Can Green Investment Reduce Carbon Emissions: Evidence from China

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Abstract. The rapid industrialization and modernization of the Chinese economy has brought about tremendous carbon emissions, causing a climate change dilemma. At the same time, green investment offers great potential for global and Chinese carbon emission reduction, however, studies on green investment and carbon emissions are still scarce and empirical findings on the relationship between the two are lacking. Therefore, this paper investigates the impact of green investment on carbon emissions using a panel dataset of 30 Chinese provinces from 2003 to 2020. The empirical results show that green investment can reduce carbon emissions in China, and its emission reduction effect only gradually comes into play when the scale of green investment reaches a certain level. Through mechanism analysis, we find that green investment mainly affects carbon emissions through two channels: energy consumption and industrial structure. The results of the analysis of the dynamic panel threshold model concluded that the green investment can reduce carbon emissions more significantly with the increase of regional economic development and urbanization level. In addition, this paper also proposes some policy recommendations to provide some political references for policy makers in carbon emission reduction.

Keywords: Green Investment;Carbon Emission Intensity;Dynamic Panel Threshold Model

1 Introduction

Since the 21st century, a series of hazards such as frequent climate extremes, droughts and agricultural destruction caused by excessive greenhouse gas emissions have increasingly threatened the survival and development of human beings, which has caused widespread concern around the world. Among the greenhouse gases, carbon dioxide has the largest proportion and negative impact on the environment [1]. China, currently experiencing an economic upswing, heavily relies on coal to meet its local energy demands. However, the rapid growth of its economy has led to substantial carbon emissions [2]. In response, at the UN General Assembly in 2020, China proposed that 2030 should be the year when carbon emissions peak and that carbon neutrality should be achieved by 2060. Therefore, while maintaining rapid economic growth, the energy conservation and emission reduction tasks in China is extremely difficult, and it is urgent to find a reasonable way to reduce carbon emissions.

Along with the increasing seriousness of environmental degradation, green investment is increasingly becoming an important tool for countries to save energy and reduce emissions. The

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European Union has prioritized green transformation as a crucial aspect of its economic recovery plan, while the U.S. President has unveiled a development strategy that involves investing over $2 trillion in green and clean energy, among other sectors. In contrast, China faces significant environmental challenges that may impede its prospective growth [3]. In response, the Chinese government has continued to rationalize and commit to achieving and meeting sustainable development goals by incorporating green investment and other forms of green economy development into China's development plans. China's "Action Plan to Reach the Carbon Peak by 2030" states that green finance should contribute to "double carbon" efforts in terms of international cooperation and economic policies. In order to help China achieve the "double carbon" goal, it is important to clarify the impact and role of green investment in the Chinese context.

At such a juncture, China needs to ensure both economic and environmental development and to verify that green investment provide a boost on the ground. From the studies available so far, the research focuses on the positive impact of green investment on economic growth and company performance. Other studies have explored the role of green investment in terms of overall macro-environmental aspects and climate change from an ecological perspective. Whether and how green investment positively affects carbon emissions is still unknown. As an investment activity with the important goal of environmental protection and management, the promotion of green investment holds significant practical implications for fostering the sustainable development of the economy and the reduction of carbon emissions. Therefore, it is crucial for China's green development to study the mechanism of green investment' s impact on carbon emissions in the current era.

This literature makes innovative contributions in the following four main areas. First, instead of aggregating the analysis at the national level, this paper presents an econometric analysis of the impact of carbon emissions at the provincial level. In China, few studies have directly benefited from provincial data to analyze its role in curbing carbon emissions, and this study helps to fill this gap. Second, this paper compiles carbon emission data for each province in China from 2003 - 2020 by collecting and calculating them. This paper also adds together industrial pollution control investment, urban environmental infrastructure construction investment, water conservancy facilities construction investment, forestry and grassland investment to compile a well-considered green investment data. Third, in the application of econometrics, this paper investigates the relationship between green investment and carbon emissions under different levels of economic development using a dynamic threshold effect model. Finally, this paper points out that there is a non-linear impact of green investment on carbon emissions, which helps us to further understand the impact of green investment on carbon emissions in China and provides useful references for carbon reduction policy makers.

