Research Article

Fiscal Decentralization and Environmental Pollution: A Spatial Analysis

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Based on annual data over the period 2003 to 2017 covering 31 provinces in China, the environmental pollution index and environmental regulation index are constructed. Moran's *I*, the widely used spatial autocorrelation index, is used to analyze the spatial distribution of environmental pollution, which provides a fairly high stability of the positive spatial correlation of environmental pollution. Then, the 0-1 matrix, distance weighting matrix, and economic distance mixed matrix are carried out to weigh space separately. To analyze the impact of fiscal decentralization on environmental pollution, the spatial Durbin model is employed. In the meanwhile, fiscal decentralization is measured from the perspective of both fiscal expenditure decentralization and fiscal revenue decentralization. The results show that the impact of fiscal decentralization on environmental pollution is positive and appears the phenomenon of "race to bottom." To improve environmental quality, appropriate environmental regulation target, implementing green GDP accounting, and adjusting economic structure should be adopted.

1. Introduction

China's economy has completed the transformation from surging growth to high-quality development, demanding requirements are put forward on resource allocation and environmental protection [1]. As environmental pollution has the features of negative externalities, the government is supposed to formulate policies to manage those issues. Then, how to exploit governmental means to intervene in the environmental governance and contamination shapes is a serious but realistic issue for the government.

In China, environmental problems are basically resulted from high industrial consumption and emissions [2]. As there exist spillover effects in pollution discharge [3] and local governments are assessed by economic growth, the local governments will try maximize their economic growth at the price of environment [4]. Long-standing, research studies on fiscal decentralization and environmental pollution concentrate on the competition between "race to bottom" and "race to top." Traditional federalism holds the opinion that local governments may choose high pollution discharge cross borders due to the transregional spillover effect of environmental contamination [5, 6]. You et al. [7] used the Chinese industrial companies' data to test the moderating effects of fiscal decentralization, and the results show that fiscal decentralization negatively moderates the effect of environmental regulation on firm eco-innovation. Liu et al. [8] explored the dynamic relationships between fiscal decentralization and environmental pollution under the framework of endogenous growth theory and found that fiscal decentralization and haze pollution decoupling display an inverse U-shaped relationship. Hao et al. [9] draw the similar conclusion by investigating the impact of fiscal decentralization on environmental quality in China both theoretically and empirically. Wang and Lei [10] studied the effect of fiscal decentralization on different industrial pollutant discharges and also held the opinion that Chinese-style fiscal decentralization exacerbates environmental pollution.

Scholars supporting "race to top" argue that governments, when confronted with residentials' potential threat

"voting by foot," will increase the supply of public goods and improve the environmental quality after embracing larger financial independence [11]. Glazer [12] held the opinion that jurisdiction can export pollution by imposing regulations that induce firms, causing the pollution to move elsewhere; therefore, fiscal decentralization may strengthen local environmental regulation and improve local environmental quality. Fredriksson and Millimet [13] believed that states are pulled to higher levels of abatement costs by improvements in neighbors with regulations. Kuai et al. [14] made an attempt to bridge the gap by making use of two kinds of fiscal decentralizations and found that both the decentralizations have positive effects on environmental improvement.

Regarding fiscal decentralization and environmental pollution, scholars at home and abroad have engaged in ample investigations which are important theoretical and approach references for the study. Fiscal decentralization potentially impacts the actions of local governments; in the meantime, environmental regulations directly influence the state of local environmental pollution. Therefore, it is of great significance to probe into the way that government regulation influences environmental pollution under fiscal decentralization.

Compared with references, shown below are the contributions of the paper. First, both fiscal expenditure decentralization and revenue decentralization are simultaneously included in the scope of analysis and their influences on environmental pollution are compared. Second, the comprehensive index of environmental pollution constructed by five kinds of pollutants is used to measure the provincial environmental pollution in China. Third, three geographic weighting matrices, that is, 0-1 weight matrix, distance weight matrix, and economic distance nesting matrix are used in the spatial analysis.

The remainder of this paper is structured as follows. Section 2 explains the model construction and variable selection. Section 3 presents the empirical results. Section 4 concludes and offers policy suggestions.

2. Model Construction and Variable Selection

2.1. Model Construction

2.1.1. Construction of the Basic Model. Environmental pollution is featured with spatial spillover. The effect of environmental regulations on the environmental pollution under fiscal decentralization was planned to be analyzed by spatial econometrics. Given that the spatial Durbin model (SDM) accounts the influences of both spatial-lag explained variable and explanatory variable on the explained variables and can well capture the externalities and spillover effects from different sources [16], the model was employed in this analysis. The general form of the SDM is expressed as

$$y_{it} = \delta \sum_{j=1}^{N} W_{ij} y_{jt} + c + X_{it}\beta + \theta \sum_{j=1}^{N} W_{ij} X_{jt} + \mu_i + \lambda_t + \varepsilon_{it},$$

$$(1)$$

where y_{it} denotes the explained variable, δ denotes the spatial autoregressive coefficient, θ denotes the spatial autocorrelation coefficient, w_{ij} denotes the element corresponding to the spatial weighting matrix, X_{it} denotes the explanatory variable, β denotes the coefficient of explanatory variables, $\sum_{j=1}^{N} w_{ij} y_{jt}$ and $\sum_{j=1}^{N} w_{ij} x_{jt}$ denote the spatial interaction terms, μ_i and λ_t denote the specific effects of space and time, respectively, and ε_{it} denotes the error term (Anselin et al., 2006).

