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An empirical analysis on spatial effects of environmental protection

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ABSTRACT

Objectives: The main objective is to provide policy recommendations on the enhancement of ecological environmental protection.
Methods: Combined with spatial correlation analysis and spatial dynamic panel models, this paper estimates the spatial effect of the local government's environmental protection expenditure on the improvement of the ecological environment based on China's 30 provinces as samples from 2007 to 2017.
Results: We find a significant impact of the environmental protection expenditure of the local government on the ecological environment improvement of neighbouring regions rather than the local region. It reveals a "free-riding" phenomenon in environmental governance. In addition, increasing the levels of economic development, urbanization, environmental regulations and industrial structure in the local region can effectively mitigate environmental pollution in the local region on one hand and contribute to the deterioration of the ecological environment in neighbouring regions on the other.
Conclusions: The present study suggests that environmental regulations can significantly improve the local environment. The local governments at all levels must reinforce the supervision of the ecological protection areas to ensure the implementation of environmental regulations.

1. Introduction

During the past four decades since the reform and opening up, China has not only achieved remarkable achievements, but also caused increasing destruction to the ecological environment (Elhorst, 2003; Ma et al., 2020). According to China Eco-Environmental Status Bulletin by Ministry of Ecology and Environment of the people's Republic of China, in 2018, 121 of China's 338 cities at the prefecture level and above met the standards for ambient air quality, accounting for only 35.8% (Zhang and Zou, 1998; Zhang, 2006). After a series of reforms in the fiscal and taxation system since the 1980 s, China has developed a fiscal decentralization system different from the fiscal systems of the west (Lin and Liu, 2000; Jia et al., 2014; Jia and Zhang, 2014; Ding et al., 2019; Jin and Zou, 2005). Air pollution data in China revealed 1900 μg/m^2 of SO^2 and 3200 μg/m^2 of NO_2 was reported (Xu et al., 2021). In China, the selection and appointment of local governments are mainly determined by the higher-level government or the central government. It drives local governments to compete for opportunities. The main means of this competition is the fiscal expenditure, since local governments have limited influence on the tax system (Chen, 2013). In this context, it is essential to analyze the spatial effect of the local government's environmental protection expenditure from the perspective of fiscal expenditure competition (Wang et al., 2021; Chen et al., 2020). We hope to provide a reference and suggestions for the central government to formulate policies on ecological environmental protection. This paper studies the spatial effect of the local government's environmental protection expenditure on environmental pollution. On basis of the spatial weight matrix, the spatial Dubin model combined with correlation test and fixed effect are used to explore the direction and the influence extent of environmental protection expenditure on environmental pollution in the research region and its neighbouring regions (Bell and Bockstael, 2000; He et al., 2019; Zhang et al., 2020; Bai et al., 2019; Zhao et al., 2020). It is aimed to provide policy recommendations on the enhancement of ecological environmental protection.

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2. Model and variable selection

2.1. Selection of spatial weight matrix

The selection of spatial weight matrix is crucial to the analysis by the spatial dynamic panel model. This is because the correct

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reflection of spatial structure guarantees the estimation validity of the spatial model. This study focuses on environmental pollution, and the discharge level of pollutants such as toxic gas and wastewater will inevitably affect the geographically adjacent areas. Thus, instead of the economic space matrix, the geospatial matrix W_{ij} is selected and built here based on the following criterion: W_{ij} is 1 for regions with a common boundary and 0 otherwise. The geographic matrix W_{ij} is expressed as:

$$Wij = \begin{cases} 1, RegionIandregionjshareacommongeographicboundary \\ 0, RegionIandregionjsharenocommongeographicboundary \end{cases}$$

2.2. Variable selection

2.2.1. Explained variables

Three industrial wastes (industrial waste gas, industrial wastewater, and industrial soot and dust) and other indicators are widely selected in previous literature on environmental issues. In this study on the spatial effect, the total provincial-level discharge of waste gas and wastewater that has a close correlation with space is adopted. The sulfur dioxide discharge of each province is taken as the major explained variable, and the wastewater discharge of each province is applied to robustness analysis. Compared with gas pollution indicators such as PM2.5, sulfur dioxide discharge has more complete available data and causes more serious environmental pollution. Notably, the Tibet Autonomous Region, where the data of sulfur dioxide discharge in some years are missing, is excluded. Finally, the data on the discharge of sulfur dioxide and wastewater in 30 provincial-level regions are extracted from the 2008–2018 *China Environmental Statistics Yearbook*.

