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The Study of Carbon Neutralization Effects with Green Credit: Evidence from a Panel Data Analysis for Interprovinces in China

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Abstract: Giving full play to carbon emission reduction of green credits is essential to achieve carbon neutrality. According to low-carbon pilot policies and the condition of industrial transfer, this paper first sorts those provinces into different research zones. The zones are as follows: (I) the first and second batch of low-carbon municipalities and the first batch of pilot provinces (L1) and other provinces (L2) and (II) strong industry transfer-out zone (STR), weak industry transfer-out zone (WTR), and industrial transfer-in area (TIR). Then, we employ a dynamic panel data model and systematic GMM (SYS-GMM) approach to empirically test the impact of green credit and nongreen credit on carbon emissions. Further, this paper analyzes how to coordinate two types of credits to achieve carbon neutrality. The results show that, first, at the national level, the nexus of green credit and carbon emissions with an inverted U-shaped curve and the current impact of green credit is still in the first half of the inverted U-shaped stage. The achievement of carbon neutrality is associated with the ratio structure of green credit to nongreen credit and the scale of green credit. Second, the achievement of carbon neutrality is with regional heterogeneity. The achievement of carbon neutrality is associated with the scale of green credit in L2 and TIR, but also with the ratio structure of nongreen credit to green credit in L2 and STR. However, the carbon neutralization effects with green credit are insignificant in L1 WTR. Finally, based on those conclusions, this paper puts forwards some suggestions to provide references for the policy formulation of green credits and carbon neutrality.

Keywords: carbon neutrality; green credit; carbon emissions; nongreen credit; systematic GMM

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1. Introduction

Climate change is occurring and leading to serious problems, such as global sea level rising, extreme weather events occurring frequently, and biodiversity decreasing. Climate change is threatening the sustainable development of human society [1]. However, mitigating climate change needs reducing greenhouse gas emissions [2]. Against this backdrop, how to achieve carbon neutrality has become a focus all over the world. As the world's second-largest carbon emitter, the overall trend of carbon emissions in China was on the rise from 1960 to 2022. Therefore, the realization of carbon neutrality in China is of great significance to the global response to climate change. Meanwhile, the world surroundings have undergone profound changes. It is crucial for developing countries, such as China, to promote sustainable economic growth and improve living standards. Therefore, the manuscript will take China as the object to investigate how to coordinate the relationship between economic growth and climate change, which has great reference values for other countries.

As an important tool of green finance, green credit plays an important role in coordinating climate change and boosting economic growth. Hence, whether green credit can promote carbon emission reduction has attracted wide attention from scholars. On the one hand, the implementation of green credit policy can reduce enterprises' financing constraints of environmental protection, new energy, new materials, and increasing spending funds on research and development. Hence, it provides more low-carbon products or services, leading to carbon emission reduction [3]. Some scholars also believe that green credit increases the debt financing cost of high-pollution industries, restrains their new investment, guides more capital to flow to green industries, eases their financing constraints, and optimizes resource allocation [3,4]. On the other hand, the development of green credit has expanded economies of scale, which in turn has increased carbon emissions [5]. In addition, a large number of studies have found that green credit has boosted economic growth [6–9]. Nevertheless, the nexus of economic growth and environmental pollution has always been controversial. The most popular theory of the environmental Kuznets curve (EKC) hypothesis has become the focus of discussion in academic and policy circles. However, most scholars have studied the EKC hypothesis just from the perspectives of the relationship between economics and environment [10]. Policy suggestions mainly focus on how to mitigate the negative externalities brought by economic growth to the environment, such as how to achieve energy conservation and emission reduction [11–13]. Few literatures have studied the EKC hypothesis from the coordination perspectives of the positive and negative externalities that economic growth brings to the environment.

In view of this, in the context of carbon neutrality, this paper takes China as an example to explore two questions: first, what effects green credit and nongreen credit have on carbon emissions; second, how to coordinate the effects of these two types of credit on carbon emissions so as to achieve carbon neutrality. It is worthy of note that the connotation of carbon neutrality in this paper is that carbon emissions increase and reduction remains relatively stable, or the sum of the two is zero. The answer to these two questions will help expand the EKC hypothesis and enrich the environmental economics theory.

To achieve this, based on the panel data of 30 provinces of China, we first sort those provinces to different research regions. Then the SYS-GMM approach is adopted to study the impact of green credit and nongreen credit on carbon emissions. Finally, this paper analyzes how to coordinate the effects of the two types of credit on carbon emissions so as to achieve carbon neutrality. The results show that the achievement of carbon neutrality is associated not only with the scale of green credit, but also with the ratio structure of green credit to nongreen credit. What is more, achieving carbon neutrality is with regional heterogeneity, which is mainly affected by regional carbon emission characteristics, carbon emission reduction policies, and inter-regional industrial transfer characteristics. According to the conclusions, this paper gives some suggestions so as to provide some references for promoting the carbon neutral processes and the transition development in China and other countries in the world.

The marginal contributions of the paper are as follows: firstly, this paper sorts 30 provinces of China according to characteristics of the implementation of low-carbon pilot policies and the condition of industrial transfer. Secondly, combined with the definition of carbon neutrality, this paper investigates how to achieve carbon neutrality in terms of green credit. Thirdly, we have analyzed the nexus of non-green credit and carbon emissions. Last but not least, from the perspectives of regional heterogeneity, this paper furtherly explores how to achieve carbon neutrality by coordinating two types of credits.

The remainder of this paper is structured as follows: Section 2 presents literature reviews. Section 3 describes the methodology, data resources, and preliminary empirical observations. Section 4 provides the research results and discussion. Finally, Section 5 summarizes the main conclusions.

2. Literature Review

2.1. Empirical Literature

A large number of studies have studied the nexus of financial development and carbon emissions. Scholars have argued that the nexus of financial development and carbon emissions is linear negative [14–16], linear positive [4,5,17], and the inverted U shape [18–20]. With the development of green finance, some scholars have focused on the nexus of green credit and carbon emissions. They believe that green credit policies force high-pollution industries to carry out technological transformation and product upgrading [21]. Meanwhile, the implementation of green credit will provide more funding for R&D and innovation in green industries and improve R&D capacity [22]. In addition, the green credit policy transmits the national development of a green economy signal to the market, which will not only serve as a warning to high-pollution industries, but also attract more private capital (such as venture capital) to the green industry and increase the supply of green capital [23]. As a result, green credit can affect carbon emissions by optimizing financial resource allocation, improving technological innovation tendency, and passing signals (see Figure 1).

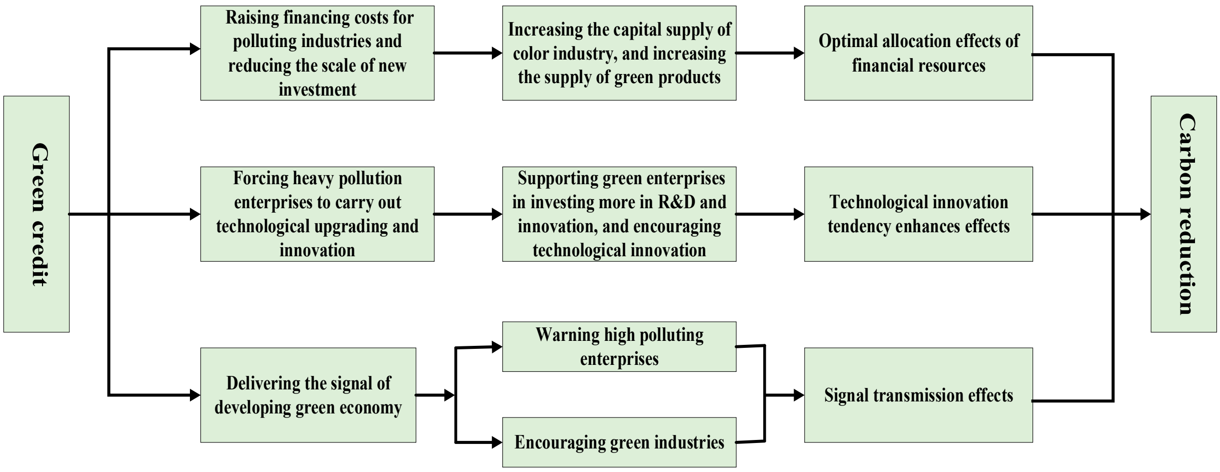


Figure 1. Carbon reduction mechanisms of green credit. Source: The figure is created by the authors.

