intensity. The threshold test found that there is a double threshold effect for both the level of green technology innovation and the level of industrial structure ecologisation as threshold variables, firstly, for the level of green technology innovation, its impact on regional carbon emissions is inhibited before it is promoted; secondly, for the industrial structure ecologisation, only when the level of industrial structure ecologisation is increased to a certain level can the promotion effect of green finance on regional green development be fully realized Secondly, for the ecology of industrial structure, only when the ecological level of industrial structure is improved can the role of green finance on regional green development be fully realized. The findings of the study will help to improve the green financial development system, enhance the effectiveness of carbon emission reduction, and provide new insights for China to achieve the double carbon goal.

Keywords

Green Financial Development; Carbon Emissions; Spatial Durbin Model; Threshold Effect.

1. Introduction

The report of the 20th Party Congress clearly points out that "we should accelerate the green transformation of the development mode, speed up the adjustment and optimization of the industrial structure, improve the fiscal, financial, investment and price systems that support green development, and improve the market-oriented allocation system of resource and environmental factors." Since the reform and opening up, China's economic development has made world-renowned achievements, but the bearing capacity of resources and environment is approaching the limit, and the crude economic development model of high input, high energy consumption and high pollution is unsustainable. It is imperative to develop green finance, promote the optimization and upgrading of industrial structure, and accelerate the formation of a green and low-carbon production and lifestyle. As China is at a critical point in the development of green finance, it is of great value to study the effect of green finance on emission reduction and analyse the path to achieve the green goal of "carbon peaking and carbon neutrality". Therefore, the analysis of the impact of green finance on carbon emissions will help improve the green finance system, enhance its energy-saving and emission reduction effectiveness, and have far-reaching significance for the future development of the financial industry to achieve the goal of "carbon peaking and carbon neutrality".

2. Review of the Literature

First, studies on the development of green finance have focused on the construction of a green financial system, analysis of the interaction of different green financial instruments, and research on the current status of green financial development. Zeng Xuewen et al. (2014) measured green finance for five existing green financial products in China through the size of weights determined by expert scoring methods. Zhang Lili et al. (2018) measured the level and efficiency of green finance development in China using the entropy value method and DEA-Malmquist index respectively, and then conducted a static comparison and dynamic analysis of the two at the national, inter-provincial and regional levels. Zhou Guanglan and Xu Ru (2022) used the BCC model (Banker, 1984) and the DEA-Malmquist index to measure the efficiency of green finance development in China, and conducted a dynamic analysis of the efficiency at the inter-provincial level, and found that the total factor productivity of green finance in China was fluctuating. Cheng Yutai and Xiao Hongye (2022) measured the heterogeneous impact of green finance policies on the clean and polluting sectors by constructing a green finance E-DSGE model and extending the heterogeneity of the production sector of the E-DSGE theoretical model.

Secondly, research results on carbon emissions have focused on the study of factors influencing carbon emissions, which mainly analyses the differences in the effects of different factors on carbon emissions. Most of the existing literature has used methods such as the LMDI (Deutch) index decomposition and the STIRPAT model to investigate the factors influencing carbon emissions. The LMDI index decomposition reveals that economic growth, energy intensity, energy mix and industrial structure are the main factors influencing carbon emissions. Through the STIRPAT model, it is found that population structure, renewable energy consumption, FDI and technological innovation are the main factors affecting carbon emissions. At the same time, urbanisation and carbon emissions are extremely closely correlated, with the urbanisation process potentially causing both a surge in resource consumption and greenhouse gas emissions, and a reduction in carbon emissions through the promotion of industrial diversification and technological progress (Qi Xin and Guo Xue-nan, 2022).

Finally, research results on green finance and carbon emissions have mainly used data on green finance and carbon emissions to analyse the role of different green finance instruments on carbon emissions. Based on data from 23 Chinese provinces (cities) from 2006-2016, Jiang Hongli et al. (2020) found that green credits all significantly suppressed carbon emissions through mechanistic and empirical analyses, and the carbon emission effect of green credits was better than that of green venture capital. Using data from 282 cities in China from 2011-2019, Liu Feng et al. (2022) found through heterogeneity tests that the development of green finance in China significantly suppressed carbon emissions, while proposing an all-green low-carbon financing system, i.e. supporting the optimization of energy consumption structure can achieve the achievement of emission reduction targets. Scholars' data studies on green finance and carbon emissions provide a practical basis and reference point for this paper.

