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The nexus between green finance and CO_2 emissions in China: New evidence from a panel smooth transition regression

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Abstract: *Green finance is a pool of resources dedicated to the development of environmentally friendly businesses. It can encourage sustainable development by placing a high value on ecological balance. Green finance is increasingly being applied to environmental governance. China has attempted to achieve its dual carbon target through the development of green finance. However, the jury is still out on whether green finance can boost China's carbon reduction efforts. This study uses a panel smooth transition regression (PSTR) model to investigate the effect of green finance on carbon emissions in China using panel data for 30 Chinese provinces and cities from 2008 to 2018, and further discusses how the economic level affects the relationship. The study concludes that there is a nonlinear relationship between green finance and carbon emissions in China. The relationship between the impact of green finance on carbon emissions and changes with the economy can be described by a PSTR model with a transition function and threshold parameters. An increase in GDP per capita strengthens green finance's emissions reduction effect. Furthermore, the study shows that an income gap above a certain threshold prevents green finance from achieving carbon emissions reduction. The study highlights the effective of the economic level on encouraging the development of green finance and achieving carbon emissions reduction.*

Keywords: *green finance, CO_2 emissions, panel smooth transition regression, China*

1. Introduction

As the world's largest carbon emitter, China's carbon reduction policies are critical to controlling global carbon emissions[1]. The process of achieving carbon reduction requires both top-level designs for long-term planning and financial and technical support from society. Finance has an important role as a means of resource allocation. China is increasingly focusing on the development of green finance (GF) to find a breakthrough in carbon emissions reduction. The key point is to achieve carbon reduction targets through the judicious use of green finance instruments to guide sustainable development. On the one hand, green finance can reduce the allocation of financial resources to high carbon emissions sectors [2]. On the other hand, green finance can guide the flow of capital to green enterprises[3], which can support green technology innovation[4]. Similarly, the development of green finance has broadened the financing channels for low-carbon and environmentally friendly industries. It can make the industrial structure gradually less dominated by heavy industry and thus drive down carbon emissions [5]. Green finance is perceived as playing a significant role in reducing carbon emissions to achieve the bright vision of a zero-carbon goal[6]. Understanding the impact of green finance on China's carbon emissions is important for China to reach its dual carbon target of reaching a carbon peak by 2030 and carbon neutrality by 2060.

Although many studies have examined the relationship between green finance and carbon emissions, the relationship between the two remains ambiguous. There are three main arguments in the current literature on how green finance affects carbon emissions. The first view is that green finance development promotes carbon emissions. In emerging economies, Sadorsky[7] demonstrated that when consumers have access to green credit, it leads to an increase in carbon emissions. Bui[8] and Jiang and Ma[9] argued that the development of green finance promotes income distribution and increases carbon emissions in the

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daily lives of residents. The second view argues that green finance market development inhibits carbon emissions. Hu and Guo[10] concluded that green finance in China curbed carbon emissions in both the short and long run, the effect being more pronounced in the long run. The third view is that the relationship between green finance and carbon emissions is not a simple linear relationship. Scholars have used time series models or panel data techniques to find that the relationship between green finance and carbon emissions varies across time in different countries[11,12]. The development of green finance in the United States does not affect carbon emissions in the long term[13]. Some scholars believe that the economic level plays an important role in the carbon emissions reduction effect of green finance, because the transition to green finance requires economic support. Nasreen and Anwar [14] found that the relationship between green finance and carbon emissions performs differently at different income levels.

The controversy in the existing literature may stem from the differences in indicators of green finance and the different statistical methods used. There are two main types of green finance indicator in previous research. The first indicator is green credit. Al-mulali and Binti[15] used the proportion of green credit to GDP as an indicator of green finance development to study its relationship with carbon emissions. Some studies have also used the inverse indicator to calculate green credit, expressed as the ratio of interest expenditure on credit in energy-consuming industries to total interest expenditure in industrial enterprises with annual main business revenues of more than 20 million yuan[16]. Furthermore, some scholars have verified that the environmental Kuznets curve (EKC) hypothesis holds in countries with low debt levels and carbon emissions increase with the debt burden in countries with different income levels. Reducing the debt burden can be an effective policy to reduce carbon emissions in developing countries[17]. Another indicator is the stock market. Abbasi and Riaz[11] found that if equity as a share of GDP is used as a long-term indicator of green finance, it yields more significant results than credit, which also indicates the feasibility of stock market independence from CO_2 emissions[18,19]. Paramati[20] and Shahbaz[19] used the stock market as an indicator of green finance and found the existence of an EKC in the relationship with carbon dioxide emissions. Given the lack of data and differences in measurement standards, the metrics of green finance have not reached a consensus in the academic community.