Optimal allocation effects of financial resources. Green credit is credit rationing based on environmental constraints. Enterprises with high energy consumption and high-pollution industries (two high) will be restricted to loan lines and punitive high interest rates [24]. Some scholars have asserted that the interest-bearing debt financing and long-term debt of heavy-pollution enterprises decreased significantly after the implementation of the green credit policy, the debt financing cost increased significantly, and new investment decreased significantly [25,26]. When financing is constrained, high-pollution industries will have less capacity, lower energy consumption and pollutant emissions, and lower carbon emissions. Furthermore, when the total amount of credit is constant, the funds flowing to high-pollution enterprises will decrease, and the credit funds flowing to low-pollution and low-energy-consumption industries (two low) will increase relatively, which is conducive to enterprises to expand their production scale, produce more low-carbon products or provide more low-carbon technologies, and achieve carbon reductions [21].

The promotion effects of technological innovation tendency. First, enterprises need capital investment to carry out technological innovation. The green credit policy can ease the financing constraints of low-pollution and low-energy-consumption industries. Therefore, those enterprises will have more funds to improve the ability of technological innovation [27,28]. Second, green credit policies can make heavy-pollution enterprises withdraw from projects of environmental problems by credit constraints. This will encourage them to develop clean projects, or reduce negative externalities to the environment through green technology innovation [27,29]. If the two high enterprises adjust their future development plans and promote technological innovation or improve their total factor productivity, carbon emissions will also be reduced.

Signal transmission effect. The two high enterprises affected by punitive high interest loans play the role of warning to other two high enterprises. Those punitive enterprises will take action. For example, the technology and production of enterprises with high pollution and high consumption should be controlled and upgraded [30]. At the same time, after receiving the signal, private capital will lay out green industries and increase the supply of capital for green industries [31].

On the other hand, compared with developed countries, China's green credit business is still in its infancy, which faces many prominent problems [26]. Green credit may be invested in high-energy-consumption, high-pollution, and excessive-production-capacity industries, which leads to the appearance of the green bleaching phenomenon and carbon increase [32,33].

All in all, existing literatures have discussed the carbon emission effect of green credit from different perspectives. However, the nexus of green credit and carbon emissions has not yet reached a consensus. In addition, there are few literatures studying the carbon neutralization effects with green credit.

2.2. Theoretical Framework

Therefore, owing to the imperfection of the green credit mechanism, it may lead to carbon emission increase through economic growth effects, capital allocation effects, and risk aversion effects (see Figure 2).

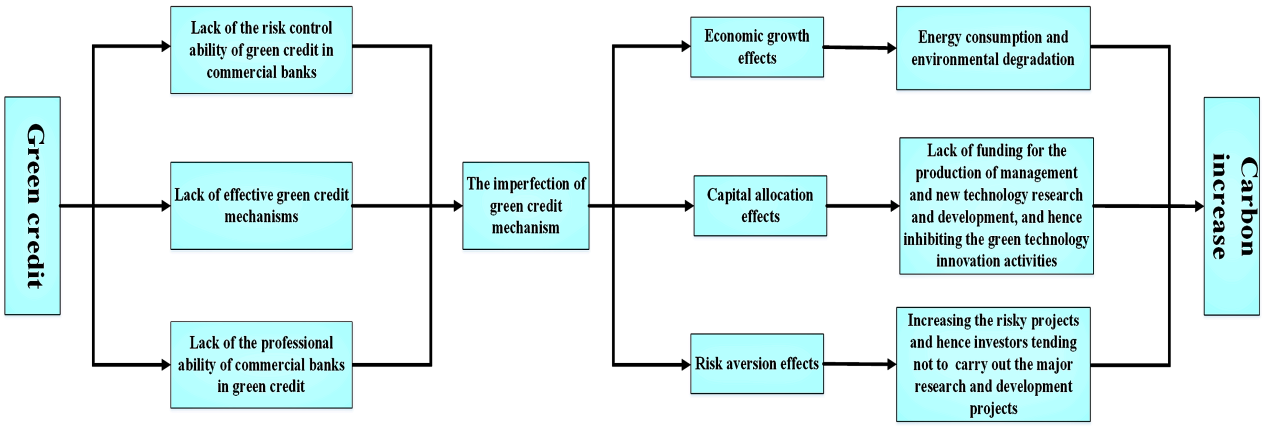


Figure 2. Carbon increase mechanisms of green credit. Source: The figure is created by the authors.

(I) Economic growth effects. Financial development will promote economic growth, but it will bring about industrial pollution and environmental degradation. Green credit promotes urbanization and energy consumption, and ultimately contributes to carbon increase [34]. (II) Capital allocation effects. The essence of the green credit policy is environmental policy. Green credit may limit the resource finance of the two high enterprises, which is not conductive to the development of research and innovation [35,36]. (III) Risk aversion effects. Green credit can allocate risks and market fund. Compared with the traditional industry, the energy conservation and environmental protection industry has a good development prospect but with high investment risk, and the market acceptance degree is unknown [37,38]. Green technology innovation has a high technical content and strong uncertainty of technology research and development [39,40]. If the research and development cannot reach the expected output, or the new energy conservation and environmental protection technology developed cannot be popularized and applied in the market, it will have a significant impact on small and medium-sized enterprises, or even lead to their bankruptcy [41]. While screening energy conservation, environmental protection, and low-carbon enterprises, green credit also increases high risk items in the asset configuration of financial institutions. Green technology research and development items require a large amount of investment and are with high risk. To hedge against risk, green credit reduces investment in research and innovation projects [42], which has a negative impact on carbon reductions.

3. Methodology and Data

3.1. Model

Existing literatures have shown that carbon emissions are path dependent; that is, the increase in carbon emissions in the previous period will lead to the increase in carbon emissions in the current period [43–45]. Therefore, the lag period of carbon emissions was added to the panel model to construct the dynamic panel data model. What is more, the systematic GMM can improve the estimation efficiency and estimate the coefficient of the variable Z_i. The prerequisite for using the systematic GMM is that the perturbation term ε_i (does not have autocorrelation and $\Delta y_{i,t-1}$, $\Delta y_{i,t-2}$, . . .) does not correspond to individual effects u_i. In a more general dynamic model, the explanatory variables may include multiorder lag values of the explained variables. The basic dynamic panel data model is as model (1):

$$y_{it} = \alpha + \rho_1 y_{i.t-1} + \rho_2 y_{i.t-2} + \cdots + \rho_p y_{i.t-p} + x'_{it}\beta + z'_{it}\delta + \mu_i + \varepsilon_{it} \tag{1}$$

In order to study the nexus of green credit and carbon emissions, based on model (1), and according to existing studies [15,46,47], this paper establishes model (2):

$$EPCO_{2it} = \partial_0 + \partial_1 EPCO_{2it-1} + \beta x_{it} + \delta control_{it} + \varepsilon_{it} \tag{2}$$

where $EPCO_{2it}$ indicates carbon emissions per capita in province *i* at time *t*, $EPCO_{2it-1}$ indicates carbon emissions per capita in province *i* at time $t-1$, x_{it} indicates core explanatory variable in province *i* at time *t*, $control_{it}$ indicates other control variables in province *i* at time *t*, and ε_{it} indicates a random error term.