2.1.2. Settings of Spatial Weighting Matrix. To avoid the defects of a single-factor spatial weighting matrix describing the spatial relevance of economic affairs and to examine the robustness of regression results, the geographic distance matrix and economic distance nesting matrix are utilized in addition to the traditional 0-1 adjacent weight matrix. These three weighting matrixes are expressed as follows:

(1) Let $w_{ij} = 1$ if geographic units i and j are adjacent to each; otherwise, $w_{ij} = 0$.

(2) The geographic distance matrix $W = \begin{cases} 1/d^2, i \neq j \\ 0, i = j \end{cases}$, where d represents the distance between two locations (measured by the longitude and latitude of the provincial capital).

(3) The economic distance nesting matrix $W = W_d \cdot \text{diag}((\overline{Y_1}/\overline{Y}), (\overline{Y_2}/\overline{Y}), \dots, (\overline{Y_n}/\overline{Y}))$, where W_d represents the geographic distance weight matrix, $\overline{Y_i}$ represents the average GDP of area i during the inspection period, and $\overline{Y}$ represents the average GDP of all regions during the inspection period. The economic distance nesting matrix reflects that the more advanced the economy of a region, the more intensified the spatial impact and radiation of the region on the backward areas surrounding it.

2.2. Variable Selection

2.2.1. Explained Variable

(1) Environmental Pollution Index (EPI). It is mainly resulted from the discharge of industrial pollutants. Calculation of environmental pollution integrated index by using the horizontal and vertical scatter-degree approach enables the prevention of environmental pollution from human subjective factors [17]. The environmental pollution integrated index was constructed by five categories of environmental pollution indicators: industrial wastewater discharge, industrial waste gas discharge, industrial sulfur dioxide discharge, industrial smoke and dust discharge, and industrial solid waste discharge. Through calculation, the combined weights of these indicators are $w_1 = 0.1526$, $w_2 = 0.2177$, $w_3 = 0.2200$, $w_4 = 0.2076$, and $w_5 = 0.2022$, respectively.

2.2.2. Explanatory Variables

(1) Fiscal Decentralization (FD). Fiscal decentralization is expressed as FD = $fdp/(fdp + fdf)$, where fdp and fdf denote the per capita fiscal expenditure and budget revenue at the provincial level and central level, respectively. If fdp and fdf represent per capita fiscal expenditure, then FD denotes fiscal expenditure decentralization (FDE). Similarly, if fdp and fdf represent per capita budget revenue, then FD denotes fiscal revenue decentralization (FDV) [18].

(2) Environmental Regulation (ER). In general, the strength of the ER was measured by input cost and output effect. With reference to the investigation by Ren el al. [19], the entropy method was adopted to measure the comprehensive potency of environmental regulation [19]. From the human cost, material cost, and financial cost of environment, the cost indicators are selected, of which the human cost indicator was measured by the number of employees in the administrative department, the material cost indicator by the sum of numbers of wastewater treatment facilities, and the financial cost indicator by the proportion of investment in environmental pollution treatment to GDP. For the environmental regulatory output indicators, the economic output of industrial waste discharge in each region was included. That is to say, the measurement was performed by the ratio of industrial added value to industrial wastewater emissions, industrial exhaust emissions, industrial sulfur dioxide emissions, industrial soot emissions, and industrial solid waste emissions.

2.2.3. Control Variables

(1) Economic Development (PGDP). With different levels of economic development, the impact of fiscal decentralization and environmental regulations on local environmental pollution also varies. Therefore, the economic development levels of different regions are measured by per capital GDP.

(2) Industrial Structure (STR). Environmental pollution is mainly produced by the secondary industry. Whether the development of the tertiary industry is conducive to improving environmental pollution was examined.

(3) Foreign Direct Investment (FDI). The actual use of foreign direct investment represents the use of foreign investment in a region and is converted into RMB using the international exchange rate.

(4) Urbanization (CITY). In the process of urbanization, huge amounts of pollution will be produced and the living and consumption habits will greatly vary between residents. Therefore, the level of urbanization in a region was expressed by the indicator of urban population/total population.

Given the demand to balancing the panel, the data of 31 provinces (municipalities) in China from 2003 to 2017 was selected for analysis, which were sourced from *China Statistical Yearbook*, *China Environmental Yearbook,* and *China*

Environmental Statistical Yearbook. Relevant data were processed with logarithm when calculated. The descriptive statistics of variables are shown in Table 1.

3. Econometric Analysis

Before the empirical analysis, the variance inflation factor (VIF) is employed to test whether data suffer from multi-collinearity or not.

As can be seen from Table 2, the maximum value of the variance inflation factor is close to 7, less than 10. Therefore, multicollinearity can be ignored in the empirical analysis of panel data [20].