Many studies have been conducted to discuss the relationship between green finance and carbon emissions. However, the impact of green finance on carbon emissions in China is still far from clear. Cheng et al.[21] demonstrated that green finance can significantly increase China's green productivity and help to drive the digital transformation of heavy polluters[22]. Furthermore, in terms of its effect on the environment, the development of green finance in China can help reduce haze pollution by improving energy efficiency, and it is more effective in areas with high levels of green finance such as Beijing, Shanghai and Guangdong[23]. However, previous studies have rarely examined the complex relationship between green finance and carbon emissions by considering the size of the economy (GDP per capita) and the income gap in China. Some studies have concluded that increased income is the main driver of household carbon emissions in China[24]. The development of the economy helps to strike a balance between green development and functional operation[25]; thus, it may further affect the carbon emissions reduction benefits of green finance[26]. This study goes further to discuss the threshold effect of economic level on the relationship between green finance and carbon emissions at the provincial level. Furthermore, the economic level is divided into two perspectives: the size of the economy (GDP per capita) and the income gap.

The purpose of this study is to examine the relationship between green finance and carbon emissions in China. It constructs green finance indicators and uses a panel smooth transition regression (PSTR) model to examine the impact of green finance on carbon emissions in 30 provinces and cities in China during the period from 2008 to 2018, and further discusses the threshold effect of economic level. The results show that there is a non-linear relationship between green finance and carbon emissions in China. The relationship between the impact of green finance on carbon emissions and changes with the economy can be described by a PSTR model with a transition function and threshold parameters. The carbon reduction effect of green finance becomes stronger as the GDP per capita increases. The conclusion further shows that an income gap above a certain threshold prevents green finance from achieving carbon emissions reduction.

The rest of the study is structured as follows. The methodology and data are discussed in the next section. The subsequent section discusses and analyses the empirical results. The final section summarizes the main findings and highlights some policy implications.

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2. Methodology and Data

2.1 Model Specification

Most of the previous literature has chosen to group data according to the regression mechanism, using pooled ordinary least squares (pooled OLS) to investigate the possible nonlinear relationship between green finance and carbon emissions. The approach has the advantage of simplicity and clarity, but it contains some limiting assumptions. Firstly, it assumes that the information for each regression group is known. The information for each group can only be divided according to some specific rule. Secondly, it assumes that the subsamples are independent, which loses some common information components among the samples. Thirdly, pooled OLS assumes that individuals within a group strictly satisfy a linear relationship. It also assumes that there is no transition process between groups and that individuals 'jump' around breakpoints, which is not reasonable if the groups are continuous variables.

To solve the problem, González et al[27] proposed the PSTR model, which can endogenously choose the number of groups and the location of breakpoints; it also allows the parameters to vary smoothly across cross-sections and time points, enabling smooth transitions between regimes. The PSTR model has been widely used in studies of the relationship between environmental pollution and economic variables. Wang[28] used the PSTR model to empirically analyse the relationship between financial development and economic growth in China. Furthermore, Aydin et al.[29] used the PSTR model to study the nonlinear effect of economic growth on the ecological footprint. Considering the transition effect of globalization, Ulucak et al[30] applied the PSTR model to study the nonlinear effect of domestic material consumption in EU countries. Therefore, the study focuses on using the PSTR model to explore whether there is a nonlinear relationship between two green finance and carbon emissions and tests the hypothesis that the level of the economy affects the relationship.