Based on model (2), and according to the existing studies [20,47–49], there is an inverted U-shaped relationship between financial development and carbon emissions. Additionally, the main influencing factors of carbon emissions include industrial agglomeration, energy consumption, environmental regulation, economic development levels, and technological innovation, and hence, those influencing factors were included in the model as control variables. Therefore, we establish the nonlinear model (3) to examine the inverted U-shaped nexus of green credit and carbon emissions:

$$\begin{aligned} EPCO_{2it} = \partial_0 + \partial_1 EPCO_{2it-1} + \beta cre^2{}_{it} + \delta agg_{it} + \kappa energy \\ \phi ers_{it} + \varphi pgdp_{it} + \gamma innova_{it} + \varepsilon_{it} \end{aligned} \tag{3}$$

where cre_{it} indicates the level of green credit in province *i* at time *t*, $cre^2{}_{it}$ indicates the square term of the green credit index in province *i* at time *t*, agg_{it} indicates the level of industrial agglomeration in province *i* at time *t*, $energy_{it}$ indicates the level of energy consumption in province *i* at time *t*, ers_{it} indicates the level of environmental regulations in province *i* at time *t*, $pgdp_{it}$ indicates the level of economic development in province *i* at time *t*, $innova_{it}$ indicates the level of scientific and technological innovation in province *i* at time *t*, and ε_{it} indicates a random error term. Other variables are the same as model (2).

Further, to examine the impact of nongreen credit on carbon emissions, we set model (4):

$$\begin{aligned} EPCO_{2it} = \partial_0 + \partial_1 EPCO_{2it-1} + \beta' ncre_{it} + \delta' agg_{it} + \kappa' energy \\ \phi' ers_{it} + \varphi' pgdp_{it} + \gamma' innova_{it} + \varepsilon_{it} \end{aligned} \tag{4}$$

where $ncre_{it}$ indicates the level of nongreen credit in province *i* at time *t*. Other variables are the same as model (3).

3.2. Variables

(1) According to IPCC [50], this paper calculates the level of carbon emissions of 30 provinces and cities (excluding Tibet) in China from 2006 to 2017. The specific calculation model is as follows:

$$CO_2 = \sum_{i=1}^{14} CO_{2,i} = \sum_{i=1}^{14} E_i \cdot NCV_i \cdot CEF_i \tag{5}$$

where CO_2 indicates carbon emissions; i indicates various energy fuels, which are coal, coke, coke oven gas, blast furnace gas, converter gas, other gas, crude oil, gasoline, kerosene, diesel oil, fuel oil, liquefied petroleum gas, natural gas, and liquefied natural gas; E_i indicates combustion consumption of various energy sources; NCV_i indicates the average low calorific value of various energy sources, which is used to convert various energy consumptions into energy units (TJ); and CEF_i indicates carbon dioxide emission factors of various energy sources. The computational model is as follows:

$$CEF_i = CC_i \cdot COF_i \cdot (44/12) \tag{6}$$

where CC_i indicates the carbon content of various energy sources; COF_i indicates the carbon oxidation factors of various energy sources (the value of it is usually 1), which represents the energy that is completely oxidized, and we set coal and coke as 0.99, while the rest are set as 1 according to [51,52]; and (44/22) indicates the molecular weight ratio of carbon dioxide to carbon. The specific values are shown in Table 1.

Table 1. Various indexes and coefficients involved in the calculation of CO_2.

Energy	**Coal**	**Coke**	**Coke Oven Gas**	**Coke Oven Gas**	**Converter Gas**	**Other Gas**	**Raw Petroleum**
NCV (kj/kg)	20,908	28,435	17,981	3855	8585	18,273.6	41,816
CEF (kg/TJ)	95,977	105,996	44,367	259,600	18,167	44,367	73,333
Energy	Gasoline	Kerosene	Diesel oil	Fuel oil	Liquefied petroleum gas	Natural gas	Liquefied natural gas
NCV (kj/kg)	43,070	43,070	42,652	41,816	50,179	38,931	44,200
CEF (kg/TJ)	70,033	71,500	74,067	77,367	63,067	56,100	64,167

Additionally, this paper uses carbon emissions per capita ($EPCO_2$) as the dependent variable to indicate the level of carbon emissions of China in regression equations.

(2) The green credit index (cre).

Considering the continuity and availability of data, according to [24], cre is measured by the total expenditure of the industrial interest of each province minus the interest expenditure of six high-energy-consumption industries (according to the National Economic and Social Development Statistical Report, the six high-energy-intensive industries are chemical raw materials, chemical products manufacturing, nonmetallic products, ferrous metal smelting and rolling processing industry, nonferrous metal smelting and rolling processing industry, oil processing and coking and nuclear fuel processing industry, electricity, and heat production and supply industry). This paper uses the form of the logarithm of cre to alleviate heteroscedasticity and multicollinearity problems. The nongreen credit index (ncre) is measured by the ratio of the total interest expenditure of the six high-energy-consumption industries to that of the industrial industries.

(3) Existing studies have shown that the influencing factors of carbon emissions include economic growth, technological innovation, industrial agglomeration, environmental regulation, financial development, etc. [53–56]. Hence, the control variables selected in this paper are as follows:

$$agg_{it} = \frac{X_{it}/X_t}{Q_{it}/Q_t} \tag{7}$$

where agg_{it} indicates the industrial concentration level in province i at time t, X_{it} indicates the national industrial added value in province i at time t, X_t indicates the national industrial added value at time t, Q_{it} indicates the GDP in province i at time t, and Q_t indicates the national GDP in t year.

Then, energy intensity (energy) is measured with the ratio of total energy consumption to GDP. Second, environmental regulation (ers) is measured with the ratio of completed investment in industrial pollution control to industrial added value. Third, the economic development level (pgdp) is measured with the GDP per capita (deflating to constant 2010 RMB amounts, the unit is CNY 10,000 per person). Finally, this paper selects four indexes (namely, technology market turnover, patent applications, internal expenditure of R&D funds, and full-time equivalent of R&D personnel) to measure the level of technical innovation (innova) with a factor analysis approach.

3.3. Data Resources

We select the panel data of China's 30 provinces and cities (Hong Kong, Macao, Taiwan, and Tibet are incomplete and eliminated) from 2006 to 2017 as samples. The data were collected from the following sources: National Bureau of Statistics, Provinces (cities, districts) Statistical Yearbook, GuoYan Statistical Database, World Bank Statistics Database, EPS Database, OECD Database, China's Industrial Statistics Yearbook (before 2013, it was called China's Industrial Economy Economic Statistics Yearbook), China Foreign Investment Report, China's Business Yearbook, China's Statistical Yearbook, China Energy Statistical Yearbook, China's Environment Yearbook, etc. In addition, all the indicators expressed in currency form are deflated by the corresponding price index and converted to constant 2010 RMB amounts to eliminate the impact of price fluctuations. The descriptive statistical results of each variable show that the heterogeneity among each variable is large and the statistical nature is good, which is suitable for regression analysis (see Table 2).