3.1. Spatial Autocorrelation Test. Whether the environmental regulations and environmental pollution hold spatial dependence in general was tested by global Moran's I index which is expressed by an equation as follows:

$$\text{Moran's } I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\sum_{i}^{n}\sum_{j=1}^{n}w_{ij}\sum_{i=1}^{n}(x_i - \overline{x})^2}, \quad (2)$$

where x_i and x_j represent the indices of spatial units i and j, respectively, n represents the total number of spatial units, and w_{ij} represents the spatial weight matrix. 31 provinces (cities) in China are put into analyses, with n is equal to 31.

From equation (2), the value of Moran's I index ranges from −1 to 1. When Moran's I index is greater than 0, it indicates a positive spatial correlation of the analysis index: the larger the value, the stronger the positive spatial correlation. Moran's I index is less than 0, indicating a negative spatial correlation of the analysis index: the closer the value is to negative 1, the stronger the spatial negative correlation. Because the setting of weighting matrix does not affect the relevance of indicators, that is, it does not affect the positive and negative nature of Moran's I index, we employed the simplest 0-1 weighting matrix to measure the value of Moran's I index. The global Moran's I index for environmental pollution and environmental regulation is shown in Table 3.

According to Table 3, China's environmental pollution comprehensive index is positive and P values are lower than 0.1. Namely, they passed the significance test at levels of 10% and above. According to the definition of Moran's I Index, the provincial environmental pollution in China harbors a positive spatial correlation and significant clustering in spatial distribution.

Despite revealing the overall characteristics of environmental pollution, global Moran's I is incapable of embodying the specific characteristics of object individuals. In contrast, local Moran's I is able to reflect individual heterogeneity and discloses the specific situation of each province [21]. The local Moran's I index is calculated as

$$\text{Local Moran's } I_i = \frac{n(y_i - \overline{y})\sum_{j=1}^{n}d_{ij}(y_j - \overline{y})}{\sum_{j=1}^{n}d_{ij}(y_j - \overline{y})^2}. \quad (3)$$

In equation (3), each symbol denotes the same meaning as global Moran's I. Local Moran's I index of each province from 2003 to 2017 was calculated by using the same

TABLE 1: Descriptive statistics of variables.

Indicator	Variable	Average	Std.dev.	Min	Max
Environmental pollution index	EPI	2.004	0.683	0.595	4.408
Environmental regulation	ER	0.0268	0.0004	0.0075	0.1108
Fiscal decentralization measured by expenditure (%)	FD_exp	0.814	0.063	0.563	0.960
Fiscal decentralization measured by revenue (%)	FD_rev	0.471	0.113	0.245	0.856
Economic development (ten thousand yuan per person)	PGDP	1.002	0.602	−1.021	2.557
Industrial structure (%)	STR	0.426	0.062	0.283	0.805
Foreign direct investment (ten thousand yuan)	FDI	14.253	1.451	8.121	16.932
Urbanization (%)	CITY	0.507	0.114	0.226	0.896

TABLE 2: Multicollinearity test.

Variable	VIF	1/VIF	Variable	VIF	1/VIF
ER	2.07	0.4829	ER	2.09	0.4786
FD_exp	2.05	0.4884	FD_rev	6.07	0.1646
PGDP	5.99	0.1669	PGDP	5.18	0.1932
STR	1.90	0.5255	STR	1.90	0.5267
FDI	2.32	0.4308	FDI	2.25	0.4451
CITY	3.85	0.2595	CITY	6.97	0.1433

TABLE 3: Global Moran's I of environmental pollution.

	Environmental pollution			
	Moran's I	VAR (I)	Z	P value
2003	0.1845	0.0118	2.0062	0.0448
2004	0.1700	0.0117	1.8816	0.0599
2005	0.2065	0.0118	2.2103	0.0271
2006	0.2130	0.0117	2.2731	0.0230
2007	0.1898	0.0117	2.0618	0.0392
2008	0.2173	0.0118	2.3082	0.0210
2009	0.2139	0.0118	2.2742	0.0230
2010	0.1937	0.0117	2.1016	0.0356
2011	0.2173	0.0109	2.3979	0.0165
2012	0.1898	0.0111	2.1212	0.0339
2013	0.1768	0.0109	2.0104	0.0444
2014	0.2035	0.0114	2.2180	0.0266
2015	0.2195	0.0116	2.3505	0.0188
2016	0.2622	0.0112	2.7931	0.0052
2017	0.2065	0.0118	2.2103	0.0271

equation. Because of the limitation in passage length, only Moran' I scatter plots of the 2003 and 2017 environmental pollution comprehensive index are shown in Figure 1.

Based on Figure 1, in the cluster inspection of environmental pollution integrated index, 13 provinces are in the first quadrant and 6 provinces are in the third quadrant in 2013, with a proportion of 61% in the total cities in the first and third quadrants; 12 provinces are in the first quadrant and 5 provinces are in the third quadrant in 2017, with a proportion of 54% in the total cities in these two quadrants. The first quadrant indicates severe pollution of an area and heavy pollution of its surrounding areas (HH). The third quadrant indicates a better environmental quality of an area and the surrounding area (LL). The second quadrant indicates that a better environmental quality of an area and severe environmental pollution in its surrounding areas (LH). The fourth quadrant indicates a serious environmental pollution of an area and a good environmental

quality of its surrounding regions (HL). The environmental pollution Moran' I scatter plot in 2003 and 2017 accounts for more than 50% in the first and third quadrants, and the trend line of scatter inclines to the upper right, indicating a positive spatial concentration of environmental pollution in regions.

