

Research Article

The Moderating Effect and Threshold Effect of Green Finance on Carbon Intensity: From the Perspective of Capital Accumulation

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Climate change has caused serious threats to global economic development and human well-being, and green finance is a new way to achieve ecological, economic, and social sustainable development, and it also has important theoretical significance and policy value. This study firstly aims to study the impact of green finance on regional carbon intensity. Then, it aims to determine the moderating effect of capital stock per capita on the relationship between green finance and carbon intensity based on moderating effect model as well as to investigate the threshold effect of capital stock per capita on the relationship between green finance and carbon intensity based on threshold effect model. The main conclusions are as follows: (1) Every 1% increase in green finance will lead to a 2% decrease in carbon intensity, and the inhibition of green finance on carbon intensity is most obvious in northeast and east China. (2) The capital stock per capita has a significant moderating effect, which could enhance the restraining effect of green financial development on carbon intensity, and this moderating effect is most obvious in northeast China. (3) The capital stock per capita has a threshold effect in the process of green finance development to suppress carbon intensity. The higher the capital stock per capita, the stronger the inhibition effect of green finance development on carbon intensity. Therefore, in the process of capital accumulation, attention should be paid to improve the relevant legal system and policy guarantee, optimization of financial structure, and stimulation of the capital allocation effect of green finance. Simultaneously, in order to strengthen the inhibitory effect of green finance on carbon intensity, differentiated green finance development policies should be formulated based on factor endowment structure and comparative advantages of different regions.

1. Introduction

Since the 20th century, the rapid economic development of Western countries has brought serious environmental problems; especially after the outbreak of the “London Smog” and the “Love Canal Incident” in the United States, industrial pollution, climate change, and other issues have attracted widespread attention around the world [1]. Environmental quality may be affected by financial development, on the one hand, because financial development increases goods, intermediation, and financial services, which can promote higher energy demand and lead to increased pollution, therefore, its impact on economic growth and energy consumption exacerbates environmental pressures [2]. On the other hand, financial development can effectively alleviate the

pressure of energy consumption on the environment [3, 4], for example, green finance. In addition, the impact of financial development on carbon emissions is also affected by income level. With low levels of income, financial development aggravates carbon emissions, while with high levels of income, financial development reduces carbon emissions [3]. For example, for developed countries, financial development has little impact on carbon emissions.

In the area of finance, “Green Finance” has emerged as a way to promote the coordinated development of environmental protection and economic growth through socially responsible investment and the establishment of carbon trading markets [5]. “Green finance” mainly refers to financial activities that support environmental improvement, address climate change, and save and use resources

efficiently, such as credit, bonds, funds, insurance, carbon finance, and other financial instruments. At the same time, it is committed to directing more funds to projects such as clean energy, green transportation, and green buildings to reduce pollution emissions in economic development [6]. The global market size of green bonds has grown at a compound annual growth rate of 75% from 2012 to 2019, rising from US\$5 billion to US\$257.7 billion. More and more economic entities are promoting the construction of green financial markets [7]. Therefore, the development scale of green finance is gradually expanding.

With the rapid advancement of China's industrialization and urbanization, carbon emissions have been increasing year by year, severely restricting the sustainable development of China's economy and society [8]. In response to climate change, the Chinese government proposes to adopt more powerful policies and measures, and promises: "CO2 emissions will peak by 2030 and achieve carbon neutrality by 2060" [9]. The "dual carbon" goal is not only a solemn commitment China has made to the world, but also a broad and profound economic and social change in China [10]. However, the reduction of carbon emissions is not an easy task. The large demand for traditional energy in industrial development and the extensive industrial development model have seriously restricted the development of China's low-carbon economy [11]. Therefore, the pressure of energy conservation and emission reduction has also given birth to the development of green finance in China. At present, China has formed a multi-level green financial market system, including green loans, green bonds, green insurance, carbon financial products, providing diversified financing channels for green projects [12]. According to data provided by the People's Bank of China in 2021, China had a green loan balance of 11.95 trillion yuan by the end of 2020, ranking first in the world, and a green bond stock of 813.2 billion yuan, ranking second in the world.

The reason why "green finance" has attracted much attention is that it strengthens the social responsibility of the region and has the dual binding effect of promoting energy conservation, emission reduction, and sustainable economic development [13]. Green finance includes regulating corporate behavior, thereby influencing the flow of venture capital, promoting green technology innovation, overcoming market failure, and guiding corporate investment behavior. These factors will have a significant impact on the regional carbon emission [14]. For example, Chevallier et al. [15] studied the impact of green finance on the decision-making of manufacturing enterprises to reduce emissions based on the dual-channel supply chain model and found that manufacturing enterprises in regions with a higher level of green finance development are more willing to reduce emissions. X. Chen and Z. Chen [16] used a spatial econometric model to explore the mechanism of green finance on carbon emissions based on China's provincial panel data and found that green finance can help reduce the regional carbon emissions. China has experienced rapid economic growth and capital accumulation since the reform and opening up. The economic growth rate of the eastern coastal regions has been significantly higher than that of the

central and western regions in the past 20 years [17]. Therefore, there may be heterogeneity in the impact of green finance on carbon emission in different regions of China. At the same time, the unevenness of economic development has also led to different stages of capital accumulation in various regions of China. With the acceleration of regional capital accumulation, the regional factor endowment structure has gradually evolved from labor-intensive to capital-intensive, and the industrial structure has also been upgraded. The effect of green finance on carbon emissions may change [18]. Secondly, the further development of the financial industry requires a certain amount of capital accumulation as a premise. Under the action of the market mechanism, green capital tends to flow to industries and regions with greater potential benefits [19]. Therefore, the regional capital stock per capita may be a key variable affecting the mechanism of green finance on carbon emission.

Since China has diversified regions and uneven economic development, it is not sufficient to measure a country's carbon emissions status from the perspective of regional carbon emissions. As carbon intensity refers to the carbon emissions per unit of GDP, it is more reasonable to use this concept to assess carbon emissions status. Hence, based on China's provincial panel data from 2005 to 2018, this study uses a variety of econometric models to explore the moderating effect and threshold effect of China's green finance development on regional carbon intensity under the process of capital accumulation. The first marginal contribution of this study is that it examines the relationship between green finance and carbon emissions from the perspective of capital accumulation process and it further expands the research dimension between green finance and carbon emissions. Secondly, this study considers whether there is regional heterogeneity in the impact of green finance on carbon emission intensity. For example, will green finance have greater advantages in capital-intensive areas? It can provide feasible and differentiated suggestions for governments at all levels to develop low-carbon economy. Thirdly, the process of capital accumulation is also the process of rapid development of industrialization and urbanization. This study verifies whether green finance can reduce the increase of carbon emissions caused by capital accumulation.

The structure of this article is arranged as follows: the second part is the literature review and theoretical hypothesis; the third part is the model and data sources; the fourth part is the analysis of empirical results, mainly including the benchmark regression, adjustment effect regression, and threshold effect regression of green finance on carbon intensity under the process of capital accumulation; the fifth part is the discussion; and the last part is the conclusion and policy recommendations of this article.

2. Literature Review and Theoretical Hypothesis

Green finance in a broad sense is the sum of environmental finance, low-carbon finance, and sustainable financial activities [20], and it not only covers green finance in the

narrow sense but it also includes financial policies, financial services, risk management, and other related financial resource allocation activities adopted by economic entities such as governments and enterprises to promote green investment and financing [21]. Different scholars have different understandings of green finance in terms of research scope, implementation subjects and essential attributes, etc. However, scholars have basically reached a consensus on the service objects of green finance, that is, green finance is a general term for all investment and financing behaviors that provide services for environmental improvement, ecological construction, and sustainable development [22]. To sum up, green finance refers to financial business innovation and environmental risk management activities carried out by financial institutions taking into account both sustainable development and environmental risks. More importantly, based on the connotation of green finance, green finance has a significant inhibitory effect on regional carbon intensity for the following reasons: (1) Green technology innovation: on the one hand, the research and development, application and promotion of green technologies often require a large amount of capital investment, and it is difficult for enterprises to provide sufficient support from traditional financing channels [23]; also, the application performance of new technologies has great uncertainty, and the high risk of investing in such activities is the primary reason why most investors avoid it. However, on the other hand, green finance can guide more capital to flow to environmentally friendly enterprises through the reallocation of capital, encourage enterprises to carry out green innovation and promote the progress of green technology, and reduce the carbon intensity in the production process of enterprises. First, the development of green finance has built a brand new financial system [24], including sustainable financing departments of banks, and green funds, thus expanding the financing channels of environmentally friendly enterprises. Second, financial instruments such as green bonds can gather more funds from investors with different risk appetites and increase funding sources for green R&D and innovation activities with greater risks. In addition, the policy support provided by the public sector for green financial activities, such as guarantees, risk, and compensation, can significantly reduce the risk loss of green R&D activities and improves the innovation willingness of environmentally friendly enterprises [25]. Therefore, the development of green finance can reduce the regional carbon intensity by stimulating the enterprises green technology innovation.