2 Literature Review

2.1 Impact assessment of green investment

In general, pollution is considered to have a non-negligible negative impact on environmental quality. Moreover, Porter and van der Linde [4] argue that pollution is not wasted resources but an inefficiency of productivity. This paper argues that investments that improve the efficiency of the production process can be referred to as green investment. In this way, the impact of green investment would not only include investments in energy efficiency and renewable energy, but could also include investments in industrial pollution control, urban environmental infrastructure development, forestry and grassland conservation. Nevertheless, the relevant literature on the impact assessment of green investment is still not extensive.

Some of the existing literature emphasizes that green investment can contribute to effective reductions in carbon emissions. For example, some scholars analyze that green investment can be invested in low-carbon energy production such as biofuel production to promote a transformation in energy consumption from high to low-carbon energy sources to reduce carbon emissions and improve environmental quality. Some researchers also showed that the more green investment, the less carbon emissions. Grasping the relationship can rationalize the use of green investment to control the negative impact of carbon emissions. In this regard, integrating green investment and finance to increase the scale of green investment in China is important for cleaner production and carbon reduction. In addition, supporting the improvement of green finance and encouraging the implementation of green investment policies can maintain stability in different areas such as economy, finance and environment, and promote sustainable development. [5]. On the other hand, encouraging a flourishing green bond market can help raise more funds to meet the needs of green investment, which can likewise help the green economy recover and strengthen green development.

2.2 Explanation of the inverted U-shaped relationship between green investment and carbon emissions

Studying how green investment affect carbon emissions is becoming a hot research topic in academia. After summarizing, the existing research findings can be summarized in one sentence: Green investment is somehow a double-edged sword, which can both increase and decrease carbon emissions.

On the one hand, green investment may cause an increase in carbon emissions. First, the development of green investment will trigger economic growth effects that will lead to phenomena such as increased per capita energy consumption and environmental degradation, which in turn will increase carbon emissions. Second, increased economic activity means demand for more energy-intensive products, which also increase carbon emissions [6]. In addition, the immature development of green investment in the initial stage may lead to the flow of investment to high energy-consuming and polluting industries, which may cause an increase in carbon emissions. Although the above studies suggest that green investment has a negative effect on carbon emissions, on the other hand, there may be a positive relationship between the two. For example, green investment can enhance technological innovation and reduce the rate of energy waste through advanced technology, thus truly achieving emission reduction. In addition, renewable energy investments are increasingly becoming an important means of reducing carbon emissions. More, the further development of green investment channels, which will prompt more companies to enter the green industry, which in turn can further reduce carbon emissions.

From the above it can be concluded that in the early stages of green investment, it will increase carbon emissions; when green investment develops to a certain stage, its emission reduction effect gradually comes into play and eventually reduces carbon emissions. In other words, green investment has an inverted U-shaped relationship with carbon emissions.

2.3 The mediating role of industrial structure and the existence of energy consumption

This paper predicts that industrial structure and energy consumption are the two mediating variables in the relationship between the impact of green investment on carbon emissions.

First, green investment can influence carbon emissions through industrial structure. Early green investment is generally small in scale and often suffers from imperfect legal system, environmental information asymmetry and inadequate regulation, which eventually weakens the positive effect of green investment on industrial structure upgrading. For example, the "push-back" mechanism helps the upgrading of the secondary industry, but inhibits the development of the tertiary industry. With the increase of green investment and expansion of scale, green investment may shift to green and clean industries, and green industries can get more financial support, and the type of industries keeps changing, thus optimizing the industrial structure. Tertiary industries tend to have high value-added, low energy dependence and low pollution, and the upgrading of industrial structure can promote the reduction of carbon emissions [7]. In addition, industrial structure upgrading can also regulate the distortion of industrial structure and thus reduce carbon emissions.