In practice, the process of transformation of Chinese provinces and cities from a lower to a higher economic level is gradual. Therefore, the study employed the PSTR model extended by González[27] that enables smooth transitions between regimes to capture the effect of different economic levels on the relationship between green finance and carbon emissions. The PSTR model is defined as follows:

$$C_{it} = \mu_i + (\alpha_0 GF_{it} + \beta_0' X_{it}) + \sum_{j=1}^{r} (\alpha_j GF_{it} + \beta_j' X_{it}) g_j(q_{it}^j; \gamma_j, c_j) + \varepsilon_{it} \tag{1}$$

where C_{it} is the total carbon dioxide emissions of province i in year t. Green finance (GF_{it}) is the explanatory variable. It includes positive and negative indicators. The regression coefficient of its linear part is α_0. The regression coefficient of its nonlinear part is α_j. The control variable is X_{it}, consisting of marketization rate ($Market_{it}$), urbanization rate ($Urban_{it}$), and external economical openness ($Open_{it}$). The term μ_i captures the individual effects and ε_{it} represents the error term. The transition function $g_j(q_{it}^j; \gamma_j, c_j)$ continues in the observed transition variable q_{it}^j. The transition variables are GDP per capita ($ln\,PGDP$) and income gap (IG), respectively. The transition function is normalized to range between 0 and 1; then the coefficient estimates of the model are smoothly transformed between α_0 and $(\alpha_0 + \alpha_j)$. This is usually represented by a logistic function as $g_j(q_{it}^j; \gamma_j, c_j) = [1 + \exp(-\gamma_j \prod_{j=1}^{m} (q_{it}^j - c_j)]^{-1}$, where γ_j is the slope coefficient of the conversion function which determines the conversion speed. The position parameter of the function is c_j. The number of transition functions is r. The number of position parameters in the conversion function is m. Therefore, the change of C_{it} caused by the change of GF_{it} is:

$$\alpha_{it} = \partial C_{it} / \partial GF_{it} = \alpha_0 + \sum_{j=1}^{r} \alpha_j g_j(q_{it}^j; \gamma_j, c_j) \tag{2}$$

From the above equation, the coefficients for each city in each period are a continuous function of the transition variable q_{it}^j. The study chose lnPGDP and IG as transition variables and discusses the nonlinear relationship between green finance and carbon emissions by analysing the relationship between α_{it} and q_{it}^j.

The study needs to perform a homogeneity test and a residual non-linearity test to set the PSTR model. When the PSTR model has only one transition function, it is defined as:

$$C_{it} = \mu_i + (\alpha_0 GF_{it} + \beta_0' X_{it}) + (\alpha_j GF_{it} + \beta_j' X_{it}) g_j(q_{it}^j; \gamma_j, c_j) + \varepsilon_{it} \tag{3}$$

The study replaces the transformation function $g_j(q_{it}^j; \gamma_j, c_j)$ with its first-order Taylor expansion to avoid identification problems. Finally, the study obtains the auxiliary regression as follows:

$$C_{it} = \mu_i + (\theta_0 GF_{it} + \pi_0' X_{it}) + (\theta_1 GF_{it} + \pi_1' X_{it}) q_{it} + \varepsilon_{it} \tag{4}$$

Referring to the method of Colletaz and Hurlin[31], SSR_0 is defined as the panel sum of squared residuals when H_0 holds. It refers to the linear panel model with individual effects. SSR_1 is the panel sum of the square's residuals of the two-regime PSTR model when H_1 holds. The Wald LM test (LM), the Fisher LM test (LMF), and the likelihood ratio test (LRT) are respectively defined as follows:

$$LM = TN \ (SSR_0 - SSR_1) \ /SSR_0 \tag{5}$$

$$LMF = [(SSR_0 - SSR_1)/Km]/[SSR_0/(TN - N - mK)] \tag{6}$$

$$LRT = -2[\log(SSR_1) - \log(SSR_0)] \tag{7}$$

Where K is the number of explanatory variables. TN denotes the total sample of the regression. Based on the null hypothesis H_0, the LM and LRT statistics were distributed as $\chi^2(mK)$, whereas LMF statistics had an approximate F (mK, TN-N-mK) distribution. The LM, LMF and LRT tests are used to determine the number of extreme regimes r. If the null hypothesis H_0 is accepted, the PSTR model is proven to have one transition function. If not, sequential tests are executed to test $H_0: r = 2$. The number of extreme regimes of the model is determined to be $r^* + 1$ until $H_0: r = r^*$ is accepted.

