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Can Financial Development Curb Carbon Emissions? Empirical Test Based on Spatial Perspective

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Abstract: To respond to global climate change and achieve a "carbon peak" and "carbon neutrality" as soon as possible has become a common goal around the world. Economic growth relies heavily on financial development; indeed, low-carbon economic development is inseparable from financial support. This paper studies the impact of financial development on carbon emission intensity and its mechanism from both theoretical and empirical aspects. Based on the 2005–2018 data on Chinese cities and the Spatial Durbin Model (SDM) research results, this paper finds that: (1) Financial development has significantly reduced China's carbon emission intensity overall. After considering spatial effects, financial development increases local carbon emission intensity, although it may lead to a more significant decrease in the surrounding area. (2) The analysis of heterogeneity shows that only the financial development in the eastern region has a substantial detrimental impact on total carbon emission intensity and the carbon emission intensity of neighboring cities. The financial development in the central and western regions has no significant effect on carbon emission intensity. (3) The mechanism test shows that financial development mainly reduces carbon emission intensity through technological innovation and structural optimization, with the effect of technological innovation being 9.5%, and the effect of structural optimization being 12.15%. The expansion of the consumption effects of financial development has no significant impact on carbon emission intensity. Accordingly, this article believes that it is necessary to further support financial development, build large-scale financial centers, continue to optimize the structure of financial products, and encourage the development of green finance.

Keywords: financial development; carbon emissions; spatial effects

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1. Introduction

Climate change and natural disasters such as global warming, drought, and floods brought about by carbon dioxide emissions will have a major impact on the development of both human society and economies [1–3]. Statistics show that, since 1880, CO_2 in the atmosphere has reached 413 ppm; over the last 100 years, this has increased the global temperature by 1.9 F and the sea level by 178 mm [4]. How to reduce carbon emissions has become a pressing issue worldwide. BP World Energy Statistics shows that China's carbon emissions reached 9.825 billion tons in 2019, an increase of 3.4% compared to 2018. China's total carbon dioxide emissions have far exceeded those of developed countries such as the United Kingdom and the United States. Faced with various climate problems caused by carbon emissions, China, as the world's largest CO_2 emitter and energy consumer [5], is undoubtedly facing huge pressure to save energy and reduce emissions. The Chinese government places a high priority on reducing carbon emissions as part of the country's economic growth. In 2020, China once again announced at the United Nations General Assembly that it will strive to achieve a "carbon peak" by 2030 and "carbon neutrality" by 2060. Therefore, whether it is developing countries such as China and India, or developed countries such as the United States, the United Kingdom and Japan, all hope to reduce carbon emissions while at the same time maintaining economic development, and to achieve a "carbon peak" and "carbon neutrality" at an early date. This has become an important goal for the government in formulating development policies and in improving the quality of economic development.

Financial development is seen as an important driving force for economic growth [6,7], and has a significant impact on promoting the transformation of economic development models and in promoting a low-carbon economy [8]. On the one hand, financial development can promote technological innovation and reduce energy consumption per unit of GDP, thereby reducing carbon dioxide emissions [9]. On the other hand, financial development has an expansion effect. Financial development can improve both the financing environment and consumer credit services, prompt companies to expand production scale, and increase consumer consumption of household appliances, automobiles, and other commodities, all of which will also increase carbon dioxide emissions [10,11]. Therefore, to promote a low-carbon transformation of the economy, it is necessary to allocate and guide the direction of the flow of financial resources and support the development of energy-saving and environmental protection industries [12]. With the development of China's financial industry and the continuous improvement in internationalization, new financial forms, such as green finance and digital finance, continue to emerge and exert economic effects. It has become an important way to allocate more credit resources to clean enterprises. This will change the backward business model of enterprises that waste resources and pollute the environment, and will help to avoid falling into the dilemma of pollution first and treatment later. According to data from the Global Financial Centers Index, among the world's top ten international financial centers, China occupies four, namely Shanghai, Hong Kong, Beijing, and Shenzhen. The level of China's financial development continues to improve, which is consistent with the trend of continuous growth in carbon emissions. An interesting topic is then whether financial development promotes China's carbon emissions or curbs its carbon emission intensity? What is the mechanism behind it? Furthermore, is the impact of financial development on carbon emissions affected by geospatial factors? The possible innovations in this paper are as follows: (1) Explain the impact mechanism of financial development on carbon emissions from three aspects: a consumption effect, an innovation effect, and a structural effect. (2) This paper uses Chinese city data from 2005 to 2018 to empirically test the impact of financial development on carbon emission intensity and to consider the role of geospatial factors on the impact of financial development on carbon emission intensity. We further test whether this role exists in the heterogeneity of urban areas so as to provide a theoretical basis for evaluating the emission reduction effects of financial development.

2. Literature Review

The following three categories can be used to organize studies on the influence of financial development on carbon emissions.

The first view is that financial development reduces carbon emissions [13,14]. Based on the panel data of APEC countries from 1990 to 2016, Zaidi et al. [15] studied the relationship between globalization, financial development, and carbon emissions and found that financial development significantly reduced carbon emissions. Liu and Song [16] investigated the influence of China's financial development on carbon intensity, with the results showing that financial development curbed carbon emissions as a whole. This is mainly due to the fact that financial development can both provide companies with lower-cost funds for investment in environmentally friendly projects and increase financial support for the development and application of cleaner production technologies and energy-saving technologies, thereby improving corporate energy efficiency and reducing carbon emissions [17]. At the same time, financial development is conducive to promoting technology spillovers and expanding the scope of use of new environmentally friendly technologies, thereby further reducing carbon emissions [10]. The second view is that financial development has increased carbon emissions, mainly because financial development increases the consumption of high-emission commodities in sectors such as production and transportation [18]. Zhang [19] found not only that financial development is a major contributor to the increase in carbon emissions, but also that different financial development indicators have different effects on carbon emissions. Among them, the scale of financial intermediation has a greater impact on carbon emissions than other financial development indicators, such as the efficiency of financial inter-mediation, the size and efficiency of the stock market, and so on. Boutabba [20] used 1971–2008 time series data to study the relationship between India's carbon emissions, financial development, economic growth, trade openness, and energy consumption. The results found that financial development has a long-term positive impact on per capita carbon emissions. Adams and Klobodu [21] found that financial development is a key factor leading to an increase in carbon emissions when considering the political system. Paramati et al. [22] studied the impact of financial deepening on carbon emissions based on panel data from 25 OECD economies from 1991 to 2016 and found that financial deepening significantly increased carbon emissions. Shen et al. [11] believe that a well-developed financial system reduces information asymmetry, making it easier for companies to finance; this is conducive to expanding the scale of production by companies, leading to increased carbon emissions. On the other hand, however, financial development has led to an increase in carbon emissions through the increase in consumer energy demand.