(2) Environmental supervision: environmental protection has the attributes of public goods, and the environmental pollution caused by carbon emissions also has negative externalities. These two characteristics may lead to the failure of the market adjustment mechanism. Therefore, it is necessary to use the relevant functions of financial system management to regulate environmental pollution, so as to better realize the environmental benefits of green finance [26]. Investors in the green financial system often carry out preassessment, in-process, and postinvestment supervision of environmental-friendly enterprises. This

series of regulatory actions can improve the ecological benefits of environmentally friendly enterprises and reduce carbon emissions in their production activities [9]. Before investing, investors will try their best to obtain all kinds of information about enterprises and projects, evaluate their possible environmental performance and risks, and eliminate projects with high carbon emissions. During the operation of the project, the investor will monitor the environmental performance of the enterprise to prevent it from producing high-pollution behaviors in the production process. After the project is completed, the investor evaluates its environmental performance and pays a long-term attention to the possible environmental impact of the project. Therefore, the development of green finance can reduce the regional carbon intensity by improving the environmental supervision of enterprises.

(3) Green consumption: financial activity could not only affect producers but also consumers. Green finance can lead consumers' green demands, promote consumption upgrades to a certain extent, and improve consumers' purchasing power for environmentally friendly products [27]. Specifically, on the one hand, green finance can directly guide consumers' green consumption by means of interest rate and credit limit adjustment, such as lowering the loan interest rate for purchasing new energy vehicles [28]. On the other hand, green finance can not only indirectly guide consumers to green consumption through the electronicization of financial bills and the network of business, but also improve people's awareness of environmental protection in their consumption behavior. Therefore, green finance development can reduce regional carbon intensity by leading green consumption. Therefore, this study proposes the first hypothesis.

Hypothesis 1. Green finance can help reduce regional carbon intensity.

At present, China's regional development is still relatively unbalanced, so the capital accumulation required for economic and social development in various regions will be heterogeneous. On the one hand, modern production requires the guarantee of public infrastructure such as electricity, running water, and sewage. At the same time, as the capital intensity of industries increases and economies of scale continue to expand, local markets are prone to saturation. This means that a wider market requires more complete transportation infrastructure to facilitate the flow of goods and people between different regions [29]. On the other hand, with the increase of capital intensity, the scale of investment is also getting larger and the risk is getting higher, which requires the financial system to play an important regulating role in the production activities of enterprises for revitalizing the capital stock and improving the efficiency of capital allocation. In addition, with the continuous expansion of the scope of modern production and transactions, a more comprehensive and complete institutional environment and legal system are essential to ensure the normal order of the economy and society [30]. Therefore, capital accumulation plays a significant role in an economy. Differences in capital stock per capita may affect the degree of green finance's effect on carbon intensity [31].

In summary, this article believes that with the accumulation of capital and the improvement of per capita capital stock, the development of green finance will have a stronger inhibitory effect on carbon intensity for the following reasons. Similar to modern finance, green finance advocates the stock market, big banks, and venture capital. However, this financial structure is suitable for developed regions or regions with high capital stock, because the industrial structure of developed regions is at the forefront of the country, and its industrial upgrading requires a large amount of capital accumulation. At the same time, the upgrading of the industrial structure is accompanied by the improving level of science and technology, which means that a more advanced financial structure is required to serve the independent innovation of enterprises. Large banks, stock markets, and venture capital are suitable for financing innovative projects with high risks while the stock market and venture capital are conducive to risk diversification [32]. Therefore, as a “lubricant” for regional green economic activities, green finance may play a more important role in developed regions with high capital stock. For the regions with low capital stock, the leading industries to promote regional economic development are generally labor-intensive processing industries or traditional agriculture. Generally speaking, these industries are small in scale, small in capital demand, mature in market, and low in technology. Therefore, economies at different stages have different industrial structures, technologies, enterprise scales, capital needs, and risk characteristics, while corresponding to different green finance needs [33]. It can be seen that capital accumulation is an important factor affecting the effect of green finance on carbon intensity. In view of this, we propose the second and third hypotheses of this study as follows.

Hypothesis 2. Capital accumulation has an adverse moderating role on the impact of green finance on carbon intensity.

Hypothesis 3. The inhibitory effect of green finance on carbon intensity becomes stronger with the increasing capital stock per capita.

3. Model and Data

3.1. Model Construction

3.1.1. Benchmark Regression Model. In this article, an ordinary least squares regression model (OLS), a moderating effect model, and a threshold regression model is established to verify the three theoretical hypotheses. First, a panel least squares model is constructed to verify the relationship between green finance and regional carbon intensity. The construction form of the benchmark least squares regression model is as follows:

$$Y_{it} = \beta_1 \times X_{it} + \beta \times \text{Control}_{it} + \beta_0 + i + t + \varepsilon_{it}. \quad (1)$$

Among them, Y is the explained variable, X is the explanatory variable, Control is a series of control variables, i is the individual fixed effect, t is the time fixed effect, β is the coefficient to be estimated, and ε is the random interference

term. And then, this study specifically introduces explanatory variables, explained variables, and control variables in Table 1.

3.1.2. Moderating Effect Model. In order to test Hypothesis 2, we refer to the moderation effect model construction method of James and Brett [37]. We add the interaction term between the moderator variable and the explanatory variable in the OLS model to verify whether the process of capital accumulation will affect the relationship between green finance and regional carbon intensity, and the moderating effect model is constructed as follows:

$$Y_{it} = \alpha_1 \times X_{it} + \alpha_2 \times M_{it} + \alpha_3 \times M_{it} \times X_{it} + \alpha \times \text{Control}_{it} + \alpha_0 + i + t + \varepsilon_{it}. \quad (2)$$

Among them, M is the moderator variable and α_3 is the coefficient to be estimated, which measures the moderating effect of the moderator variable between the explained variable and the explanatory variable.

3.1.3. Threshold Effect Model. The model used by Caner and Hansen [38] contains endogenous variables compared to Hansen (1999). However, the threshold model proposed by Hansen [39] is more widely accepted [40–44]. Therefore, in order to test Hypothesis 3, this study adopts the panel threshold model [39] to explore the effect of green finance on carbon emissions in regions with different capital stock per capita. The threshold regression model can select an appropriate threshold value according to the characteristics of the sample itself [45, 46] and examine whether the effect of green finance on carbon intensity will change with the difference of regional capital stock per capita. The construction form of the threshold effect model is as follows:

$$Y_{it} = \sum_{j=1}^n \gamma_{j+1} * I(T_{it} \in [\text{inf}_j, \text{sup}_j]) * X_{it} + \gamma * \text{control}_{it} + i + t + \varepsilon_{it}. \quad (3)$$

Among them, β is the coefficient to be estimated; I is a piecewise function, if the conditions in the parentheses are true, then I takes 1, otherwise, takes 0; T is the threshold variable; inf and sup are the intervals of the capital stock per capita, that is, the critical value of the threshold; n is the number of thresholds. In Table 1, we show the variables selected in this study and their specific description.

3.2. Data

3.2.1. Explained Variable: Carbon Intensity (C). At present, China’s existing statistics and data cannot directly query the relevant data on the total carbon emissions of different regions and industrial sectors. Therefore, indirect accounting is required based on the energy consumption of various sectors in China. Currently, the internationally accepted calculation method is the reference method in the

TABLE 1: Data description.

Variables	Name	Symbol	Description
Explained variable	Carbon intensity	C	Based on the accounting method of IPCC [34], this study measures the energy consumption of each province in China from 2008 to 2017 through the regional energy balance sheet.
Explanatory variables	Green finance development level	Gfd	We use index of green credit, green investment, and green insurance to measure green finance development index, and EVM method is used to combine them together.
Threshold variable and moderating variable	Capital stock per capita	Kpl	The estimation method of capital stock in various regions of China used in this study is based on Lu et al. [35]; and use resident population to proxy labor quantity.
Control variables	Logarithm of GDP	Gdp	Gross region production
	Logarithm of GDP per capita	Gpp	The ratio of gross region production to population.
	Proportion of industrial output value to GDP	Ssr	The proportion of industrial output value to GDP as a proxy variable of industrial development
	Proportion of service output value to GDP	Tsr	The proportion of service industry output value in GDP as a proxy variable for the development level of the regional service industry
	Foreign direct investment	Fdi	The amount of foreign direct investment as a proportion of GDP as a proxy variable to measure the degree of regional openness.
	Regional patent applications	Pat	The number of regional patent applications as a proxy variable to measure the level of regional scientific and technological innovation.
	Environmental regulation.	Er	Industrial wastewater discharge, industrial sulfur dioxide discharge, and industrial soot discharge are selected to characterize the environmental regulation index of each region [36]

Greenhouse Gas Emissions Inventory Guidelines developed by the IPCC (International Panel on Climate Change) (2006). The basic steps of this method are to estimate the energy consumption of various sectors in China, to unify the energy units, then multiply by the carbon content coefficient to calculate the total carbon amount, deduct the carbon amount used as raw material and nonenergy use, and finally correct it with the oxidation coefficient and convert it into carbon emissions [47].

Based on the accounting method of IPCC [34], this study measures the energy consumption of each province in China from 2008 to 2017 through the regional energy balance sheet, and then calculates the carbon dioxide emissions from energy consumption in each region, and then divide by the regional gross domestic product to get the magnitude of carbon intensity:

$$E_{co_2} = \frac{\sum_i A_i \cdot c_i}{GDP}. \quad (4)$$

Among them, A_i is the consumption of the i_{th} energy (unit: ton) and c_i is the carbon dioxide emission coefficient of this energy (unit: kg-CO₂/kg).

$$A_i = F_i + T_i + H_i + N_i. \quad (5)$$

Among them, F_i is the terminal consumption of the i_{th} energy in the region, T_i is the consumption of the i_{th} energy in the region for power generation, H_i is the consumption of the i_{th} energy in the region for heating, N_i is the consumption of industrial raw materials in the i_{th} region, which refers to the use of fuel as nonenergy, such as chemical raw materials, industrial or construction materials, and carbon dioxide into final products, activities that do not emit or do not immediately emit.