The PSTR model can be set up by following the above steps. In the next step, the study uses the nonlinear least squares (NLS) method to estimate the unknown parameters.

2.2 Data and Sources

Table 1: Data description of the study

Variable	Variable description	Source of data
Carbon dioxide emissions (C)	Carbon dioxide emissions (million tons)	CEADs
Economic level (lnPGDP)	GDP per capita (yuan)	National Bureau of Statistics of China
Income gap (IG)	Using the Thiel index to represent income gap. The calculation formula is: $theil_{i,t} = \sum_{j=1}^{2} \left(\frac{Y_{i,t}}{Y_i}\right) \ln\left(\frac{\frac{Y_{ij,t}}{Y_{i,t}}}{\frac{X_{ij,t}}{X_{i,t}}}\right)$	
Structural effect (SE)	Share of tertiary sector in GDP	
Green finance (GF)	Green credit balance/GDP by province (billion yuan) (%)	Almanac of China's Finance and Banking
Reverse green finance (RGF)	Interest on loans for the six high-energy-consuming industries/Total interest for the whole industry (billion yuan) (%)	
Marketability level (Market)	China Marketization Index compiled by Fan Gang	National Bureau of Statistics of China
Urbanization rate (Urban)	Urbanization rate of resident population (%)	
External economical openness (Open)	Total import and export trade/GDP (yuan) (%)	

Due to the limitation of data availability, the empirical analysis was based on the panel data of 30 Chinese provinces, autonomous regions, and municipalities directly under the central government (excluding Tibet, Macau, Hong Kong, China and Taiwan, China) over the years from 2008 to 2018. To

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better understand the role of green finance in carbon emissions, the study introduces a comprehensive indicator system that incorporates green-oriented positive and negative credits rather than relying on a single low-carbon finance measure of the green credit dimension. This helps to provide a more comprehensive evaluation of green finance development. Green finance is measured in two dimensions: positive green finance (GF) and reverse green finance (RGF). As China only publishes the green credit balance of banks for each year, the study uses the credit balance of each province for the current year in relation to the total credit of the country for the current year as the weight of green credit for each province. Therefore, it can calculate the green credit balance of each province for the current year. In addition, Boyce's[32] study points out that income inequality can exacerbate environmental depreciation, mainly due to the weak ability of low-income groups to protect the environment and bear the cost of environmental pollution. Jalan and Ravallion[33] concludes that a narrowing income gap makes the marginal impact of economic growth on pollutant emissions decrease. Therefore, the economic level is measured in terms of GDP per capita and income gap. Definitions of the variables and the data sources are available in Table 1.

3. Empirical Results and Discussion

3.1 Description of Statistics

The data description is presented in Table 2. It can be seen that there is a large gap in carbon emissions between Chinese provinces and cities, accompanied by a large standard deviation of about 274.70. This shows that lnPGDP has a maximum value of 11.93 (about 151,752 yuan) and a minimum value of 9.18 (about 9,701 yuan). There is also a tenfold difference between the maximum and minimum income gap values. This suggests that the economic level and carbon emissions are uneven across Chinese provinces and cities. Therefore, the core question of the study is to explore the relationship between green finance and carbon emissions, and the threshold effect of economic level.

Table 2: Descriptive statistics

Variable	N	Mean	Std. Dev.	Min	Max
C	330	345.8026	274.6919	32.1191	1650.2450
lnPGDP	330	10.5543	0.5114	9.1796	11.9248
IG	330	0.1080	0.0511	0.0200	0.2600
GF	330	0.0438	0.0346	0.0050	0.1354
RGF	330	0.5591	0.1724	0.2292	2.0670
Market	330	7.5884	1.8342	3.3590	11.3790
Urban	330	0.5525	0.1313	0.2910	0.8960
Open	330	0.4166	1.0034	0.0002	8.8664