2.2.2. Explanatory variable

In this study per capita environmental protection expenditure is taken as the explanatory variable. To weaken the impact of population size on environmental protection expenditure and ensure comparability among provinces, we calculate per capita environmental protection expenditure in each province by the ratio of the annual environmental protection expenditure to the year-end permanent residential population. The two types of data for calculation are from the 2008–2018 *China Statistical Yearbook*.

2.2.3. Control variables

In addition to per capita environmental protection expenditure, other variables may also affect environmental pollution. In this paper, four control variables are taken into account, including the levels of local economic development, industrial structure, urbanization, and environmental regulations. First, the level of economic development in each province is calculated by the ratio of annual GDP to the number of year-end permanent residents. Regions with high-level economic development tend to take measures to meet high standards of environmental pollution improvement; while regions subject to low-level economic development are more inclined to sacrifice the environment for economic benefits. Second, the level of industrial structure is denoted by the ratio of the added value of the secondary industry to GDP. The secondary industry is characterized by high energy consumption and huge pollution, and its increased proportion in the national economy will contribute to more serious industrial pollution, thus aggravating regional environmental pollution. Third, the level of urbanization is measured by the ratio of urban population to the year-end permanent residents. The growing urbanization is often accompanied by more pollution. Fourth, according to the common practices of scholars in Europe and the United States, the level of environmental regulations is calculated by the ratio of the treatment costs of industrial wastewater and waste gas to the added value. No doubt, the strengthening of environmental regulations plays a role in reducing the environmental pollution. The bigger the calculated value of this indicator, the higher the level of environmental regulations in the industry. Annual GDP, year-end permanent resident population, urban population, and added value of the secondary industry in each province are collected from the 2008–2018 *China Statistical Yearbook*; the industrial costs of wastewater and waste gas treatment are from the 2008–2018 *China Environmental Statistics Yearbook*.

2.3. Selection of the space panel model

Spatial autocorrelation refers to the potential interdependence of some variables on the observed data in the same distribution area. In this study, the impacts of local government's environmental protection expenditure on both the local region and neighbouring regions should be comprehensively considered. Because of China's fiscal decentralization system, governments have to compete for limited resources, resulting in the competition in the allocation of fiscal expenditure with neighbouring provinces. This paper employs a spatial econometric model to examine the spatial correlation between environmental protection expenditure and pollutant discharge in the research region and its neighbouring regions. On this basis, it further analyzes the spatial spillover effect of local government's fiscal expenditure on the improvement of environmental pollution. Specifically, Moran's I and the spatial dynamic panel Dubin model are applied to the empirical research.

2.3.1. Moran's I

Moran's I was put forward by Cliff and Ord in 1073 to measure the extent to which a specific variable impact on neighbouring areas and to test the similarity and dissimilarity of neighbouring regions in the entire area. It is mainly applied to global convergence test. Generally, the value of Moran's I ranges between −1 and 1. The value greater than 0 reflects the spatial autocorrelation; the larger the value, the stronger the correlation. When the value is equal to 0, it means the spatial distribution is random. The value<0 reveals that the adjacent units in the space have no similarities; the smaller the value, the larger the difference. Moran's I is calculated as:

$$I = \frac{N\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(X_i - \overline{X}\right)\left(X_j - \overline{X}\right)}{\left(\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\right)\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2} \quad (1)$$

where N is the number of regions studied; $\overline{X}$ is the per capita environmental protection expenditure of each province; X_i and X_j are the per capita environmental protection expenditure of specific provinces i and j, respectively. W_{ij} denotes the relationship between province i and province j in the weight matrix. W_{ij} is 1 when province i and province j are adjacent and 0 otherwise

