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Research Article

The Spatial Effect of Green Tax Policy on Energy Efficiency: Evidence from China

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Abstract: Based on the 30 provinces(cities, autonomous regions) panel data of China from 2007 to 2016, this paper establishes a Spatial Durbin Model to explore the spatial effects of green tax policies in broad and narrow sense on energy efficiency. The results show that: (1)China's provincial energy efficiency has significant spatial correlation. (2) the relationship between the intensity of narrow sense green tax policy and the energy efficiency of the surrounding areas is an inverted U-shaped curve. (3) the relationship between the generalized green tax policy intensity and the energy efficiency of the surrounding areas is a U-shaped curve.

Keywords: Green tax policy; Energy consumption; Environment; Spatial effect

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1 Introduction

Since 2011, China has become the world's largest energy consumer, when coal played a leading role in China's energy consumption. The use of inefficient energy such as coal has produced a large number of harmful gases and greenhouse gases, causing environmental problems such as haze and acid rain, which not only greatly threaten the ecological environment, but also seriously affect the sustainable development of economy and Society (WHO, 2014). In order to deal with a series of problems caused by unreasonable energy consumption, the state has constantly introduced policies to intervene, encourage the improvement of energy utilization efficiency, and hope to reduce pollution emissions. Green tax policy is one of the policy tools of China's environmental regulation,it refers to a set of tax system that is conducive to the prevention and control of pollution and environmental protection. According to the international tax glossary, green tax refers to the tax relief granted to taxpayers who invest in pollution prevention or environmental protection, or the tax levied on the pollution industry and the use of pollutants. By intervening in resource allocation, it affects the energy type, utilization mode and consumption level used in the production process, and then affects the environmental quality by summarizing energy consumption and pollutant emission. [1] The green tax policy can be divided into two parts[2]: the narrow sense green tax which is directly levied for the protection of the environment and the generalized tax which plays an indirect role in the protection of the environment. In terms of the effect of these two tax policies on China's economic growth, there is a significant difference between them(An Furen et al., 2017). Based on the fact that there are differences in the role of narrow sense green tax and generalized green tax, and there are obvious regional differences in China's energy distribution, energy consumption and energy efficiency[3]. The spatial impact of these two green tax policies on energy efficiency remains to be discussed. Based on the above, this paper attempts to answer the following questions: is there a spatial spillover effect of green tax policy on energy efficiency? What are the differences between the broad and narrow green tax on energy efficiency? Based on the inter provincial panel data of China from 2007 to 2016, this paper constructs a Spatial Durbin Model to explore the spatial effects of green tax policies in broad and narrow sense on energy efficiency in China. The research results are expected to provide a theoretical basis to design reasonable tax policies to improve energy efficiency and achieve sustainable energy development for similar regions.

2 Methods

2.1 Spatial correlation test

Before choosing the spatial econometric model, it is necessary to test the spatial autocorrelation of energy efficiency. In this paper, Moran's I index is used to test the spatial autocorrelation of energy efficiency. The global Moran's I formula is as follows:

$$\text{Global Moran's I} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(Y_i - \bar{Y})(Y_j - \bar{Y})}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \quad (1)$$

$$S^2 = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \bar{Y})^2 \quad (2)$$

$$\bar{Y} = \frac{1}{n}\sum_{i=1}^{n} Y_i \quad (3)$$

W_{ij} is the standardized spatial weight matrix;The Moran's I index ranges from [-1,1]. If Moran's I is less than 0, it means that the observed values of spatial units show a negative correlation, and if Moran's I is greater than 0, it means that the observed values of spatial units show a positive correlation.Based on the global Moran's I test results, this paper shows that the Moran's I values of energy efficiency from 2007 to 2016 are all greater than 0, and all pass the 10% significance level test, which shows that China's energy efficiency has a significant positive spatial correlation. This not only verifies the correctness of empirical judgment, but also means that it is necessary to consider geographical factors and spatial effects when studying China's energy efficiency. The global Moran's I index test results of energy efficiency are shown in Table 1.

Table 1. Energy Efficiency (lnEQ) Global Moran's I Index

variable	I	P	variable	I	P
lnEQ2007	0.456*	0.000	lnEQ2012	0.448*	0.000
lnEQ2008	0.473*	0.000	lnEQ2013	0.448*	0.000
lnEQ2009	0.457*	0.000	lnEQ2014	0.468*	0.000
lnEQ2010	0.457*	0.000	lnEQ2015	0.468*	0.000
lnEQ2011	0.453*	0.000	lnEQ2016	0.455*	0.000