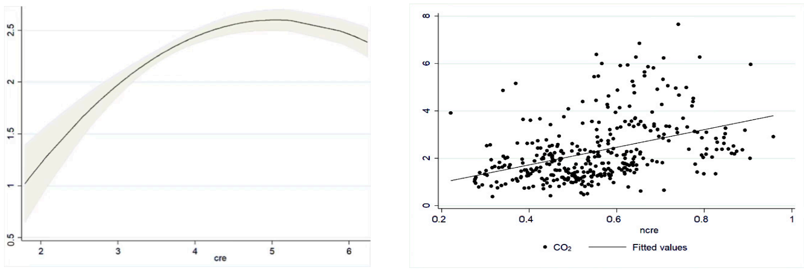
Table 2. Descriptive statistics and correlation matrix.

Variables	Mean	sd	Min	Max	Skewness	Kurtosis
$EPCO_2$	2.283	1.322	0.372	7.664	1.359	4.627
cre	4.047	1.063	1.791	6.238	0.0410	2.651
ncre	0.553	0.143	0.221	0.958	0.317	2.737
agg	1.031	0.206	0.349	1.326	−1.317	4.518
energy	0.994	0.488	0.308	2.699	1.121	3.573
ers	0.395	0.338	0.0360	2.804	2.627	13.90
pgdp	3.946	2.221	0.790	12.000	1.224	4.234
innova	0.0670	0.169	−0.0670	0.962	2.632	10.86

Variables	VIF	1/VIF
pgdp	1.40	0.7131
cre	1.37	0.7277
agg	1.07	0.9371
innova	1.05	0.9548
pop	1.03	0.9667
Mean VIF	1.19	

3.4. Preliminary Empirical Observations

Before analyzing the estimation results, we first draw the trend chart of the nexus of green credit, nongreen credit, and carbon emissions (see Figure 3). It is found that the nexus of green credit and carbon emissions is with an inverted U-shaped curve in China. It indicates that different from existing studies, green credit not only promotes carbon emission reduction by supporting green development projects, but also increases carbon emissions through economic growth, capital allocation, and risk aversion effects. While the chart on the right shows a significant positive correlation between nongreen credit and carbon emissions in China, nongreen credit contributes to carbon emission increase. However, there are differences in carbon emission characteristics, economic development level, and geographical and cultural environments among different regions in China. Therefore, the nexus of green credit or nongreen credit with carbon emissions is with regional heterogeneity.



(**a**) (**b**)

Figure 3. The trend chart of the nexus of green credit or nongreen credit with carbon emissions. (**a**) The relationship between green credit and carbon emissions; (**b**) The relationship between non-green credit and carbon emissions. Source: The figure is created by the authors.

4. Results and Discussion

4.1. Basic Results

The spatial distribution of China's carbon emissions in 2006 and 2017 is shown in Figure 4. The white areas are the missing parts of the data. It is found that the dark green areas gradually decreased during the study period, implying that China's economic restructuring in recent years has promoted energy conservation and emissions reduction. In addition, observing the carbon emissions in the low-carbon pilot areas, we can find that the first batch of pilot provinces and the first and second batches of pilot municipalities are located in the low-carbon-emission areas in 2017. It indicates that the low-carbon pilot policies have already paid off and also shows that the trend change of carbon emissions in China is related to the duration of the implementation of low-carbon pilot policies and the scope of the areas covered. Furthermore, we can also find that the provinces of Jiangsu and Guangdong remain in the low-carbon-emission areas during the study period. The trend of carbon emissions in the province of Shandong declines significantly during the study period particularly. In contrast, carbon emissions in the Guizhou province show an increasing trend during the study period. It indicates that the trend of carbon emissions in China is associated with the level of industrialization and the trend of industrial transfer in each province and city. Therefore, the implementation of low-carbon pilot policies and the situation of industrial transfer in different areas are taken into consideration to study the regional heterogeneity.

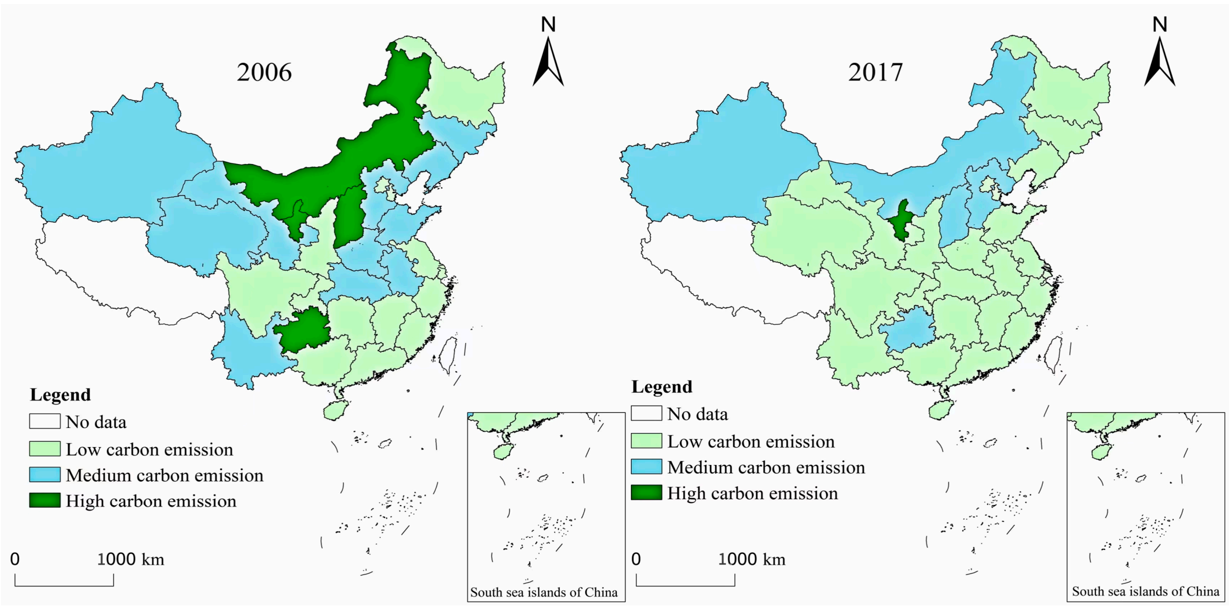


Figure 4. Spatial pattern of carbon emissions in China in 2006 and 2017. Source: The figure is created by the authors.

Based on the above analysis, we reckon that green credit policies should be designed according to the development situation of different regions in order to achieve carbon neutrality. Therefore, this paper sorts 30 provinces and cities into different samples on the basis of low-carbon pilot policies and the industrial transfer circumstance.

(1) Existing studies confirm that the nexus of low-carbon pilot policies and carbon emissions is related significantly [57,58]. The National Development and Reform Commission PRC (NDRC) carried out low-carbon provincial and regional pilot projects in 2010, 2012, and 2017. Considering the time lag effects of policy implementation and the coverage scope, we sort the first and second batches of low-carbon municipalities (owing to the fact that low-carbon pilot policies cover the whole municipality, the coverage scope is larger than other low-carbon pilot provinces) and the first batch of pilot provinces into a category of regions (L1), and other provinces are as another category (L2). See the Appendix A for more details.
(2) Previous studies confirm that the impact of industrial relocation on carbon emissions is profound and complex [59–61]. Based on the current characteristics of carbon emission reduction in China and the situation of industrial transfer between regions, and according to the existing studies [62,63], we sort 30 provinces into different samples according to the share of the total industrial output and comprehensive ranking of industrialization.