In summary, research has focused on both the improvement of economic and social benefits of green finance and the influencing factors of carbon emissions, while relatively little literature has combined the two organically, especially exploring the intrinsic mechanisms of green finance development affecting carbon emissions. Most of the studies focus on the carbon reduction of green finance, while the path-dependent characteristics and spatial effects of carbon emissions are less considered, and there is a lack of dynamic comparison. In addition, the mechanisms of carbon emissions from green finance need to be clarified, i.e. whether there are other pathways for the reduction effect of green finance and whether the existing reduction pathways can be optimised, which are less reflected in previous studies. Therefore, this paper investigates the above issues: ① based on the perspective of green finance development and ecological transformation of industrial structure, the spatial and threshold effects of green finance on carbon emissions are studied in depth to enrich the research content of green finance and carbon emission development. ②Analysis of panel data on the relationship between green finance development and carbon emission intensity in different regions, and the construction of corresponding spatial econometric models using three types of spatial weight matrices to enhance the reliability of the model results. ③Verify whether industrial restructuring, optimisation and green technology innovation can improve the efficiency of green finance emission reduction, and provide new insights for the optimisation of green finance carbon emission path and the improvement of green finance development system.

3. Theoretical Analysis and Hypothesis Formulation

By reviewing and sorting out the existing literature in the relevant fields, it is clear that green finance is a financial innovation based on environmental protection, guiding the flow of funds to the energy-saving and environmental protection industry through green financial instruments. The essence of green finance is to provide enterprises with differentiated exogenous financing based on environmental constraints, using punitive high interest rates and financing limits as a means to further raise the "two high and one leftover "This will control the scale of development of polluting enterprises, force them to transform and achieve "pollution reduction and carbon reduction". Conversely, green finance can also guide capital to support green projects such as environmental industries and clean energy by lowering financing costs, relaxing quota restrictions and increasing financial leverage, thereby promoting green and low-carbon development.

In summary, this project proposes the following research hypotheses.

Hypothesis 1: Green financial development is conducive to regional carbon emission reduction

At the same time, as there is a certain economic correlation between the outputs of green financial development, thus the green financial development of one region will affect the development of emission reduction in the surrounding areas. This paper uses a spatial econometric model to study the impact of green financial development on regional carbon emissions, thereby compensating for the lack of geographical location dependence of green financial development neglected in the research process. The following research hypothesis is further proposed.

Hypothesis 2: Green financial development has a spatial effect on regional carbon emission reduction.

Through reviewing and sorting out the existing literature in related fields, it can be found that green financial development mainly achieves emission reduction through green technological innovation and industrial structure transformation. On the one hand, driven by environmental regulations and market demand for green products, enterprises increase green R&D investment, improve and innovate green production technology, enhance resource and energy utilisation, promote production mode to green and efficient development, and promote enterprise carbon emission reduction; on the other hand, green finance, through the differentiation of green assets On the other hand, by differentiating between green and brown assets and risk weighting, green finance discourages the flow of funds to highly polluting and energy-consuming enterprises, "forcing" these enterprises to carry out green technology research and development and achieve carbon emission reduction. However, as green financial development emphasises environmental protection, it may have a "crowding-out effect" on R&D by regional enterprises, which in turn may lead to a disincentive to innovation. Furthermore, in conjunction with Ma Dan et al. (2023), the study suggests that as the level of green finance development continues to increase, it will gradually show a facilitating effect.

In summary, this project proposes a research hypothesis.

Hypothesis 3a: The promotion effect of green financial development on carbon emission reduction is influenced by the threshold effect of the level of green technology innovation.

Secondly, the realization of regional green financial development cannot be achieved without the transformation of economic development mode and the transformation and upgrading of industrial structure, while industrial development has a certain path dependency. The higher the ecological level of industrial structure, the better the foundation of green industry development, and the more green finance can play its role of resource allocation to support local green development to achieve carbon emission reduction. The higher the ecological structure of the industry, the less impeded green finance is from driving carbon emissions, but whether green finance development drives carbon emissions reduction is subject to the threshold effect of the degree of transformation of the ecological structure of the industry has not yet been determined.