2.2 Model

Hausman test is used to select fixed effect or random effect data model. The narrow green tax model rejects the original hypothesis: "H0: UI is not related to xit." Thus, the narrow green tax model establishes the fixed effect model. The generalized green tax model does not reject the original hypothesis, so a stochastic effect model is established. Meanwhile, Wald test and LR test strongly reject the original hypothesis. Thus, this paper chooses Spatial Panel Durbin Model (SPDM) between Spatial Panel Lag Model (SPAR), Spatial Panel Error Model (SPER) and Spatial Panel Durbin Model (SPDM). The Spatial Panel Durbin Model is formulated in Eq. (4).

$$y = \rho W_{nt} y + X\beta + \theta W_{nt} X + \varepsilon \quad (4)$$

Among them, ρ represents space lag coefficient; $W_{nt}=I_t \otimes W$, W_{nt} represents block diagonal matrix; I_t represents unit time matrix of order t*t; W represents standard space adjacency matrix, $\otimes$ is Crohneck product; X represents a series of explanatory variables; $\theta W_{nt} X$ represents the influence of neighbor independent variables and θ represents corresponding coefficient vector; ε represents the random disturbance term and satisfies the hypothesis of zero mean, homovariance, zero covariance and homodistribution. In order to alleviate the influence of heteroscedasticity on regression results, the indexes were logarized. In order to test the spatial effect of green tax on energy consumption, considering the possible non-linear effect of green tax on energy efficiency, the following spatial panel Doberman model is established by adding the square term of green tax, as Eq.(5)

$$\begin{aligned} lnEQ_{it} = {} & c + \rho WlnEQ_{it} + \beta_1 lngti_{it} + \beta_2 (lngti_{it})^2 + \beta_3 lnpgdp_{it} + \beta_4 lnis_{it} \\ & + \beta_5 lnurban_{it} + \beta_6 lnfi_{it} + \beta_7 lnopen_{it} + \beta_8 lnti_{it} + \beta_9 lnkl_{it} + \theta_1 Wlngti_{it} \\ & + \theta_2 W(lngit_{it})^2 + \theta_3 Wlnpgdp_{it} + \theta_4 Wlnis_{it} + \theta_5 Wlnurban_{it} + \theta_6 Wlnfi_{it} + \\ & \theta_7 Wlnopen_{it} + \theta_8 Wlnti_{it} + \theta_9 Wlnkl_{it} + \lambda_i + u_t + \nu_{it} \end{aligned} \quad (5)$$

Among them,EQ is energy efficiency, gti is green tax policy intensity, pgdp is economic development level, urban is urbanization level, is represents industrial restructuring, fi is foreign investment, open is foreign trade dependent level, ti is scientific and technological innovation level, kl is resource endowment structure. W represents the block diagonal matrix above, $\beta 1 \sim \beta 9$ and $\theta 1 \sim \theta 9$ are regression coefficients, ρ is spatial autoregressive coefficient, i and t represent provinces and time, λ_i is the spatial effect, U_t is the time effect and V_{it} is random error.

2.3 Variable

2.3.1 Interpreted variables

Energy Efficiency (EQ): Referring to the practices of Xuan et al(2012), Liu and Huang (2019), the SFA model is applied to calculate energy efficiency, and the model is constructed as follows:

$$\ln 1/E_{it} = \beta_0 + \beta_k \ln K_{it} + \beta_l \ln L_{it} + \beta_y \ln Y_{it} + \beta_{kk}(\ln K_{it})^2 + \beta_{ll}(\ln L_{it})^2 + \beta_{yy}(\ln Y_{it})^2 + \beta_{kl}\ln K_{it}\ln L_{it} + \beta_{ky}\ln K_{it}\ln Y_{it} + \beta_{ly}\ln L_{it}\ln Y_{it} + \nu_{it} - u_{it} \quad (6)$$

Among them, i and t represent regions and years respectively; K is capital, measured by capital stock; L is labor, measured by employment; Y is output, measured by GDP. V_{it}-U_{it} is compound error, $\nu_{it} \sim iidN(0, \sigma_v^2)$, independent of u_{it}; $u_{it}=1nD_E(K_{it}, L_{it}, E_{it}, Y_{it})$are non-negative random variables, assuming that it can explain the technical inefficiency in production. On this basis, energy efficiency $EQ_{it}=exp\text{-}u_{it}$ can be calculated.

2.3.2 Explanatory variables

Green tax policy (gti): referring to the conclusions of Wang et al. (2018) and Deng et al. (2013), the green tax policy is divided into two aspects: narrow sense green tax policy intensity (gti1) and generalized green tax policy intensity (gti2). The pollution discharge fee with the function of environmental protection tax is the index of the narrow sense green tax policy, and the resource tax, consumption tax, land occupation tax, vehicle and ship tax, vehicle purchase tax, urban maintenance and construction tax and urban land use tax are all included as the index of the generalized green tax policy. Thus, the narrow sense green tax policy intensity = pollutant discharge fee / (total revenue + pollution discharge fee), the generalized green tax policy intensity = (7 green tax revenue + pollution discharge fee) / (total revenue + pollutant discharge fee).