Table 3: Spearman’s correlation coefficient results

Correlation	C	lnPGDP	IG	GF	RGF	Market	Urban	Open
C	1.0000	-	-	-	-	-	-	-
lnPGDP	0.1182** (0.0319)	1.0000	-	-	-	-	-	-
IG	-0.0840 (0.1279)	-0.8213* (0.0757)	1.0000	-	-	-	-	-
GF	-0.0207* (0.0757)	0.5632*** (0.0000)	-0.3913*** (0.0000)	1.0000	-	-	-	-
RGF	-0.3083*** (0.0000)	-0.4213*** (0.0000)	0.4922*** (0.0000)	0.0249 (0.6516)	1.0000	-	-	-
Market	0.0992* (0.0720)	0.7248*** (0.0000)	0.7248*** (0.0000)	0.2187*** (0.0001)	-0.6385*** (0.0000)	1.0000	-	-
Urban	-0.0173 (0.7540)	0.8641*** (0.0000)	-0.8598*** (0.0000)	0.3994*** (0.0000)	-0.3868*** (0.0000)	0.7052*** (0.0000)	1.0000	-
Open	-0.1647*** (0.0027)	-0.2271*** (0.0000)	-0.2271*** (0.0000)	-0.1065* (0.0533)	0.0998* (0.0703)	-0.1537*** (0.0052)	-0.1184** (0.0315)	1.0000

Note: P-values in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Spearman’s correlation matrix results are presented in Table 3. The results show that the two indicators of green finance are negatively correlated with CO2 emissions at 10 per cent and 1 per cent significance levels, respectively. This may imply that the development of green finance is beneficial to carbon emissions reduction. However, economic development may lead to an increase in carbon

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emissions.

Table 4: Test for multicollinearity

Variables	VIF	1/VIF
lnPGDP	6.76	0.1480
IG	4.80	0.2084
GF	1.80	0.5562
RGF	1.88	0.5310
Market	3.27	0.3056
Urban	5.91	0.1691
Open	1.09	0.9205

Multicollinearity tests were conducted for all explanatory variables in the study as in Table 4, where the VIF statistics for all explanatory variables remained below 10, indicating the absence of multicollinearity.

3.2 Unit Root Test Results

Table 5 presents the results of panel unit root for both LLC and ADF-Fisher tests. For all the variables, the LLC test significantly rejects the hypothesis of the existence of unit roots. The results of the ADF test on the first order lagged terms of GF, RGF and Market show a significant rejection of the hypothesis of the existence of a unit root. The results indicate that all the variables are stationary.

Table 5: Levin-Lin-Chu and ADF-Fisher panel unit root results

Variable	At levels LLC	At levels ADF-Fisher chi-square	At first difference ADF-Fisher
C	-7.6931*** (0.0000)	169.8705*** (0.0000)	-
lnPGDP	-11.7321*** (0.0000)	191.1725*** (0.0000)	-
IG	-7.3324*** (0.0000)	131.4044*** (0.0000)	-
GF	-16.8288*** (0.0000)	10.5768 (1.0000)	-3.0302** (0.0415)
RGF	-3.7584*** (0.0001)	62.8445 (0.3759)	-6.5812*** (0.0000)
Market	-12.8013*** (0.0000)	50.1935 (0.8126)	-6.8920*** (0.0000)
Urban	-33.4162*** (0.0000)	313.0807*** (0.0000)	-
Open	-17.2794*** (0.0000)	308.3550*** (0.0000)	-

Notes: P-values in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

3.3 Non-Linearity Test Results

According to Table 6, the original hypothesis that the relationship is linear is significantly rejected at the 1 per cent level for both values of m. This implies that the relationship between carbon emissions and green finance is non-linear across Chinese provinces and cities. The effect of green finance on carbon emissions is not constant. The remaining nonlinearity tests found that the LM, LMF and LRT statistics could not reject the null hypothesis that there is only one transformation function for all the values of m. Therefore, model (3) has nonlinear characteristics with one transformation function.