Second, green investment can affect carbon emissions through energy consumption. Li et al. [8] state that investments in green projects significantly reduce environmental harms, improve energy efficiency, and reduce fuel consumption. And green investment not only have their positive effects in energy recovery and protection of the environment, but also enhance technological improvements that bring about significant improvements in energy efficiency and have a positive impact on reducing energy consumption [9].After studying the link between energy consumption and carbon emissions, The increase in industrialization and energy use has also led to an increase in greenhouse gas carbon dioxide emissions.

2.4 Non-linear effects of green investment

Besides the potential presence of an inverted U-shaped relationship between green investment and carbon emissions, this study asserts that the influence of green investment on carbon emissions can also be affected by additional factors, including regional economic development and urbanization levels. Wang et al. [10] demonstrated that a certain level of economic development is necessary for environmental regulations to have an impact. Additionally, the effect of environmental regulations on green productivity transitions from negative to positive as the level of economic development rises. In contrast, the increase in urbanization level will lead to a greater concentration of resources and labor, which will help increase regional productivity and finally drive economic development [11]. Therefore, in regions with higher levels of economic development and urbanization, the soundness of environmental institutions and regulation promotes the development of green industries, and green investment will be more effective in reducing environmental pollution and energy saving. In contrast, in regions with lower levels of urbanization, governments may focus more on economic development and green investment have a weaker relationship to carbon emissions.

3 Methodology and data

3.1 Econometric model

The baseline regression model in this paper was selected as a two-way fixed effects model with logarithms for all variables to eliminate heteroskedasticity.

$$\ln CO_{it} = \alpha_i + \beta_1 \ln GI_{it} + \gamma X_{it} + \lambda_i + \lambda_t + \varepsilon_{it} \tag{1}$$

where the subscript i and subscript t denote the region individual and year, respectively. CO_{it} is the dependent variable and GI_{it} is the core explanatory variable. X_{it} is a set of control variables including environmental regulation (ER), trade factor (TF), infrastructure (BF), demographic factor (PF), and technology factor (TEF). λ_i is a province fixed effect, λ_t is a time fixed effect, and ε_{it} is a random error term.

To further investigate the mechanism of the impact of green investment on CO, a reference is made to a stepwise test proposed by Baron and Kenny (1986), whose specific model is shown in Eq. 2-4:

$$\ln Y_{it} = \chi_i + \delta_t + \theta_1 \ln X_{it} + \theta_2 lnC_{it} + \zeta_{it} \tag{2}$$

$$\ln D_{it} = \varepsilon_i + \varphi_t + \beta_1 \ln X_{it} + \beta_2 \ln C_{it} + \mu_{it} \tag{3}$$

$$\ln Y_{it} = \eta_i + \nu_t + \gamma_1 \ln X + \gamma_2 \ln D_{it} + \gamma_3 \ln C_{it} + \tau_{it} \tag{4}$$

Although this mediation model is widely used for mechanism analysis, its high check criteria make it easy to draw irrelevant conclusions. Moreover, because mechanism variables are generally variables that occur after the cause variables and before the outcome variables, and are also largely endogenous, it is difficult to treat its endogeneity in our mechanism analysis. Therefore, this paper regresses the mechanism variable (IS,EI) using green investment and its quadratic term, and argues the causal effect of mechanism variable on CO through existing literature, as shown in Eq. 5-6:

$$\ln IS_{it} = \beta_1 \ln GI_{it} + \beta_2 (\ln GI_{it})^2 + \gamma X_{it} + \varepsilon_i + \varphi_t + \mu_{it} \tag{5}$$

$$\ln EI_{it} = \beta_3 \ln GI_{it} + \beta_4 (\ln GI_{it})^2 + \gamma X_{it} + \varepsilon_i + \varphi_t + \mu_{it} \tag{6}$$

According to the model, the significance of the coefficients β_1, β_2, β_3, and β_4 and their positive and negative relationships are mainly examined to obtain a specific nonlinear relationship between green investment and mechanism variables. In addition, considering that the strong exogeneity assumption required by the statistical threshold model may be limited in many practical applications, a dynamic panel threshold model is developed in this paper, as shown in Eq. 7:

$$y_{it} = x_{it}'\beta + (1, x_{it}')\delta 1\{q_{it} > \gamma\} + \mu_i + \varepsilon_{it} \quad i = 1, \dots, n; \quad t = 1, \dots, T \tag{7}$$

where the dependent variable is denoted as y_{it}. The vector x_{it} represents a set of time-varying regressors. The function $1\{\}$ is an indicator function, while q_{it} serves as the threshold variable. The threshold parameter is represented by γ, the slope parameter by δ, and ε_{it} represents the random error term.