In summary, this project proposes research hypotheses.

Hypothesis 3b: The contribution of green finance development to carbon emission reduction is influenced by the threshold effect of the degree of industrial ecological transformation.

4. Research Methodology and Data Description

4.1. Research Methodology

4.1.1. Constructing a Simple OLS Model to Test the Baseline Impact of Green Finance Development on Carbon Emissions

Firstly, in order to empirically test the benchmark impact of green finance development on regional carbon emissions, this paper constructs the following benchmark econometric model based on the modelling strategies of existing studies on the impact factors of regional carbon emissions:

$$CO_{2it} = \beta_0 + \beta_1 GF_{it} + \sum_{\varphi=1}^{n} \alpha_\varphi X_{\varphi,it} + \varepsilon_{it} \tag{1}$$

where i and t denote region and year respectively, β_0 is a constant term and ε_{it} is a random error term. The explanatory variable CO2it denotes the carbon emissions of region i in year t, and the explanatory variable GF_{ij} denotes the green financial development of region i in year t. Both are measured by constructing corresponding indices. coefficient β_1 before GF_{ij} reflects the total effect of green financial development on regional carbon emissions and is one of the coefficients of most interest in this paper. X_{it} denotes the control variables, including per capita gross regional product (GDP), foreign direct investment (FDI), urbanisation level (UR), etc.

4.1.2. Construction of a Spatial Econometric Model to Examine the Spatial Spillover Effect of Green Finance Development on Regional Carbon Emissions

(1) Econometric model

In order to analyse the impact of green finance development on carbon emissions from a spatial perspective, spatial autoregressive models (SAR), spatial error models (SEM) and spatial Durbin models (SDM) are constructed respectively.

First, the spatial autoregressive model.

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$$CO_{2_{it}} = \beta_0 + \beta_1 W_{ij} * GF_{it} + \sum_{\varphi=1}^{n} \beta_\varphi x_{\varphi,it} + \tau W_{ij} \cdot CO_{2_{it}} + \varepsilon_{it} \quad (2)$$

where w_{ij} is the spatial weight matrix, $w_{ij} * \varepsilon_{it}$ is the spatial lagged variable of the dependent variable, and τ is the spatial regression coefficient reflecting the direction and extent of the influence of observables from neighbouring regions in region i on venture capital investment in the region.

Second, the spatial error model.

$$CO_{2_{it}} = \beta_0 + \beta_1 W_{ij} * GF_{it} + \sum_{\varphi=1}^{n} \beta_\varphi x_{\varphi,it} + \tau w_{ij} \cdot \varepsilon_{it} + \varphi_{ij} \quad (3)$$

where w_{ij} is the spatial weight matrix, $w_{ij} * \varepsilon_{it}$ is the spatial lagged error term, and τ is the spatial regression coefficient reflecting the direction and extent to which unobservable influences or stochastic shocks in the region's neighbourhood i affect the region's venture capital.

Third, the spatial Durbin model.

$$CO_{2_{it}} = \beta_0 + \beta_1 GF_{it} + \sum_{\varphi=1}^{n} \beta_\varphi x_{\varphi,it} + \tau w_{ij} * CO_{2_{it}} + \eta_1 w_{ij} * GF_{it} + \eta_2 w_{ij} * \sum_{\varphi=1}^{n} x_{\varphi,it} + \varepsilon_{it} \quad (4)$$

Where w_{ij} is the spatial weight matrix, $w_{ij} * CO_{2it}$ is the spatial lagged variable of the dependent variable, $w_{ij} * X_{it}$ is the spatial lagged variable of the explanatory variable, η_1 and η_2 are the core explanatory variables and the elasticity coefficients of the spatial interaction terms of the control variables. The spatial Durbin model examines both the impact of green financial development in neighbouring regions on the region and the impact of influencing factors or stochastic shocks in neighbouring regions on carbon emissions in the region.