First, we use the share of the total industrial output value of each province and its changing trend to reflect the situation of interprovincial industrial transfer. Second, we construct a comprehensive evaluation system of industrialization level. The evaluation system includes (i) the industrial added value, (ii) the industrial structure, (iii) the ratio of the total export–import volume to GDP and FDI, (iv) the number of domestic patent applications and full-time equivalent of R&D personnel, (v) the total wages of employed persons in urban units, (vi) the urbanization rate, (vii) the dual economic structure (DES), and (viii) the sulfur emissions and industrial waste water emissions (see the Appendix B for more details). Then, we use a factor analysis approach to evaluate the industrialization level of 30 provinces and cities. Finally, we employ the systematic cluster analysis approach to perform analysis.

The results of cluster analysis are shown in Figure 5. We sorted the 30 provinces and cities into three types. To be specific, Jiangsu, Shandong, and Guangdong belong to the first category, which is strong industry transfer-out zone (STR); Beijing, Tianjin, Hebei, Liaoning, Shanghai, Zhejiang, Anhui, Fujian, Henan, Hubei, Hunan, and Sichuan belong to the second class, which is weak industry transfer-out zone (WTR). The remaining 15 provinces and cities fall into the third category, which is industrial transfer-in area (TIR).

4.2. The Impact of Green Credit on Carbon Emissions

In order to accurately estimate the impact of green credit on carbon emissions, according to Kim et al. (2020), this paper employs a systematic GMM estimation model to mitigate the potential endogeneity bias [64]. The empirical results of model (3) are shown in Table 3. It is found that the AR(1) test of the results of model (3) is significant at the 5% level, while the AR(2) test is insignificant, indicating that the results of model (3) have at most first-order autocorrelation, but no second-order autocorrelation, and the estimation approach is applicable. The result of the overidentification test (Sargan test) accepts the null hypothesis that all instrumental variables are valid, indicating that the instrumental variables are valid.

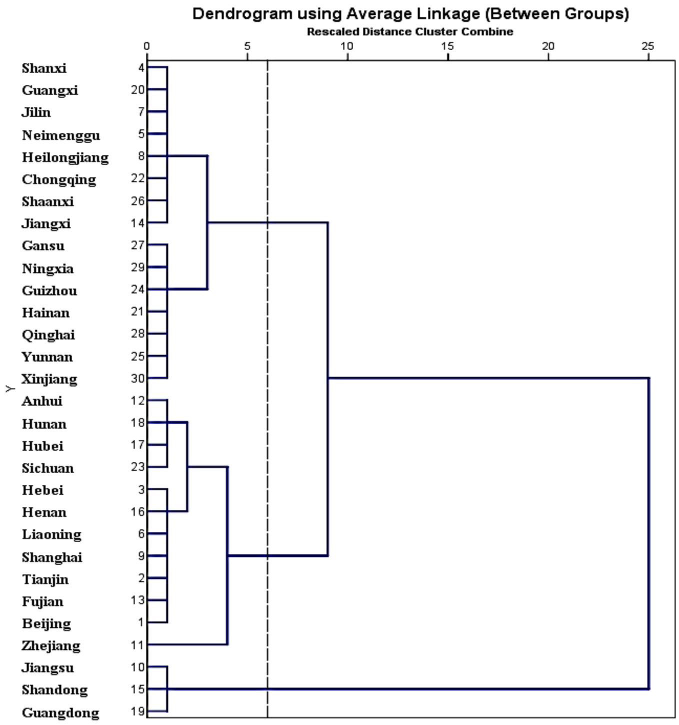


Figure 5. Clustering pedigree of industrial transfer in China. Source: The figure is created by the authors.

Table 3. Results of Equation (3).

	(a)	**(b) L1**	**(c) L2**	**(d) STR**	**(e) WTR**	**(f) TIR**
	$EPCO_2$	**$EPCO_2$**	**$EPCO_2$**	**$EPCO_2$**	**$EPCO_2$**	**$EPCO_2$**
L.$EPCO_2$	0.531 [a]	−6.106	0.487 [a]	2.094 [a]	−1.944	0.434 [a]
	(0.015)	(7.314)	(0.049)	(0.329)	(1.900)	(0.059)
cre	2.144 [a]	10.559	2.786 [a]	0.209 [b]	25.885	4.630 [a]
	(0.402)	(11.792)	(0.492)	(0.084)	(18.536)	(0.891)
cre^2	−0.252 [a]	−1.042	−0.318 [a]	−0.098 [a]	−2.133	−0.602 [a]
	(0.056)	(1.469)	(0.060)	(0.011)	(1.528)	(0.119)
agg	−0.224 [b]	−15.770	−0.376	0.034	−27.923	−0.349
	(0.089)	(15.117)	(0.238)	(0.309)	(20.172)	(0.256)
energy	1.678 [a]	6.487	1.797 [a]	2.654 [a]	−17.457	2.109 [a]
	(0.050)	(7.193)	(0.168)	(0.160)	(13.331)	(0.219)
ers	−0.099 [a]	−1.091	−0.053 [a]	−0.202	−4.023	−0.052 [b]
	(0.006)	(1.262)	(0.017)	(0.325)	(3.006)	(0.023)
gdp	0.095 [a]	−0.713	0.096 [a]	−0.321 [a]	−6.116	0.147 [a]
	(0.008)	(0.569)	(0.020)	(0.056)	(4.363)	(0.028)
innova	−0.176	2.938	−0.203	0.035	70.444	−0.801
	(0.147)	(2.859)	(0.188)	(0.043)	(5.149)	(0.500)
constant	−4.986 [a]	0.001	−6.265 [a]	−3.313 [a]	0.010	−9.512 [a]
	(0.743)	(1.000)	(1.111)	(0.760)	(1.000)	(1.775)
Sargan test	22.816	0.825	14.301	18.761	0.550	11.389
	(0.742)	(1.000)	(0.984)	(0.990)	(1.000)	(0.998)
AR(1) test	−2.169	−1.370	−1.986	−2.041	−1.591	−1.903
	(0.030)	(0.010)	(0.047)	(0.040)	(0.010)	(0.057)
AR(2) test	−1.316	−0.737	−0.834	−0.893	−0.913	−1.184
	(0.188)	(0.460)	(0.404)	(0.370)	(0.360)	(0.236)
N	330	88	242	33	88	209

Note: [a] and [b] are significant at 1%, 5% respectively. Sargan test, AR(1) test, and AR(2) test are probability *p*-values in parentheses. The other variables are standard errors in parentheses.

4.2.1. The Impact of Green Credit on Carbon Emissions at a National Level

The nonlinear estimation results of model (3) show that the lag term coefficient of carbon emissions is positive and significant at the 1% level, implying that carbon emissions have path-dependent effects. To be specific, the current 0.531 increase in carbon emissions is linked to 1 rise in carbon emissions in the previous period by keeping other things constant. The nonlinear estimation results of model (3) also show that the coefficient of the first-order term of green credit is positive and significant at the 1% level, while the coefficient of the secondary-order term is negative, indicating that the nexus of green credit and carbon emissions is with an inverted U-shaped curve relationship. When green credit is at a low level, it leads to carbon emission increase. It also implies that China's current green credit mechanism is imperfect. Owing to the lack of risk control ability, effective green credit mechanisms, and the professional ability of green credit in commercial banks, it fails to provide effective financing support for green development projects, namely, the existing phenomenon of bleaching green. Furthermore, green credit expands economies of scale, which in turn increases carbon emissions. The theory is similar to Sadorsky [5], assuming that green credit is a means of financial development that makes consumers more easily obtain loans to buy large appliances, such as refrigerators and washing machines. Hence, the use of these appliances contributes to carbon emission increase.