3.2. Empirical Analysis. Before spatial econometric analysis, the existence of spatial autocorrelation was tested and the rationality of the selected spatial model was verified. The fundamental panel model is shown in the following equation:

$$y_{it} = \alpha_0 + \alpha_1 X_{it} + \alpha_2 Z_{it} + \varepsilon_{it}, \quad (4)$$

where i and t, respectively, represent the data of the i-th province in the t-year, y represents the comprehensive index of environmental pollution, X represents the core
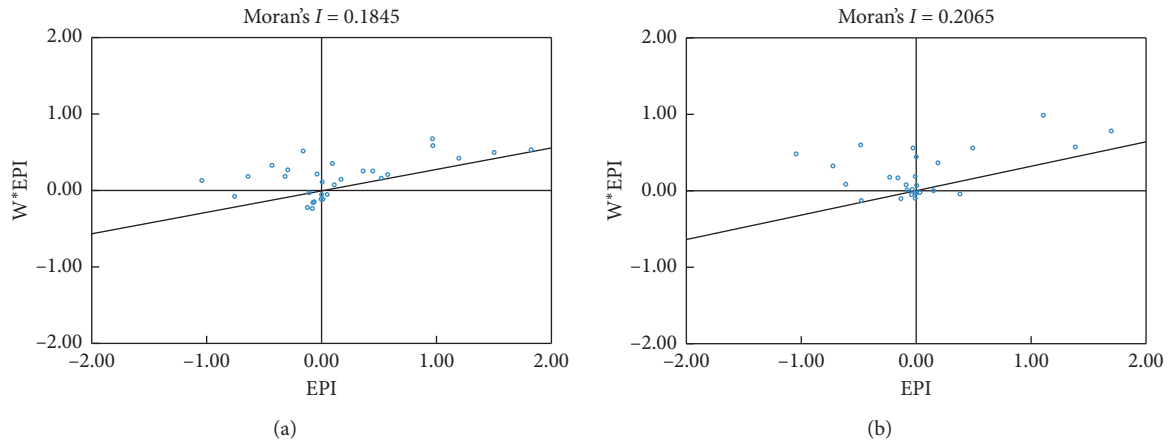
FIGURE 1: Moran scatter plot for environmental pollution in (a) 2003 and (b) 2017.

TABLE 4: Estimation results of panel data models without spatial interaction effects.

Variable	Expenditure fiscal decentralization				Revenue fiscal decentralization			
	Pooled OLS	Spatial fixed effects	Time-period fixed effects	Spatial and time-period fixed effects	Pooled OLS	Spatial fixed effects	Time-period fixed effects	Spatial and time-period fixed effects
FD	10.777*** (8.362)	4.649** (2.552)	17.293*** (4.166)	4.156** (2.042)	5.507 (1.533)	2.831** (2.001)	5.771* (1.704)	3.954*** (2.618)
ER	−0.472* (−1.885)	−0.161*** (−7.578)	−0.141*** (−6.550)	−0.146*** (−6.672)	−0.540*** (−3.171)	0.191 (−1.559)	−1.531*** (−5.823)	−0.297** (−2.336)
ER^2	0.074*** (11.073)	0.010*** (2.618)	0.061*** (7.511)	0.010** (2.545)	0.043*** (4.418)	0.005 (0.957)	0.088*** (6.912)	0.009 (1.572)
FD*ER	−1.161*** (−4.271)	0.059 (0.324)	−1.747*** (−4.445)	0.088 (0.444)	−0.120 (−0.389)	0.296** (2.057)	−0.480 (−1.636)	0.312** (2.160)
PGDP	−0.097 (−0.867)	0.039 (0.666)	0.124 (0.812)	0.056 (0.513)	−0.566*** (−6.891)	−0.168*** (−3.320)	0.106 (0.597)	−0.390*** (−2.878)
STR	−2.342*** (−6.441)	−0.718*** (−2.824)	−2.140*** (−5.504)	−0.557 (−1.498)	−1.516*** (−3.707)	−0.123 (−0.502)	−1.954*** (−4.203)	−0.092 (−0.242)
CITY	−0.021 (−0.058)	0.961*** (2.757)	−1.096** (−2.168)	1.208*** (3.271)	−1.493*** (−3.196)	0.514 (1.470)	−2.012*** (−4.373)	0.567 (1.592)
FDI	−0.033 (−0.161)	0.470*** (5.291)	−0.188 (−0.921)	0.495*** (5.519)	0.200** (2.364)	0.171*** (3.362)	0.034 (0.425)	0.167*** (3.295)
FD*FDI	0.011 (0.044)	−0.583*** (−5.465)	0.199 (0.806)	−0.611*** (−5.687)	−0.223 (−1.178)	−0.460*** (0.001)	0.017 (0.099)	−0.483*** (−4.374)
σ^2	0.688	0.028	0.221	0.027	0.281	0.030	0.236	0.109
R^2	0.682	0.157	0.706	0.169	0.627	0.088	0.686	0.029
LogL	−318.856	176.392	−305.001	181.556	−360.335	158.213	−320.008	165.297
LM$_{lag}$	33.831***	0.463	36.003***	3.175*	6.535**	1.447	11.061***	5.750**
LM$_{error}$	48.470***	0.169	41.406***	3.436*	4.956**	0.927	3.238**	5.066**
LR test	Spatial fixed effects		LR = 973.129, $P \leq 0.001$				LR = 970.611, $P \leq 0.001$	
	Time-period fixed effects		LR = 10.327, $P = 0.079$				LR = 14.167, $P = 0.091$	