(2) Weighting matrix

Spatial weight matrices are a prerequisite for spatial econometric analysis. To prevent a priori errors arising from the construction of spatial weight matrices, this paper will construct and analyse the empirical results of three types of spatial weight matrices, namely 0-1 type matrices (WG_{ij}), geographical distance matrices (WD_{ij}) and economic matrices (WE_{ij}). The following are the specific formulas for each matrix:

① The spatial weight matrix WG of type 0-1. is noted as 1 if the two regions are geographically adjacent and 0 if they are not. are different radius thresholds reflecting the significance of spatial spillover effects within different radii of influence.

$$WG_{ij} = \begin{cases} W = \frac{1}{d_{ij}}, d_{ij} \le d_0 \\ W = 0, d_{ij} > d_0 \end{cases} \quad (5)$$

② Geographical distance matrix WD. is the geographical distance between and province, measured using the shortest railway mileage between the corresponding provincial capitals.

$$WD_{ij} = (1/d_{ij})/\left[\sum_{j=1}^{N}(1/d_{ij})\right] \tag{6}$$

③ Economic matrix WE. is the average of the level of economic development of the area over the sample period.

$$WE_{ij} = \left(1/\left|\overline{pgrp_i} - \overline{pgrp_j}\right|\right)/\left[\sum_{j=1}^{N}\left(1/\left|\overline{pgrp_i} - \overline{pgrp_j}\right|\right)\right] \tag{7}$$

The spatial econometric model in this paper will use the WD matrix and the robustness tests will use the WG and WE matrices.

4.1.3. Constructing a Panel Threshold Model to Examine the Non-linear Impact of Green Finance Development on Carbon Emissions

$$\boldsymbol{CO_{2}}_{it} = \boldsymbol{\beta_0} + \boldsymbol{\gamma_1 GT_{it}} \times \boldsymbol{I(GT_{it} \le \pi)} + \boldsymbol{\gamma_2 GT_{it}} \times \boldsymbol{I(GT_{it} > \pi)} + \boldsymbol{\gamma_c X_{it}} + \boldsymbol{\varepsilon_{it}} \tag{8}$$

$$\boldsymbol{CO_{2}}_{it} = \boldsymbol{\beta_0} + \boldsymbol{\gamma_1 TE_{it}} \times \boldsymbol{I(TE_{it} \le \pi)} + \boldsymbol{\gamma_2 TE_{it}} \times \boldsymbol{I(TE_{it} > \pi)} + \boldsymbol{\gamma_c X_{it}} + \boldsymbol{\varepsilon_{it}} \tag{9}$$

Where GT_{it} and TE_{it} are threshold variables indicating the level of green technology innovation and the level of ecological industrial structure in different years and regions, respectively, and 3 is the unknown threshold I(·) is an indicative function taking the value of 1 or 0, which is 1 if the condition in brackets is met and 0 otherwise. here is a single-threshold case, which can be expanded to a multi-threshold case based on steps such as measurement tests of the sample data.

Estimation using the 2SLS method, according to HANSEN (1999), is used to obtain the optimal threshold value by continuously screening the estimated sum of squares of residuals under the assumed threshold value. Once the threshold values are determined, the values can be used to estimate the coefficients for different intervals (Regime) in the model and to further test the significance of the presence of the thresholds.

4.2. Data Sources

4.2.1. Data Selection

(1) Explanatory variables

Carbon emissions. The data are derived from raster simulation data set of global atmospheric carbon dioxide concentration published by the National Tibetan Plateau Scientific Data Center.

(2) Explanatory variables

Green finance development. Existing literature mainly adopts principal component analysis method, entropy method and expert scoring method, etc. In this paper, entropy method is used to describe the development level of green finance in accordance with previous studies

First, data standardization:

$$X_{ij} = \frac{x_{ij} - minx_{ij}}{maxx_{ij} - minx_{ij}} \tag{10}$$

$$X_{ij} = \frac{maxx_{ij} - x_{ij}}{maxx_{ij} - minx_{ij}} \tag{11}$$

Formula (1) is the standardization of positive indicators, while Formula (2) is the standardization of negative indicators. Meanwhile, in order to eliminate the influence of 0 and negative values, a minimum unit value of θ is added to all data results after standardization to make it meet the operation requirements.

