

Original Research

How Does Public Participation in Environmental Protection Affect Air Pollution in China? A Perspective of Local Government Intervention

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Abstract

Weak institutions hinder the improvement of air quality in developing countries. This paper focuses on whether public environmental participation can correct the adverse effects of government behavior on air quality in weak institutional settings using the spatial econometric model based on China's panel data during 2003-2017. The results show that local government intervention is not conducive to environmental improvement. This adverse impact has spatial spillover effects due to competition among local governments for promotion. The public cannot rely on their own strength to form constraints on local government behavior. However, with the central government's help, public environmental participation can effectively restrain the adverse effects of improper intervention by local governments on air quality. After considering the heterogeneity of air pollutants, with the central government's assistance, public environmental participation only has a statistically significant improvement effect on sulfur dioxide. We believe that the characteristics of pollutants and local governments' strategic response to the public are the main reasons for this result. The findings indicate that local governments are mainly accountable to the central government under the performance-based appointment system. The impact of public environment participation is highly dependent on the central government.

Keywords: local government intervention, public environmental participation, central government pressure on pollution control, air pollution

Introduction

Air pollution has been a global problem. The high pollution concentrations can cause a series of diseases and even shorten human life [1-3]. Since some pollutants that affect air quality, such as sulfur dioxide (SO₂), mainly come from developing countries¹, air quality improvement in these countries plays an important role in improving global air quality.

The weak institutions are the main obstacle to improving well-being in many developing countries [1]. It is becoming more and more important to analyze the dilemmas of environmental governance from the institution and design effective environmental governance mechanisms for these countries. As the largest developing country, China is currently at a critical stage of economic transformation. To achieve the coordination of economic development and environmental protection, the Chinese government has implemented a series of environmental protection policies [4]. However, according to the “Global Environmental Performance Index (EPI)” released by Yale University, although China has formulated a series of environmental policies, China’s environmental performance is still at a low level, especially in the air. Therefore, studying China’s environmental governance dilemma from the institutional perspective will give other developing countries a reference in environmental governance.

In the process of China’s environmental governance, the central government and local governments have clear responsibilities and concrete work-division. China’s environmental policies are generally made and prompted by the central government but implemented by local governments [5, 6]. Scholars believe that the dilemma of environmental governance in China is caused by the ineffective implementation of environmental policies [7-9]. So the perverse incentive structure set by the central authorities affects the policy implementation gap at the local level [8]. The existing researches advises that the central government can effectively control China’s environmental pollution by changing its incentive structure to local governments [10, 11].

However, in the national governance system, the central government assigns various tasks to local governments, including fiscal revenue, social stability, and employment, in addition to environmental protection. It is impossible for the

central government to blindly increase the assessment weight of environmental protection to promote local governments to fulfill their environmental protection responsibilities while ignoring other tasks. From this perspective, it is unreasonable to rely solely on the central government to change the incentive structure to correct local government behavior. From the experience of developed countries such as the United States and the European Union, a scientific environment governance system includes the government and the public. Nowadays, the central government is paying more and more attention to the public’s role in environmental protection. In the new “Environmental Protection Law,” the central government puts forward the modern environmental governance model of multi-governing. This environmental governance model has changed the traditional way of mainly relying on the government to control pollution alone, highlighting the importance of public environmental participation. So does public environmental participation help correct the adverse effects of local government intervention on the air quality? If so, how does public environmental participation achieve it? This paper attempts to answer the above questions based on the Chinese institution and data. Compared with existing researches, the contributions of this paper lie in the following aspects.

Firstly, to our best knowledge, this is the first study to empirically incorporate the central government, local government, and the public into a research framework and investigate the mechanism of public environmental participation affecting the air quality. The role of public environmental participation has long been concerned [12-17]. However, these studies focus on the influencing factors of public environmental participation or the impact of public environmental participation on environmental quality. Research on the public environmental participation mechanism is still insufficient. We find that for a developing country like China, it is difficult for the public to restrain the adverse effects of local government intervention on air quality, relying on its strength. Only with the assistance of the central government can the restraining effect of public environmental participation be significant.