2.3.2. Spatial Dubin model

SDM is used to analyze the endogenous interaction effect between explained variables and the exogenous interaction effect between explanatory variables; while the interaction effects between the distraction terms are excluded. The baseline model applied in this study is expressed as:

$$SO2_{it} = \beta_0 + \delta WPO_{it} + \beta_1 PCEXP_{it} + \beta_2 GDP_{it} + \beta_3 IS_{it} + \beta_4 URBAN_{it} + \beta_3 ER_{it} + \theta_1 WPCEXP_{it} + \theta_2 WGDP_{it} + \theta_3 WIS_{it} + \theta_4 WURBAN_{it} + \varepsilon_{it} \quad (2)$$

where $SO2_{it}$ is the explanatory variable of this paper, denoting the discharge amount of sulphur dioxide of the i-th province in the t-th year; $PCEXP_{it}$ is the core explanatory variable, denoting the per capita environmental protection expenditure of the i-th province in the t-th year; GDP_{it} represents the economic development level of the i-th province in the t-th year; IS_{it} represents the industrial structure level of the i-th province in the t-th year; $URBAN_{it}$ represents the urbanization level of the i-th province in the t-th year; ER_{it} represents the environmental regulation level of the i-th province in the t-th year.

3. Model identification test and spatial effect analysis

3.1. Spatial correlation test

Spatial autocorrelation refers to the potential interdependence of some variables on the observed data in the same distribution area (Douglas et al., 2000). Before spatial measurement, it is necessary to determine whether variables are related to or independent of each other (Koo et al., 2021). Therefore, a spatial correlation test is carried out. During the analysis of spatial measurement, spatial autocorrelation is measured by the spatial autocorrelation statistic Moran's I, i.e. formula (1). The results of Moran's I test are listed in Table 1.

From Table 1, we can see that the global Moran's I of sulphur dioxide discharge has a positive value. In addition, the data between 2011 and 2016 pass 5% of the significance level test, and the remaining years pass 10% of the significance level test. It suggests a significant positive spatial correlation between the levels of sulphur dioxide discharges among 30 provincial-level regions in China. This finding reveals the accumulation of environmental pollution occurs in the provincial regions in space (Vieira et al., 2021). Thus, the spatial econometric model is applicable to this study.

3.2. Identification test of space panel model

An identification test of spatial panel model is essential so as to build a correct spatial panel model and avoid the impact of model setting errors on the estimation results (Zhai and An, 2021). This paper integrates the LR test and Hausman test to make identification between random effect and fixed effect, as well as among the spatial lag model, spatial error model, and spatial Dubin model.

Table 1
Moran's I.

Year	SO2
2007	0.130* (1.480)
2008	0.126* (1.440)
2009	0.141* (1.582)
2010	0.147* (1.631)
2011	0.155** (1.714)
2012	0.160** (1.762)
2013	0.165** (1.808)
2014	0.167** (1.828)
2015	0.158** (1.746)
2016	0.150** (1.671)
2017	0.144* (1.619)

t statistics in parentheses.
$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

The result of chi2 = -1.17 < 0 in the Hausman test denies the hypothesis of random effect but supports fixed effect. Further, two p-values of 0.000 < 0.01 in the LR test strongly reject the assumption that SAR or SDM can replace SDM, indicating that the spatial dynamic panel Dubin model is unlikely to degenerate into a spatial lag model or a spatial error model. Combined with the results of the LR test and Hausman test, we conclude that the fixed-effect SDM is applicable to this study.

3.3. Spatial effect analysis

Based on the previous spatial correlation test and spatial panel model test, we employed the fixed-effect of SDM to investigate 30 provincial-level regions in China (Wang et al., 2021). Notably, the control was added to improve the robustness of the empirical result, as shown in Table 2.

It can be seen that the coefficients of all control variables are at a significant level, proving the reliability of the control variables selected in this paper. First, the regression coefficient of the core explanatory variable, per capita environmental protection expenditure is significantly positive before and after the sequent adding of control variables. It means that the per capita environmental protection expenditure promotes the local pollution level; for every 1% increment in the expenditure, the local pollution level increases by 0.0695% (Maji and Namdeo, 2021). Second, from the regression coefficients of the spatial interaction terms of the explanatory variables, we observe that the regression coefficients of the core explanatory variable remain significantly negative after the control variables are added. In other words, the per capita environmental protection expenditure significantly mitigates the pollution of neighbouring regions, revealing an obvious "free-riding" phenomenon. It means that the levels of local economic development, urbanization, environmental regulations and industrial structure all contribute to more serious environmental pollution in neighbouring regions (Xiong and Xu, 2021).