The third view is that there is a non-linear relationship between financial development and carbon emissions, such as the "inverted U-shaped" or "U-shaped" curves [23,24]. Hao et al. [25] used 29 provinces in China as examples and found that the influence of financial development on CO_2 emissions varies at different stages of economic development. In the initial stage of economic growth, financial development reduced CO_2 emissions, but when the degree of economic development increased, financial development increased CO_2 emissions. Shahbaz et al. [26] studied the relationship between economic growth, R&D expenditure, energy consumption, financial development, and carbon dioxide emissions based on historical data on the British economy from 1870 to 2017. They also concluded that there was a U-shaped relationship between financial development and carbon dioxide emissions. Acheampong et al. [27] used panel data from 83 countries from 1980 to 2015 and found that in both independent financial economies and emerging financial economies there is an inverted U-shaped relationship between financial market development and carbon emission intensity.

In summary, research on the influence of financial development on carbon emissions has shown certain results, but no consistent research conclusion has yet been established. At the same time, the mechanism by which the impact of financial development affects carbon emissions is still unclear. Not only does the existing literature rarely incorporate spatial factors into the study of financial development and carbon emissions, but it also lacks micro-level evidence at the city level, which, ultimately, will bias the estimation results. Based on this, this paper uses Chinese city-level data to integrate spatial factors into the analysis of the influence of financial development on carbon emission intensity, and then analyzes and tests its mechanism of action.

3. Influence Mechanism

From a theoretical point of view, financial development may reduce carbon emissions both by promoting technological innovation to achieve cleaner production and by adjusting the industrial structure. It is also possible to increase energy consumption and promote carbon emissions through the expansion of consumer demand and economic scale. As a result, the influence of financial growth on carbon emissions remains uncertain, dependent on the contrast between the positive and negative effects of carbon emissions.

3.1. The Effect of Technological Innovation

Technological innovations such as renewable energy technologies and cleaner production technologies are important factors in reducing carbon emissions [26,28,29]. Through research and development, innovation, and the application of green technology to actual production, emissions of CO_2 can be effectively reduced. Financial development will promote technological innovation by three means, and so reduce carbon emissions. The first is to reduce financing costs and promote technological innovation. Enterprise technological innovation is a complex and special input–output process with high-risk and high-input characteristics. Whether or not it can obtain sufficient external financial support is key to the success or failure of innovation [30]. A developed financial market can provide diversified financing tools and channels for corporate green innovation activities. Special financial products such as green bonds and innovation and entrepreneurship bonds can continuously enrich the market investment and financial product system, reduce corporate financing costs, improve financing constraints, and promote green technological innovation. At the same time, the development of new financial forms such as digital finance will also help to break the administrative barriers of traditional finance, promote the cross-regional flow of financial resources, reduce the information and matching costs of capital cross-regional flows, promote green technological innovation, and reduce carbon emission intensity. The second is to optimize the efficiency of financial resource allocation and promote technological innovation. An increase in the level of financial development, to a certain extent, not only means that the level of financial marketization has also increased, but also that the government's direct interference in the allocation of financial resources has decreased; this will help to change the distortion of traditional financial resource allocation [31]. Financial institutions can transfer more financial resources from state-owned enterprises with low innovation efficiency [32,33] to the more efficient and dynamic private sector based on the principles of risk and return, facilitate new technological innovation, and reduce carbon emissions by promoting technological innovation. The third is to promote the diffusion and spillover of knowledge and promote technological innovation. Regional innovation activities are susceptible to the dual influence of input factors and innovation environment. In addition to reducing financing costs and increasing R&D capital investment, financial development can both promote knowledge diffusion and spillover and promote technological innovation. Cities with a high level of financial development usually have a high level of internationalization, which helps to accelerate the introduction of foreign capital. By driving the flow of R&D personnel and the spillover of technological elements, the level of energy-saving and emission-reduction technologies, and green production technologies, will be improved, thereby encouraging regional innovation and reducing carbon emissions. Based on this, Hypothesis 1 is proposed.

Hypothesis 1. *Financial development reduces carbon emissions by promoting technological innovation.*

3.2. Structural Effects

Industrial structure is closely related to the spatial distribution of regional energy consumption and carbon emissions [33], and plays an important role in achieving low-carbon economic development in China [34]. Financial development has achieved resource conservation and a reduction in carbon emissions by promoting the optimization of the industrial structure. On the one hand, financial development can optimize the capital allocation structure, and then, by guiding the flow of capital, can promote the optimization and upgrading of the industrial structure, thereby reducing carbon emissions. First of all, at the policy level, national policy banks specifically support high-tech industries that are needed for future development through loan subsidies and credit rationing. This high-end industry usually has the characteristics of high technology, low energy consumption, and low emissions. Secondly, at the market level, as China's requirements for carbon emission reduction work continue to increase, the financial system will continuously optimize the capital allocation structure by controlling the flow of capital. Financial institutions will strengthen the review of capital flows, consciously restrict the flow of capital to high-emission and high-energy-consuming industries, and actively guide financial capital to increase its tilt toward both green and clean industries and smart, high-end industries. This will help to optimize the industrial structure and reduce carbon emissions. On the other hand, financial development can optimize the structure of financial products. With the improvement in the level of financial development, there is an obvious green trend, with new financial forms, such as green credit and green bonds, becoming more abundant. For example, carbon neutral bonds are a sub-type of green bonds, and the funds raised by them will be earmarked for green projects with carbon emission reduction benefits. The optimization of this kind of financial structure can effectively reduce the financing difficulty and capital borrowing cost of green projects and green industries, and can provide positive incentives for enterprises to carry out both green technology research and development and industrial upgrading activities, as well as reduce carbon emissions. Based on this, Hypothesis 2 is proposed.

Hypothesis 2. *Financial development reduces carbon emissions by optimizing industrial structure*.