Secondly, this paper studies the impact of local government behavior on the environment from the perspective of government economic intervention and makes up for the lack of existing research on government economic intervention behavior. On the one hand, the government can restrict corporate pollution emissions through environmental regulations. On the other hand, it can influence the environment by guiding the flow of resources. The existing researches focus on government environmental regulation behavior [18-20], while the latter is relatively lacking. Although Yu [21] considers the impact of government intervention on the environment, the research regards each local government as an independent individual and ignores the competition among local governments. The “relative performance appraisal” under the centralized

¹ According to the Global SO₂ emission hotspot database, 23 of the 25 countries with the highest SO₂ emissions in 2018 are developing countries. Countries with annual emissions exceeding 1,000Kt are all developing countries. The top three with the most SO₂ emissions are India, Russia, and China, with 4586kt, 3683kt, and 2578kt, respectively. The United States has the most sulfur dioxide emissions among developed countries, but the average annual emissions are only 967Kt.

political power has made local governments pay close attention to competitors' behavior, which leads to mutual influence among local governments. This paper introduces the spatial econometric model to describe the competition among governments.

Thirdly, our paper provides an explanation for a relatively controversial topic-whether public environmental participation can achieve air quality improvement. The existing literature has two opposing views on the impact of public participation on pollution. Cole et al. [22] found that no evidence has been found to prove that there is an important relationship between pollutant emissions and public environmental participation in China. However, Wu et al. [17] found that public participation can help reduce pollutant emissions. After considering the heterogeneity of air pollutants, we find that under the pressure of the central government's willingness to control pollution, public environmental participation has a significant improvement effect on SO_2 . In contrast, the improvement effects on CO_2 and Smoke and Dust (SD) are not significant. Our results show that public environmental participation has a limited effect on reducing air pollutants that are colorless, tasteless, or non-binding emission reductions.

Methodology and Data

Methodology

Bernauer and Koubi [23] conduct an in-depth study of the relationship between government behavior and the environment. Bernauer and Koubi [23] set a panel data model as Equation (1) to test the impact of government size on environmental pollution.

$$POL_{it} = a_0 + \sum \beta_j X_{jit} + \varepsilon_{it} \quad (1)$$

where POL_{it} is the pollution level of the period t in the region i . X_{jit} is the control variable. a_0 is constant. ε_{it} is the error term. β_j is the parameter to be estimated.

Combined with the research purpose, this paper expands Equation (1).

$$POL_{it} = a_0 + \beta_1 LGEI_{it} + \beta_2 EPCG_{it} + \beta_3 EPP_{it} + \beta_4 LGEI_{it} * EPCG_{it} + \beta_5 LGEI_{it} * EPP_{it} + \beta_6 EPCG_{it} * LGEI_{it} + \beta_7 EPCG_{it} * EPP_{it} * LGEI_{it} + \sum \beta_j X_{jit} + \varepsilon_{it} \quad (2)$$

where $LGEI_{it}$ is the local government intervention. $EPCG_{it}$ is the environmental protection pressure from the central government. EPP_{it} is public participation in environmental protection. They are the core explanatory variables of this article.

For China, under the performance-based personnel appointment system, local governments face promotion pressure. To gain an advantage in promotion, local governments may compete with other governments.

The behavioral decisions of local governments may have spatial spillover effects. So this paper introduces the spatial weight matrix based on Equation (2).

$$\begin{cases} POL_{it} = a_0 + \rho w'_i POL_{it} + \sum_{j=1}^6 \beta_j z_{ijt} + \sum_{j=7}^n \beta_j x_{ijt} + \sum_{j=1}^6 \theta_j d'_i z_{jt} + \sum_{j=7}^n \theta_j d'_i x_{jt} + \varepsilon_{it} \\ \varepsilon_{it} = \lambda m'_i \varepsilon_{it} + v_{it} \end{cases} \quad (3)$$

where, z_{it} include $LGEI_{it}$, $EPCG_{it}$, EPP_{it} , and interaction terms. w'_i is the i th row of the spatial weight matrix W . d'_i is the i th row of the spatial weight matrix D . m'_i is the i th row of the spatial weight matrix M .

Equation (3) is the general expression of the spatial econometric model.

When $\theta_j = 0$, Equation (3) is the spatial autocorrelation model (SAC).