In order to deeply examine the impact extent of independent variables on dependent variables as well as their spatial spillover effect in SDM, we introduce the direct, indirect and total impacts of all influence factors on sulfur dioxide discharge based on the adjacent space weight matrix. As shown in Table 3, the core explanatory variable has a significant direct impact on environmental pollution, and the direct impact is significantly lower than the indirect impact. Moreover, the levels of local economic development, industrial structure, urbanization and environmental regulations all display negative direct impacts on environmental pollution, though the total impacts of the latter three are at a positive level (Khan et al., 2019; Zmami and Ben-Salha, 2020).

3.4. Spatial correlation test

To enhance the robustness of the empirical results, this paper first changes the core explanatory variable from per capita environmental protection expenditure to the total environmental protection expenditure and inputs it into the model for regression. The model is transformed into:

$$SO2_{it} = \beta_0 + \delta WPO_{it} + \beta_1 EXP_{it} + \beta_2 GDP_{it} + \beta_3 IS_{it} + \beta_4 URBAN_{it} + \beta_3 ER_{it} + \theta_1 WEXP_{it} + \theta_2 WGDP_{it} + \theta_3 WIS_{it} + \theta_4 WURBAN_{it} + \varepsilon_{it} \quad (3)$$

where EXPit denotes the total environmental protection expenditure, and other explanatory variables remain unchanged. From the results in Table 4, we can see that both the regression direction and significance of all explanatory variables are basically in line with the benchmark regression. It suggests that the conclusion of this study is robust.

Table 2
Baseline regression result.

	(1)	(2)	(3)	(4)	(5)
	lnSO2	lnSO2	lnSO2	lnSO2	lnSO2
Wx					
lnPCEXP	0.0474	−0.132**	−0.128**	−0.122**	−0.0987*
	(1.01)	(-2.43)	(-2.37)	(-2.32)	(-1.86)
lnGDP		0.859***	0.765***	0.0724	−0.00704
		(6.82)	(5.17)	(0.36)	(-0.04)
lnIS			0.345**	0.774***	0.844***
			(2.01)	(4.07)	(4.35)
lnURBAN				2.599***	2.763***
				(5.06)	(5.34)
lnER					0.0599***
					(2.61)
Spatial					
rho	−0.116	−0.0712	−0.0850	−0.0410	0.00146
	(-1.44)	(-0.89)	(-1.05)	(-0.52)	(0.02)
Variance					
sigma2_e	0.0204***	0.0177***	0.0174***	0.0161***	0.0156***
	(12.83)	(12.84)	(12.84)	(12.84)	(12.85)

t statistics in parentheses* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3
Direct effect, indirect effect and total effect estimation results.

	(1)	(2)	(3)
	lnSO2	lnSO2	lnSO2
	LR_Direct	LR_Indirect	LR_Total
lnPCEXP	0.0710*	−0.0976*	−0.0266
	(1.72)	(-1.87)	(-0.61)
lnGDP	−0.128	−0.00536	−0.134
	(-0.84)	(-0.03)	(-1.03)
lnIS	−0.282**	0.834***	0.551***
	(-2.17)	(4.52)	(3.60)
lnURBAN	−1.252***	2.786***	1.534***
	(-4.71)	(5.30)	(3.32)
lnER	−0.0488***	0.0614***	0.0126
	(-3.12)	(2.61)	(0.63)

t statistics in parentheses* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Second, this paper replaces the explanatory variable of the total sulphur dioxide discharge by the total wastewater discharge. The model is then transformed into:

$$WA_{it} = \beta_0 + \delta WPO_{it} + \beta_1 PCEXP_{it} + \beta_2 GDP_{it} + \beta_3 IS_{it} + \beta_4 URBAN_{it} + \beta_3 ER_{it} + \theta_1 WPCEXP_{it} + \theta_2 WGDP_{it} + \theta_3 WIS_{it} + \theta_4 WURBAN_{it} + \varepsilon_{it} \quad (4)$$

where WA_{it} denotes the total wastewater discharge of the i-th province in the t-th year. Other variables remain unchanged. The same result is obtained, i.e., the regression direction and significance level of each variable are consistent with the baseline regression, proving the robustness of the model results as well. From the results in Table 5, when other variables are controlled, the local government's environmental protection expenditure makes a significant contribution to the increased environmental pollution in the local region and the mitigating environmental pollution in neighboring regions. It highlights that the "free-riding" phenomenon of local pollution improvement deserves more attention (Li et al., 2021).