3.3. Consumption Effect

Financial development can increase the breadth and depth of financial services, make financial services more convenient, and reduce transaction costs. This allows consumers who are constrained by liquidity to conveniently use the financial market to achieve intertemporal smoothing of consumption and release potential consumer demand. This will mainly promote carbon emissions from both consumption and production. From the perspective of the household sector, when a country develops financial services, consumers will expand consumption due to the availability of loans and increase the purchase and use of large commodities, such as houses, cars, and air conditioners, which will directly increase energy demand and increase carbon emissions in the household sector [35]. From a corporate perspective, financial development can make corporate financing more convenient and reduce corporate friction costs and transaction costs. Stock market financing has also reduced corporate financing costs to a certain extent, which will encourage enterprises to expand production. At the same time, as the consumer demand for various commodities in the household sector increases, it will further promote the expansion of scale production and the expansion of business activities by enterprises, which will increase the demand for energy consumption such as coal and electricity. This in turn causes an increase in carbon emissions from the industrial production sector. In addition, financial development helps attract more foreign direct investment, thereby further increasing energy consumption from production and economic development [36]. In particular, the currently imperfect environmental regulatory system in China, and the low level of energy-saving and emission-reduction technologies, will further increase carbon emissions. Based on this, Hypothesis 3 is proposed.

Hypothesis 3. *Financial development increases carbon emissions by promoting consumption*.

4. Model Setting and Variable Description

4.1. Model Setting

This article first establishes a common Fixed Effects Model (Model (1)) to investigate the influence of financial development on carbon emission intensity. Carbon emissions show a certain degree of autocorrelation when their spatial locations are correlated. To explore the spatial effect of financial development on carbon emission intensity, this article draws on the work of Liu and Song [16] and uses the spatial econometric model to further test and judge the possible direct and indirect effects. This is carried out in order to better interpret the spatial dependence between regions due to the increasing economic exchanges. Based on this, we establish three spatial measurement models: Spatial Autoregressive Model (SAR), Spatial Error Model (SEM), and Spatial Durbin Model (SDM). Among them, the SAR can better measure the influence of the neighbors of the explained variable on itself. The SEM uses random disturbance terms to construct the model, which can resolve the bias caused by the inclusion of missing variables, while taking into account the existence of spatial heterogeneity. The SDM has the advantages of the above two models at the same time. Not only will the model cause no major errors, but it will also eliminate errors caused by missing variables.

$$lnci_{it} = \beta_1\, lnfin_{it} + \beta_2 lnpop_{i()t} + \beta_3 lngov_{it} + \beta_4 lnfdi_{it} + \beta_5 lnedu_{it} + \beta_6 lncy_{it} + \beta_7 lnjt_{it} + u_i + \varepsilon_{it} \quad (1)$$

$$\begin{gathered} lnci_{it} = \beta_1\, lnfin_{it} + \beta_2 lnpop_{it} + \beta_3 lngov_{it} + \beta_4 lnfdi_{it} + \beta_5 lnedu_{it} + \beta_6 lncy_{it} + \beta_7 lnjt_{it} + u_i + \varepsilon_{it}, \\ \varepsilon_{it} = \lambda \sum_{j=1}^{n} W_{ij}\varepsilon_{it} + \mu_{it} \end{gathered} \quad (2)$$

$$\begin{gathered} lnci_{it} = \rho \sum_{j=1}^{n} W_{ij}\, lnci_{it} + \beta_1\, lnfin_{it} + \beta_2 lnpop_{it} + \beta_3 lngov_{it} + \beta_4 lnfdi_{it} + \beta_5 lnedu_{it} + \beta_6 lncy_{it} \\ +\beta_7 lnjt_{it} + u_i + \mu_{it},\ \mu_{it} = \lambda \sum_{j=1}^{n} W_{ij}\varepsilon_{it} + \varepsilon_{it} \end{gathered} \quad (3)$$

$$lnci_{it} = \alpha_i + \rho \sum_{j=1}^{N} W_{ij} lnci_{it} + \beta_1 lnci_{it} + \beta X_{it} + \varphi_1 W * lnci_{it} + \varphi \sum_{j=1}^{n} W_{ij} X_{it} + U_{it},\ U_{it} = \lambda W \mu_{it} + \varepsilon_{it} \quad (4)$$

where $lnci_{it}$ represents carbon emission intensity, which is an explained variable; $lnfin_{it}$ represents the level of financial development and is the core explanatory variable; $lnpop_{it}$, $lngov_{it}$, $lnfdi_{it}$, $lnedu_{it}$, $lncy_{it}$, $lnjt_{it}$ are control variables, which respectively represent population density, government expenditure, foreign direct investment, human capital, industrial structure, and transportation development; ρ, λ, φ are the space lag coefficient, the space error coefficient, and the space coefficient of the explanatory variable, respectively; and W_{ij} is the spatial weight matrix. This paper selects the geographically adjacent distance to establish the weight matrix.

$$W_{ij} = \begin{cases} 1, & \text{When the space unit } i \text{ and } j \text{ have a common boundary} \\ 0, & \text{When the space unit } i \text{ and } j \text{ do not have a common boundary} \end{cases} \quad (5)$$

4.2. Variable Description

4.2.1. Explained Variable: Carbon Emission Intensity (CI)

As China has no official carbon emissions data, this article draws on the practices of Hao et al. [37] and Wang et al. [9] to measure carbon emissions and uses the calculation methods published by the IPCC to measure carbon dioxide emissions in the various cities. Carbon dioxide emissions in Chinese cities between 2005 and 2018 are measured by taking coal, coke, crude oil, gasoline, kerosene, diesel, natural gas, and fuel oil as the terminal consumption of eight types of energy in each city and by multiplying the consumption of the eight types of energy by their respective carbon emission coefficients. The carbon dioxide emissions of each city are divided by the GDP of each city as the carbon emissions per unit of GDP. The specific calculation formula and steps are as follows:

$$CO_{2it} = \sum_{k=1}^{8} CO_{2tik} = \sum_{k=1}^{8} E_{tik} \times NCV_k \times CEF_k \times COF_k \times \frac{44}{12} = \sum_{k=1}^{8} \frac{44}{12}\rho_k E_{tik} \quad (6)$$

where t represents the year and i represents the city; CO_{2tik} represents the emission of CO_2 of the k-th energy in city t in year t; E_{tik} represents the consumption of the k-th energy in city i in year t; NCV_k represents the low calorific value of the k-th energy; CEF_k represents the carbon emission factor of the k-th energy; COF_k represents the carbon oxidation rate of the k-th energy; 44/12 means that carbon is oxidized to CO_2 with the molecular weight changing from 12 to 44. When calculating the emissions of CO_2, you need to multiply 44 and divide by 12. ρ_k is the carbon emission coefficient. Formula (7) is then used to calculate the carbon emission intensity of each city.

$$CI_{it} = \frac{EC_{it}}{GDP_{it}} \quad (7)$$

4.2.2. Core Explanatory Variables

Financial development level (FD): Drawing on the research of Liu and Song [16], the ratio of total credit of financial institutions to GDP is used to express financial development. The higher the ratio of total credit to GDP, the easier it is for companies to finance, which means the higher the level of financial development.