Table 6: Tests for linearity and remaining nonlinearity in the PSTR model

	(1)		(2)	
Threshold variables (q_{it})	Economic level (lnPGDP)		Income gap (IG)	
Number of thresholds (m)	m=1	m=2	m=1	m=2
H0: r=0 vs. H1: r=1				
LMw	18.603*** (0.002)	25.681*** (0.004)	23.724*** (0.000)	36.791*** (0.000)
LMF	3.525*** (0.004)	2.447*** (0.008)	4.570*** (0.000)	3.639*** (0.000)
LRT	19.147** (0.002)	26.736*** (0.003)	24.620*** (0.000)	39.008*** (0.000)
H0: r=1 vs. H1: r=2				
LMw	5.059 (0.409)	15.261 (0.123)	15.006 (0.122)	16.047 (0.298)
LMF	0.887 (0.490)	1.358 (0.200)	2.715 (0.230)	1.431 (0.166)
LRT	5.098 (0.404)	15.625 (0.111)	15.358 (0.144)	16.451 (0.287)
AIC	8.763	8.810	8.673	8.673
BIC	8.891	8.960	8.822	8.892
RSS	1837149.687	1957542.780	1614956.545	1706001.263

Notes: r is the number of transition functions; m is the location parameter; P-values in parentheses.

3.4 Estimation Results

3.4.1 The impact of green finance on CO2 emissions concerning GDP per capita

The results of the previous sections show that a PSTR model with one location parameter and one transition function is appropriate. The results of parameter estimates for the PSTR model are shown in Table 7.

Table 7: Parameter estimates for the PSTR model

	(α_0)	($\alpha_0 + \alpha_1$)
Variable	Lower regime	Upper regime
GF	-0.4035* (-1.6829)	-0.7516** (-2.3872)
RGF	0.0710** (1.9811)	-0.2439*** (-3.5962)
Market	0.0311*** (3.0438)	-0.0251*** (-5.2902)
Urban	0.7818*** (3.8629)	1.9338*** (5.3812)
Open	0.0034* (1.6487)	-0.0156 ** (-2.5484)
Slope parameter: γ=1.5061		
Location parameters: c=10.4145 antilog: 33,340 RMB		

Notes: T-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; transition variable is *lnPGDP*; dependent variable is CO_2 emissions.

The results show that the coefficients of the linear and nonlinear parts of all variables are significant. They show that the link between green finance and carbon emissions is nonlinear. China has only one transition function at different stages of accumulation of GDP per capita. The turning point of the transition function is about 33,340 yuan of GDP per capita. An increase in GDP per capita promotes the carbon reducing effects of green finance. Notably, GF has a significant negative impact on carbon emissions in both regimes, but the carbon reduction benefits of GF are amplified when GDP per capita grows to cross the threshold. Meanwhile, the impact of RGF on carbon emissions shows significant differences in the two regimes. In the first regime, when RGF increases by 1 per cent, carbon emissions increase by 0.071 megatons. In the second regime, a 1 one per cent increase in RGF reduces carbon emissions by 0.2439 megatons. This indicates that RGF has a positive inhibitory effect on carbon emissions only when the GDP per capita of a province or city exceeds 33,340 yuan. It also shows that

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increasing the loan interest rate of the six high energy-consuming industries to the proportion of the total interest rate of the whole industry could increase the carbon emissions reduction effect.

The above results show that improving the GDP per capita enhances the effect of green finance on carbon emissions reduction in Chinese provinces and cities. For regions with lower levels of GDP per capita, the need to develop the economy may outweigh the need for environmental protection. These regions tend to use large amounts of low-cost energy such as coal, resulting in excessive carbon emissions. The significant carbon reduction effect of green finance in China's provinces illustrated in the study is consistent with most studies. Ma[34] suggested that green finance can promote green innovation, which is important for developing countries to improve their environmental performance. Wang[28] found that green finance has a greater impact on carbon intensity in high-emission regions. Policies to enhance green finance are crucial during times of high national energy demand.

The slope parameter γ in the transition function is 1.5061, which indicates that the effect of GDP per capita on green financial carbon emissions is quite flat. Figure 1 illustrates the transition process. The results are consistent with the generally long cycle, high investment, and high-risk characteristics of green economy activities. Due to financial constraints, it takes time to realize the green transformation of economic outputs[35].