4. Conclusion and suggestions

4.1. Conclusions

This paper investigates the spatial effect of local government's environmental protection expenditure combining the panel data from 30 provincial-level regions in China from 2007 to 2017 with Moran's I and spatial Dubin model. The conclusions are summarized below:

Table 4
Robustness test for different explanatory variables.

	(1)	(2)	(3)	(4)	(5)
	lnSO2	lnSO2	lnSO2	lnSO2	lnSO2
Wx					
lnEXP	0.0133	−0.154***	−0.150***	−0.135***	−0.112**
	(0.29)	(-2.91)	(-2.84)	(-2.63)	(-2.14)
lnGDP		0.862***	0.763***	0.0750	−0.00307
		(6.90)	(5.20)	(0.38)	(-0.02)
lnIS			0.348**	0.774***	0.844***
			(2.03)	(4.07)	(4.34)
lnURBAN				2.564***	2.731***
				(5.02)	(5.30)
lnER					0.0590***
					(2.58)
Spatial					
rho	−0.113	−0.0659	−0.0793	−0.0371	0.00397
	(-1.40)	(-0.82)	(-0.98)	(-0.47)	(0.05)
Variance					
sigma2_e	0.0203***	0.0175***	0.0173***	0.0160***	0.0155***
	(12.83)	(12.84)	(12.84)	(12.84)	(12.85)

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5
Robustness test for different explained variables.

	(1)	(2)	(3)	(4)	(5)
	lnWA	lnWA	lnWA	lnWA	lnWA
Wx					
lnEXP	−0.279***	−0.313***	−0.238**	−0.208**	−0.128
	(-3.26)	(-3.04)	(-2.41)	(-2.11)	(-1.28)
lnGDP		0.805***	1.022***	0.684*	0.524
		(3.39)	(3.79)	(1.81)	(1.39)
lnIS			1.164***	1.368***	1.712***
			(3.42)	(3.72)	(4.50)
lnURBAN				1.127	1.686*
				(1.15)	(1.71)
lnER					0.136***
					(3.14)
Spatial					
rho	0.655***	0.668***	0.492***	0.528***	0.505***
	(16.55)	(16.75)	(9.69)	(10.17)	(9.48)
Variance					
sigma2_e	0.0668***	0.0638***	0.0584***	0.0568***	0.0554***
	(12.48)	(12.45)	(12.61)	(12.55)	(12.57)

t statistics in parentheses* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

- The local government's per capita environmental protection expenditure shows an insignificant impact on the ecological environment of the local region. It may be because the level of local economic development does not reach the "inflection point" of the environmental Kuznets curve.
- The local government's per capita environmental protection expenditure plays a significant role in mitigating the environmental pollution of neighbouring areas and shows a positive space spillover effect. It reveals a serious "free-riding" phenomenon.
- Increasing the level of economic development, urbanization, environmental regulation and industrial structure in the local region can effectively improve the environmental pollution in the local region, while causing the deterioration of the ecological environment in the neighbouring regions.

4.2. Policy suggestions

4.2.1. Establish an intergovernmental ecological transfer payment system

On one hand, the transfer payment system of the central government to local governments should be perfected. Considering the spatially related effects of environmental pollution, we suggest increasing transfer payments to the regions where financial resources for environmental protection are insufficient. On the other hand, it is essential to perfect the ecological transfer payment system between governments at the same level. For example, building the ecological compensation mechanism between provinces or between municipalities is a good way.

4.2.2. Reform the appraisal system for officials that involve GDP only

We suggest adding economic development, environmental improvement and other indicators in the system. Introducing the concept of green GDP and including the local government's environmental protection performance into the appraisal system will encourage the local government to increase environmental protection expenditure and in turn generate a positive space spillover effect.

4.2.3. Clarify environmental protection responsibilities among local governments at all levels

From the empirical results, we find that the competition between provincial-level governments in fiscal expenditure may contribute to the deterioration of the ecological environment in neighboring areas. Therefore, it is urgent to clearly divide the environmental protection responsibilities of local governments at all levels, especially when it comes to cross-region ecological protection.

4.2.4. Strengthen the supervision in ecological protection regions

The present study suggests that environmental regulations can significantly improve the local environment. The local governments at all levels must reinforce the supervision of the ecological protection areas to ensure the implementation of environmental regulations.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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