If I take $\theta = 0.0001$, I get $X_{ij}{}'$.

Calculate the weight of each index:

$$P_{ij} = \frac{X_{ij}{}'}{\sum_{i=1}^{n} X_{ij}{}'}$$

Calculate index entropy value:

$$D_j = -\frac{1}{\ln n}\sum_{i=1}^{n} P_{ij} \ln P_{ij}$$

To obtain the redundancy of index entropy:

$$G_j = 1 - D_j$$

Weight calculation results:

$$w_j = \frac{G_j}{\sum_{j=1}^{m} G_j}$$

Comprehensive development level index calculation:

$$U_j = \sum_{j=1}^{m} w_j \times X_{ij}$$

(3) Threshold variable

From the perspective of green technology innovation development and ecological transformation of industrial structure, this paper examines the mechanism of green finance development to inhibit regional carbon emissions. Therefore, the innovation level of green technology and ecological transformation of industrial structure are the core variables of this paper.

The measurement indicators of green technology innovation in many empirical literatures focus on indirect indicators such as R&D and green productivity. However, with the improvement of the availability of patent data and the in-depth mining of patent information, it is concluded that patent data is more authentic than the self-reported R&D investment of enterprises. Therefore, the number of green patents is adopted in this project to measure the level of green technology innovation (GT). As for the ecological level of industrial structure (TE), this paper mainly refers to the approach of Lv Mingyuan and Chen Lei (2016) and uses environmental efficiency index to measure the ecological level of industrial structure.

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$$TE = \frac{1}{PI}\text{, among them , } PI = \frac{\sum_{i=1}^{n} pi_i}{n}\text{, so, } TE = \frac{n}{\sum_{i=1}^{n} pi_i} \quad (12)$$

Among them, P_{i_i} said i kind of total pollutant emissions per unit of GDP, n said index number, PI said per unit of GDP pollutant total amount indicators. When other conditions remain unchanged, the higher the value of TE, the higher the degree of ecological industrial structure; conversely, the lower the degree of ecological industrial structure.

(4) Control variables

Referring to existing studies, the following variables are controlled, including: economic development level, which is measured by logarithm of real per capita GDP based on 2010; Foreign direct investment (FDI), measured as the ratio of FDI actually employed to GDP. Urbanization level (UR). The expansion of urbanization tends to promote consumption, which in turn leads to the increase of carbon emissions. In this paper, the proportion of urban population in total population of each province is used to measure. Financial development degree (FID), referring to the practice of Zhang Chengsi and Zhu Yueteng (2017), the proportion of the loan balance of financial institutions in the GDP of the province (loan balance/nominal GDP) as the proxy variable; Government intervention (GOV), using the proportion of government expenditure to GDP as a proxy variable.

4.2.2. Data Description

According to data availability, 30 provinces (municipalities directly under the Central Government and autonomous regions) in mainland China (excluding Hong Kong, Macao, Taiwan and Tibet) from 2010 to 2020 are selected as research samples. The data for calculating the development level of green finance mainly come from China Statistical Yearbook, statistical Yearbook and bulletin of provinces (municipalities directly under the Central Government and autonomous regions), China Insurance Yearbook, official website of local governments, Wind and EPS database, etc. The relevant data of calculating industrial structure and green patents are derived from CNRDS database. Indicators such as the level of economic development, foreign direct investment, financial development, environmental infrastructure investment and government intervention are derived from CNRDS database, China Environmental Statistical Yearbook and Wind database. Partial missing data was completed by linear difference method.