3.2.2. Explanatory Variables: Green Finance Development Level (Gfd). According to the definition of green finance by the International Development Finance Club (IDFC), that is, green finance refers to providing financial support to projects such as sustainable development, environmental protection, and pollution reduction, including financial services that promote the development of circular economy, clean energy, and reduce greenhouse gas emissions. It can be seen that green finance is a financial business that includes the attributes of “sustainable development” and “cleanness.” Therefore, this study characterizes the development level of regional green finance from the following three dimensions: (1) Green credit: the larger the scale of green credit in one region, the more financial support the low-energy-consumption and low-polluting enterprises receive, and the flow of funds to high-energy-consumption and high-polluting enterprises is relatively reduced, which contributes to the reduction of regional carbon emission intensity. Thus, this study measures the level of green credit in a region using a reciprocal ratio of interest payments to total industrial interest payments for highly polluting and energy intensive industries [22]. (2) Green investment: green investment behavior refers to the unification of production investment and prevention and control of environmental pollution, while achieving economic growth and minimizing the negative impact of industrial development on the environment, thereby achieving sustainable economic and social development [48]. Therefore, this study uses the proportion of environmental pollution control investment in GDP and the proportion of regional fiscal environmental protection expenditure in the general fiscal budget expenditure to represent the regional green investment level. (3) Green insurance, also known as ecological insurance, is a basic

means of environmental risk management under market economy conditions. For example, environmental pollution compulsory liability insurance, and green industry product quality liability insurance because they help enterprises to strengthen environmental risk management, reduce pollution accidents, and also reduce the environmental pollution in the production process of enterprises. At present, agricultural production activities in China are also one of the main sources of greenhouse gas emissions due to the overuse of chemical fertilizers and inefficient land use [49]. Therefore, this study adopts the ratio of agricultural insurance income to the total agricultural output value as the indicator of the green insurance level in the region. Based on the above analysis, this study uses green credit, green investment, and green insurance to measure the development level of regional green finance. In this study, the above three indicators are normalized and weighted by the entropy value method (EVM). The calculation steps are as follows:

- (1) The indicators are quantified at the same time.

Calculate the proportion of the i_{th} sample to the j -index under the j_{th} index (p_{ij}) as follows:

$$p_{ij} = \frac{r_{ij}}{\sum_{i=1}^n r_{ij}}, \quad (i = 1, 2, \dots, n; j = 1, 2, \dots, m). \quad (6)$$

- (2) Calculate the entropy value of the j_{th} index (e_j) as follows:

$$e_j = -k \sum_{i=1}^n p_{ij} \ln(p_{ij}). \quad (7)$$

Among them, $k = (1/\ln(n))$, $e_j \geq 0$.

- (3) Calculate the coefficient of variance of the j_{th} index (g_j) as follows:

$$g_j = 1 - e_j, \quad 0 \leq g_j \leq 1. \quad (8)$$

- (4) Calculate the weight of j_{th} index (w_j):

$$w_j = \frac{g_j}{\sum_{j=1}^m g_j}. \quad (9)$$

- (5) Calculate the composite score of the i_{th} sample (S_i) as follows:

$$S_i = \sum_{j=1}^m w_j p_{ij}. \quad (10)$$

3.2.3. Threshold Variable and Moderating Variable: Capital Stock per Capita (Kpl). The estimation method of capital stock in various regions of China used in this study is based on Lu et al. [35], where I_{it} is the capital flow in region i at time t and g_{it} is the average growth rate of GDP in region i during the investigation period. The calculation method is to use the geometric mean of the actual GDP growth data published in the "China Statistical Yearbook (2006–2019)" during the inspection period. The capital stock in the base period at this time can be estimated as follows:

$$k_{i,0} = \frac{I_{i,t}}{(g_{i,t} + \delta_{i,t})}. \quad (11)$$

The capital stock in region i at time t is as follows:

$$k_{i,t} = (1 - \delta_{i,t})k_{i,t-1} + I_{i,t-1}. \quad (12)$$

Among them, the depreciation rate is 10%, the regional resident population data is used to represent the population variable, and the ratio of the regional capital stock to the resident population is used to represent the capital stock per capita.

3.2.4. Control Variables. In order to control the impact of other variables on carbon intensity, this study selects control variables from five dimensions, namely, economic development, industrial structure, opening to the outside world, technological innovation, and environmental regulation. (1) Economic development: the increase of economic activities will bring more energy consumption, and fossil energy combustion is one of the important sources of carbon emissions. Therefore, the level of economic development will have an impact on regional carbon emissions [50]. This study uses the logarithm of GDP (Gdp) and GDP per capita (Gpp) as proxy variables for economic development to control the impact of economic development scale on regional carbon intensity. (2) Industrial structure: industry is the main field of fossil energy combustion and one of the important sources of carbon emissions, especially industries with high consumption and high emission such as steel, chemical industry, cement, and nonferrous metals [51]. Therefore, this study chooses the proportion of industrial (Ssr) output value to GDP as a proxy variable of industrial development to control the impact of industrial development scale on regional carbon emissions; at the same time, as an important development strategy industry to adjust the industrial structure and promote energy conservation in the socio-economic industrial system, the service industry may help reduce the regional carbon emission intensity [52]. Therefore, this study uses the proportion of service industry output value (Tsr) in GDP as a proxy variable for the development level of the regional service industry to control the impact of the development scale of the service industry on the regional carbon emission intensity. (3) The degree of openness: generally speaking, the more open an area is, the more likely it will bring advanced management experience and clean technology, which will help to reduce carbon emissions. Therefore, this study chooses the amount of foreign direct investment as a proportion of GDP (Fdi) as a proxy variable to measure the degree of regional openness. (4) Technological innovation: regions with a higher level of science and technology may have stronger green technology innovation capabilities, which are conducive to the research and development and use of clean energy and technology. Therefore, this study chooses the number of regional patent applications (Pat) as a proxy variable to measure the level of regional scientific and technological innovation. (5) Environmental regulation: due to the external uneconomical

nature of environmental pollution, the government can adjust the economic activities of enterprises by formulating corresponding policies and measures to achieve the purpose of energy conservation and emission reduction. Therefore, environmental regulation will have an important impact on regional carbon emissions. In this study, industrial wastewater discharge, industrial sulfur dioxide discharge, and industrial soot discharge are selected to characterize the environmental regulation index of each region [44].

3.3. Data Sources. Based on the availability of data, the sample we selected is the provincial-level panel data of 29 provincial-level administrative units except Tibet from 2005 to 2018, and the missing data are filled by the difference method. At the same time, the data based on explanatory variables, explained variables, moderator variables, threshold variables, and control variables are all from the “China Statistical Yearbook,” “China Insurance Yearbook,” Eps database, Wind data, and statistical yearbooks of provincial administrative units. As shown in Figure 1, the darker the color, the higher the green finance development level; the lighter the color, the lower the green finance development level. In 2005, the development level of green finance in the eastern region was significantly higher; in 2018, the development level of green finance in the eastern and central regions was significantly higher. It shows that with the passage of time, the development level of green finance in the central region has been significantly improved, and the overall development level of green finance in the eastern and central regions of the country is relatively high. It should be noted that the primary reason why we chose 2005–2018 as the time period is that there were a lot of administrative division adjustments and mergers between cities in China before 2004, which may affect the conclusions of this study. Second, years after 2019 were not selected as the research interval because of the following reasons: (1) COVID-19 was first detected in China at the end of 2019, which may affect the conclusions of this study. (2) In 2019, China implemented a policy of reforming the household registration system, which not only abolished the household registration restrictions in cities with a population of less than 3 million, but also comprehensively relaxed the household registration conditions for large cities with a population of 3 to 5 million. These lead to a certain scale of population movement across cities, which may have an impact on the regression results.

4. Results

4.1. Benchmark Regression Results

4.1.1. Benchmark Regression Results of China as a Whole. This study uses Stata15.1 software to perform statistical analysis on the benchmark regression, and the regression results are shown in Table 2. Among them, the first column is the OLS regression result before adding control variables. The second column is the regression results of the least squares two-way fixed effects model (OLS-FE). The third column is still based on the least squares model, replacing the *T* test in the statistical regression with the regression

result of the D-K standard error, in order to eliminate the influence of variable heteroscedasticity and cross-sectional correlation on statistical analysis, so as to obtain more accurate regression results. The fourth column is the regression results of system moment estimation (GMM), using two lag periods and three lag periods as instrumental variables, considering the possible time lag in the development level of green finance, which may interfere with the regression results. The core of the GMM model is to use the difference equation and the horizontal equation in the parameter estimation as an equation system, so that the difference variable and the horizontal variable can be used as instrumental variables for each other for systematic estimation, so that the parameter estimation is more effective. The fifth column is the de-extremum value. In this study, the samples with the highest 5% and the lowest 5% of carbon emission intensity in various regions of China are removed, and then the benchmark regression is performed again to reduce the error caused by outliers to the regression results as much as possible. Since green finance may affect regional carbon emissions, and the continuous increase in total carbon emissions will also force relevant regional decision-making departments to vigorously develop green finance, that is, there may be a two-way causal relationship between the explanatory variables and the explained variables in this study. This may cause bias in the regression results.

