# An Empirical Analysis on Spatial Effects of Environmental Protection Expenditure ——Evidence from China Provincial Panel Data

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**Abstract**

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. The results reveal the significant impact of environmental protection expenditure of the local government on the ecological environment improvement of neighbouring regions rather than the local region. This demonstrates a 'free-riding' phenomenon in environmental governance. In addition, increasing the levels of economic development, urbanisation, environmental regulations and industrial structure in the local region can effectively mitigate environmental pollution in the local region from one perspective and contribute to the deterioration of the ecological environment in neighbouring regions from another.

## 1. Introduction

During the past four decades since the reform and opening up, China has not only attained remarkable achievements, but also caused increasing destruction to the ecological environment (Pan, 2019). According to the 2018 China Eco-Environmental Status Bulletin by the Ministry of Ecology and Environment of the People's Republic of China, 121 of China's 338 cities at the prefecture level and above met the standards for ambient air quality, accounting for only 35.8 percent. After a series of reforms in the fiscal and taxation system since the 1980s, China has developed a fiscal decentralisation system different from the fiscal systems of the west (Zhang and Zou, 1998). In China, the selection and appointment of local governments is primarily determined by the higher-level or central government (Tsui, 2005). This urges local governments to compete for opportunities. The primary means of this competition is the fiscal expenditure (Jin *et al.*, 2005), as local governments have limited influence on the tax system. In this context, it is essential to analyse the spatial effect of the local government's environmental protection expenditure from the perspective of fiscal expenditure competition. This research intends 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 the basis of the spatial weight matrix, the spatial Dubin model (SDM) combined with the correlation test and fixed effect are used to explore the direction and influence of environmental protection expenditure on environmental pollution in the research region and nearby areas. Moreover, this research aims to provide policy recommendations for the enhancement of ecological environmental protection.

## 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 (Anselin, 2009). This is because the correct reflection of spatial structure guarantees the estimation validity of the spatial model (Anselin, 2009). The present study focuses on environmental pollution and how the discharge level of pollutants such as waste 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 herein 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:

$$Wij = \begin{cases} 1, \text{Region I and region j share a common geographic boundary} \\ 0, \text{Region I and region j share no common geographic boundary} \end{cases}$$

### *2.2. Variable selection*

*2.2.1. Explained variables.* Three forms of industrial waste (industrial waste gas, wastewater, and soot and dust) and other indicators are widely referred to in existing literature on environmental issues. In the present 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 sulphur dioxide discharge of each province is taken as the major explained variable, and the wastewater discharge of each province is applied to robustness analysis. In comparison with gas pollution indicators such as PM2.5, sulphur dioxide discharge has more complete available data and causes more severe environmental pollution. Notably, the Tibet Autonomous Region, where the data of sulphur dioxide discharge in some years are missing, is excluded. Finally, the discharge of sulphur dioxide and wastewater data in 30 provincial-level regions are extracted from the 2008 to 2018 *China Environmental Statistics Yearbook.*

*2.2.2. Explanatory variable.* Herein, 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 amongst provinces, per capita environmental protection expenditure in each province is calculated using 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 to 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, urbanisation, and environmental regulations. Firstly, the level of economic development in each province is calculated by the ratio of annual gross domestic product (GDP) to the number of year-end permanent residents. Regions with high-level economic development tend to take measures to meet the high standards of environmental pollution improvement whereas regions subject to low-level economic development are more inclined to sacrifice the environment for economic benefits. Secondly, the level of industrial structure is denoted by the ratio of the added value of the secondary industry to GDP. The secondary industry is characterised by high energy consumption and substantial pollution, and its increased proportion in the national economy will contribute to more serious industrial pollution, thus aggravating regional environmental pollution. Thirdly, the level of urbanisation is measured by the ratio of urban population to the year-end permanent residents. The growing urbanisation is often accompanied by more pollution. Fourthly, according to the common practices of scholars in Europe and the US, the level of environmental regulations is calculated by the ratio of the treatment costs of industrial wastewater and waste gas to the added value. Undoubtedly, the strengthening of environmental regulations plays a role in reducing the environmental pollution. The larger the calculated value of this indicator, the higher the level of environmental regulations in the industry (Greenstone, 2002). Annual GDP, year-end permanent resident population, urban population, and added value of the secondary industry in each province are collected from the 2008 to 2018 *China Statistical Yearbook*, whereas the industrial costs of wastewater and waste gas treatment are derived from the 2008 to 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 research, the impact of local government's environmental protection expenditure on both the local and neighbouring regions should be comprehensively considered. Due to China's fiscal decentralisation system, governments have to compete for limited resources, resulting in competition in the allocation of fiscal expenditure with neighbouring provinces (Zhang, 2006). 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. As such, it further analyses 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 proposed by Cliff and Ord in 1973 to measure the extent to which a specific variable influences neighbouring area and to test the similarity and dissimilarity of neighbouring regions in the entire area. It is primarily applied to the global convergence test. Generally, the value of Moran's I ranges between -1 and 1. The value greater than 0 reflects the spatial autocorrelation, namely, the larger the value, the stronger the correlation (Cliff and Ord, 1981). When the value is equal to 0, it indicates that the spatial distribution is random. A value less than 0 reveals that the adjacent units in the space have no similarities; thus, the smaller the value, the larger the difference. Moran's I is calculated as:

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

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 analyse the endogenous interaction effect between explained variables and the exogenous interaction effect between explanatory variables(Anselin and Griffith, 1988); whilst the interaction effects between the distraction terms are excluded. The baseline model applied in this research is expressed as:

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

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 urbanisation level of the i-th province in the t-th year and $ER_{it}$ 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 (Cliff and Ord, 1981*)*. Prior to spatial measurement, it is necessary to determine whether variables are related to or independent of each other. Therefore, a spatial correlation test is conducted. During the analysis of spatial measurement, spatial autocorrelation is measured by the spatial autocorrelation statistic Moran's I, namely Equation (1). The results of Moran's I test are presented in Table 1.

**Table 1.** Moran's I

| Year | $SO_2$ |
|---|---|
| 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

$^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

From Table 1, it can be observed that the global Moran's I of sulphur dioxide discharge has a positive value. In addition, the data between 2011 and 2016 exceeds 5 percent of the significance level test, and the remaining years exceed 10 percent of the significance level test. This suggests a significant positive spatial correlation between the levels of sulphur dioxide discharge amongst 30 provincial-level regions in China. This finding reveals the accumulation of environmental pollution occurring in the provincial regions in space. Thus, the spatial econometric model is applicable to the present study.

### *3.1.1 Identification test of space panel model*

An identification test of the spatial panel model is essential to build a correct spatial panel model and avoid the impact of model setting errors on the estimation results. This paper integrates the LR and Hausman tests to differentiate between random and fixed effects, as well as between the spatial lag model, spatial error model and SDM. The result of $chi^2 = -1.17 < 0$ in the Hausman test denies the hypothesis of random effect but supports fixed effect. Further, two p-values of 0.000 less than 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 and Hausman tests, it is concluded that the fixed-effect SDM is applicable to this research.

### *3.2. Spatial effect analysis*

According to the previous spatial correlation test and spatial panel model identification test, the fixed-effect SDM was employed to investigate 30 provincial-level regions in China. Notably, the control variables are added successively to enhance the robustness of the empirical result, as shown in Table 2.

**Table 2.** Baseline regression result

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | $lnSO_2$ | $lnSO_2$ | $lnSO_2$ | $lnSO_2$ | $lnSO_2$ |
| 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 $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

It can be observed that the coefficients of all control variables are at a significant level, proving the reliability of the control variables selected in this paper. Firstly, the regression coefficient of the core explanatory variable, per capita environmental protection expenditure, is significantly positive before and after the sequent addition of control variables. This indicates that the per capita environmental protection expenditure promotes the local pollution level; for every 1 percent increment in the expenditure, the local pollution level increases by 0.0695 percent. The levels of local economic development, urbanisation, environmental regulations, and industrial structure all demonstrate effectiveness in the improvement of environmental pollution in the local region. Secondly, from the regression coefficients of the spatial interaction in terms of the explanatory variables, it can be observed that the regression coefficients of the core explanatory variable remain significantly negative after the control variables are added. More specifically, the per capita environmental protection expenditure significantly mitigates the pollution of neighbouring regions, revealing an obvious ‘free-riding’ phenomenon. Moreover, the regression coefficients of the interaction terms of the control variables and the spatial weight matrix remain significantly positive. This demonstrates that the levels of local economic development, urbanisation, environmental regulations and industrial structure all contribute to more severe environmental pollution in neighbouring regions .