However, with the continuous expansion of the green credit scale, the carbon emission increase will reach the upper limit, and the emission reduction effect of green credit will take a dominant position, hence promoting carbon emission reduction. The inflection points from the effects of green credit on increasing carbon emissions to reducing carbon emissions appear at 4.254, and the current impact of green credit in China (the value is 4.047) is still in the first half of the inverted U-shaped stage. Therefore, in order to play the emission reduction effect of green credit, the green credit investment should be strengthened in the future. Additionally, the green credit supervision mechanism should be established and improved. It also indicates that other developing countries with an imperfect green credit mechanism should promote the establishment of an environmental risk assessment standard, financial risk assessment system, and green credit policy incentive mechanism to better achieve carbon reductions.

4.2.2. Regional Heterogeneity Analyses with the Effects of Green Credit on Carbon Emissions

According to model (3), the coefficient of the primary term is positive, and the coefficient of the secondary term is negative and significant in L2, STR, and TIR by keeping other things constant, implying that the nexus of green credit and carbon emissions is with an inverted U shape. The inflection points from the effects of green credit on increasing emissions to reducing emissions appear at 4.381, 1.066, and 3.846 in the three regions, respectively. The current impact of green credit in L2 (the value is 4.087) and TIR (the value is 3.584) is still in the first half of the inverted U-shaped curve stage in the three regions. Thus, the investment of green credit should be increased, promoting the impact of green credit to cross the inflection point. Furthermore, compared with the appearance of the inflection point in TIR, the inflection points from the effects of green credit on increasing emissions to reducing emissions appear earlier in L2. It shows that low-carbon pilot policies have played a significant role in carbon emission reduction. Hence, the enforcement of low-carbon pilot policies should be strengthened. Additionally, other countries of the world can learn from the experiences of China's low-carbon pilot policies to reduce carbon emissions at home.

What is more, different from L2 and TIR, the current impact of green credit in STR (the value is 5.727) is across the inflection point and in the right of the inverted U-shaped curve. On account of the higher level of economic development, industrialization, and scientific and technological innovation and the predominant geological location in STR, the green credit mechanism is relatively complete and can better serve green and innovative development projects by providing financial support. Additionally, industries with high pollution and high carbon emissions have been transferred out, which has avoided the occurrence of green bleaching and provided more space for the development of green economy in STR. The increase in green credit has contributed to carbon emission reduction at the current stage in STR. The enthusiasm of the public sector, the private sector, and the public for green credit investment should be motivated so as to increase the scale of green credit and thus continuously promote carbon emission reduction. It also indicates that some developed countries with high industrial level can strengthen the implementation of green credit policies to promote the sustainable and green development of industries.

Nevertheless, the nexus of green credit and carbon emissions with an inverted U shape is insignificant in L1 and WTR. It is likely that the emission-boosting effects of green credit cancel out the emission-reducing effects in these two regions. It indicates that green credit can promote carbon emission reduction partly. However, owing to the unsound green credit mechanism, the emission increase effect of green credit offsets the emission reduction effect. As a result, green credit mechanisms should be established through various ways to achieve carbon reductions.

4.3. The Impact of Nongreen Credit on Carbon Emissions

The AR(1) and AR(2) test results show that all equations are with first-order autocorrelation, but no second-order autocorrelation, and the estimation approach is applicable. The result of the overidentification test (Sargan test) accepts the null hypothesis that all instrumental variables are valid, indicating that the selected instrumental variables are valid.

4.3.1. The impact of Nongreen Credit on Carbon Emissions at the National Level

The linear estimation results of model (4) show that the lag term coefficient of carbon emissions is positive and significant at 1%, indicating that carbon emissions have a path-dependent effect. To be specific, the current 0.565 increase in carbon emissions is linked to 1 rise in carbon emissions in the previous period by keeping other things constant. What is more, the impact of nongreen credit on carbon emissions is positive and significant at the 1% level in China by keeping other things constant. A 1 increase in nongreen credit raises carbon emissions by 0.727 in China by keeping other things constant. It indicates that at the present stage, nongreen credit mainly supports the development of two high industrial enterprises in pursuit of high profits, which is not conducive to technological innovation and, hence, leads to carbon emission increase.

Therefore, governments should raise the awareness of the social responsibility of the government, enterprises, and individuals; improve the information disclosure system of the nongreen credit market; and motivate the enthusiasm of participants. In order to transform the economy to high-quality development, it is necessary to improve the understanding of the social responsibility of all social parties and build a social responsibility system including environmental protection and the culture of social responsibility. At the same time, the regulatory system for nongreen credit flow should be strengthened, environmental evaluation standards for bank credit should be established, and preferential loan policies should be formulated for green enterprises and projects.

4.3.2. Regional Heterogeneity Analyses with the Effects of Nongreen Credit on Carbon Emissions

The linear estimation results of Equation (4) show that the effect of nongreen credit on carbon emissions is positive and significant at 1% by keeping other things constant in L2, WTR, and TIR. The impact of nongreen credit on carbon emissions is positive and significant at the 5% level in L2. Specifically, a 1 increase in nongreen credit growth raises carbon emissions by 0.614 in L2 by keeping other things constant. It indicates that there are a large number of high-energy-consumption and high-pollution enterprises in L2. That is to say, the higher the total amount of nongreen credit is put on the market, the bigger the scale of these pollution companies will become, accelerating resource consumption and increasing carbon emissions. Thus, governments should take measures to reduce credit support to energy-intensive industrial enterprises. It also indicates that other countries in the world with a low level of industries should strengthen the supervision over the flow of nongreen credit, focus on promoting the technological innovation capability of enterprises (providing talents and scientific and technological support), and improve economic and industrial transformation.

While the impact of nongreen credit on carbon emissions is negative and significant at the 1% level in STR. To be specific, a 1 increase in nongreen credit growth raises carbon emission reduction by 0.463 in STR by keeping other things constant. Different from the above regions, there is a carbon emission reduction of nongreen credit in STR. The reason is that the degree of economic growth and industrialization is relatively higher in STR than that of other regions. Additionally, enterprises with high pollution, high energy consumption, and high emissions are transferred out in STR. There are only scientific, technological, and innovative enterprises. Those enterprises are with low-carbon characteristics. However, those enterprises need more financial support to carry on with the scientific and technological innovation, then obtain the market competitive advantage. As a form of credit, nongreen credit can provide indirect financing support for these enterprises. Moreover, the increase in nongreen credit will promote the high-quality level of economic development. Owing to a strong public awareness of green environmental protection in STR, the high level of economic development increases people's disposable income and stimulates residents' consumption, thus increasing the demand for environmental, friendly, and low-carbon products, hence promoting carbon emission reduction. It also indicates that credits should be increased and supplied in some developed countries with high-level industries to provide R&D and innovation funds for industrial enterprises. Hence, it further promotes the transformation of an industrial production mode. Nevertheless, the linear relationship between nongreen credit and carbon emissions is insignificant in L1, WTR, and TIR. The possible explanation is that carbon emissions increase the effect of nongreen credit, and carbon emission reduction effects cancel each other out (Table 4).

Table 4. Results of Equation (4).