In order to solve the interference of the endogeneity problem on the regression results, we choose an instrumental variable (IV), that is, the number of green utility model patents granted. Additionally, the Sargan test was first used to test whether the tool variable was over-identified. After the test, the *P* value of the Sargan test was 0.421, which meant that the null hypothesis was not rejected, which meant that the tool variable was not over-identified. Then, we adopted the AR Wald test to ensure whether the instrumental variable was a strong instrumental variable. After the test, the *P* value of the AR(1), AR(2), and Wald statistics were 0.073, 0.9011, and 0.0425, respectively, which meant that the null hypothesis was rejected at least at the significance level of 10%, which meant that the instrumental variable was not a weak instrumental variable. Hence, the choice of the instrumental variable is reasonable. Because the green use of new patents does not directly participate in production and directly affects the intensity of carbon emissions, but it has a very strong positive correlation with regional awareness of environmental protection, so it will affect green finance. Therefore, the sixth column is a robustness check against the benchmark model using a two-stage least squares model (2SLS). In this study, multiple methodologies are used to explain the conclusions because we need to ensure that the conclusions are still reliable when some basic assumptions in econometrics are not satisfied, which is consistent with the method of Fan et al. [53].

It can be seen from Table 2 that in columns (1)–(6), the regression coefficients of green finance on regional carbon intensity range from -1.104 to -2.209 and are significant at the 1% level. It can be found that green finance contributes to the reduction of regional carbon emission intensity, that is, Hypothesis 1 of this study is established. This study uses

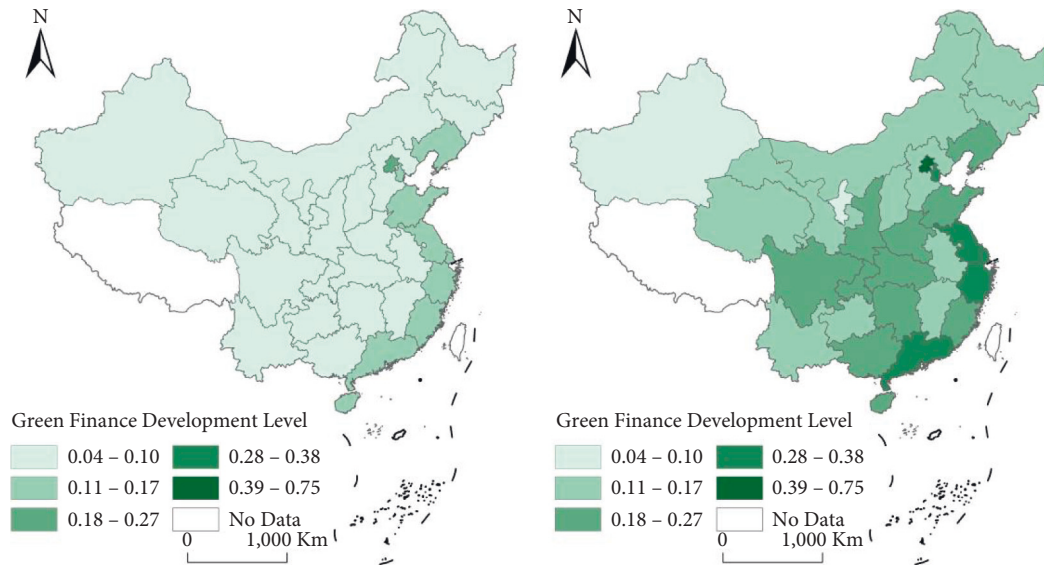


FIGURE 1: Green finance development level in 2005 and 2018.

TABLE 2: Benchmark regression results.

	(1) OLS	(2) OLS-FE	(3) D-K	(4) GMM	(5) D-Peak	(6) 2SLS
Gfd	-2.209*** (-8.71)	-1.494*** (-4.28)	-1.494*** (-6.92)	-2.177*** (-5.82)	-1.104*** (-2.67)	-1.909*** (-3.23)
Gdp		0.231*** (7.95)	0.231*** (3.24)	0.127* (1.88)	0.242*** (3.87)	0.346*** (2.61)
Gpp		0.183*** (4.74)	0.183* (1.77)	0.009*** (3.04)	0.033*** (3.14)	0.202*** (3.96)
Ssr		2.027*** (5.76)	2.027*** (2.96)	0.404 (0.89)	2.170*** (4.85)	2.632 (0.53)
Tsr		2.713*** (9.54)	2.713*** (8.08)	0.396*** (5.41)	1.435*** (8.63)	5.024*** (7.68)
Fdi		-0.107 (-1.08)	-0.107 (-1.17)	-0.168** (-2.07)	-0.169 (-0.06)	-0.098** (-2.10)
Pat		-0.090 (0.43)	-0.090 (0.25)	-0.048 (-0.20)	-0.060 (-0.24)	-0.072 (-0.38)
Er		-0.114*** (-5.41)	-0.114*** (-3.26)	-0.120*** (-6.16)	-0.121*** (-6.15)	-0.067*** (-3.72)
Time * ind fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Cons	7.215*** (11.04)	9.138*** (4.14)	9.138*** (5.62)	9.582*** (6.11)	8.636*** (4.74)	6.474*** (6.98)
R ²	0.3138	0.7942	0.7942	0.7181	0.5654	0.8013
Obs	420	420	420	330	378	420
Sargan test						0.421
AR (1)						0.073
AR (2)						0.9011
Wald						0.0425

Note. *, **, and *** represent significant at 10%, 5%, and 1%, respectively. Hypothesis test statistics are in parentheses.

Stata15.1 to make a partial correlation analysis diagram between green finance and carbon emissions. Figure 2 is a partial correlation analysis diagram between green finance and carbon emissions before adding control variables. Figure 3 shows the partial correlation analysis of green finance and carbon emissions after adding control variables, which proves Hypothesis 1 again, that is, the development of green finance helps regions to reduce regional carbon emissions. The primary reason is that the development of green finance can further expand the proportion of green credit. On the one hand, green credit increases the financing constraints of high-pollution and high-emission enterprises, and limits the expansion of the production scale of polluting enterprises; on the other hand, green credit can guide funds to flow to environment-friendly

enterprises and help energy-saving enterprises to develop green technologies and control pollution, thereby reducing carbon emissions in their production activities. Secondly, the development of green finance can further increase the proportion of green investment, guide social investment activities to favor environment-friendly enterprises, and attract more private capital (such as venture capital) to flow to green industries, increasing the supply of green funds. In addition, green financial institutions can rely on professional risk identification to conduct comprehensive risk management of supporting projects, and the development of green insurance business can also urge enterprises to consider ecological and environmental factors in production and operation activities to reduce environmental pollution and carbon intensity.

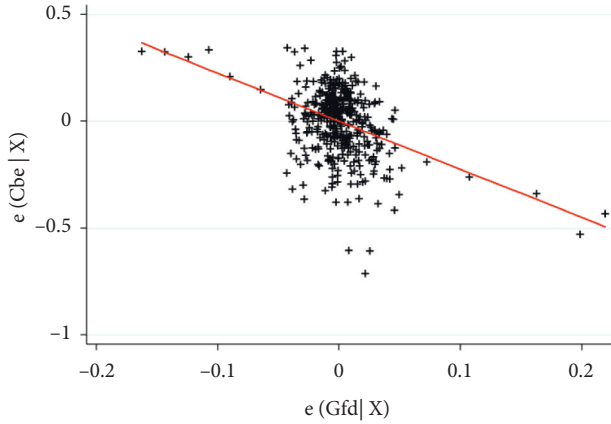


FIGURE 2: Partial correlation (before adding control variables).

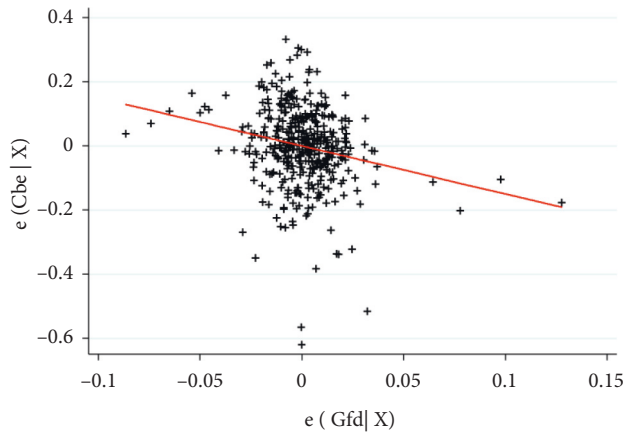


FIGURE 3: Partial correlation (after adding control variables).