2.3.3 Control variables

The following variables are selected according to the conclusion of previous literature (Wang et al, 2018; Fu et al,2017;Tao et al.,2019),Economic development level (pgdp): measured by the actual per capita regional production in 2007 as the base period Urbanization(urban): measured by the proportion of urban population to the permanent population at the end of the year Industrial structure adjustment (is): measured by the ratio of the added value of the tertiary industry to the added value of the secondary industry Foreign investment (fi): it is measured by the proportion of foreign investment in regional GDP in each region. Foreign trade dependence (open): measured by the proportion of total import and export of regional goods in regional GDP. Technological progress (ti): measured by three kinds of patent authorizations. Resource endowment structure (kl): measured by the ratio of capital stock to labor force in each region. Calculation formula of capital stock: nominal fixed capital formation amount / deflator index (actual fixed capital stock) + (1-0.1096) * capital stock of the last period.

2.4 Data sources

In this paper, data of 30 provinces in China from 2007 to 2016 are included. Hong Kong, Macao and Taiwan are excluded because of the availability of data. Tibet is excluded for data discontinuity. There are very few missing explanatory variable index data in the remaining 30 provinces, and linear interpolation method is used to complete the data. The original data come from China Statistical Yearbook, China Tax Yearbook, China Environmental Yearbook and provincial statistical yearbooks.

3 Regression results

According to the regression results of spatial Doberman model in Table 2, wlngti1 and $w(lngti1)^2$ are significant at the level of 1%, and the coefficient is negative, which indicates that there is spillover effect (other spillover effect), and the collection of pollution charges by neighboring provinces will have a negative impact on local energy efficiency. Wlngti2 and $w(lngti2)^2$ are significant at the level of 1%, and the coefficient is positive, that is, the intensity of green tax policy in the adjacent region has a positive impact on the energy efficiency of the region. Because of the feedback effect of Spatial Panel Durbin model, the influence on the region will be transmitted to the neighboring region, and the influence of the neighboring region will be transmitted back to itself. Its coefficient can not be directly used to measure the direct effect and spatial spillover effect of explanatory variables on the explained variables. Therefore, according to the method proposed by Lesage and pace (2009), the coefficient estimates are decomposed into direct effect and indirect effect by the method of partial differentiation.

The direct effect, spatial spillover effect (indirect effect) and total effect of green tax intensity on energy efficiency are shown in Table 3.As shown in Table 3, the spatial spillover effect of narrow green tax intensity lngti1 is significant and coefficient is negative at the level of 1%, and the spatial spillover effect of （lngti1) ^{2} is significant and coefficient is negative at the level of 1%, indicating that the relationship between narrow green tax and energy efficiency in surrounding areas is inverted U-shaped curve. When the intensity of narrow green tax is low, it will promote the energy efficiency of the surrounding areas to a certain extent; when lngti1 reaches the critical value of -8.688 (- 0.417 / (2 * (0.024)), that is, gti1 reaches 0.000169 (exp-8.688), it will promote the energy efficiency of the surrounding areas to the greatest extent. The continuous increase will restrain the energy efficiency of the surrounding areas. It may be because with the gradual increase of the collection of pollution charges, the producers will move the factories with more pollution and emissions due to the low energy efficiency to the places with less supervision, so that the energy efficiency of the surrounding areas will decline.The spatial spillover effect of the generalized Green Tax intensity lngti2 is significant and coefficient is positive at the level of 1%, and the spatial spillover effect of lngti2 is significant and coefficient is positive at the level of 1%, indicating that the relationship between the generalized Green Tax and the energy efficiency of the surrounding areas presents a U-shaped curve. When the generalized Green Tax intensity is low, it will restrain the energy efficiency of the surrounding areas to a certain extent; when lngti2 reaches the critical value of -1.888 (- 0.952 / (2 * 0.252)), that is, gti2 reaches 0.151253 (exp-1.888), it will restrain the energy efficiency of the surrounding areas to the greatest extent; as the generalized Green Tax intensity continues to increase, it will promote the energy efficiency of the surrounding areas. It can be understood that when the government departments in the region put forward a stronger green tax policy, which has a certain demonstration effect, under the pressure of environmental protection, the surrounding areas will implement policies more effectively to prevent a large number of industries with low energy efficiency and heavy pollution from moving in, that is, the energy efficiency of surrounding areas can be driven by a region with high green tax policy intensity.