3.2 Variables and data

This study employs a balanced panel dataset encompassing 30 Chinese provinces from 2003 to 2020. The variables under consideration are constructed in the following manner.

3.2.1. Dependent variable

This paper uses carbon intensity (CO) as a proxy variable for carbon emissions.CO is calculated as "CO_2 emissions/GDP". As shown in the formula, it represents the cost of generating 10,000 Yuan of GDP to environmental quality. The CO_2 emissions are calculated based on updated emission factors for China's provincial carbon emissions, referring to the studies on carbon emission measurement methods in Shan et al. [12].

3.2.2. Independent variable

The explanatory variable is green investment. Green investment is defined as any investment aimed at enhancing the overall efficiency of the production process. Green investment in this paper is the investment made to reduce the carbon emissions generated in each province, which is specifically equal to the sum of investment in industrial pollution control, investment in water facilities construction, investment in urban environmental infrastructure construction, and investment in forestry grass conservation.

3.2.3 Control variables

Referring to the relevant literature, the following control variables are selected: (1) Environmental regulation (ER), expressed as the ratio of industrial pollution control investment to regional GDP. (2) Trade factor (TF), expressed using the ratio of regional import and export trade to regional GDP. (3) Infrastructure (BF), we measure the level of infrastructure development through regional traffic density, which is expressed as the ratio of the sum of regional road mileage and rail mileage to regional land area. (4) Population factor (PF), using population density to proxy for the population factor, expressed as the population per unit area of the region. (5) Technology factor (TEF), expressed using the ratio of internal expenditure on research and experimental development to regional GDP.

3.2.4 Threshold and mediator variables

The analysis includes two threshold variables: the level of economic development, measured by GDP, and the level of urbanization (UB). In this paper, GDP per capita is used to indicate economic development, and the urbanization rate is used to measure the degree of urbanization of a region.

Two mediating variables, industrial structure (IS) and energy consumption (EI), are selected. In order to show the upgrading changes of regional industrial structure more intuitively, the ratio of the share of the tertiary industry to the share of the secondary industry is employed as an indicator reflecting the industrial structure. Energy consumption is the sum of various energy consumed by each production sector and domestic consumption in the region in a certain period.

3.3 Data sources and data description

In this paper, thirty provinces in China from 2003 to 2020 were selected as the initial sample. Due to the lack of data, the statistical sample does not include China's Tibet Autonomous Region, Hong Kong, Macau and Taiwan.

The provincial carbon emission data in this paper are mainly from the CEADs dataset. The data on green investment in each province are relatively scattered, and the data integrated in this paper are mainly from the China Environmental Statistical Yearbook. The data of control variables are derived from China Regional Economic Statistics Yearbook, China Population Census Yearbook and other publications.

4 Empirical results

4.1 Descriptive Statistics

The results of the descriptive analysis on the variables related to carbon emission intensity and green investment are shown in Table 1.

Table 1. Descriptive statistical characteristics of the variables.