	(a)	**(b) L1**	**(c) L2**	**(d) STR**	**(e) WTR**	**(f) TIR**
	$EPCO_2$	**$EPCO_2$**	**$EPCO_2$**	**$EPCO_2$**	**$EPCO_2$**	**$EPCO_2$**
L. $EPCO_2$	0.565 [a]	−1.857	0.591 [a]	1.521 [a]	−1.601	0.590 [a]
	(0.021)	(2.769)	(0.045)	(0.187)	(1.698)	(0.064)
ncre	0.727 [a]	−1.561	0.614 [b]	−0.463 [a]	−7.973	0.436
	(0.098)	(1.165)	(0.278)	(0.054)	(5.945)	(0.403)
agg	−0.119	1.786	−0.279	−0.885 [a]	4.233	−0.482 [c]
	(0.080)	(2.146)	(0.186)	(0.312)	(4.923)	(0.257)
energy	1.454 [a]	2.610	1.286 [a]	2.742 [a]	−0.285	1.463 [a]
	(0.065)	(2.349)	(0.148)	(0.157)	(1.944)	(0.259)
ers	−0.091 [a]	0.112	−0.125 [a]	0.048	−0.446	−0.035
	(0.005)	(0.688)	(0.012)	(0.094)	(0.702)	(0.028)
gdp	0.095 [a]	−0.372	0.079 [a]	−0.155	−0.856	0.104 [a]
	(0.009)	(0.318)	(0.020	(0.112)	(0.632)	(0.036)
innova	−0.053	−1.460 [c]	−0.297 [a]	0.027	−6.829	−0.761
	(0.110)	(0.885)	(0.077)	(0.964)	(5.775)	(0.786)
constant	−1.080 [a]	3.727	−0.642	−0.151	9.736	−0.688
	(0.119)	(2.674)	(0.393)	(1.162)	(7.504)	(0.645)
Sargan test	22.797	0.825	17.328	2.712	0.100	12.545
	(0.743)	(1.000)	(0.941)	(1.000)	(1.000)	(0.995)
AR(1) test	−2.165	−0.918	−2.069	−1.991	−1.736	−2.084
	(0.030)	(0.030)	(0.039)	(0.040)	(0.030)	(0.037)
AR(2) test	−1.376	−0.810	−1.017	−0.201	−1.207	−1.356
	(0.169)	(0.418)	(0.309)	(0.840)	(0.228)	(0.175)
N	330	88	242	33	88	209

Note: [a], [b], and [c] are significant at 1%, 5%, and 10%, respectively. Sargan test, AR(1) test, and AR(2) test are probability *p*-values in parentheses. The other variables are standard errors in parentheses.

4.4. The Analysis of the Carbon Neutralization Effect with Green Credit

4.4.1. The Analysis of Carbon Neutrality at the National Level

Based on the empirical results above, it shows that when green credit reaches an inflection point of 4.254, green credit will promote carbon emission reduction in China, while the impact of nongreen credit on carbon emissions increases linearly, and the elasticity coefficient is 0.727. Thus, we take the derivatives of models (3) and (4), aiming to calculate the impact elasticity of green credit and nongreen credit on carbon emissions. The model is as follows:

$$\frac{dy}{dx} = -2 \times 0.252x + 2.144 = -0.504x + 2.144 \tag{8}$$

$$\frac{dy'}{dx'} = 0.727 \tag{9}$$

To achieve carbon neutrality, first, green credit needs to reach the inflection point of the inverted U-shaped curve. Then, after reaching the inflection point, whether the scale of green credit or the structural ratio change of nongreen credit to green credit will promote the realization of carbon neutrality should be clarified. Based on the optimal scale of the green credit scale or the structural ratio of nongreen credit to green credit, the carbon emission reduction effect of green credit offsets the carbon emission increase effect of nongreen credit. The derivation of formulas with relationships between green credit and nongreen credit is as follows (a indicates green credit; b indicates nongreen credit):

$$(-0.504a + 2.144)a + 0.727b = 0 \tag{10}$$

$$0.504a - 0.727\frac{b}{a} - 2.144 = 0 \tag{11}$$

As it is shown in model (11), it is confirmed that the achievement of carbon neutrality is associated not only with the scale of green credit, but also with the ratio structure of nongreen credit to green credit. To be specific, when green credit reaches the inflection point at 4.254, the growth rate of the green credit scale released to the market is 0.504, and the decline speed of the structural ratio of nongreen credit to green credit is 0.727, which will achieve carbon neutrality. As a result, the scale of green credit should be steadily expanded, and investors from all walks of life should be encouraged to increase their investment in green credit so as to reach the carbon emission reduction stage of green credit. After reaching the inflection point, the elasticity of increasing the green credit scale is 0.504, and the elasticity of decreasing the ratio of nongreen credit to green credit is 0.727; hence, carbon neutrality can be achieved.

4.4.2. Regional Heterogeneity Analysis of Carbon Neutrality

First of all, as with the analysis above, we analyze how to achieve carbon neutrality at the regional level. For L2, the scale of green credit needs to exceed the inflection point at 4.381. Furthermore, the growth rate of the green credit scale and the structural ratio change speed of nongreen credit to green credit are as follows:

$$0.636a' - 0.614\frac{b'}{a'} - 0.786 = 0 \tag{12}$$

As it is shown in model (12), it is confirmed that the achievement of carbon neutrality is not only with the scale of green credit, but also with the ratio structure of nongreen credit to green credit. To be specific, when green credit reaches the inflection point, the growth rate of the green credit scale released to the market is 0.636, and the decline speed of the structure ratio of nongreen credit to green credit is 0.614, which will promote the achievement of carbon neutrality. As a result, the scale of green credit should be steadily expanded, and investors from all walks of life should be encouraged to increase their investment in green credit so as to reach the carbon emission reduction stage of green credit. After reaching the inflection point, the elasticity of the green credit scale increase is 0.636, and the elasticity of the ratio of nongreen credit to green credit decline is 0.614, hence achieving carbon neutrality.

Second, different from L2, for STR, the green credit scale has crossed the inflection point (1.066) because the economic development level and industrialization degree are higher in L2. To be specific, the low-technical-level and energy-intensive and highly polluting enterprises are transferred to other areas. There are mainly high-tech industrial enterprises with energy conservation and environmental protection characteristics in STR. Therefore, with the development of those high-tech industrial enterprises and the accessibility of financial support provided by green credit, the industrial production mode is transitioned towards low-carbon environmental protection and clean type in STR, and hence promotes carbon emission reduction. As a result, at present, there is no need to continuously increase the green credit to reach the inflection point, and there is only a need to reasonably adjust the growth rate of the green credit scale and the ratio structure of nongreen credit to green credit so as to achieve carbon neutrality. The growth rate of the green credit scale and the ratio structure of nongreen credit to green credit are as follows:

$$0.196a'' + 0.463\frac{b''}{a''} - 0.209 = 0 \quad (13)$$

As it is shown in model (13), the increased speed of the structural ratio of nongreen credit to green credit is 0.463, hence achieving carbon neutrality.

Third, different from L2 and STR, for TIR, the impact of nongreen credit on carbon emissions is statistically insignificant. Therefore, the achievement of carbon neutrality is only relevant to the scale of green credit. The scale of green credit released to the market needs to be satisfied as follows:

$$1.204a''^2 - 0.463a''' = 0 \quad (14)$$

As it is shown in model (14), we can figure out that the value of a is 3.846 (zero casted out), which is the same value as the inflection point. It indicates that the total scale of green credit needs to be increased to 3.846, aiming to achieve carbon neutrality. Since industries with high pollution and high emissions in STR and WTR are transferred to TIR, the main task of TIR at present is to coordinate the contradiction between ecological and environmental protection problems brought by the transferred industrial enterprises and economic development. The implementation of green credit policies can lead to carbon emission reduction by raising financing costs for polluting industries and reducing the scale of new investment, forcing heavy-pollution enterprises to carry out technological upgrading and innovation, and delivering the signal of developing a green economy. Therefore, governments should strengthen the intensity of green-credit policy implementation. Then the supervision mechanism for the green credit policy needs to be established and improved. It also provides references for other developing countries that undertake the transfer of backward industrial industries from developed countries.