4.2.3. Control Variables

- Population density (lnpop): Low population density will lead to an increase in commuting distance and will increase carbon emission levels. An increase in population density is conducive to saving space and improving compactness, and reducing the energy cost of urban operations by sharing infrastructure reduces carbon emissions [38]. This is measured by the proportion of the population in the city area at the end of the year in the city jurisdiction.
- Government expenditure (lngov): With the continuous enhancement of the Chinese government's requirements for a "carbon peak" and "carbon neutrality", carbon emissions reduction has been included as an important indicator in the evaluation system for government officials. Local governments will increase the regulation of, and expenditure on, carbon emissions reduction in order to meet the central government's "carbon peak" requirement as soon as possible. Using the ratio of government fiscal expenditure to GDP as a proxy variable, it is expected that government expenditure will have a positive effect on carbon emissions reduction.
- Foreign direct investment (lnfdi): Foreign direct investment has two effects on carbon emissions. FDI companies often relocate some polluting companies to countries with lower environmental standards for production, thereby increasing the CO_2 emissions of the host country. That said, foreign direct investment may also bring advanced, clean technology and management experience to host country enterprises, and so lead to a reduction in CO_2 emissions [39].
- Human capital (lnedu): Human capital is a manifestation of labor force knowledge and skill levels. The higher the level of human capital, the more conducive it is to promoting technological innovation, carrying out related clean production activities, and reducing carbon emissions caused by production activities [40]. In general, people with higher human capital have stronger environmental awareness and pay more attention to low-carbon life. This article uses per capita education level as a proxy variable. Edu = number of primary school students/total population*6 + number of middle school students/total population*12 + number of college students/total population*16.
- Industrial structure (lncy): Industrial activity is an important cause of carbon emissions. The higher the proportion of urban industry, the higher the proportion of enterprises using fossil energy. This will lead to an increase in total carbon emissions. This article uses the ratio of the added value of a city's secondary industry to GDP to measure the industrial structure.
- Public transportation (lnjt): Grazi and Bergh [41] maintained that energy-related carbon emissions brought about by the transportation sector accounted for 21% of total emissions, this makes it an important sector that causes increased carbon emissions. We selected the number of publicly operated vehicles in the city as a proxy variable as a control for the impact of the transportation sector on carbon emissions.

4.3. Data Sources and Descriptive Statistics

This paper selected the panel data of 223 cities in China from 2005 to 2018 as the sample data. The data sources included the "China City Statistical Yearbook" (2006–2019) and the "China Energy Statistical Yearbook" (2006–2019). We made descriptive statistics on the data characteristics of the main variables (see Table 1). In order to investigate the multicollinearity of the model, correlation coefficients between the explanatory variables were calculated. The correlation coefficients between the variables were mostly less than

0.5. We further investigated the variance expansion factor and found that they were all around 2, which is lower than the empirical criterion of 10. Therefore, there was no multicollinearity problem.

Table 1. Descriptive statistics and correlation analysis.

Variables	lnci	lnfin	lnpop	lngov	lnfdi	lnedu	lncy	lnjt
Obs	3122	3122	3122	3122	3122	3122	3122	3122
Mean	−8.499	−0.021	5.857	−1.952	10.025	2.242	3.861	6.746
Std.Dev.	0.829	0.502	0.919	0.424	1.79	0.09	0.232	1.269
Min	−10.709	−2.187	0.3	−4.176	1.099	1.931	2.705	2.303
Max	−3.817	1.67	7.887	0.396	14.941	2.587	4.453	13.172
lnci	1.000							
lnfin	−0.190 ***	1.000						
lnpop	−0.060 ***	0.113 ***	1.000					
lngov	−0.062 ***	0.361 ***	−0.365 ***	1.000				
lnfdi	−0.349 ***	0.331 ***	0.444 ***	−0.283 ***	1.000			
lnedu	−0.013	0.398 ***	0.099 ***	−0.202 ***	0.406 ***	1.000		
lncy	0.148 ***	−0.221 ***	0.243 ***	−0.395 ***	0.120 ***	−0.041 **	1.000	
lnjt	−0.111 ***	0.309 ***	0.374 ***	−0.393 ***	0.522 ***	0.513 ***	−0.003	1.000
VIF	1.77	2.01	1.48	2.25	1.71	1.65	1.28	2.00

Note: *** and ** indicate that the variable coefficient has passed the significance test at 1% and 5%, respectively.

5. Empirical Test and Discussion

5.1. Spatial Autocorrelation Test

Before performing spatial metrological inspection, it is necessary to verify whether the object under study has spatial dependence. Drawing lessons from Moran [42], Moran's I index was used for the autocorrelation test.

$$\text{Global Moran's I} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(X_i - \overline{X}\right)\left(X_j - \overline{X}\right)}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \tag{8}$$

$$\text{Local } I_i(d) = Z_i \sum_{j \neq 1}^{n} W'_{ij} Z_j \tag{9}$$

where $S^2 = \frac{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2}{n}$, X_i is the sample observation value of area i; n is the total number of regions; W_{ij} is the spatial weight; $\sum_{j \neq 1}^{n} W'_{ij} Z_j$ is the space lag vector, representing the weighted average of carbon emissions and financial development index deviations in neighboring areas.

Based on the geographical proximity matrix, we calculated the local Moran's I value of each city's carbon emission intensity (CI) and financial development (FD). Table 2 shows the local Moran's I values for each city from 2008 to 2018. The estimated results were significantly positive and showed a trend of increasing year on year. It can be observed that the carbon emission intensity (CI) and financial development (FD) of each region have a significant positive spatial correlation with this geographic correlation increasing year by year over time.

Table 2. Moran index based on geographic adjacency matrix.

Year	Carbon Intensity (CI)		Financial Development (FD)	
	Moran's I Value	p Value	Moran's I Value	p Value
2005	0.277 ***	0.000	0.086 *	0.052
2006	0.282 ***	0.000	0.141 ***	0.002
2007	0.266 ***	0.000	0.151 ***	0.001
2008	0.279 ***	0.000	0.188 ***	0.000
2009	0.263 ***	0.000	0.243 ***	0.000
2010	0.254 ***	0.000	0.252 ***	0.000
2011	0.260 ***	0.000	0.253 ***	0.000
2012	0.274 ***	0.000	0.245 ***	0.000
2013	0.262 ***	0.001	0.247 ***	0.000
2014	0.330 ***	0.001	0.234 ***	0.000
2015	0.347 ***	0.001	0.206 ***	0.000
2016	0.382 ***	0.004	0.240 ***	0.000
2017	0.407 ***	0.000	0.227 ***	0.000
2018	0.417 ***	0.000	0.206 ***	0.000

Note: *** and * indicate that the variable coefficient has passed the significance test at 1% and 10%, respectively.