Figures in parentheses are T Statistic; *, **, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

explanatory variable of fiscal decentralization and the intensity of environmental regulations and their interaction terms, and Z represents the set of other control variables that affect environmental pollution, which here refers to the level of economic development, industrial structure, foreign direct investment, and urbanization.

Nonspatial panel parameter estimation and spatial autocorrelation test results are shown in Table 4.

From the mixed estimates and joint significance tests in Table 4, the null hypothesis of no spatial effects is rejected. For the environmental regulation of fiscal decentralization measured separately by expenditure and income, the Hausman test statistics of the space-specific effects of the pollution equation were 27.4982 and 23.4613, respectively, and both obeyed the chi-squared distribution ($2 * K + 1$) with 19 degrees of freedom. The null hypothesis of spatial random effects was rejected at the level of 5%

and above, so the two-dimensional fixed space-time model is more suitable for characterizing data. A corresponding spatial Durbin model was structured with a basic form as

$$y_{it} = c + \delta \sum_{j=1}^{31} W_{ij} y_{jt} + \alpha_1 X_{it} + \alpha_2 Z_{it} + \alpha_1 \sum_{j=1}^{31} W_{ij} X_{it} \\ + \alpha_2 \sum_{j=1}^{31} W_{ij} Z_{it} + \mu_i + \lambda_t + \varepsilon_{it}. \tag{5}$$

In equation (5), all parameters have the same meaning with the ones in the previous equation. The estimated results of the spatial Durbin model of environmental pollution treatment under different specific effect forms are shown in Table 5.

The results of environmental pollution estimation based on fiscal decentralization in terms of expenditure were first analyzed. When the geographic distance matrix and the economic distance nested matrix were used for spatial weighting, the influence coefficient (W * EPI) of the spatial lag of environmental pollution on the environmental pollution of this space unit was positive and passed the significance test at the level of 5% or above. When spatial weighting was performed with a 0-1 matrix, the influence factor of the spatial lag of environmental pollution on the environmental pollution of the space unit is negative, and it failed in the significance test. This shows that when the spatial lag of environmental pollution is accounted, the weight of distance should be considered as well; moreover, it was not supposed to depend solely on whether geographically borders are used as the judging conditions for the proximity of two spatial units. A positive symbol indicates that the environmental pollution in adjacent areas will aggravate the degree of environmental pollution in this space unit, which was due to the spillover effect of environmental pollution and reflected the characteristics of spatial concentration of environmental pollution.

The first-order coefficient (ER) of the impact of environmental regulation on environmental pollution is positive, and the second-order coefficient (ER2) is negative; the impact of environmental regulation on environmental pollution is U-shaped. When the degree of regulation is low, as the intensity increases, environmental regulation reduces environmental pollution. When the regulatory intensity reaches a certain value, as the intensity increases, environmental regulations will exacerbate environmental pollution. This shows that when the environmental protection investment is low, various local enterprises will cooperate with the government to save energy and reduce emissions and environmental pollution. However, when companies with high environmental protection requirements cannot afford it, output-oriented enterprises and GDP-oriented governments begin to seek their own development paths, even at the expense of the environment. The spatial lag term (W * ER) of environmental regulation is negative and passed the significance test at the level of 5% and above, indicating

that environmental pollution features public goods and environmental pollution treatment exerts a significant spillover effect. Although the impact of a region's environmental regulations on environmental pollution in the region changes with the development of its regulatory intensity, it will slow down the degree of environmental pollution in the surrounding regions. Therefore, environmental pollution treatment requires overall planning at the national level; otherwise, it is easy for local governments to be "hitchhiker." When the distance matrix is used for spatial weighting, the interaction coefficient of fiscal decentralization and environmental regulation (FD * ER) has an impact coefficient of 0.091 and passes the significance test at the level of 10%. It shows that environmental regulation under the decentralization system does exacerbate environmental pollution. This is because the main incentive for local governments under the decentralization system is to increase government GDP, and environmental quality is not a very important indicator for government assessment.

The positive impact of fiscal decentralization (FD) on environmental pollution indicates that finance has exacerbated environmental pollution. This is consistent with the research results of Liu et al. [22], which confirm the "race to bottom" hypothesis. The spatial lag of fiscal decentralization (W * FD) has a negative impact on environmental pollution, but the coefficients have not passed the significance test, suggesting that the fiscal policies of neighboring governments wield no significant stable impact on the environmental quality of the region.