In order to comprehensively examine the impact extent of independent variables on dependent variables as well as their spatial spillover effect in SDM, the present study introduced the direct, indirect and total impact of all influence factors on sulphur 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. Thus, per capita environmental expenditure that closely correlates with a province's environmental pollution may change the pattern of national environmental pollution through the indirect impact (space spillover) transmission mechanism. Moreover, the levels of local economic development, industrial structure, urbanisation and environmental regulations all exhibit a negative direct impact on environmental pollution, although the total impact of the latter three are positive.

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

| | (1) | (2) | (3) |
|---|---|---|---|
| | $\ln SO_2$ | $\ln SO_2$ | $\ln SO_2$ |
| | 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 $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

*3.3. Robustness test*

To enhance the robustness of the empirical results, this paper initially 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:

$$\begin{aligned} SO2_{it} &= \beta_0 + \delta WPO_{it} + \beta_1 EXP_{it} + \beta_2 GDP_{it} + \beta_3 IS_{it} + \beta_4 URBAN_{it} + \\ &\beta_3 ER_{it} + \theta_1 WEXP_{it} + \theta_2 WGDP_{it} + \theta_3 WIS_{it} + \theta_4 WURBAN_{it} + \varepsilon_{\mathrm{it}} \end{aligned} \tag{3}$$

where $EXP_{it}$ denotes the total environmental protection expenditure and other explanatory variables remain unchanged. From the results in Table 4, it can be observed that both the regression direction and significance of all explanatory variables essentially correlate with the benchmark regression. This suggests that the conclusion of the present study is robust.

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

$$\begin{aligned} WA_{it} = \beta_0 + \delta WPO_{it} + \beta_1 PCEXP_{it} + \beta_2 GDP_{it} + \beta_3 IS_{it} + \beta_4 URBAN_{it} + \\ \beta_3 ER_{it} + \theta_1 WPCEXP_{it} + \theta_2 WGDP_{it} + \theta_3 WIS_{it} + \theta_4 WURBAN_{it} + \varepsilon_{\mathrm{it}} \end{aligned} \tag{4}$$

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, for example, 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 neighbouring regions. It highlights that the 'free-riding' phenomenon of local pollution improvement deserves more attention.

**Table 4.** Robustness test for different explanatory variables

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | $\ln SO_2$ | $\ln SO_2$ | $\ln SO_2$ | $\ln SO_2$ | $\ln SO_2$ |
| 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 $^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

## 4. Conclusion and recommendations

*4.1. Conclusion*

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 SDM. The conclusions are summarised as follows:

- The local government's per capita environmental protection expenditure demonstrates 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 exhibits a positive space spillover effect. It reveals a prominent 'free-riding' phenomenon.
- Increasing the level of economic development, urbanisation, environmental regulation and industrial structure in the local region can effectively improve the environmental pollution in the local region, whilst causing the deterioration of the ecological environment in the neighbouring regions.

*4.2. Policy recommendations*

*4.2.1. Establish an intergovernmental ecological transfer payment system.* From one perspective, the transfer payment system of the central government to local governments should be perfected (Czajkowski *et al.*, 2017). Considering the spatially related effects of environmental pollution, it is suggested that transfer payments to the regions where financial resources for environmental protection are insufficient should be increased (Brouwer, 2000). In contrast, 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 municipalities is an efficient method (Shang *et al.*, 2018).

*4.2.2. Reform the appraisal system for officials whilst involving GDP only.* It is advisable to introduce economic development, environmental improvement and other indicators into the system. Establishing 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 (Talberth and Bohara, 2006).

*4.2.3. Clarify environmental protection responsibilities amongst local governments at all levels.* From the empirical results, it was discovered that the competition between provincial-level governments in fiscal expenditure may contribute to the deterioration of the ecological environment in neighbouring areas. Therefore, it is urgent to clearly divide the environmental protection responsibilities of local governments at all levels, especially in terms of 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 (Li et al., 2020). Meanwhile, each financial sector should strengthen the construction of self-regulatory systems by monitoring the use of fiscal funds, conducting the performance evaluation of fiscal expenditure for environmental protection and other aspects (Lin and Zhu, 2019).

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