5. Analysis of Empirical Results

5.1. Analysis of Regression Results

The result of global autocorrelation analysis shows that there is obvious spatial correlation in Chinese venture capital activities, so the spatial spillover effect should be considered when investigating regional venture capital influencing factors. The Hausman test results of venture capital scale regression show that P values are all significant at 1% level, rejecting the assumption that there is no difference between fixed effect and random effect estimation. At the same time, the fixed effect model has the best effect, so this paper adopts the fixed effect model to construct. As can be seen from Table 5-1, the fitting degree of OLS estimated venture capital scale was 0.971, which was good and passed the significance test at the 1% level on the whole. In order to further analyze the spatial effects of regional green finance development on regional carbon emissions, a lagged term was introduced to construct a spatial econometric model for analysis. The results show that the fitting degrees of SAR, SEM and SDM are 0.298, 0.203 and 0.247, respectively. By comparing the three models Log-L, it is concluded that SDM model has a better fitting effect. At the same time, rho values of SAR, SEM and SDM are all significantly negative, indicating that green finance development has a strong spatial

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dependence, that is, green finance development in the region will have an impact on carbon emissions in the surrounding areas, even reducing carbon emissions in the surrounding areas.

Because the model contains spatial lag term of explanatory variables, point estimation method is difficult to reflect the real effect of direct parameter and spillover effect. Combined with partial differential solving, the empirical results were discussed from two aspects of direct and indirect effects (Table 1). The effect decomposition shows that the direct effect of green finance is negative, indicating that green finance reduces regional carbon emissions. Table 1 shows that the indirect effect of green finance is also negative and stronger than the direct effect, indicating that green finance can not only reduce local carbon emissions, but also inhibit the carbon emissions in neighboring areas, indicating that green finance also needs integrated and overall development among regions. Only in this way can the trans-regional synergistic emission reduction effect of green finance be brought into play and the global regional carbon reduction target be achieved.

Table 1. Spatial Dubin model

CO2	Coef.	P > [z]
Main		
GF	-2.194	0.177
PGDP	0.345***	0.000
UR	3.521**	0.048
FDI	-25.035***	0.003
GOV	27.119***	0.000
FID	-1.107***	0.000
Wx		
GF	-28.736***	0.004
PGDP	1.764***	0.000
UR	-15.723*	0.091
FDI	-32.022	0.597
GOV	9.110	0.365
FID	0.542	0.505
Obs	330	
rho	-0.488**	0.043
Sigma2_e	2.065***	0.000
R-sq	0.406	

Note: ***p<0.01, **p<0.05, *p<0.1, the same below.

Since this paper adopts the common econometric model and the spatial econometric model, WG and WE matrix will be used in this paper for the secondary test of the spatial econometric model. Among them, data from 2010 to 2020 were used for analysis by WG and WE matrix test.

As can be seen from Table 2, green finance development (GF) has a significant positive effect on regional carbon emissions, but green finance development in neighboring areas will increase regional carbon emissions. The results of other control variables and robustness test are approximately consistent with the above analysis results, so it can be considered to pass the robustness test.

Table 2. Robustness test

CO_2	Coef.	P > [z]
Main		
GF	4.507***	0.576
Control variable	yes	
Wx		
GF	-5.817***	0.005
Control variable	yes	
Obs	150	
rho	-0.775**	0.042
Sigma2_e	0.924***	0.000
R-sq	0.751	

Panel threshold model regression results analysis:

This paper reference xthreg command is used to estimate threshold effect, specific estimate steps are as follows: first, to determine the threshold number. Specifically, we assume that the models are single threshold, double threshold and triple threshold respectively, and use the "cycle method" to search for threshold values. For the multi-threshold model, the remaining threshold values are searched on the basis of gradually fixing the determined threshold values. In the second step, hypothesis testing was conducted on the basis of determining the threshold value, so as to determine whether the setting form of threshold regression in this paper is single threshold, double threshold or three threshold. Third, based on the threshold value that has been determined, threshold regression is carried out to obtain the estimation parameters required in this paper.

Table 3. Test results of threshold effect

Threshold variable	Threshold number	F value	P value	10% critical level	5% critical level	1% critical level
	One-threshold	200.33	0.0000	34.9561	45.0580	107.6981
GF	Two-threshold	54.70	0.0100	26.1890	32.7324	50.7808
	three-threshold	13.46	0.6380	46.3493	65.7922	128.7018
	One-threshold	34.42	0.0340	25.261	30.9718	40.6643
TE	Two-threshold	24.85	0.0332	18.2689	22.6590	29.8510
	three-threshold	11.77	0.5140	41.3111	57.2277	81.8048

Note: Confidence interval is 95%; 500 samples were taken using the bootstrap self-sampling method.