For the control variables, economic growth and industrial scale increase will increase regional carbon intensity. The main reason is that China's industrialization development and rapid economic growth depend on a large amount of energy consumption, and the combustion of fossil energy is one of the most important sources of carbon emissions, which aggravates the growth of carbon emissions. In addition, the increase in the scale of the service industry has also significantly increased the regional carbon emission intensity. The possible reason is that the daily services and consumption of residents may lead to resource consumption, which will also increase the regional carbon emission intensity. The improvement in the level of scientific and technological innovation helps to reduce the regional carbon intensity, but it is not significant. This shows that China still needs to further increase investment in scientific and technological innovation, especially green technology innovation, and use clean production technology to drive the continuous upgrading of the industrial structure. Environmental regulation can significantly reduce regional carbon intensity, which shows that China's environmental regulation policies have achieved certain results in environmental governance.

4.1.2. Robustness Test. Referring to Fan et al. [53], the following methods are selected for robustness test in Table 3: (1) The possible influence of control policies, that is, the influence that endogenous factors of the policy selection sample. For example, policies in low-carbon pilot areas may lead to a high level of green finance development in one region, so the impact of green finance development on carbon emissions is more likely to come from low-carbon pilot areas. In July 2010, the National Development and Reform Commission officially launched the pilot work of national low-carbon provinces and cities, and decided to carry out low-carbon pilot work in Guangdong, Liaoning, Hubei, Shaanxi, and Yunnan provinces. Therefore, this study makes empirical regression on low-carbon pilot areas and non-low-carbon pilot areas in column 1 and column 2, respectively. (2) The possible influence of the provincial-level system. Currently in China, Beijing, Shanghai, Tianjin, and Chongqing are municipalities directly under the government. Therefore, the impact of its green finance development level on its carbon emissions may be different from that of other regions. Therefore, the regression results of these four regions are shown in the third column, and the regression results of other regions are shown in the fourth column. Since the heterogeneity of microenterprises may influence the results. We matched the city-level data and enterprise-level explained variables with the macro-provincial level explained variables, so as to investigate whether the effect existing at the macrolevel also exists at the microlevel, as shown in columns 5 and 6. It can be found that no matter what robustness test method is adopted, the inhibitory impact of green finance development on carbon intensity is still significant, so it passes the robustness test.

4.1.3. Benchmark Regression Results in Four Regions of China. China is a vast country, and there are great differences in the level of economic development and pollution discharge in different regions. This study conducts group regressions according to the eastern, central, western, and northeastern regions, and explores the heterogeneity mechanism of green finance development on carbon emissions in different regions of China. The regression results are shown in Table 4. Columns (1)–(4) represent the regression results for the eastern, central, western, and northeastern regions of China, respectively.

From the regression results of the four regions in China in Table 4, it can be seen that green finance still has a significant inhibitory effect on carbon intensity, the coefficient is from -1.022 to -2.017 , with 1% significant level. It should be noted that the inhibitory effect of green finance on carbon emissions is most significant in eastern China. The possible reason is that the eastern region has a higher level of economic development, a mature capital operation model, and a sound policy environment. Therefore, more green finance projects tend to be implemented in the eastern region of China. In addition, the eastern region of China is currently undergoing a process of transition from high-polluting manufacturing to high-tech manufacturing, so a lot of green credit and green investment are needed to

TABLE 3: Robustness test.

	(1) Low-carbon pilot areas	(2) Non-low-carbon pilot areas	(3) Municipalities	(4) Nonmunicipalities	(5) City-level	(6) Enterprise-level
Gfd	-1.232*** (-3.23)	-1.453*** (-4.75)	-2.345*** (-5.23)	-1.565*** (-3.11)	-1.433*** (-2.77)	-5.334*** (-3.69)
Gdp	0.281*** (5.08)	0.352*** (4.15)	0.423*** (8.31)	0.178** (1.99)	0.682*** (3.56)	0.341*** (2.91)
Gpp	0.282*** (3.08)	0.170** (4.22)	0.183** (1.96)	0.011** (2.48)	0.033*** (3.64)	0.241*** (3.72)
Ssr	2.062*** (4.06)	2.177*** (3.17)	2.262*** (3.91)	1.431 (1.57)	2.173*** (2.61)	2.281 (1.03)
Tsr	2.517*** (7.15)	2.284*** (3.26)	2.965*** (3.71)	2.629*** (3.26)	2.544*** (3.15)	4.262*** (4.70)
Fdi	-0.163 (-1.08)	-0.227 (-1.08)	-0.138 (-1.17)	-0.184 (-1.22)	-0.151 (-0.13)	-0.131 (-0.22)
Pat	-0.090 (0.43)	-0.090 (0.43)	-0.090 (0.25)	-0.048 (-0.20)	-0.060 (-0.24)	-0.072 (-0.38)
Er	-0.114*** (-5.41)	-0.114*** (-5.41)	-0.114*** (-3.26)	-0.120*** (-6.16)	-0.121*** (-6.15)	-0.067*** (-3.72)
Time * Ind fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Cons	4.521*** (7.04)	6.251*** (4.55)	6.904*** (3.72)	5.251*** (3.79)	6.252*** (4.28)	17.518*** (11.93)
R ²	0.7050	0.7643	0.7521	0.7707	0.5265	0.2178
Obs	70	350	56	364	3920	16514

Note. *, **, and *** represent significant at 10%, 5%, and 1%, respectively. Hypothesis test statistics are in parentheses.

TABLE 4: Subregional regression results of benchmark model.

	(1) Eastern	(2) Central	(3) Western	(4) Northeast
Gfd	-2.017*** (-3.67)	-1.022*** (-2.61)	-1.309*** (-5.37)	-1.917*** (-3.92)
Gdp	0.014*** (6.28)	0.455*** (3.89)	0.207** (2.15)	0.191 (0.93)
Gpp	0.306 (1.63)	0.327** (2.27)	0.194 (1.22)	0.064 (1.56)
Ssr	0.527*** (3.77)	2.727*** (3.88)	1.657*** (4.76)	3.013*** (4.64)
Tsr	4.777*** (4.79)	0.566*** (5.23)	1.432*** (10.709)	3.019*** (7.94)
Fdi	-0.109* (-1.76)	-0.085 (-0.29)	-0.207 (-0.53)	-0.210* (-1.85)
Pat	-0.166 (-0.37)	-0.105 (-0.01)	-0.063 (-0.01)	-0.101 -0.360
Er	-0.166*** (-6.27)	-0.205* (-1.91)	-0.188*** (-3.09)	-0.020* (-1.99)
Time * ind fixed effect	Yes	Yes	Yes	Yes
Cons	9.031*** (8.12)	10.646*** (7.03)	7.013*** (6.84)	8.821*** (9.44)
R ²	0.6438	0.7017	0.8056	0.8321
Obs	140	84	154	42

Note. *, **, and *** represent significant at 10%, 5%, and 1%, respectively. Hypothesis test statistics are in parentheses.

support the transition from polluting industries to environmentally friendly industries. Therefore, the inhibitory effect of green finance on carbon intensity in the eastern region is more obvious. However, compared with the eastern region, the central and western regions of China have undertaken more high-polluting industries from the eastern region. The economic development is still in the stage of pursuing volume and ignoring environmental benefits, and the overall carbon intensity is relatively high. In addition, the green financial system in the central and western regions is not yet sound enough, lacking advanced management and mature institutional mechanisms, and green financial products are relatively simple, so green finance is weak in helping carbon emission reduction. It is worth mentioning that the economic development of the northeast region is dominated by heavy industries, such as steel, coal, oil and gas, and chemical industries. It faces great excess pressure and lacks economic growth and financial innovation. However, due to the superior natural conditions in northeast

China and the great pressure on industrial transformation and upgrading, green finance has a broader space for development, and its inhibitory effect on carbon emissions continues to increase.

4.2. Moderating Effect Results

4.2.1. Moderating Regression Results of China as a Whole. Under the moderation effect test model constructed in this study, the regression results are shown in Table 5. Columns (1)–(6) in Table 5 are still similar to those in (1)–(6) in Table 2, and the moderation effect model is also tested for robustness and endogeneity.

It can be seen from Table 5 that in columns (1)–(6), the regression coefficients of capital stock per capita (Kpl) on regional carbon intensity range from 0.079 to 0.220, and are significantly positive at the 10% significance level. The regression coefficient of the interaction term of per capita

TABLE 5: Regression results of regulatory effect.

