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Does green finance have spatial spillover effects on carbon efficiency in China?

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Abstract. To meet the carbon peaking target, it is critical to understand the spatial impact of green finance. The entropy weight approach is used to create a green finance index. The SBM-GML model was used to calculate carbon efficiency. With SDM model, we analyze how green finance affects carbon efficiency.Transmission mechanism was investigated using threshold and mediation models. In terms of carbon emission efficiency, green finance has a spatial spillover effect, and green finance development can effectively enhance carbon emission efficiency improvement. The effect of green finance on carbon emission efficiency can be enhanced when PGDP and ER exceed a certain level. With a 7.6% effect size, ER played a partial mediation role.

Keywords: Green Finance;Carbon Efficiency;SBM-GML;Mediation model;Threshold model;SDM.

1. Introduction

After reform and opening up, China has quickly become the world's second-largest economy. An energy resource conflict and human activity cause rapid economic growth. A greenhouse effect, which is caused by excessive carbon emissions, will affect man's ecological balance with nature. While China struggles to expand its economy and protect the environment, it continues to follow the "Double Carbon" path. China's top ten economies that support green finance demonstrate that green finance can reduce carbon dioxide emissions and produce high-quality economic growth(Saeed Meo and Karim, 2022)[1]. Few studies have integrated factors influencing green finance and carbon emission effectiveness into one framework, and most literatures ignore space spillovers and externalities as well. There needs to be a paper that examines how green finance and carbon efficiency are spatially related.

2. Literature Review

Reducing carbon dioxide emissions appears to have developed into a significant contribution from various nations to ecological environmental protection under the constraints of the "Kyoto Protocol," the "United Nations Framework Convention on Climate Change," and the holding of the climate summit(Oh and Chua, 2010)[2]. According to Al Mamun et al. (2022)[3], established financial markets and highly inventive economies have a better success rate for green finance.

Specifically, green financing, as a key intermediary mechanism that influences green growth and carbon emission, is crucial for lowering emissions, according to Zhao et al. (2022)[4]. The effects of reducing carbon emission and encouraging economic transformation are substantial. According to Feng et al. (2022)[5], green finance can substantially reduce carbon emissions regardless of the location of the institution.The SBM model was employed by Zhang et al. (2022b)[6] to calculate carbon efficiency.

In conclusion, we employ a spatial econometric model.The threshold effect model is added, and environmental regulation is used as the mediating variable. Besides.By using a super-efficient SBM (Slack Based Model) model with undesired outputs, we calculated the carbon emission efficiency of 30 Chinese provinces. In order to analyze the dynamic characteristics of carbon emission efficiency, the GML (Global Malmquist-Luenberger) index is used with directional distance functions.(Zhang

et al., 2022b)[6].Therefore, we can measure carbon efficiency more scientifically and accurately with this technology.

3. Research Design

The degree of green financing development, together with other variables in the current region and other provinces, affects the level of CE development in a given area. Therefore, the spatial Durbin model is built in this article using the Geographic Weight Matrix.

$$CE_{\mathrm{it}} = a_0 + a_1 W * CE_{jt} + a_2 GF_{it} + a_3 W * GF_{it} + \theta_1 \mathrm{controls}_{\mathrm{it}} + \theta_2 W * \mathrm{controls}_{\mathrm{it}} + pro_{it} + time_{it} + \varepsilon_{it} \quad (1)$$

In equation (1), W stands for the geographic weight matrix. The control variables are represented by controls. Pro and time stand for the fixed impacts of time and place. denotes the phrase for disruption. to determine whether PGDP or ER restricts the GF's boosting influence on CE. The panel threshold effect model developed in this paper is based on PGDP or ER.

$$\begin{aligned} CE_{it} = a + \beta_1 GF_{it} + \theta_1 GF_{it} * I(M_{it} \le q_1) + \theta_2 GF_{it} * I(q_1 < M_{it} \le q_2) \\ + \theta_3 GF_{it} * I(q_2 \le M_{it}) + \beta_2 controls_{it} + \varepsilon_{it} \end{aligned} \quad (2)$$

In equation (2), M is the threshold variable. q is the threshold value. We use the entropy approach to determine the Green Finance Indicator (GF) for 30 Chinese provinces from 2011 to 2020 (excluding Tibet, Hong Kong, Macao, and Taiwan).Table 1 displays the green finance indicator system.

Table 1. Green Finance Indicator System

Primary Index	Formula	Direction	Weights
Green Credit	Industrial interest expenses/total industrial interest expenses of six energy-intensive industries	-	0.2398
Green Investment	Investment in environmental pollution/GDP	+	0.2535
Green Insurance	Value is output by agricultural insurance income/gross agricultural	+	0.2733
Carbon Finance	Carbon dioxide emissions/GDP	-	0.2334

Energy use and undesirable output are incorporated into the accounting framework via the CE (Carbon Efficiency). The undesirable and extremely effective SBM model is used in this paper to calculate CE.Table 2 displays the essential input-output variables.