The negative impact of industrial structure (STR) on environmental pollution and coefficients passing the significance test at the level of 10% and above indicates the contribution of an increased proportion of third industry to mitigation on environmental pollution. The negative spatial lag terms (W * STR) of industrial structure implies the betterment of tertiary industry's development on the optimization of the environment in surrounding space units. Because of the spillover and spatial agglomeration characteristics of environmental pollution, fundamental alleviation of current environmental pollution in China requires the government to adjust the industrial structure fundamentally, guiding it to upgrade and enabling more high energy-consuming and high-polluting industries to transform into technology and capital-intensive ones.

The coefficient of urbanization on environmental pollution is negative and significant at the 1% significance level. At present, China's urbanization process is exacerbating environmental pollution largely due to the large-scale implementation of infrastructure construction, pollution-intensive industries, required in the process of urbanization. The coefficient of urbanization spatial lag terms (W * CITY) vary greatly with the stability levels of weight matrix, suggesting significant stable effect of a region's urbanization on the environmental pollution of its surrounding space units.

When using the 0-1 matrix, geographic distance matrix, and economic distance nested matrix to perform spatial weighting, the impact coefficient of foreign direct investment (FDI) on environmental quality is around 0.4 and passed the significance test at the level of 1%. Foreign direct

TABLE 5: Estimation results of the SDM model.

	Expenditure fiscal decentralization			Revenue fiscal decentralization		
	0-1 rook matrix	Geographic distance matrix	Economic distance nesting matrix	0-1 rook matrix	Geographic distance matrix	Economic distance nesting matrix
$W * EPI$	−0.063 (−0.979)	0.283*** (3.229)	0.237** (2.559)	−0.028 (−0.444)	0.118* (1.686)	0.047* (1.724)
FD	2.696 (1.398)	5.912*** (2.848)	4.724** (2.232)	4.370*** (2.901)	5.131*** (3.463)	5.537*** (3.688)
ER	−0.330* (−1.658)	−0.063 (−0.306)	−0.177 (−0.836)	−0.368*** (−3.037)	−0.403*** (−3.441)	−0.350*** (−2.864)
ER^2	0.011*** (3.012)	0.010*** (2.685)	0.012*** (2.929)	0.013** (2.424)	0.014*** (2.650)	0.012** (2.103)
$FD * ER$	0.174 (0.849)	0.091* (1.675)	0.007 (0.033)	0.217 (1.535)	0.302** (2.207)	0.287** (2.012)
PGDP	0.145 (1.341)	−0.025 (−0.229)	0.008 (0.078)	−0.188 (−1.327)	0.351*** (2.710)	0.266* (1.922)
STR	−0.852** (−2.358)	−1.045*** (−2.671)	−0.648* (−1.670)	−0.232* (−1.675)	−0.245* (−1.684)	−0.170** (2.423)
CITY	1.456*** (4.092)	1.163*** (3.322)	1.045*** (2.890)	1.097*** (3.090)	0.887*** (2.606)	0.625* (1.773)
FDI	0.446*** (4.334)	0.392*** (3.627)	0.407*** (3.944)	0.182*** (3.534)	0.210*** (4.305)	0.212*** (4.290)
$FD * FDI$	−0.533*** (−4.301)	−0.494*** (−3.780)	−0.506*** (−4.063)	−0.455*** (−4.037)	−0.556*** (−5.101)	−0.574*** (−5.260)
$W * ER$	−0.889** (−2.134)	−1.667** (−2.425)	−2.994*** (−2.615)	0.412 (1.623)	−0.221 (−0.354)	−0.643 (−0.568)
$W * ER^2$	−0.005 (−0.737)	−0.007 (−0.276)	0.024 (0.609)	−0.024** (−1.940)	−0.003 (−0.132)	0.012 (0.312)
$W * FD$	−17.522 (−1.348)	−18.687 (−1.317)	−14.072 (−1.514)	−4.363 (−1.358)	−2.533 (−0.591)	−4.805 (−0.806)
$W * FD * ER$	1.347*** (3.362)	2.499*** (3.417)	3.019*** (3.300)	0.754** (2.276)	1.116*** (2.845)	0.867* (1.653)
$W * PGDP$	−0.612*** (−3.272)	−1.142*** (−3.368)	−0.714* (−1.915)	−0.802*** (−3.044)	−0.045 (−0.105)	0.101 (0.201)
$W * STR$	−2.448*** (−2.762)	−2.261* (−1.817)	−0.947 (−0.579)	−1.142 (−1.217)	−0.450 (−0.352)	−2.381 (−1.415)
$W * CITY$	−1.832** (−2.370)	−1.898 (−1.500)	−0.486 (−0.335)	−2.524*** (−3.262)	−3.799*** (−3.202)	−1.573 (−1.108)
$W * FDI$	0.010 (0.049)	0.836*** (0.106)	1.504*** (3.772)	0.114 (0.975)	0.415*** (2.867)	0.335 (1.605)
$W * FD * FDI$	−0.047 (−0.185)	−1.059*** (−3.322)	−1.986*** (−1.986)	−0.314 (−1.286)	−1.113*** (−3.519)	−0.692 (−1.563)
σ^2	0.023	0.022	0.024	0.025	0.024	0.026
R^2	0.768	0.869	0.967	0.965	0.967	0.964
LogL	216.592	218.120	205.224	194.893	205.448	186.422
Wald (SAR)	76.138***	82.435***	56.235***	61.989***	88.960***	44.707***
LR (SAR)	70.064***	73.037***	47.204***	58.452***	79.722***	40.863***
Wald (SEM)	74.754***	74.458***	51.693***	62.263***	87.643***	44.762***
LR (SEM)	69.728***	69.558***	46.782***	59.087***	79.962***	41.418***