To disclose the spatial agglomeration status of green economic growth and financial development in various provinces and cities, a local spatial correlation analysis of two cross-sections in 2005 and 2018 was carried out. Figures 1–4 are Moran's I scatter plots of carbon emission intensity and financial development. This map divides the carbon emission intensity and financial development of each city into four agglomeration modes: high-high (H-H) agglomeration areas where provinces and cities with high levels of carbon emission intensity and financial development are surrounded by similarly high-level surrounding cities; low-high agglomeration areas (L-H) surrounded by low levels and high levels; low-low agglomeration areas (L-L) surrounded by low levels; and high-low agglomeration (H-L) surrounded by high-level and low-level provinces and cities. It can be seen from the figure that the carbon emission intensity and financial development of most cities in China in 2005 and 2018 were in H-H agglomeration areas and L-L agglomeration areas, indicating a significant positive spatial autocorrelation.

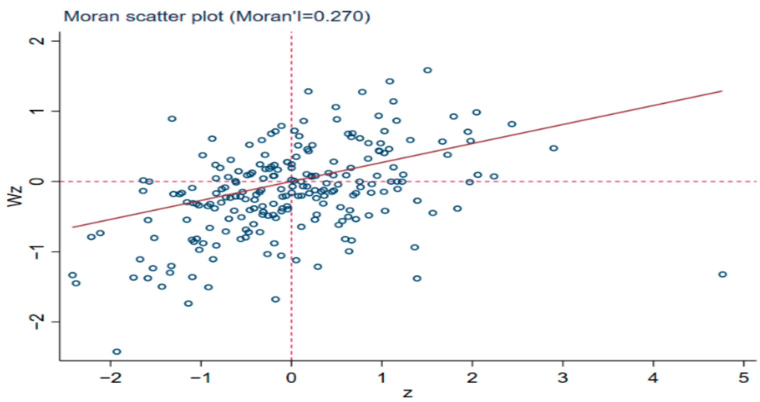

Figure 1. Global Moran scatter plot of CI in 2005.

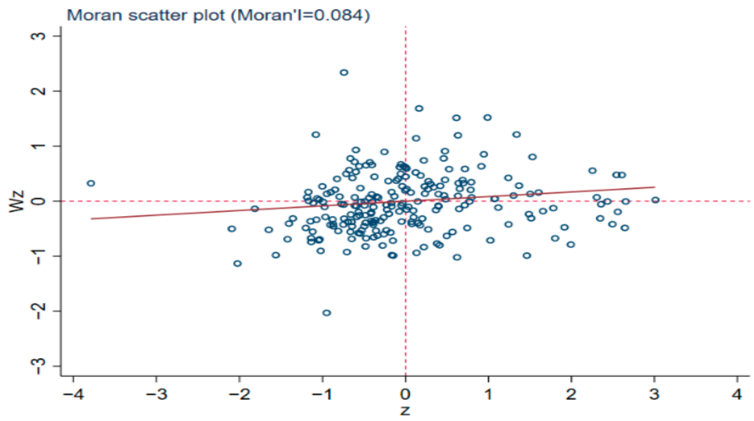

Figure 2. Global Moran scatter plot of FD in 2005.

Figure 3. Global Moran scatter plot of CI in 2018.

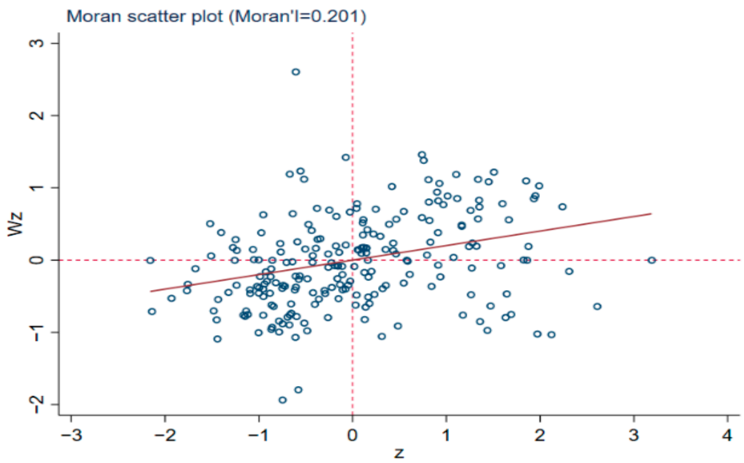

Figure 4. Global Moran scatter plot of FD in 2018.

5.2. Spatial Measurement Model Inspection and Selection

Before model estimation, this article first conducted LM, Wald, and LR tests to select the spatial model. The results in Table 3 show that, under the geographical proximity weight matrix, both the LM-Lag statistic and the LM-Error statistic are significant at the 1% significance level. The robust LM-Lag and robust LM-Error statistics are not significant, but the *p* value of the robust LM-Error is smaller, indicating that the spatial SEM is more suitable than the SAR. The Wald and LR tests both rejected the null hypothesis that the SDM cannot be reduced to the SEM or SAR, therefore the SDM was finally chosen for interpretation.

Table 3. Spatial model test results.

Test	Index	Statistics	p Value
LM Test	LM_Error_test	22.185 ***	0.000
	R_LM_ Error_test	0.900	0.343
	LM_Lag_test	330.655 ***	0.000
	R_LM_Lag_test	0.490	0.522
Wald Test	Wald_SAR	186.67 ***	0.000
	Wald_SEM	272.70 ***	0.000
LR Test	LR_SAR	186.78 ***	0.000
	LR_SEM	355.92 ***	0.000

Note: *** indicates that the variable coefficient has passed the significance test at 1%.

5.3. Benchmark Results

In Table 4, Model (1) shows the Fixed Effects (FE) models. According to the Hausman test of the model, the Fixed Effect Model (Model (1)) was selected. Model (1) revealed the coefficient of financial development as −0.168, which passes the 1% significance test, showing that financial development has a specific and significant inhibitory effect on the carbon emission intensity of Chinese cities. Specifically, when the level of financial development increases by 1%, the urban carbon emission intensity decreases by 0.168%. In order to explore the impact of the level of financial development on the carbon emission intensity of the local and neighboring regions, we established the SEM and SDM to take into account the impact of geographical location on economic activities. Based on the above test results, we then chose to discuss the research findings on the basis of the SDM.