Table 4 shows the parameter estimation results of the threshold model, in which the explained variables in columns (1) and (2) are carbon emission intensity (CO_2). As can be seen from the results in column (1), the coefficient of green finance development goes through a stage from

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positive to negative and from large to small, indicating that the impact of green finance on carbon emissions is influenced by the level of green technology innovation, which specifically presents the imagination of promoting before inhibiting. This is because the development of green finance emphasizes environmental protection, which may cause the "crowding out effect" of regional enterprises' research and development, and thus hinder enterprises' innovation. In addition, according to the study of Ma Dan et al. (2023), with the continuous improvement of the development level of green finance, it will gradually show a promoting effect, which verifies the conclusions of this paper. As can be seen from the results in column (2), the coefficient of green finance development has experienced a stage from negative to positive and from small to large, which indicates that the influence of green finance on carbon emissions is affected by the degree of ecological adjustment of industrial structure. The higher the degree of ecological adjustment of industrial structure, the more significant the positive promoting effect of green finance on carbon emission intensity will be. When the ecological level of industrial structure is less than the second threshold value of 1.186, green finance has a negative effect on carbon emissions. This result means that in the process of ecological adjustment of industrial structure, green finance can really promote the reduction of regional carbon emission intensity only when the industrial structure achieves sufficient ecological transformation. If the ecological transformation of industrial structure is not in place, green finance will not play a positive role in promoting regional carbon emission reduction, but will hinder it.

Table 4. Estimation results of threshold model parameters

Variables	GT(1)	Variables	TE(2)
GF_{it}*I(GT≤87)	37.532*** (0.000)	TE*I(TE≤0.561)	7.8151*** (0.008)
GF_{it}*I(87<GT≤340)	5.3123* (0.057)	TE*I(0.561<GT≤1.186)	1.523 (0.412)
GF_{it}*I(GT>340)	-0.190 (0.810)	TE*I(GT>1.186)	-1.059*** (0.000)
PGDP	-0.7337** (0.041)	PGDP	-1.367** (0.016)
UR	-2.195 (0.261)	UR	-6.141** (0.086)
FDI	-2.242 (0.477)	FDI	-2.773 (0.457)
GOV	-4.199 (0.280)	GOV	-5.306 (0.220)
FID	0.119 (0.556)	FID	0.497 (0.867)
rho	0.968*** (0.000)	rho	-0.734*** (0.000)
Observations	330	Observations	330
R-squared	0.594	R-squared	0.350

Note: *** p<0.01, ** p<0.05, * p<0.1

6. Research Conclusions and Suggestions

From the perspective of green technology innovation and industrial structure transformation and upgrading, this paper empirically tests the impact of green finance development on green development based on the panel data of 30 provinces and municipalities from 2010 to 2020. The main conclusions are as follows: (1) Green finance can effectively reduce the overall regional carbon emission intensity. (2) Further research on its spatial effect shows that green finance has a significant positive impact on carbon emissions in neighboring regions. (3) Taking the ecological level of industrial structure as the threshold variable, the threshold regression shows that there is a double threshold effect. Only when the level of green technology innovation and the ecological level of industrial structure is raised to a certain level, can green finance fully promote regional carbon emission reduction.

On this basis, the policy implications are as follows: First, the government should realize that green finance is a powerful tool to promote regional carbon emission reduction. The government should attach importance to the development of green finance and give full play to its functions such as resource allocation, price discovery of ecological products and environmental risk management. Green finance has played a positive role in curbing carbon emissions. On the one hand, it fully guides financial institutions to continue to expand the scale of green credit, sets the growth target of green loan, and innovates green financial products. On the other hand, we should increase the means of direct green financing, such as supporting the issuance of local government bonds for green and low-carbon projects, enriching green insurance products, and actively setting up green industry investment funds. Social capital and institutional investors will be attracted to invest in enterprises (projects) in key fields of green development, such as energy conservation and emission reduction, research on the carbon emission reduction effect of clean energy and green finance and its influence channels, and expand the scale of green finance. Finally, local governments should be guided to achieve green and low-carbon transformation, improve their industrial structure and ecological level, and advocate green technology innovation at the same time.

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