Figures in parentheses are T Statistic; *, **, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

investment has indeed exacerbated environmental pollution, which confirms the "pollution refuge" hypothesis. The spatial lag of foreign direct investment (WFDI) has a positive impact coefficient on environmental pollution, indicating that foreign investment in China is mainly a pollution-intensive industry, and there is a significant pollution spillover effect. The estimated coefficient of the cross term of fiscal decentralization and foreign direct investment (FD * FDI) is negative and passed the significance test at the level of 1%, indicating that foreign investment behavior under the decentralization system will reduce environmental pollution. This is mainly because after the local government has the

financial autonomy, it is more inclined to introduce enterprises using more advanced production technologies and pollution emission systems, thereby alleviating the pressure on local environmental pollution.

The environmental pollution estimation results based on revenue-based fiscal decentralization (on the right side of Table 4) were basically consistent with the results of fiscal decentralization measured by expenditures, reflecting the robustness of the calculation results.

The spatial Durbin model not only includes the influence of a region on spatial weighting but also reflects the influence of the explanatory variables of a region on its surrounding

TABLE 6: The direct effects, indirect effects, and total effects of the spatial Durbin model (expenditure fiscal decentralization).

	0-1 rook matrix			Geographic distance matrix			Economic distance nesting matrix		
	Direct effect	Indirect effect	Total effects	Direct effect	Indirect effect	Total effects	Direct effect	Indirect effect	Total effects
ER	−0.308 (−1.467)	−0.807* (−1.996)	−1.115** (−2.542)	0.001 (0.006)	−1.339** (−2.403)	−1.338** (−2.354)	−0.113 (−0.510)	−2.464** (−2.650)	−2.578*** (−2.863)
ER²	0.011*** (2.869)	−0.006 (−0.874)	0.004 (0.542)	0.011** (2.639)	−0.007 (−0.380)	0.003 (0.142)	0.010** (2.579)	0.019 (0.570)	0.030 (0.926)
FD	2.907 (1.485)	−16.787*** (−4.178)	−13.879*** (−3.101)	6.669*** (3.064)	−16.422** (−2.510)	−9.752 (−1.524)	5.081** (2.340)	−12.444 (−1.615)	−7.363 (−0.975)
FD * ER	0.148 (0.712)	1.270*** (3.282)	1.419*** (3.496)	−0.186 (−0.859)	2.039*** (3.372)	1.852*** (3.348)	−0.058 (−0.260)	2.490*** (3.309)	2.432*** (3.445)
PGDP	0.155 (1.420)	−0.602*** (−3.112)	−0.447** (−2.126)	0.020 (0.182)	−0.923*** (−3.322)	−0.903*** (−3.262)	0.022 (0.200)	−0.594* (−1.914)	−0.571* (−1.781)
STR	−0.822** (−2.257)	−2.328*** (−2.750)	−3.150*** (−3.111)	−0.966** (−2.662)	−1.600* (−1.726)	−2.567** (−2.352)	−0.644 (−1.693)	−0.661 (−0.487)	−1.306 (−0.868)
CITY	1.484*** (4.222)	−1.820** (−2.500)	−0.336 (−0.423)	1.252*** (3.569)	−1.816* (−1.820)	−0.564 (−0.558)	1.054*** (2.926)	−0.576 (−0.479)	0.477 (0.385)
FDI	0.441*** (4.195)	−0.017 (−0.086)	0.423** (2.242)	0.366*** (3.254)	0.587** (2.569)	0.953*** (4.886)	0.377*** (3.487)	1.166*** (3.415)	1.543*** (5.276)
FD * FDI	−0.526*** (−4.194)	−0.013 (−0.054)	−0.539** (−2.334)	−0.459*** (−3.376)	−0.745** (−2.734)	−1.205*** (−5.272)	−0.466*** (−3.541)	−1.547*** (−3.605)	−2.014*** (−5.474)

Figures in parentheses are *T* Statistic; *, **, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

TABLE 7: The direct effects, indirect effects, and total effects of the spatial Durbin model (revenue fiscal decentralization).