Table 4. Benchmark regression.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	FE	SEM	SAR	SDM	Direct Effect	Indirect Effect	Total Effect
Wx ∗ lnfin				−0.241 ***			
				(−6.54)			
lnfin	−0.168 ***	0.281 ***	0.2278 ***	0.183 ***	0.159 ***	−0.288 ***	−0.129 **
	(−4.37)	(8.98)	(8.07)	(5.70)	(5.12)	(−5.52)	(−2.55)
lnpop	−0.155 ***	−0.0560 *	−0.0635 **	−0.0521 *	−0.0742 **	−0.244 *	−0.318 **
	(−4.63)	(−1.87)	(−2.22)	(−1.65)	(−2.35)	(−1.93)	(−2.30)
lngov	−0.487 ***	0.170 ***	0.1939 ***	−0.00243	−0.0430	−0.510 ***	−0.553 ***
	(−5.69)	(4.77)	(5.83)	(−0.07)	(−1.25)	(−6.42)	(−6.47)
lnfdi	−0.107 ***	−0.0208 ***	−0.0205 ***	−0.0284 ***	−0.0407 ***	−0.143 ***	−0.183 ***
	(−5.95)	(−3.05)	(−3.24)	(−3.96)	(−5.85)	(−7.07)	(−8.26)
lnedu	−0.419	−0.0514	−0.0775	−0.538 ***	−0.545 ***	−0.113	−0.658
	(−0.92)	(−0.31)	(−0.51)	(−3.09)	(−3.16)	(−0.21)	(−1.12)
lncy	0.107	−0.00166	−0.0235	0.0986 *	0.115 *	0.143	0.258 *
	(0.76)	(−0.03)	(−0.47)	(1.65)	(1.93)	(1.10)	(1.76)
lnjt	0.00340	0.0565 ***	−0.0512 ***	0.0572 ***	0.0502 ***	−0.0796 ***	−0.0294
	(0.33)	(4.20)	(3.90)	(4.25)	(3.80)	(−3.97)	(−1.54)
_cons	−6.969 ***						
	(−6.01)						
Hausman	70.11 ***						
N	3122	3122	3122	3122			
Spatial		0.463 ***	0.4473 ***	0.566 ***			
λ/ρ		(22.58)	(21.90)	(31.60)			
σ^2		0.0571 ***	0.05731 ***	0.0627 ***			
		(38.65)	(38.70)	(38.31)			

Note: (1) the value in parentheses is the t value; (2) ***, **, * indicate that the variable coefficient has passed the significance test at 1%, 5%, and 10%, respectively. The following table is the same.

In Table 4, Models (2)–(4) respectively report the SEM, SAR, and SDM. The SDM considers the joint impact of spatially lagging financial development and spatially lagging carbon emission intensity on carbon emission intensity. The SDM is a general form of the SEM and SAR, which can provide an unbiased estimation [43]. It is possible to better observe the spillover effects of financial development. At the same time, according to the test results in Section 5.2, the SDM should be more appropriate. From the results of Model (4), the coefficient of influence of financial development on the local carbon emission intensity was 0.183 and passed the significance test at 1%. This shows that a 1% increase in the level of financial development will increase local carbon emission intensity by 0.183%. At the same time, both the coefficient of the spatial spillover term ($Wx * \ln fin$) of financial development, which was −0.241 and positive at the 1% significance level, and space ρ or space λ of the two spatial measurement models, are significant. This shows that, although improvements in financial development level are not conducive to reductions in the carbon emission intensity of the region, they can significantly reduce the carbon emission intensity of neighboring regions. Specifically, a 1% increase in the level of local financial development will reduce the carbon emission intensity of neighboring areas by 0.241%. One possible reason is that high levels of urban financial development will have a siphonic effect on neighboring areas (these areas are usually villages with low financial levels or small, underdeveloped cities), and will promote the migration of labor and enterprises from neighboring areas. This leads to an increase in local industrial activities and transportation demand, which in turn leads to an increase in local carbon emissions. The emigration of enterprises and people in neighboring rural or small urban areas reduces surplus labor and non-essential industrial activities, thereby reducing the intensity of carbon emissions.

In Table 4, Models (5)–(7) show the spatial effect decomposition based on the SDM model. The direct effect refers to the impact of financial development on the carbon emission intensity of the region, the indirect effect refers to the impact of local financial development on the carbon emission intensity of neighboring cities, and the total effect is the sum of the two. The impact of financial development is variable; financial development significantly promoted the intensity of local carbon emissions but reduced the carbon emission intensity of neighboring regions. The total effect was −0.129 and passes the 5% significance test. This shows that, after considering the space factor, on the whole, financial development has a restraining effect on carbon emission intensity. This is consistent with the situation wherein the space effect is not considered. In the SDM, direct effects accounted for 35.57% of the total utility, and indirect effects accounted for 64.43%. This shows that financial development has obvious spatial effects, with the restraining influence on the carbon emission intensity of neighboring areas greater than the promotional effect on local carbon emission intensity. The reason why the total effect reduces the intensity of carbon emissions is that carbon emissions have the nature of economies of scale in which the marginal emissions decrease as the industrial scale increases [44]. The population and enterprises of the same size are scattered in areas with low levels of financial development and the carbon emissions caused by repeated construction, such as newly built industrial areas and paved roads, will be higher than their carbon emissions in areas with high levels of financial development. Pollution treatment requires equipment, and the unit cost required for treatment of concentrated pollution sources may be lower. Therefore, this agglomeration contributes to the reduction in overall emissions. This is similar to the research conclusions of Lu and Feng [44].

5.4. Analysis of Regional Heterogeneity

Taking into account the differences in the economic status, resource richness, and technological development level of different regions, for heterogeneity analysis this article further divides the sample into three major economic regions: east, middle, and west of China. This article introduces regional dummy variables (we set the western and central regions to 1, respectively), and cross-multiplies the financial development with the regional dummy variables (lnfin ∗ Dummy), with estimates still based on the SDM.