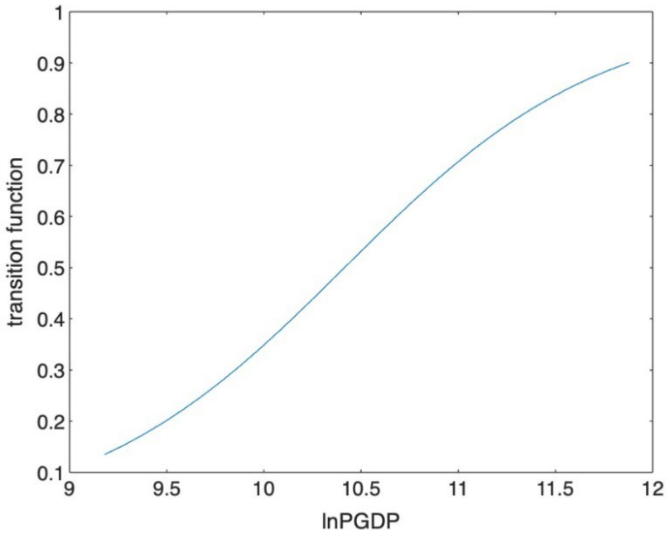

Figure 1: Graph of conversion function for transition variable lnPGDP

In general, the estimated coefficients show that the impact of green finance on carbon emissions varies across Chinese provinces and cities at different GDP per capita. In the early stages of economic development, carbon emissions increase with the development of green finance. However, when the economy grows to a GDP per capita of more than 33,340 yuan, emissions decrease. The relationship between carbon emissions and reverse green finance appears to follow an inverted U-shaped pattern with respect to GDP per capita. The findings support the validity of the EKC hypothesis in China. The impact of green finance on carbon emissions is influenced by GDP per capita. In some areas where GDP per capita is less than 33,340 yuan, the impact of green finance on carbon emission reduction is concealed.

3.4.2 The impact of green finance on CO2 emissions concerning income gap

Due to the uneven economic development of China's provinces and cities, the study considers different income levels. This section will examine how the impact of green finance on carbon emissions varies with the widening or narrowing of the income gap.

According to the results of the nonlinearity test in Table 6, the PSTR model with one transition function and one location parameter can be better used to estimate the parameters. The estimation results in Table 8 show that the impact of green finance on carbon emissions is significantly different in the two income gap regimes. When the income gap is below 0.1365, both GF and RGF are beneficial to carbon emissions reduction. When the income gap is greater than 0.1365, a one unit increase in GF generates 1.0455 megatons of carbon emissions. Moreover, a one unit increase in RGF causes 0.5061 megatons of carbon emissions, which can hinder the carbon reduction process. As shown in Figure 2, the rate of change from the low-income gap to the high-income gap is relatively fast. It means that when the income gap exceeds 0.1365, policymakers may act quickly to adjust it.

Table 8: Parameter estimates for the final PSTR

	(α_0)	$(\alpha_0 + \alpha_1)$
Variable	Lower regime	Upper regime
GF	-0.3517*** (-2.6019)	1.0455 *** (2.8380)
RGF	-0.1108** (-2.4162)	0.5061 *** (3.6267)
Market	-0.0314*** (-3.3326)	0.0526 *** (4.6002)
Urban	1.5067*** (6.8256)	-1.6615 *** (-4.9678)
Open	-0.0075** (-2.3103)	0.0114 * (1.9060)
Slope parameter: γ=3.3755		
Location parameters: c=0.1365		

Notes: T-statistics in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1; transition variable = income gap; dependent variable = CO_2 emissions.