Finally, the nexus of green credit and carbon emissions is with an inverted U shape insignificant in L1 and WTR. The impact of nongreen credit on carbon emissions is also insignificant in L1 and WTR. The reason is that the carbon emission reduction effect and carbon emission increase effect of green credit and nongreen credit cancel each other out. It manifests that governments should innovate the green credit mechanism so that the emission reduction effect of the green credit policy will dominate in order to avoid the carbon emission increase effects and maintain a stable carbon emission trend, which promotes the achievement of carbon neutrality. Furthermore, industrial restructuring strategies and economic restructuring plans should be formulated. Then, the industrial and economic structures need to be transformed to digital, intelligent, and low-carbon development. Additionally, publicity and education should be strengthened to foster the low-carbon development concept. Those suggestions can provide references to some emerging countries with a relatively high level of industrial industries in the world.

5. Conclusions

This paper provides new evidence of the achievement of carbon neutrality from green credit. First, 30 provinces of China are sorted into different research regions. Then, linear and nonlinear models are constructed respectively, and the systematic GMM estimating approach is employed to investigate the effects of green credit and nongreen credit on carbon emissions. Based on the above results, the carbon neutralization effects with green credit from the perspectives of regional heterogeneity are further explored.

The results indicate that from the perspectives at the national level, the achievement of carbon neutrality is associated not only with the scale of green credit, but also with the ratio structure of green credit to nongreen credit. First, there is a nexus of green credit and carbon emissions with an inverted U-shaped curve. The inflection points of the impact of green credit on carbon emissions from increasing emissions to reducing emissions appear at 4.254. The current impact of green credit in China is still in the first half of the inverted U-shaped curve stage. Second, there is a positive linear correlation between nongreen credit and carbon emissions. Finally, when green credit has crossed the inflection point, the growth rate of the green credit scale released to the market is 0.504, and the decline speed of the structural ratio of nongreen credit to green credit is 0.727, which will promote the realization of carbon neutrality.

From perspectives of regional heterogeneity, first, the nexus of green credit and carbon emissions is with an inverted U-shaped curve in L2, STR, and TIR. The inflection points are 4.381, 1.066, and 3.846, respectively. The current impact of green credit in L2 and TIR is still in the first half of the inverted U-shaped curve stage, while the current impact of green credit in STR has exceeded the inflection point and is in the right half part of the inverted U-shaped curve stage. Then, there is a positive linear correlation between nongreen credit and carbon emissions in L2, while there is a negative linear correlation in STR. Nevertheless, the impact of nongreen credit on carbon emissions in TIR is insignificant statistically. Third, when green credit has crossed the inflection point, the growth rate of the green credit scale released to the market is 0.636 in L2, and the decline speed of the structural ratio of nongreen credit to green credit is 0.614 so as to achieve carbon neutrality. Compared with L2, the growth rate of the green credit scale released to the market is 0.196 in STR, and the increase speed of the structural ratio of nongreen credit to green credit is 0.463. Different from L2 and STR, there is only a need to increase the total scale of green credit arriving at an inflection point of 3.846 so that green credit plays a continuous role in reducing carbon emissions to gradually achieve carbon neutrality. In addition, the nexus of green credit and carbon emissions with an inverted U-shaped curve is insignificant in L1 and WTR. The impact of nongreen credit on carbon emissions is also insignificant statistically in L1 and WTR.

The results also indicate that China's green credit mechanism is not sound so that green credit does not play a completely positive role in reducing carbon emissions. Therefore, China can learn from the advanced experiences of developed countries, such as the United States, Britain, Canada, and Germany. For example, (I) clarifying environmental responsibility is the key point of legal construction. (II) Incentive mechanisms are a favorable guarantee for policy guidance. (III) Standard setting is an effective means of green credit. As a result, the development of an environmental legal system needs to be promoted in China. Then, the green credit management standard system needs to be standardized. Furthermore, effective information communications and incentive mechanisms need to be established. Finally, innovations of banks need to be improved. More importantly, international exchanges and cooperation are crucial to achieving carbon neutrality. The Chinese government can cooperate with other countries to adjust the green credit structure and develop low-carbon financial products to offset carbon emissions. These conclusions and suggestions can help China achieve carbon neutrality and develop green credit and green finance. Meanwhile, they also provide a reference for other emerging economies and countries with imperfect green finance. Last but not least, the suggestions proposed with the regional heterogeneity analysis in this paper can provide references for other countries with similar characteristics.

The study can be extended from the following two aspects: One is that the spatial spillover effect of green credit and nongreen credit on carbon emissions needs to be investigated, considering that there are strong economic ties between regions. The other one is that the measurement of green credit can be improved by constructing a comprehensive evaluation system, which can consider the development of credit products and corporate environmental performance.

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Appendix A

The L1 region includes the municipalities of Beijing, Tianjin, Shanghai, and Chongqing and the provinces of Liaoning, Hubei, Guangdong, Hainan, and Shaanxi. The L2 region includes the provinces of Hebei, Shanxi, Jilin, Jiangsu, Heilongjiang, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hunan, Sichuan, Guizhou, Yunnan, Gansu, and Qinghai and the Nei Mongol Autonomous Region, Guangxi Zhuang Autonomous Region, Ningxia Hui Autonomous Region, and Xinjiang Uygur Autonomous Region.

Appendix B

The 6 specific indicators are as follows: (1) The industrial added value and industrial structure (the added value of secondary and tertiary industries accounted for the added value of the current year's GDP) to reflect industrial economic development; (2) the ratio of dependence on foreign trade (the ratio of the total value of imports and exports of the business unit to GDP) and FDI to reflect foreign trade; (3) the number of domestic patent applications and full-time equivalent of R&D personnel to reflect scientific and technological innovation; (4) the total wages of employed persons in urban units to reflect labor cost; (5) the urbanization rate (the ratio of urban population to total population at year-end) and DES (dual economic structure) according to Johnston, B. F., and Mellor, J. W. [65]); the role of agriculture in economic development (*The American Economic Review, 51*(4), 566–593) in order to reflect the urbanization level; (6) the sulfur emissions and industrial waste water emissions to reflect the ecological environment. The specific 6 indexes' data of the industrial transfer circumstance we obtained in this paper were from China Statistical Yearbook, China's Foreign Economic Statistical Yearbook, China's Population and Employment Statistics Yearbook, China's Industrial Statistics Yearbook (before 2013, it was called China's Industrial Economy Economic Statistics Yearbook), China's Environmental Statistics Yearbook, China's Statistical Yearbook on High Technology Industry, China Statistical Yearbook on Science and Technology, China's Labor Statistical Yearbook, and Statistical Yearbooks of 30 provinces, municipalities, and autonomous regions in corresponding years.

Cluster analysis is to classify Q samples or P indicators, of which the former is called Q-type clustering and the latter is called R-type clustering. Based on the dimensionality reduction of panel data by factor analysis, cluster analysis of panel data is carried out. According to the characteristics of panel data, the implementation of Q-type clustering for sample objects has certain economic significance and potential application value. Therefore, this paper intends to select the spatial distance between samples to measure the degree of proximity between samples.

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