	(1) OLS	(2) FE	(3) D-K	(4) GMM	(5) de-extremum	(6) 2SLS
Gfd	-1.243*** (-3.47)	-0.160* (-1.71)	-0.160* (-1.71)	-0.311** (-2.14)	-0.135** (-2.16)	-1.696*** (-3.90)
Kpl	0.220* (1.85)	0.079* (1.84)	0.079** (2.14)	0.072 (1.39)	0.131* (1.83)	0.190* (1.82)
Kpl * Gfd	-0.793*** (-5.50)	-0.223** (-1.99)	-0.223** (-1.99)	-0.188** (-2.41)	-0.484*** (-3.87)	-0.476*** (-3.00)
Gdp		0.184*** (3.13)	0.184*** (3.13)	0.106 (1.66)	0.293** (3.18)	0.414** (2.37)
Gpp		0.223 (1.41)	0.223 (1.41)	-0.010*** (-3.65)	0.039*** (3.73)	0.191*** (4.55)
Ssr		1.530** (2.34)	1.530** (2.34)	0.454 (0.943)	1.933*** (5.09)	2.585 (0.86)
Tsr		2.882*** (7.67)	2.882*** (7.67)	0.436*** (4.21)	1.713*** (7.35)	4.811*** (7.00)
Fdi		-0.098 (-1.17)	-0.098 (-1.17)	-0.207** (-1.99)	-0.171 (-0.04)	-0.084** (-2.44)
Pat		-0.099 (-0.27)	-0.099 (-0.27)	-0.054 (-0.21)	-0.049 (-0.21)	-0.055 (-0.30)
Er		-0.114*** (-3.75)	-0.114*** (-3.75)	-0.112*** (-5.99)	-0.102*** (-6.57)	-0.069*** (-4.64)
Time * Ind fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Cons	8.284*** (4.53)	7.618*** (5.29)	7.618*** (5.29)	7.660*** (7.16)	8.325*** (5.16)	6.678*** (7.68)
R ²	0.4969	0.8031	0.8031	0.7268	0.6230	0.8539
Obs	420	420	420	330	378	420

Note. *, **, and *** represent significant at 10%, 5%, and 1%, respectively. Hypothesis test statistics are in parentheses.

capital stock and green finance (Kpl * Gfd) on regional carbon intensity ranges from -0.188 to -0.793 , and is significantly positive at the 1% significance level. It can be found that after adding the interaction terms of capital stock per capita and green finance, capital stock per capita into the benchmark regression model, the inhibitory effect of green finance development on regional carbon intensity has decreased. Therefore, per capita capital stock has a significant negative moderating effect on the relationship between green finance and regional carbon emissions, that is, Hypothesis 2 is established. The reason is that the essence of green finance is the reallocation of capital stock and the realization of sustainable economic, social and environmental development through the optimal combination of financial instruments and financial products. Therefore, under the efficient green financial market adjustment mechanism, through the combination of green credit, green investment, green insurance and other green financial services. Enterprises can further improve the operation mode, optimize and reorganize production factors, such as human resources, capital, technology, etc., in order to reduce pollution emissions in production activities, strengthen pollution control at the end of production, and then reduce carbon emissions. Therefore, the accumulation of capital could be a feasible path to better exert the effect of green finance on carbon emissions. Moreover, the increase in carbon intensity caused by the process of capital accumulation can also be mitigated through the development of green finance.

4.2.2. Moderating Regression Results in Four Regions of China. In order to further explore the heterogeneity of the moderating effect of capital stock per capita on green finance and carbon emissions in different regions of China, this section conducts group regressions on the eastern, central, western, and northeastern regions of China. The regression results are shown in Table 6.

It can be seen from Table 6 that whether it is the overall regression result of China or the regression results of the four regions, per capita capital stock (Kpl) plays a significant moderating role, helping green finance curb carbon intensity, the coefficients ranges from 0.048 to 0.221. From the regression coefficients, the moderating effect of capital stock per capita is more significant in northeast China. The possible reason is that the northeast region is a traditional old industrial base in China, and the problems of environmental pollution and ecological damage are becoming more and more serious. Therefore, it needs a lot of funds to support the upgrading and transformation of traditional manufacturing industries. However, the economic growth rate of the northeast region has slowed down in recent years, and the local financial capacity is extremely limited, which cannot support the development of the green economy in the northeast region. Therefore, capital stock per capita is crucial to the development of green economy in northeast China. The capital factor integration function of green finance enables green enterprises to have more opportunities to obtain production factors for further development. Under the continuous action of the factor integration mechanism, more capital will be gathered in environment-friendly enterprises, which will promote the realization of scale effect of green production enterprises, and further create conditions for the development of green economy.

4.3. Threshold Effect Results. Due to the significant heterogeneity of capital stock per capita in different regions, this part continues to explore whether there is a threshold effect of green finance on carbon intensity under different levels of capital stock per capita. The threshold effect test results are shown in Table 7. Specifically, it shows that there is a non-linear relationship between the impact of per capita capital stock on effect of green finance on carbon intensity. Hence, this study can use the threshold effect model to analyze the mechanism of green finance on regional carbon intensity.

TABLE 6: Subregional regression results of regulatory effects.

	(1) Eastern	(2) Central	(3) Western	(4) Northeast
Gfd	-0.291* (-1.87)	-0.316** (-2.31)	-0.192** (-2.17)	-0.227** (-2.01)
Kpl	0.048 (1.04)	0.103* (1.70)	0.131** (1.99)	0.221*** (3.66)
Kpl * Gfd	-0.327*** (-2.87)	-0.319** (-2.21)	-0.322*** (-2.78)	-0.508*** (-3.01)
Gdp	0.280*** (3.12)	0.311*** (2.62)	0.281*** (4.35)	0.227*** (4.48)
Gpp	0.142** (2.39)	0.259* (1.87)	0.230* (1.94)	0.162 (1.16)
Ssr	1.390*** (3.36)	1.934*** (3.14)	2.290* (1.87)	1.893*** (3.10)
Tsr	2.689*** (7.31)	2.488*** (5.67)	1.841*** (8.08)	2.937*** (7.41)
Fdi	-0.099 (-1.28)	-0.076 (-0.98)	-0.104 (-0.95)	-0.067 (-1.34)
Pat	-0.091 (-0.27)	-0.072 (-0.27)	-0.087 (-0.16)	-0.126 (-0.15)
Er	-0.138*** (-4.53)	-0.077*** (-4.33)	-0.071*** (-3.20)	-0.141*** (-3.02)
Time * ind fixed effect	Yes	Yes	Yes	Yes
Cons	12.596*** (5.08)	10.919*** (6.78)	7.519*** (7.85)	10.723*** (3.90)
R ²	0.6892	0.7369	0.8528	0.8931
Obs	140	84	154	42

Note. *, **, and *** represent significant at 10%, 5%, and 1%, respectively. Hypothesis test statistics are in parentheses.

TABLE 7: Threshold effect test.

	F-value	P value	1% critical value	5% critical value	10% critical value
Single threshold	18.937***	0.003	15.303	7.955	5.922
Double threshold	40.923***	0.007	34.044	18.871	11.045
Third threshold	-11.530*	0.090	11.707	-6.286	-12.327

Note. *, **, and *** represent significant at 10%, 5%, and 1%, respectively.

The threshold regression results are shown in Table 8. Under different per capita capital levels, the development of green finance has a significant threshold effect on regional carbon emissions. Green finance helps reduce carbon emission intensity, and with the increase of capital stock per capita, green finance's inhibitory effect on regional carbon emissions is enhanced. Specifically, in the single-threshold model, green finance has a significant inhibitory effect on carbon emissions only when the per capita capital stock is greater than 8.353, and its elasticity coefficient is -1.799 . For the double-threshold model, only when the per capita capital stock is greater than 8.775, green finance has a significant inhibitory effect on carbon emissions, and its elasticity coefficient is -1.997 . And with the increase of per capita capital stock, the inhibitory effect of green finance on carbon emissions is increasing. For the three-threshold model, only when the capital stock per capita is greater than 8.231, green finance has a significant inhibitory effect on carbon emissions, and its elasticity coefficient is -1.744 . After crossing the second threshold, its elasticity coefficient becomes -2.565 , and this inhibitory effect will continue to increase as the capital stock per capita increases. Therefore, with the increase of per capita capital stock, the inhibitory effect of green finance on carbon emissions is enhanced. The reason is that the impact of green finance on economic entities is mainly achieved by restructuring capital allocation. Only when the capital stock of the region reaches a certain level,

enterprises can use more funds to develop green technologies and control pollution emissions from production activities, thereby reducing regional carbon intensity.

5. Discussion

The conclusion of this study is basically consistent with the theory of ecological modernization and urban environmental change [54–56]. Although the development and progress of cities will bring ecological environment pressure to cities, with the improvement of the innovation level and modernization level of cities, environmental problems will be reduced, such as the increase of the scale of green finance. This is similar to the view that the improvement of China's green finance development index helps reduce carbon intensity [11, 57]. In particular, financial development can reduce carbon emissions and be environmentally friendly if it encourages investment in environmental projects and enables firms to adopt and use advanced, energy-efficient, clean technologies, or renewable energy projects [58, 59]. In addition, Sun [60] pointed out that the development of green finance has a moderating effect on the carbon emissions of high-income groups, while it has an opposite effect on the carbon emissions of middle- and low-income groups. This is also the future research direction between green finance and carbon intensity, that is, further refinement of research samples is required to verify whether there will be differences in the regression results.

TABLE 8: Threshold effect regression results.

	(1) Single threshold	(2) Double threshold	(3) Third threshold
	Threshold < δ_1	-0.385 (-0.70)	-1.125 (-1.02)
Gfd	$\delta_1 \leq \text{Threshold} < \delta_2$	-1.799*** (-4.40)	-1.997*** (-4.67)
	$\delta_2 \leq \text{Threshold} < \delta_3$	—	-3.601*** (-7.61)
	$\delta_3 < \text{threshold}$	—	-2.565*** (-3.07)
Gdp	0.152*** (5.68)	-0.112*** (3.99)	0.279*** (6.70)
Gpp	0.157*** (4.09)	0.166*** (2.81)	0.450*** (3.07)
Ssr	4.408 (0.22)	0.302*** (6.09)	2.865*** (4.41)
Tsr	0.857 (1.14)	4.100*** (2.73)	4.542*** (4.02)
Fdi	-0.240 (-0.61)	-0.134*** (-2.60)	-0.262 (-0.89)
Pat	-0.051 (-0.02)	0.010 (-0.47)	-0.223 (-0.25)
Er	-0.176*** (-5.44)	-0.074*** (-6.81)	-0.039*** (-7.62)
Time fixed effect	Yes	Yes	Yes
Individual fixed effect	Yes	Yes	Yes
Cons	9.156 (0.48)	8.079* (1.76)	7.990*** (2.07)
R^2	0.6243	0.7581	0.7846
Obs	420	420	420
δ_1	8.353	8.775	8.231
δ_2	—	9.243	8.781
δ_3	—	—	9.913

Note. *, **, and *** represent significant at 10%, 5%, and 1%, respectively. Hypothesis test statistics are in parentheses.