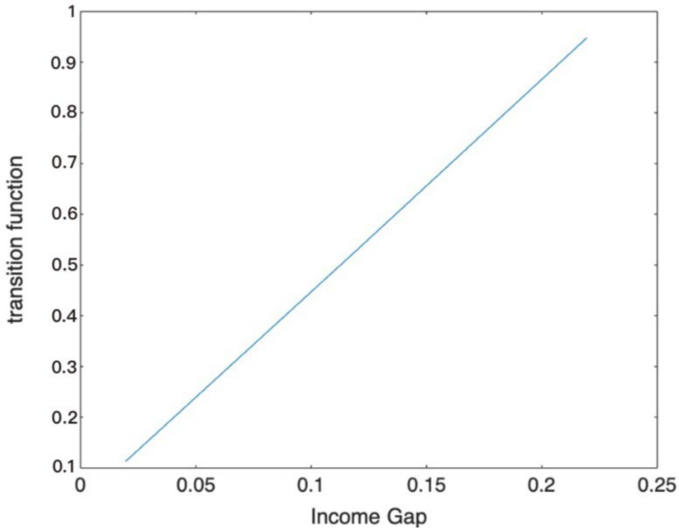

Figure 2: Graph of conversion function for transition variable income gap

The findings are consistent with many existing studies. Sun's[36] research pointed out that an income gap widens the inequality of global carbon productivity. The scope for carbon reduction is greatest for high-income groups, while the opposite is true in low- and middle-income groups. Huang[37] found that income level has the most direct impact on household carbon footprint in Japanese prefectures, as income determines the amount and structure of household consumption, liquefied petroleum gas (LPG) being the main source of energy in low-income households and electricity being the main source in high-income households[38]. Wiedenhofer et al.[39] showed that the poor and the rich in China have unequal household carbon emissions distribution. The results suggested that widening the income gap triggers the negative impact of green finance on carbon emissions reduction, while reducing the income gap is a key factor in improving the effectiveness of carbon emissions reduction.

4. Conclusion and Policy Implications

This study aimed to discuss the dynamic relationship between green finance, carbon emissions, GDP per capita and income gap in 30 provinces and cities in China during 2008–2018 based on PSTR modelling, which adds new evidence to the existing literature. On the one hand, the study further extends the green finance indicator from the widely used green credit to the interest rate on loans in six energy-intensive industries. On the other hand, considering that the inequality of economic levels among Chinese provinces and cities may affect the relationship between green finance and carbon emissions, the study considers both GDP per capita and income gap. An increase in GDP per capita may increase the share of funds spent on green energy, and the income gap may ultimately affect carbon emissions reduction by changing the green consumption structure and consumption tendency. Our findings support the above hypothesis that the response of carbon emissions to green finance is nonlinear.

The study concludes that the impact of green finance on CO_2 in China changes smoothly with the economic level. Firstly, when the GDP per capita develops beyond 33,340 yuan, the carbon emissions reduction benefits of green finance can be promoted. Secondly, the carbon emissions reduction effect of green finance can be realized only when the income gap is below 0.1365. Conversely, an income gap above the threshold will promote carbon emissions. The results of the Spearman's correlation matrix show that both positive and negative green finance, the level of marketization, the level of urbanization, and the degree of openness are significantly associated with CO_2 emissions. More specifically, the urbanization process and the expansion of openness to the outside world contribute to the reduction of carbon emissions, green finance has a lagging effect on the reduction of carbon emissions, and the marketization process expands carbon emissions.

Based on the above findings, the study can help Chinese policymakers to outline a different model for low-carbon economic growth. Firstly, China can focus on establishing a mature green financial system. The findings indicate that the development of green finance is helpful in meeting the expectations of carbon emission reduction. Consistent with the findings of previous studies, promoting the development of green finance can allocate financial market funds to green development. This is an important issue for realizing carbon emissions reduction and high-quality economic development. Secondly, the findings show that economic development has a positive effect in reducing carbon emissions. Therefore, solving the problem of environmental pollution caused by excessive carbon emissions does not mean giving up on economic development. The policy should focus on economic development. Furthermore, the income gap weakens the carbon emissions reduction benefits of green finance. Therefore, promoting greening of the economy should also pay attention to the income gap and employment in high-polluting enterprises to reduce the potential negative impacts of green financial development. Finally, the study reminds China to accelerate the opening and marketization process further and to build a green city system.

This study contributes to the promotion of carbon emissions reduction in China. It also offers reference value for countries and regions in the world with similar national conditions. It is worth noting that although the PSTR model is applicable to China with its uneven economic development across provinces and cities, it does not capture the nonlinear relationship between variables with absolute accuracy. However, PSTR model is a good method to improve the reliability of the results. Another limitation is that the study only covers 30 provinces and cities in China due to the availability of data. Therefore, future studies that improve the completeness of the data would help to improve the accuracy of the results. Furthermore, the green finance indicators used in the study are only measured from the green credit balance and interest on loans to six high energy-consuming industries. Not all perspectives are covered. Future studies can expand the construction of green finance indicators in various respects, such as green investment and green insurance.

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