Table 2. Input-output variable table

Variable category	Variable name	Specific instructions
Input variable	Labor input	Year-end employment
	Capital input	Real capital stock
	Energy input	Total energy consumption
Expected output variable	GDP	GDP at constant prices
Unexpected output variable	Carbon emission	IPCC method

The following control variables were chosen:(1)Green Technology Innovation(gti).A green technology innovation index is calculated by summing corporate green patent filings by the logarithm.(2)Industrial Structural Upgrade(Upgrade) is calculated using Equation 3.Ci represents the ratio between the output value and GDP of the i-th industry.(3)Research and Development(RD). RD is expressed as the logarithm of industrial enterprises' RD funds.(4)Per capita GDP(PGDP).The logarithm of the PGDP.(5)Foreign direct investment (FDI).The the logarithm of FDI.

$$\mathrm{up}grade = \sum_{i=1}^{3} c_i \times i = c_1 \times 1 + c_2 \times 2 + c_3 \times 3 \quad (3)$$

The mediating variable is environmental regulation (ER). The entropy weight method was used to create an environmental regulation index based on industrial wastewater, industrial SO2, and industrial soot emissions.

4. Empirical Analysis

4.1 Spatial Effect Test

In terms of spatial econometrics, neither green finance nor carbon efficiency fail the Moran index test. In all LM tests except LM lag, the significance level is 1%. Next, we should select the SDM model with fixed effects.

Table 3. Selection test of the spatial metrology model.

Variable	Main	W	Direct Effect	Indirect Effect	Total Effect
GF	0.4900***	0.6226***	0.5372***	0.9744***	1.5116***
	(0.0795)	(0.1827)	(0.0795)	(0.2496)	(0.2687)
gti	-0.0409***	0.0208	-0.0419***	0.0079	-0.0340
	(0.0135)	(0.0230)	(0.0114)	(0.0280)	(0.0305)
Upgrade	0.3274***	-0.2321*	0.3236***	-0.1890	0.1346
	(0.0731)	(0.1336)	(0.0740)	(0.1604)	(0.1618)
RD	0.0878***	-0.0524*	0.0880***	-0.0329	0.0551
	(0.0136)	(0.0268)	(0.0122)	(0.0354)	(0.0397)
PGDP	-0.0381	-0.1286**	-0.0525*	-0.1849**	-0.2374**
	(0.0234)	(0.0543)	(0.0282)	(0.0763)	(0.0923)
Fdi	0.3193***	0.0638	0.3319***	0.1902**	0.5221***
	(0.0337)	(0.0696)	(0.0359)	(0.0761)	(0.0848)
Rho	0.2545***				
R2	0.8125				

Note: ***, ** and * are significant at 1%, 5%, and 10% confidence levels, respectively. The data in parentheses are standard errors.

The SDM regression with the fixed effect is presented in Table 3. Green finance plays an important role in rural revitalization and development. 0.7001 indicates a significant positive spatial spillover effect between green finance and carbon efficiency. By increasing green finance levels in adjacent provinces, a spatially related region can effectively improve its carbon efficiency. Increased green finance can promote the development of carbon efficiency in this province and neighboring provinces.

4.2 Robustness Test

The spatial adjacency matrix was used to conduct a robustness analysis. There is a clear spatial spillover effect of green finance on carbon efficiency.

4.3 Threshold effect analysis

Result of threshold existence test. The PGDP threshold is double, while the ER threshold is single. Table 4 shows the threshold regression results. There are two threshold values for PGDP: 11.1410 and 11.4428. Therefore, green finance is more effective when GDP exceeds the threshold. Green finance can effectively promote carbon efficiency when the ER threshold exceeds 0.9221.

Table 4.Threshold regression results

Variable	Estimated Value	Estimated Value
GF(PGDP≤11.1410)	0.1246*	

GF(11.1410<PGDP⩽11.4428)	0.2140***	
GF(11.4428<PGDP)	0.4847***	
GF(ER⩽0.9221)		0.0142
GF(0.9221<ER)		0.4109***
Controls	Y	Y
R2	0.7456	0.6976

Note: The same as Table 3.

4.4 Mediating effect analysis

As a mediating variable, we looked at the environmental regulation (ER) effect. A stepwise regression analysis is shown in Table 5. Green finance has a coefficient of 0.2150 on environmental regulation without environmental regulation. Green finance has a coefficient of 0.4443 after accounting for environmental regulations. Carbon efficiency is influenced by environmental regulation by 0.1700. The level of environmental regulation is 0.2150*0.1700/0.4809=7.6%. Increasing the level of environmental regulation improves carbon efficiency.

Table 5. Mediation model regression

Variable	CE	ER	CE
ER			0.1700***
			(0.0423)
GF	0.4809***	0.2150*	0.4443***
	(0.0825)	(0.1111)	(0.0809)
Controls	YES	YES	YES
R2	0.8811	0.5138	0.8874
Sobel			1.74*
bootstrap			1.93*

Note: The same as in Table 3.

5. Summary

This paper examine the impact of green finance on carbon efficiency in China from 2011 to 2020 by using panel data. To calculate carbon efficiency, we first use SBM-GML. To examine the spatial spillover relationship between green finance and carbon efficiency, we use the SDM model. Finally, we use a mediation model and a threshold model to investigate the influencing mechanism. We find that green finance significantly improves carbon efficiency, with significant spatial spillovers. As threshold variables, pgdp and ER were examined for their threshold effect. As pgdp and ER increase, the promotion effect of green finance improves. By promoting environmental regulation, green finance can improve carbon efficiency. Regulation of the environment has a partial mediating effect of 7.6%.

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