	0-1 rook matrix			Geographic distance matrix			Economic distance nesting matrix		
	Direct effect	Indirect effect	Total effects	Direct effect	Indirect effect	Total effects	Total effects		Direct effect
ER	−0.362*** (−2.954)	0.411 (1.662)	0.048 (0.169)	−0.402*** (−3.391)	−0.154 (−0.263)	−0.557 (−0.932)	−0.347** (−2.741)	−0.605 (−0.556)	−0.953 (−0.879)
ER²	0.013** (2.341)	−0.024* (−1.983)	−0.011 (−0.788)	0.014** (2.656)	−0.004 (−0.189)	0.010 (0.456)	0.012* (2.001)	0.011 (0.298)	0.023 (0.606)
FD	4.330*** (2.952)	−4.318 (−1.363)	0.012 (0.003)	5.198*** (3.435)	−2.774 (−0.706)	2.423 (0.617)	5.623*** (3.705)	−4.639 (−0.806)	0.984 (0.169)
FD * ER	0.224 (1.620)	0.770** (2.293)	0.995** (2.597)	0.283* (2.067)	0.980** (2.555)	1.264*** (3.085)	0.287* (2.032)	0.832 (1.503)	1.120* (1.898)
PGDP	−0.202 (−1.434)	−0.826*** (−3.127)	−1.028*** (−3.673)	−0.356** (−2.704)	0.006 (0.017)	−0.349 (−0.863)	−0.264* (−1.862)	0.096 (0.201)	−0.168 (−0.343)
STR	−0.246 (−0.690)	−1.163 (−1.246)	−1.409 (−1.292)	−0.232 (−0.577)	−0.348 (−0.281)	−0.581 (−0.398)	0.166 (0.414)	2.310 (1.420)	2.476 (1.363)
CITY	1.085*** (3.102)	−2.554*** (−3.223)	−1.468* (−1.730)	0.969*** (2.776)	−3.616*** (−3.202)	−2.646** (−2.296)	0.625* (1.726)	−1.516 (−1.079)	−0.891 (−0.615)
FDI	0.182*** (3.563)	0.120 (1.031)	0.303** (2.293)	0.204*** (4.161)	0.359** (2.486)	0.563*** (3.575)	0.213*** (4.246)	0.322 (1.488)	0.536** (2.400)
FD * FDI	−0.456*** (−4.080)	−0.328 (−1.365)	−0.785*** (−2.999)	−0.538*** (−4.910)	−0.962*** (−2.993)	−1.501*** (−4.358)	−0.579*** (−5.223)	−0.665 (−1.406)	−1.245** (−2.555)

Figures in parentheses are *T* Statistic; *, **, and *** denote statistical significance levels at 10%, 5%, and 1%, respectively.

areas [23]. Shown in Table 6 are the estimated results of the direct, indirect, and total effects of the spatial Durbin model.

From Table 7, the direct effects of explanatory variables are basically the same as the direction and significance level of coefficient estimation under the spatial Dubin model. However, there were slight differences in the values, which is due to the existence of explanatory variables and spatial lags of explanatory variables in the spatial Dubin model, namely, the feedback effect [23]. Weighted by a 0-1 matrix, the direct impact coefficient of environmental regulations on environmental pollution is −0.380, while the impact coefficient of nonspatial panel environmental regulation on environmental pollution is −0.472. This meant an overestimation by 34.7% on the absolute value of nonspace panel's environmental pollution treatment and investment coefficient. The spatial regulatory coefficient of the spatial Durbin model is −0.330, while the feedback effect of environmental regulation was 0.022, accounting for 7.1% of the direct effect. Other explanatory variables showed different degrees of feedback effects, further proving the rationality of the spatial Durbin model selection.

4. Conclusion and Enlightenment

The problem of environmental pollution has always been a hotspot of concern for the government and academia. Although China's fiscal system is unique, it is of great significance to explore how environmental regulation under Chinese fiscal decentralization affects environmental pollution. Therefore, with the 2003–2017 panel data of 31 provinces (cities) in China, the global spatial autocorrelation index and local spatial autocorrelation index were used to characterize the spatial distribution of environmental pollution and environmental regulations. The effect of environmental regulation intensity on environmental pollution was empirically analyzed by a spatial Durbin model. The results are as follows:

(1) There is a significant positive correlation between environmental pollution and environmental regulations in spatial distribution

(2) The impact of environmental regulation on environmental pollution is U-shaped, and the decentralization system in China has exacerbated the environmental pollution effect of environmental regulation

(3) Because of the existence of feedback effects, the direct effects of various influencing factors on environmental pollution are basically the same as the coefficient estimation direction and significance level under the spatial Durbin model, but there are slight differences in the values

Based on the conclusions of the above empirical study, the following inspirations for policy were drawn:

(1) Establish a multidimension assessment mechanism and implement green GDP accounting. Fiscal decentralization has a clear "race to bottom" effect on environmental pollution. Environmental regulations under a decentralized system have exacerbated environmental pollution, mainly because the main incentives for local governments under the decentralized system are to increase government GDP and pay little attention to environmental quality. Therefore, a more comprehensive government assessment mechanism should be established, environmental quality should be included in the assessment category, and green GDP should be used as an assessment indicator of government performance, so as to avoid local governments from adopting "race to bottom" in order to increase the local economic aggregate.

(2) Adjust the economic structure and realize industrial transformation and upgrading. Increasing the proportion of the tertiary industry can effectively alleviate environmental pollution. Therefore, the government should vigorously develop the tertiary industry with low pollution emissions, such as the modern service industry. At the same time, the government should increase research and development efforts and guide the upgrading of the industrial structure to transform more high energy-consuming and highly polluting industries into technology and capital-intensive industries. At this stage, foreign investment is mainly pollution-intensive industries, which has exacerbated China's environmental pollution. In response, the government should adjust the trade structure and implement a green trade strategy.

Data Availability

The data used to support the findings of this study are included within the supplementary information files.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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