Variables	n	Mean	SD	Min	Max
CO	540	2.6753	2.2909	0.1966	13.3221
GI	540	354.5379	308.9718	9.651	1581.542
ER	540	0.0039	0.0033	0.0001	0.0285
TF	540	0.3075	0.3739	0.0076	1.7922
BF	540	8406.614	5110.442	352.7205	22254.19
PF	540	443.6486	636.8922	7.3903	3949.206
TEF	540	0.0014	0.0013	0.0001	0.0080
EI	540	12824.85	8432.93	684	41845.29
IS	540	2.3246	0.1358	2.0276	2.836
GDP	540	18145.01	18218.08	385	110760.9
UB	540	0.5401	0.1452	0.2502	0.896

4.2 Multiple regression analysis

Table 2 reports the results of the baseline regression of green investment on carbon intensity. Column (1) has a significantly negative green investment coefficient without considering the control variables, which initially indicates that green investment can reduce carbon intensity. Column (3) still has a significant green investment coefficient after including the control variables. Therefore, green investment can reduce carbon emissions in China. Column (2) adds the quadratic term of green investment, and the results show that the effect of green investment scale has an inverted U-shape, i.e., its emission reduction effect only gradually comes into play when the scale of green investment reaches a certain level. Column (4) considers the effect of control variables on the basis of column (2), and the result is consistent with column (2). It indicates that green investment may flow to the crude industries at the early stage of development, resulting in more input of natural resources and mineral energy and other factors of production. And when green investment develops to a certain scale, the effect of green investment in energy saving and emission reduction will be brought into play, and the positive effect that outweighs the negative effect will be achieved to reduce carbon emission.

Table 2. Impact of green investment on carbon intensity.

Variable	CO(1)	CO(2)	CO(3)	CO(4)
GI	-0.0696** (-2.28)	0.4783*** (4.81)	-0.0776*** (-2.65)	0.3703*** (3.78)
GI2		-0.0503*** (-5.77)		-0.0413*** (-4.78)
ER			0.0732*** (4.16)	0.0644*** (3.72)
TF			-0.0379 (-1.11)	-0.0055 (-0.16)
BF			-0.3939*** (-4.86)	-0.4076*** (-5.14)
PF			-1.0525*** (-5.38)	-0.9777*** (-5.09)
TEF			0.1661*** (4.19)	0.1354*** (3.44)
The year effect	Yes	Yes	Yes	Yes
The regional effect	Yes	Yes	Yes	Yes
Constant	1.4878*** (11.10)	0.0975 (0.36)	11.8979*** (7.89)	10.2578*** (6.77)
R2	0.7221	0.7398	0.7585	0.7693
Obs	540	540	540	540

Note: *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively. The numbers in () indicate the t-values of the relevant statistics.

4.3 Mechanism Analysis

After the above analysis, the possible mediating effects of energy consumption and industrial structure were further examined considering that green investment may affect carbon emissions through two mediating channels: energy consumption and industrial structure. The statistical results of the mediating effect model study with energy consumption and industrial structure as mediating variables are shown in Table 3. Column (1) is a study of the nonlinear effect of green investment and energy consumption with the addition of a quadratic term. Column (3) is a study of the nonlinear effect of green investment and industrial structure with the addition of a quadratic term. Columns (2) and (4) considers the effect of control variables on the basis of Columns (1), (3), respectively. From the results it is clear that, the addition or not of control variables does not affect the nonlinear relationship between energy consumption, industrial structure and green investment. There is an inverted U-shaped relationship between green investment and energy consumption, and energy consumption will be gradually reduced only when the scale of green investment reaches a certain level. There is a U-shaped relationship between green investment and industrial structure, that is, after the development of green investment level to a certain degree, it is conducive to the transfer of economic structure from the secondary industry to the tertiary industry and promotes the upgrading of industrial structure.

This is because green investment when immaturely developed may lead to investment flows to energy-intensive industries, increasing the output of energy-intensive products and leading to an increase in CO2 emissions. After the development of green investment reaches a certain level, technologies such as energy recovery and energy storage are subsequently upgraded, bringing significant improvements in energy efficiency and positively affecting the reduction of energy consumption, which in turn has an impact on carbon emissions. In terms of industrial structure, green investment may be invested in some industries with high pollution and high energy consumption at the initial stage of development, which will have a negative impact on the upgrading of industrial structure. With the increase of green investment and expansion of scale, green investment may shift to green and clean industries, green industries can get more financial support and the type of industries shift to tertiary industries, thus optimizing the industrial structure. And because the tertiary industry has the characteristics of high value-added, low energy dependence and low pollution, gradually upgrading the industrial structure can effectively reduce carbon emissions.