In Table 5, Models (1)–(3) are the direct effect, indirect effect, and total effect, respectively. From the estimation results of Model (1), financial development has promoted local carbon emission intensity. As the reference group in the eastern region, the influence coefficient of financial development on urban carbon emission intensity was 0.2187, the estimated coefficient of the central region was 0.1881, and the influence coefficient of the western region was 0.0036. Of these, only the central region failed the significance test. From the perspective of Models (2) and (3), the impact of financial development on carbon emission intensity is significantly heterogeneous. Not only did the financial development in the eastern region reduce the carbon intensity of neighboring regions, but it also showed a significant inhibitory effect on the overall effect. The indirect effects and the total effects in the central and western regions were not significant.

Table 5. Analysis of regional heterogeneity.

Variable	**(1)**	**(2)**	**(3)**
	Direct Effect	**Indirect Effect**	**Total Effect**
lnfin	0.2187 ***	−0.3461 ***	−0.1275 **
	(4.61)	(−4.59)	(−2.01)
lnfin_west	−0.2151 ***	0.1467	−0.0684
	(−2.91)	(1.33)	(−0.67)
lnfin_central	−0.0306	0.0644	0.0338
	(−0.61)	(0.73)	(0.43)
Control	YES	YES	YES
N	3122	3122	3122

Note: *** and ** indicate that the variable coefficient has passed the significance test at 1% and 5%, respectively.

This indicates that financial development directly increases the carbon emission intensity of cities. However, among the indirect effects, it is only financial development in the eastern region that has a significant negative effect on both neighboring cities and the total carbon emission intensity, which were −0.3461 and −0.1275, respectively. This may be due to the fact that the eastern region is an area wherein various factors of production such as talents, science, technology, and capital are concentrated in China. The level of financial development is relatively high. The exchange of technology and capital among cities in the eastern region is more convenient. Cities with better financial development have advantages in the financing environment for small- and medium-sized enterprises in the region and the reduction in financing costs, which attract the population and the enterprises from neighboring underdeveloped cities to migrate to the region, and which in turn promotes increases in local carbon emission intensity and a reduction in the carbon intensity of neighboring areas. The level of financial development in the central and western regions is mostly low, and the attractiveness between cities is weak. At the same time, in the past few decades, cities in the central and western regions have carried out a large number of public infrastructure constructions and have undertaken the transfer of a large number of labor-intensive industries in order to develop their economies [45]. Although some cities with better financial development in the central and western regions have attracted some enterprises and populations, the effect is relatively weak, therefore it is difficult to have a substantial effect on the carbon intensity of neighboring areas.

5.5. Robustness Test

To further verify the robustness of the estimation results, we first changed the measurement method of core explanatory variables and used the proportion of the number of employees in the financial industry to the working population to measure financial development. The second step is to replace the spatial weight matrix with a geographic distance matrix and an economic distance matrix for robustness testing. The results are reported in

Table 6. The results show that, whether the measurement method of the core explanatory variables is replaced or the spatial weight matrix is replaced, the overall inhibitory effect of financial development on a city's carbon emission intensity remains steady. After the introduction of the spatial matrix, the promotional effect of financial development on local carbon intensity and the restraining effect on the carbon intensity of neighboring areas are still significantly established, with the negative spatial effect significantly greater than the positive promotion effect on the local carbon intensity.

Table 6. Robustness test.

Variable	Change Measurement Method		Replace the Space Matrix	
	FE	SDM	Geographic Distance Matrix	Economic Distance Matrix
lnfin	−0.0331 ***	0.0429 ***	0.2671 ***	0.2483 ***
	(−6.44)	(3.20)	(8.00)	(7.89)
Wx ∗ lnfin		−0.0443 ***	−0.6082 ***	−0.2573 ***
		(−3.27)	(−2.87)	(−6.54)
Spatial		0.2321 ***	0.7004 ***	0.2351 ***
ρ		(7.89)	(10.45)	(8.05)
Control	YES	YES	YES	YES
N	3122	3122	3122	3122

Note: *** indicates that the variable coefficient has passed the significance test at 1%.

5.6. Mechanism Inspection

According to the previous mechanism analysis, the impact of financial development on carbon emissions mainly comes from innovation effects, structural effects, and consumption effects. This article tested the above-mentioned influence mechanism by constructing an intermediary effect model. Drawing on research by Hayes [46], a step-wise regression is performed on Models (10)–(12) to test whether there is such a transmission pathway.

$$lnci_{it} = \beta lnfin_{it} + X'_{it}\gamma + \varepsilon_{it} \tag{10}$$

$$lnM_{it} = \psi lnfin_{it} + X'_{it}\gamma + \varepsilon_{it} \tag{11}$$

$$lnci_{it} = \beta' lnfin_{it} + \varphi lnM_{it} + X'_{it}\gamma + \varepsilon_{it} \tag{12}$$

In the formula, $lnci_{it}$ is the logarithm of the carbon emission intensity of city i at time t; $lnfin_{it}$ is the level of financial development; X'_{it} is the control variable; and ε_{it} is the random disturbance term. lnM_{it} is an intermediate variable, including technological innovation (inno), industrial structure (is), and consumption level (consmue). Technological innovation (inno) is characterized by the amount of urban green patents granted; industrial structure (is) is measured by the proportion of tertiary industry in GDP; consumption level (consmue) is measured by the fraction of total retail sales of social consumer goods in GDP.

(1) The mediating effect of technological innovation. We used the number of urban patent grants as an intermediary indicator of technological innovation. Judging from the estimated results in Model (1) of Table 7, the estimated coefficient of financial development was −0.1685 and significant at the 1% level; this means that the influence of financial development on carbon emission intensity has a mediating effect (the same below). Looking at the estimated results in Model (2) of Table 7, the estimated coefficient of financial development on technological innovation was 0.1068, which is significant at the 5% level. This means that financial development has a significant effect on promoting the improvement in technological level, which is manifested as an increase in financial development. A 1% increase in financial development will increase the level of technological innovation by 0.1068%. In Model (3), both technological innovation and financial development are included in the model. The coefficient of influence of technological innovation on carbon emission intensity was −0.1502, which is significant at the 1% level. It shows that improvements in the level of technological innovation are conducive to reducing the intensity of

carbon emissions. The results of both financial development and technological innovation significantly show that there is a partial mediation effect. The mediation effect accounts for 9.5% of the total effect. This means that financial development reduces carbon emission intensity by increasing the level of technological innovation, which validates Hypothesis 1.