6. Conclusions and Policy Recommendations

Issues such as resource consumption and ecological deterioration caused by China's extensive growth for a long time have made green development an inevitable choice for China's current economic transformation. However, in order to achieve green development, in addition to the active guidance of the government, it also requires the operation of the capital market mechanism. Among them, green finance plays an important role.

7. Conclusions

- (1) The development of green finance has a significant inhibitory effect on the regional carbon intensity. For every 1% increase in the level of green finance development, the regional carbon intensity can be reduced by 2%. There is heterogeneity in the regions, with the eastern region having the strongest inhibitory effect, followed by the northeastern region, then the central region, and the western region, respectively. Therefore, different green financial policies should be classified and implemented according to the factor resource endowment and industrial structure in different regions of China to maximize the effect of emission reduction.
- (2) There is a moderating effect of per capita capital stock on the relationship between green finance and carbon intensity, that is, the accumulation of regional capital helps to enhance the inhibitory effect of green finance on carbon intensity. From the regression results of the four regions in China, green finance has the most significant inhibitory effect on carbon intensity in northeast China under the process of capital accumulation. Therefore, regional

development should not overemphasize the development of service industries to reduce carbon emission intensity. It is also possible to optimize the allocation of production factors of the industrial economy through green finance, and increase investment in clean energy and clean production, in order to achieve the coordinated development of capital accumulation and green industries.

- (3) There is a significant threshold effect between green finance and carbon emission intensity between per capita capital stock, that is, with the increase of per capita capital stock, the inhibitory effect of green finance on carbon emission increases. Therefore, in the process of capital accumulation, attention should be paid to the improvement of the regional financial structure. Among them, green finance is matched with economic development and industrial structure to stimulate a stronger capital allocation effect and guide more capital to flow to environment-friendly industries to achieve a continuous decline in carbon intensity.

7.1. Policy Recommendations

- (1) Accelerate the improvement of relevant legal systems and policy guarantees for the development of green finance. Due to the late start of green finance development in China, the policy system and legal and regulatory system need to be further improved. Therefore, first of all, some legal policies with higher level, wider coverage, more specificity, and stronger legal effect should be introduced, for example, a certain level of tax relief for green bond investors. Secondly, based on the successful experience of some western developed countries, adjust China's existing

green finance standards, unify the norms, strengthen information communication, and improve the green finance development mechanism, quantify environmental risks, and improve supervision, so as to mobilize the enthusiasm of financial institutions to actively participate in green finance.

- (2) Give play to the decisive role of the market in resource allocation. In terms of expanding the scale of green assets, it is recommended that financial institutions accelerate the deployment of green industries such as new energy, green buildings, low-carbon transportation, energy conservation, and environmental protection, and increase the proportion of green assets. At the same time, financial institutions have also increased financial support for the green transformation of high-carbon industries such as petrochemicals, electric power, and steel, and optimized asset structures. At the same time, financial institutions should actively follow up and participate in the construction of the carbon market, develop carbon financial products such as carbon funds and carbon trusts, and help reduce the “green premium.”
- (3) The impact of green finance on carbon emission intensity is heterogeneous in different regions of China. Therefore, different green finance development goals should be formulated in combination with the regional factor endowment structure and comparative advantages. In particular, the eastern region is the leader of China’s economic development. While promoting the development of green credit products, it should actively promote the diversified development of green products and enhance its demonstration effect of green financial development. At the same time, the business environment in northeast China should be continuously optimized, and more green financial information consulting service agencies and environmental risk assessment agencies should be cultivated, thereby accelerating the transformation and upgrading of traditional industries. The central and western regions have undertaken a large number of industrial transfers from the eastern regions, and the economic development momentum is strong, but the participation of market players in green finance needs to be improved. Therefore, preferential policies such as financial subsidies, tax relief and financial incentives should be implemented as soon as possible to encourage more institutions to participate in the development of green finance. [61–63].

Data Availability

Due to the confidentiality and privacy of the data, they will only be provided upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

- [1] C. Nedopil, T. Dordi, and O. Weber, “The nature of global green finance standards—evolution, differences, and three models,” *Sustainability*, vol. 13, no. 7, p. 3723, 2021.
- [2] S. T. Katircioglu and N. Taspinar, “Testing the moderating role of financial development in an environmental Kuznets curve: empirical evidence from Turkey,” *Renewable and Sustainable Energy Reviews*, vol. 68, pp. 572–586, 2017.
- [3] K. U. Ehigiamusoe, H. H. Lean, and R. Smyth, “The moderating role of energy consumption in the carbon emissions-income nexus in middle-income countries,” *Applied Energy*, vol. 261, Article ID 114215, 2020a.
- [4] K. U. Ehigiamusoe and H. H. Lean, “Effects of energy consumption, economic growth, and financial development on carbon emissions: evidence from heterogeneous income groups,” *Environmental Science and Pollution Research*, vol. 26, no. 22, Article ID 22624, 2019.
- [5] C. Fischer, “Environmental protection for sale: strategic green industrial policy and climate finance,” *Environmental and Resource Economics*, vol. 66, no. 3, pp. 553–575, 2017.
- [6] L. Liu, C. Chen, Y. Zhao, and E. Zhao, “China’s carbon-emissions trading: overview, challenges and future,” *Renewable and Sustainable Energy Reviews*, vol. 49, no. 9, pp. 254–266, 2015.
- [7] Q. Chen, B. Ning, Y. Pan, and J. Xiao, “Green finance and outward foreign direct investment: evidence from a quasi-natural experiment of green insurance in China,” *Asia Pacific Journal of Management*, vol. 1, pp. 1–26, 2021.
- [8] S. A. Sarkodie and V. Strezov, “Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries,” *Science of the Total Environment*, vol. 646, pp. 862–871, 2019.
- [9] Y. Liu, J. Lei, and Y. Zhang, “A study on the sustainable relationship among the green finance, environment regulation and green-total-factor productivity in China,” *Sustainability*, vol. 13, no. 21, Article ID 11926, 2021.
- [10] L. P. Koh, Y. Zeng, T. V. Sarira, and K. Siman, “Carbon prospecting in tropical forests for climate change mitigation,” *Nature Communications*, vol. 12, no. 1, p. 1271, 2021.
- [11] Y. Wang and Q. Zhi, “The role of green finance in environmental protection: two aspects of market mechanism and policies,” *Energy Procedia*, vol. 104, pp. 311–316, 2016a.
- [12] L. Sun, J. Wang, Z. Wang, and L. Marquez, “Mechanism of carbon finance’s influence on radical low-carbon innovation with evidence from China,” *Sustainability*, vol. 12, no. 18, p. 7708, 2020.
- [13] P. Soundarrajan and N. Vivek, “Green finance for sustainable green economic growth in India,” *Agricultural Economics*, vol. 62, no. 1, pp. 35–44, 2016.
- [14] C. Carraro, A. Favero, and E. Massetti, “Investments and public finance in a green, low carbon, economy,” *Energy Economics*, vol. 34, no. 1, pp. S15–S28, 2012.
- [15] J. Chevallier, S. Goutte, Q. Ji, and K. Guesmi, “Green finance and the restructuring of the oil-gas-coal business model under