Table 3. Results of mechanism analysis.

Variable	EI(1)	EI(2)	IS(3)	IS(4)
GI	0.4068***	0.3713***	-0.2268***	-0.2516***
	(8.34)	(7.53)	(-3.61)	(-3.98)
GI2	-0.0303***	-0.0264***	0.0060	0.0099*
	(-7.09)	(-6.07)	(1.10)	(1.79)
ER		0.0152*		0.0422***
		(1.74)		(3.78)
TF		-0.0194		-0.0177
		(-1.13)		(-0.80)
BF		0.1849***		-0.0888*
		(4.63)		(-1.74)
PF		0.3015***		0.3780***
		(3.12)		(3.05)
TEF		0.0358*		0.0288
		(1.81)		(1.14)
The year effect	Yes	Yes	Yes	Yes
The regional effect	Yes	Yes	Yes	Yes
Constant	7.4179***	4.6891***	0.1730***	-0.2073
	(55.27)	(6.15)	(3.83)	(-0.21)
R2	0.8934	0.9005	0.7643	0.7833
Obs	540	540	540	540

Note: *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively. The numbers in () indicate the t-values of the relevant statistics.

4.4 Nonlinear Characterization

This paper uses a dynamic panel model to test the nonlinear characteristics. The results in Table 4 verify that the effect of green investment on carbon emission intensity is nonlinear under the heterogeneity of economic development level and urbanization level.

The results show that the effect played by green investment is not significant below the threshold. After the economic development level exceeds the threshold, the coefficient of green investment is significantly negative at the 1% level, i.e., it indicates that the effect of green investment on the reduction of carbon emission intensity is significantly played out. Similarly, when the urbanization level is below the threshold, the effect is not significant until it exceeds the threshold, and the coefficient of green investment is significantly negative at the 1% level, which promotes the reduction of carbon emission intensity. This is because as the regional economic development level increases, the industrial structure is well configured, and the infrastructure construction is more perfect, the effect of green investment on reducing environmental pollution. Increased level of urbanization has led to progressive improvements in environmental systems and regulation, allowing for a greater concentration of resources and labor, which plays a significant role in the process of green investment in reducing carbon emission.

Table 4. Non-linear effects of green investment on carbon intensity.

Variable	CO(1)	CO(2)
L1.CO	0.6749***	0.8184***
	(18.22)	(23.25)
Below thres	-0.0168	-0.0354
	(-0.81)	(-0.90)
Above thres	-0.0629***	-0.0515***
	(-4.31)	(-3.38)
ER	-0.0015	-0.0272***
	(-0.19)	(-2.71)
TF	-0.0192	-0.0260
	(-0.53)	(-0.96)
BF	-0.1250***	-0.0513**
	(-5.78)	(-1.96)
PF	-1.1381*	-0.2167
	(-1.94)	(-0.64)
TEF	0.1993***	0.0851***
	(4.13)	(3.64)
The year effect	Yes	Yes
The regional effect	Yes	Yes
Constant	8.9885***	2.3604
	(2.60)	(1.20)
R2		
Obs	510	510

Note: The letter "L" in the table indicates the first-order lag of the variable, *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

4.5 Robustness tests

4.5.1. Endogeneity test

Allow for possible two-way causal relationship, this paper regresses green investment, the quadratic term of green investment with the control variables lagged to -th order and second order, respectively. As shown in columns (2) and (3) of Table 5, there is still an inverted U-shaped relationship between lagged-order green investment and carbon intensity, and the estimation results are still robust, which is preliminary evidence that the main findings of this study are reliable. To further alleviate the bias of the estimation results caused by the endogeneity problem of the variables, the first- and second-order lagged values of green investment are chosen as instrumental variables in this paper. First, the endogenous explanatory variables are significantly correlated with their lagged variables. Second, since the lagged variables have already occurred, their values are fixed from the current period's perspective and are not correlated with the current period's stochastic disturbance terms. Column (4) of Table 5 shows the results of the instrumental variables approach estimation, where the effect of green investment on carbon intensity remains significant and consistent with the previous paper, which again confirms the reliability of the results of the previous analysis.