Table 2. Estimation Results of Spatial Durbin Model Of Green Tax policy On Energy Efficiency

variable	Narrow sense green tax				Generalized Green Tax			
	(1)		(2)		(3)		(4)	
	FE		RE		FE		RE	
	Main	Wx	Main	Wx	Main	Wx	Main	Wx
lngti1	0.030	-0.377***	0.062	-0.353***				
	(0.042)	(0.098)	(0.042)	(0.090)				
$(\text{lngti1})^2$	0.002	-0.021***	0.004	-0.020***				
	(0.003)	(0.003)	(0.003)	(0.003)				
lngti2					-0.086	0.777***	-0.089	0.756***
					(0.083)	(0.140)	(0.088)	(0.141)
$(\text{lngti2})^2$					-0.036	0.185***	-0.032	0.201***
					(0.024)	(0.040)	(0.025)	(0.040)
lnpgdp	0.222***	0.163	0.240***	-0.181	0.228***	0.403***	0.221***	0.0121
	(0.068)	(0.164)	(0.067)	(0.113)	(0.068)	(0.149)	(0.068)	(0.114)

Continued table 2

variable	Narrow sense green tax				Generalized Green Tax			
	(1)		(2)		(3)		(4)	
	FE		RE		FE		RE	
	Main	Wx	Main	Wx	Main	Wx	Main	Wx
lnis	0.034	0.084	0.035	-0.089*	0.018	0.066	0.039	-0.030
	(0.034)	(0.083)	(0.031)	(0.052)	(0.034)	(0.081)	(0.031)	(0.052)
lnurban	0.371***	-0.809***	0.366***	-0.197	0.421***	-0.890***	0.447***	-0.219
	(0.126)	(0.283)	(0.128)	(0.244)	(0.123)	(0.276)	(0.127)	(0.245)
lnfi	0.068***	0.005	0.086***	-0.022	0.076***	-0.021	0.084***	-0.055
	(0.015)	(0.041)	(0.015)	(0.033)	(0.015)	(0.041)	(0.015)	(0.035)
lnopen	-0.040***	0.004	-0.034**	0.0446*	-0.024*	0.062*	-0.022	0.086***
	(0.014)	(0.034)	(0.014)	(0.024)	(0.014)	(0.033)	(0.014)	(0.026)
lnti	0.013	0.022	0.018	-0.018	0.018	0.049	0.020	-0.007
	(0.014)	(0.031)	(0.013)	(0.021)	(0.014)	(0.030)	(0.014)	(0.022)
lnkl	-0.057	0.197***	-0.0784**	0.063	-0.080**	0.056	-0.099**	-0.034
	(0.038)	(0.076)	(0.040)	(0.074)	(0.037)	(0.079)	(0.039)	(0.077)
Constant			-1.904**				-1.732**	
			(0.845)				(0.836)	
rho	0.143*		0.329***		0.070		0.274***	
	(0.085)		(0.073)		(0.087)		(0.075)	
sigma2_e	0.002***		0.002***		0.002***		0.002***	
	(0.000)		(0.000)		(0.000)		(0.000)	
Hausman test	23.18***				2.04			
Wald test	51.24***				56.25***			
Lratio test	44.12***				49.88***			
Id fixed	YES		YES		YES		YES	
Time fixed	YES		YES		YES		YES	
N	300		300		300		300	
R^2	0.662		0.74		0.673		0.746	

Note: *, **, and *** indicate significant levels of significance at 10%, 5%, and 1%; standard errors are reported in parentheses.

Table 3. Direct, Spatial and Total Effects of Green Tax Intensity on Energy Efficiency

variable	Direct effect		Space spillover effect		Total effect	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
lngti1	0.019	0.044	-0.417***	0.117	-0.398***	0.140
$(\text{lngti1})^2$	0.001	0.003	-0.024***	0.007	-0.023***	0.009
lngti2	-0.034	0.091	0.952***	0.199	0.918***	0.235
$(\text{lngti2})^2$	-0.018	0.025	0.252***	0.056	0.234***	0.065

Note: *, **, and *** indicate significant levels of significance at 10%, 5%, and 1%.

4 Conclusion and policy implication

Using panel data of 30 provinces in China from 2007 to 2016, this paper establishes a Spatial Panel Durbin Model, and empirically studies the spatial effect of green tax on energy consumption from the narrow sense and the broad sense of green tax policy. The main conclusions are as follows: (1)the relationship between the intensity of green tax policy in narrow sense and the energy efficiency of surrounding areas shows an inverted U-shaped curve. (2)the relationship between the generalized green tax policy and the energy efficiency of the surrounding areas presents a U-shaped curve. Thus, the suggestions are as follows: (1)The collection intensity of sewage charges should be moderate and keep the same in the surrounding areas. Only in this way can manufacturers not be forced to move to the surrounding areas with lower collection fees, but make them choose cleaner production activities, so as to truly achieve the purpose of reducing the environmental burden. (2)Moderately improving the intensity of generalized green tax. When the intensity is maintained at a high level, it can not only improve the loc nergy efficiency, but also promote the energy efficiency of adjacent regions one after another, so as to achieve common progress in multiple regions.

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