- carbon asset stranding constraints,” *Energy Policy*, vol. 149, no. 3, Article ID 112055, 2021.
- [16] X. Chen and Z. Chen, “Can green finance development reduce carbon emissions? Empirical evidence from 30 Chinese provinces,” *Sustainability*, vol. 13, no. 21, Article ID 12137, 2021.
- [17] K. Behrens and J. F. Thisse, “Regional economics: a new economic geography perspective,” *Regional Science and Urban Economics*, vol. 37, no. 4, pp. 457–465, 2007.
- [18] A. Gao, M. Sun, D. Han, and C. Shen, “Multiresolution analysis of information flows from international carbon trading market to the clean energy stock market,” *Journal of Renewable and Sustainable Energy*, vol. 12, no. 5, Article ID 055901, 2020.
- [19] B. Rui, J. Leitão, Z. J. Acs, and D. B. Audretsch, “Entrepreneurship, human capital, and regional development,” *Quarterly Journal of Economics*, vol. 128, no. 1, pp. 105–164, 2015.
- [20] L. He, R. Liu, Z. Zhong, D. Wang, and Y. Xia, “Can green financial development promote renewable energy investment efficiency? a consideration of bank credit,” *Renewable Energy*, vol. 143, no. 10, pp. 974–984, 2019.
- [21] J. Huang, L. V. Hailong, and L. Wang, “Mechanism of financial development influencing regional green development: based on eco-efficiency and spatial econometrics,” *Geographical Research*, vol. 33, no. 3, pp. 532–545, 2014.
- [22] L. Li, W. Wu, M. Zhang, and L. Lin, “Linkage analysis between finance and environmental protection sectors in China: an approach to evaluating green finance,” *International Journal of Environmental Research and Public Health*, vol. 18, no. 5, p. 2634, 2021.
- [23] C. H. Yu, X. Wu, D. Zhang, S. Chen, and J. Zhao, “Demand for green finance: resolving financing constraints on green innovation in China,” *Energy Policy*, vol. 153, no. 1, Article ID 112255, 2021.
- [24] H. Yu, G. Cai, and Y. Li, “Dynamic analysis and control of a new hyperchaotic finance system,” *Nonlinear Dynamics*, vol. 67, no. 3, pp. 2171–2182, 2012.
- [25] H. Chen, J. Miao, and N. Wang, “Entrepreneurial finance and non-diversifiable risk,” *Review of Financial Studies*, vol. 23, no. 12, pp. 4348–4388, 2010.
- [26] H. Cui, R. Wang, and H. Wang, “An evolutionary analysis of green finance sustainability based on multi-agent game,” *Journal of Cleaner Production*, vol. 269, Article ID 121799, 2020.
- [27] M. M. Shi, Z. Jiang, and X. Y. Zhou, “Consumption upgrading or consumption degradation,” *China industrial economy*, no. 07, pp. 42–60, 2019.
- [28] A. Gilg, S. Barr, and N. Ford, “Green consumption or sustainable lifestyles? identifying the sustainable consumer,” *Futures*, vol. 37, no. 6, pp. 481–504, 2005.
- [29] D. Donaldson, “Railroads of the raj: estimating the impact of transportation infrastructure,” *The American Economic Review*, vol. 108, no. 4-5, pp. 899–934, 2018.
- [30] J. M. Domínguez-Jurado, F. Triguero-Ruiz, and A. Avila-Cano, “Firm growth in the 21st century: does the Andalusian economy comply with Gibrat’s Law?” *Physica A: Statistical Mechanics and its Applications*, vol. 577, Article ID 126064, 2021.
- [31] J. Ju, J. Y. Lin, and Y. Wang, “Endowment structures, industrial dynamics, and economic growth,” *Journal of Monetary Economics*, vol. 76, no. 11, pp. 244–263, 2015.
- [32] P. Eichholtz and J. M. Quigley, “Green building finance and investments: practice, policy and research,” *European Economic Review*, vol. 56, no. 5, pp. 903–904, 2012.
- [33] Y. Hu, H. Jiang, and Z. Zhong, “Impact of green credit on industrial structure in China: theoretical mechanism and empirical analysis,” *Environmental Science and Pollution Research*, vol. 27, no. 10, Article ID 10519, 2020.
- [34] The Intergovernmental Panel on Climate Change (Ipcc), *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Institute for Global Environmental Strategies (IGES), Hayama, Kanagawa, Japan, 2006.
- [35] F. Lu, M. H. Liu, and Y. Y. Sun, “Agglomeration, total factor productivity and industrial growth,” *Studies Science of Science*, vol. 36, no. 09, pp. 1575–1584+1614, 2018.
- [36] H. Ke, S. Dai, and F. Fan, *Does Innovation Efficiency Inhibit the Ecological Footprint? an Empirical Study of China’s Provincial Regions*, pp. 1–15, Technology Analysis & Strategic Management, 2021.
- [37] L. R. James and J. M. Brett, “Mediators, moderators, and tests for mediation,” *Journal of Applied Psychology*, vol. 69, no. 2, pp. 307–321, 1984.
- [38] M. Caner and B. E. Hansen, “Instrumental variable estimation of a threshold model,” *Econometric Theory*, vol. 20, no. 05, pp. 813–843, 2004.
- [39] B. E. Hansen, “Threshold effects in non-dynamic panels: estimation, testing, and inference,” *Journal of Econometrics*, vol. 93, no. 2, pp. 345–368, 1999.
- [40] T. H. Chang, C. M. Huang, and M. C. Lee, “Threshold effect of the economic growth rate on the renewable energy development from a change in energy price: evidence from OECD countries,” *Energy Policy*, vol. 37, no. 12, pp. 5796–5802, 2009.
- [41] A. Chudik, K. Mohaddes, M. H. Pesaran, and M. Raissi, “Is there a debt-threshold effect on output growth?” *The Review of Economics and Statistics*, vol. 99, no. 1, pp. 135–150, 2017.
- [42] F. Fakhri, “Relationship between inflation and economic growth in Azerbaijani economy: is there any threshold effect?” *Asian Journal of Business and Management Sciences*, vol. 1, no. 1, pp. 1–11, 2011.
- [43] H. Ke, S. Dai, and H. Yu, “Effect of green innovation efficiency on ecological footprint in 283 Chinese Cities from 2008 to 2018,” *Environment, Development and Sustainability*, vol. 24, no. 2, pp. 2841–2860, 2022.
- [44] H. Ke, S. Dai, and H. Yu, “Spatial effect of innovation efficiency on ecological footprint: city-level empirical evidence from China,” *Environmental Technology & Innovation*, vol. 22, no. 67, Article ID 101536, 2021a.
- [45] X. Luo and W. Zhang, “Green innovation efficiency: a threshold effect of research and development,” *Clean Technologies and Environmental Policy*, vol. 23, no. 1, pp. 285–298, 2021.
- [46] H. Zhang and H. Ke, “Spatial spillover effects of directed technical change on urban carbon intensity, based on 283 cities in China from 2008 to 2019,” *International Journal of Environmental Research and Public Health*, vol. 19, no. 3, p. 1679, 2022.
- [47] G. Ali and V. Nitivattananon, “Exercising multidisciplinary approach to assess interrelationship between energy use, carbon emission and land use change in a metropolitan city of Pakistan,” *Renewable and Sustainable Energy Reviews*, vol. 16, no. 1, pp. 775–786, 2012.
- [48] G. Dong, Y. Ge, W. Zhu, Y. Qu, and W. Zhang, “Coupling coordination and spatiotemporal dynamic evolution between green urbanization and green finance: a case study in China,” *Frontiers in Environmental Science*, vol. 8, Article ID 621846, 2021.
- [49] O. Shafique and A. Majeed, “Factors influencing bankers’ intention to adopt green finance in Pakistan,” *Review of*

- Economics and Development Studies*, vol. 6, no. 4, pp. 773–785, 2020.
- [50] L. Liu, H. Zong, E. Zhao, C. Chen, and J. Wang, “Can China realize its carbon emission reduction goal in 2020: from the perspective of thermal power development,” *Applied Energy*, vol. 124, no. 6, pp. 199–212, 2014.
- [51] P. Zhou, B. W. Ang, and J. Y. Han, “Total factor carbon emission performance: a Malmquist index analysis,” *Energy Economics*, vol. 32, no. 1, pp. 194–201, 2010.
- [52] J. Qin, Y. Zhao, and L. Xia, “Carbon emission reduction with capital constraint under greening financing and cost sharing contract,” *International Journal of Environmental Research and Public Health*, vol. 15, no. 4, p. 750, 2018.
- [53] F. Fan, S. Dai, K. Zhang, and H. Ke, “Innovation agglomeration and urban hierarchy: evidence from Chinese cities,” *Applied Economics*, vol. 53, no. 54, pp. 6300–6318, 2021.
- [54] K. U. Ehigiamusoe, H. H. Lean, S. J. Babalola, and W. C. Poon, “The roles of financial development and urbanization in degrading environment in Africa: unravelling non-linear and moderating impacts,” *Energy Reports*, vol. 8, pp. 1665–1677, 2022.
- [55] G. McGranahan, P. Jacobi, J. Songsore, C. Surjadi, and M. Kjellen, *The Citizens at Risk: From Urban Sanitation to Sustainable Cities*, Earthscan (Routledge) Publisher, England UK, 2010.
- [56] A. P. Mol and G. Spaargaren, “Ecological modernisation theory in debate: a review,” *Environmental Politics*, vol. 9, no. 1, pp. 17–49, 2000.
- [57] X. Ren, Q. Shao, and R. Zhong, “Nexus between green finance, non-fossil energy use, and carbon intensity: empirical evidence from China based on a vector error correction model,” *Journal of Cleaner Production*, vol. 277, Article ID 122844, 2020.
- [58] S. Claessens and E. Feijen, *Financial Sector Development and the Millennium Development Goals*, World Bank Publication, Washington D. C., USA, 2007.
- [59] A. Tamazian, J. P. Chousa, and K. C. Vadlamannati, “Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries,” *Energy Policy*, vol. 37, no. 1, pp. 246–253, 2009.
- [60] C. Sun, “The correlation between green finance and carbon emissions based on improved neural network,” *Neural Computing & Applications*, vol. 34, Article ID 12413, 2021.
- [61] K. U. Ehigiamusoe, V. Guptan, and H. H. Lean, “Impact of financial structure on environmental quality: evidence from panel and disaggregated data,” *Energy Sources, Part B: Economics, Planning and Policy*, vol. 14, no. 10-12, pp. 359–383, 2019.
- [62] M. A. Jun and Y. Shi, *Green Finance Policy and its Applications in China*, China Finance Review, Shanghai, China, 2014.
- [63] X. Liu, W. Wang, W. Wu, L. Zhang, and L. Wang, “Using cooperative game model of air pollution governance to study the cost sharing in Yangtze River Delta region,” *Journal of Environmental Management*, vol. 301, Article ID 113896, 2022.