4.5.2. Other robustness tests

In this paper, carbon intensity is explained by carbon emissions per capita. The specific results are shown in column (1) of Table 5, where the relationship between the substituted carbon emission variable and green investment remains significant and consistent with the estimation results obtained from the previously adopted measures, and the conclusion still holds.

Table 5. Robustness tests.

Variable	Replace variables (1)	Lagged by one period (2)	Lagging Phase II (3)	Instrumental variable method (4)
GI	0.7412***	0.2629***	0.0586	0.3904*
	(7.86)	(2.61)	(0.56)	[1.86]
GI2	-0.0592***	-0.0329***	-0.0162*	-0.0480***
	(-7.12)	(-3.67)	(-1.76)	[-2.70]
ER	0.0286*	0.0819***	0.0828***	0.0497***
	(1.72)	(4.38)	(4.19)	[2.70]
TF	-0.0214	-0.0504	-0.1207***	0.0044
	(-0.65)	(-1.37)	(-3.08)	[0.11]
BF	-0.0946	-0.4282***	-0.3433***	-0.4098**
	(-1.24)	(-5.20)	(-4.05)	[-2.25]
PF	-1.5351***	-0.9877***	-0.9595***	-0.9374***
	(-8.31)	(-4.65)	(-4.32)	[-4.46]
TEF	0.0557	0.0627	0.0634	0.1563***
	(1.47)	(1.54)	(1.48)	[3.64]
The year effect	Yes	Yes	Yes	Yes
The regional effect	Yes	Yes	Yes	Yes
Constant	8.6800***	10.2303***	9.8248***	10.3283***
	(5.96)	(6.17)	(5.59)	[4.85]
R2	0.7476	0.7578	0.7418	0.9429
Obs	540	510	480	480

Note: *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively.

5 Conclusions and policy implications

5.1 Conclusion

This paper uses a panel dataset of 30 Chinese provinces from 2003 to 2020 to examine the linear relationship between the two while considering the channels through which green investment affects carbon emissions in terms of the role of mechanisms, and introduces two structural variables, GDP and the level of urbanization, to examine the nonlinear effects of green investment on carbon emissions by applying a dynamic threshold panel model. The main research results are as follows.

First, green investment can significantly reduce carbon emissions. By incorporating the quadratic term for green investment in the regression analysis, we observe an inverted U-shaped relationship between green investment and carbon emissions, i.e., the emission reduction effect will gradually come into play when the scale of green investment reaches a certain critical value. This result still holds through endogeneity and robustness tests. The analysis of potential mechanisms indicates that green investment reduces carbon emissions partly through reducing energy consumption and promoting industrial structure upgrading. The results derived from the dynamic panel threshold model show that the inhibitory effect of green investment on carbon emissions is not obvious in regions with lower levels of economic development or lower levels of urbanization. As regional economic development and urbanization increase, green investment can reduce carbon emissions more significantly.

5.2 Policy implications

First, the empirical evidence shows that green investment has effectively reduced carbon emissions in China. In the long run, the emission reduction effect of green investment will be better developed with its improvement. Therefore, policy makers should design policies that encourage green investment to better leverage their long-term energy saving and emission reduction effects. Secondly, for regions with low urbanization levels and industrial structures that have yet to be transformed, policy makers should introduce relevant laws and regulations to improve the overall planning of the green economic development system. In addition, the government should accelerate the promotion of regional economic development level to efficiently reduce regional carbon emissions under the guidance of green development. Finally, the government should promote high-speed and high-quality economic development, and promote the development of regional urbanization scale. In general, the positive effect of green investment on carbon emissions is more pronounced in more developed economies and higher levels of urbanization. The increase in the level of regional economic development and urbanization is beneficial to the improvement of environmental systems and regulations, the promotion of industrial structure upgrading, and the improvement of green economic development.

In summary, the adoption of the policy measures suggested in this section can effectively contribute to the reduction of carbon emissions in China.

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