Table 7. Mechanism Test.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	lnci	**inno**	**lnci**	**is3**	**lnci**	**consmue**	**lnci**
lnfin	−0.1685 ***	0.1068 **	−0.1524 ***	0.0533 ***	−0.1480 ***	0.4527 ***	0.0302
	(0.0385)	(0.0432)	(0.0347)	(0.0135)	(0.0360)	(0.0628)	(0.0467)
inno			−0.1502 ***				
			(0.0291)				
is3					−0.3840 ***		
					(0.1380)		
consmue							−0.0626
							(0.1314)
_cons	−6.9686 ***	7.2717 ***	−5.8763 ***		−4.2634 ***		−0.0917
	(1.1597)	(1.0300)	(1.1187)		(1.5943)		(1.7281)
N	3122	3122	3122	3122	3122	3122	3122
R^2	0.3436	0.0924	0.3899	0.3145	0.3659	0.6553	0.4985

Note: *** and ** indicate that the variable coefficient has passed the significance test at 1% and 5%, respectively.

(2) The mediating effect of structural optimization. We used the ratio of tertiary industry to GDP as an intermediary indicator for structural optimization. Judging from the estimated leads to Models (4) and (5) of Table 7, the estimated coefficient of financial development on the proportion of tertiary industry in GDP was 0.0533, which is significant at the 1% level. This means that financial development has a significant effect on increasing the ratio of tertiary industry. Specifically, if the level of financial development increases by 1%, the proportion of tertiary industry will increase by 0.0533%. Incorporating the proportion of tertiary industry and financial development into the model at the same time, it is found that the coefficient of influence of the proportion of tertiary industry on carbon emission intensity was −0.3840, indicating that the increase in the proportion of tertiary industry promotes a reduction in carbon emission intensity. Meanwhile, the results of financial development and the proportion of tertiary industry both clearly indicate that there is a partial mediation effect. The mediation effect accounts for 12.15% of the total effect, indicating that financial development can reduce carbon emission intensity by optimizing the industrial structure. As a result, Hypothesis 2 is verified.

(3) The mediating effect of promoting consumption. We used the ratio of the total retail sales of consumer goods to GDP to represent the intermediate indicator of consumption effects. From the sequential test in Models (6) and (7) of Table 7, it is found that the coefficient of financial development on social consumption was 0.4527, and significant at the 1% level; this indicates that financial development can significantly promote social consumption. Then, in Model (7), financial development and social consumption were included in the model at the same time, but the results are not significant, indicating that there is no mediating effect. This means that financial development cannot increase carbon emissions by promoting social consumption; therefore, Hypothesis 3 is not supported.

6. Conclusions and Policy Recommendations

Based on the panel data of prefecture-level cities in China from 2005 to 2018, this paper studied the impact of financial development on China's carbon emission intensity and its mechanism from both theoretical and empirical aspects. Studies have shown that financial development has significantly reduced China's carbon emission intensity overall. This is consistent with the findings of Zaidi et al. [15] and Shahbaz et al. [17]. However, they all ignore the spatial effect of financial development on carbon emissions. After considering the spatial effect, financial development has significantly promoted the intensity of local carbon emissions, while reducing the intensity of carbon emissions in neighboring areas. Among them, the direct effects of financial development on the local area accounted for 35.57% of the total utility, and the indirect effects on neighbors accounted for 64.43%. The possible reason for this is that cities with a higher level of financial development will have a siphonic effect on surrounding villages and underdeveloped small cities with lower levels of financial development, causing the population and enterprises in neighboring areas to migrate to the local area. This in turn leads to increased demand for local industrial activities and transportation, and promotes carbon emissions. However, neighboring rural areas or small cities have reduced industrial activities due to the emigration of enterprises and populations, thereby reducing the intensity of carbon emissions. The reason why the total effect reduces the intensity of carbon emissions is that marginal carbon emissions have economies of scale that decrease as industrial scale increases [47]. The population and enterprises of the same size are scattered in areas with lower levels of financial development. The carbon emissions caused by repeated constructions, such as newly-built industrial areas and paved roads, will be higher than those in areas with high levels of financial development. At the same time, the unit cost required for the centralized management of carbon emissions is also lower, which in turn reduces the total emissions. After a series of robustness tests, the conclusion is still clearly established.

The basic conclusion of the article is consistent with the research of Liu and Song [16]. The difference is that this article further examined the impact mechanism and analyzed the possible heterogeneity of the impact of financial development on carbon emission intensity. Heterogeneity analysis shows that financial development has directly increased the carbon emission intensity of cities. However, among the indirect effects, only urban financial development in the eastern region has a substantial detrimental impact on neighboring cities and the total carbon emission intensity, while in the central and western regions it has no significant impact. Finally, this paper examined the mechanism between financial development and carbon emission intensity. The results show that financial development mainly reduces carbon emission intensity through technological innovation and industrial structure optimization. Among them, the effect of technological innovation was 9.5%, and the effect of industrial structure optimization was 12.15%; thus, industrial structure optimization has a greater impact on reducing carbon emissions.

Accordingly, this article proposes the following policy implications: (1) Further support for financial development and the building of a large financial center. It is found that, after adding spatial factors, financial development has a significant spatial spillover effect on carbon emissions reduction. Financial centers are conducive to achieving the scale effect of emissions reduction and reducing overall carbon intensity. Therefore, further support is needed for financial development and the building of large financial centers. Strengthen the construction of financial infrastructure, especially fintech facilities, attach importance to the introduction of fintech talents, strengthen the supervision of financial development, and develop a new type of financial center through the benign integration of finance and technology. This will give play to the important role of financial development in reducing carbon emission intensity. (2) Build a financial service system that supports green technological innovation and further use the role of financial development in promoting green technological innovation. Encourage banking and financial institutions to provide professional investment services for green technology innovations such as renewable energy technologies and cleaner production technologies. Vigorously support and cultivate private equity and venture capital institutions that focus on investing in green technologies and build a multi-level financing and risk management mechanism. (3) Optimize the capital allocation structure and financial product structure. In terms of optimizing the capital allocation structure, it is critical to perform a good job in guiding the flow of capital in the capital market. Restrict the flow of financial capital to high-emission and high-energy-consuming industries, and actively guide financial capital to invest in high-tech, low-energy, low-emission green and clean industries and smart, high-end industries. In terms of optimizing the structure of financial products, it is necessary to further encourage financial innovation. Vigorously develop new financial formats such as digital finance and green finance, and enrich the types of green credit, green bonds, green stock indexes, and related products.

Owing to data limitations, this article only used the proportion of total financial institution loans to GDP to measure financial development, and it failed to further consider the breadth and depth of financial development and the impact of its internal structure on carbon emissions. All these factors may reveal differences in the impact of financial development on carbon emission intensity. In this regard, it is crucial to further refine our research to summarize more targeted financial development proposals.

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