When $\theta_j = 0$ and $\lambda = 0$, Equation (3) is the spatial autoregressive model (SAR).

When $\theta_j = 0$ and $\rho = 0$, Equation (3) is the spatial error model (SEM).

When $\lambda = 0$, Equation (3) is the spatial Durbin model (SDM).

When $\rho = 0$ and $\lambda = 0$, Equation (3) is the spatial lag of X model (SLX).

In the research process, the appropriate model should be selected according to the real situation.

Variables Selection

Air Pollution POL_{it}

Many pollutants affect air quality. The researchers usually choose SO_2 , $PM_{2.5}$, and CO_2 [23, 24] to reflect air quality. However, the pollutant concentration in the air is not only affected by the government's behaviors but also by natural conditions such as weather and topography. This paper mainly discusses the air pollution caused by the government's behaviors from the institutional perspective. The pollutant concentration in the air is not conducive to analyzing government behavior. On the contrary, the Chinese government conducts environmental governance mainly by regulating enterprises. So adopting corporate pollution emissions is more helpful to analyze changes in government behavior. Therefore, according to the existing researches, this paper adopts industrial SO_2 and CO_2 to measure air quality. As industrial smoke and dust (SD) is one of the main pollutants that cause haze weather, this paper replaces $PM_{2.5}$ with SD.

Existing researchers often use a single pollutant or comprehensive index to measure environmental pollution. However, Bai et al. [10] believe that a single pollutant cannot fully reflect the pollution situation. So Bai et al. [10] adopt many pollutants to construct a pollution index. This paper follows Bai et al. [10] to adopt a comprehensive pollution index to measure

air quality. The entropy method [17] and principal component analysis [10] are often used to construct a comprehensive index. Therefore, this paper adopts the entropy method to carry out research and uses principal component analysis to test the result's robustness.

This paper divides the pollutant by the scale of production to avoid the impact of enterprises' production scale. The industrial added value is deflated with 2003 as the base period. The greater the intensity of pollution discharge, the more serious the air pollution. It is worth noting that since 2011 industrial smoke and industrial dust are combined into one indicator. So this paper sums up industrial smoke and industrial dust before 2011. Fig. 1 shows the distribution of air quality in different regions. It can be seen that the difference in air quality was relatively large in the early period, but after 2009 this difference has gradually decreased.

Local Government Intervention LEI_{it}

Government spending is the primary tool for the government to realize resource allocation. The low proportion of government spending indicates that the proportion of resources allocated by the market is relatively high. On the contrary, the high proportion of government spending indicates that the high the proportion of the government in allocating resources, that is, the stronger the government's ability to intervene. Therefore, we adopt the proportion of government spending to GDP to measure local government intervention [25, 26]. Since government spending is a positive function of government power, institutions, and employees, it can better reflect the government's ability to intervene.

Public Environmental Participation PEP_{it}

The existing researches measure public environmental participation according to environmental protection awareness and environmental actions [14, 20]. However, environmental awareness only indicates the possibility of public environmental participation and does not reflect the real level of public environmental participation. Therefore, this paper uses letters of environmental complaints to measure public environmental participation. The letters of environmental complaints are divided by the total population to eliminate the impact of population size.

The Environmental Protection Pressure of the Central Government $EPCG_{it}$

The environmental protection pressure of the central government is abstract and difficult to be measured. Because the text's conception mode and language characteristics can reflect the author's intention [27], the $EPCG_{it}$ can be measured through the government work report issued by the central government. Chen et al. [28] use environment-related words to measure the intensity of local government environmental regulations. These words are *huanjing*, *nengyuan*, *wuran*, *jianpai*, *huanbao*. Another scholar's research uses richer words [29]. These words are *huanjingbaohu*, *huanbao*, *wuran*, *nenghao*, *jianpai*, *paiwu*, *shengtai*, *lvse*, *ditan*, *kongqi*, *eryanghualiu* (SO_2), *eryanghuatan* (CO_2), *huaxuexuyangliang* (COD), PM_{10} , $PM_{2.5}$. In terms of processing methods, Chen and Chen [29] first perform word segmentation processing on the text of the government work report, then count the frequency of environment-related words, and calculate its proportion

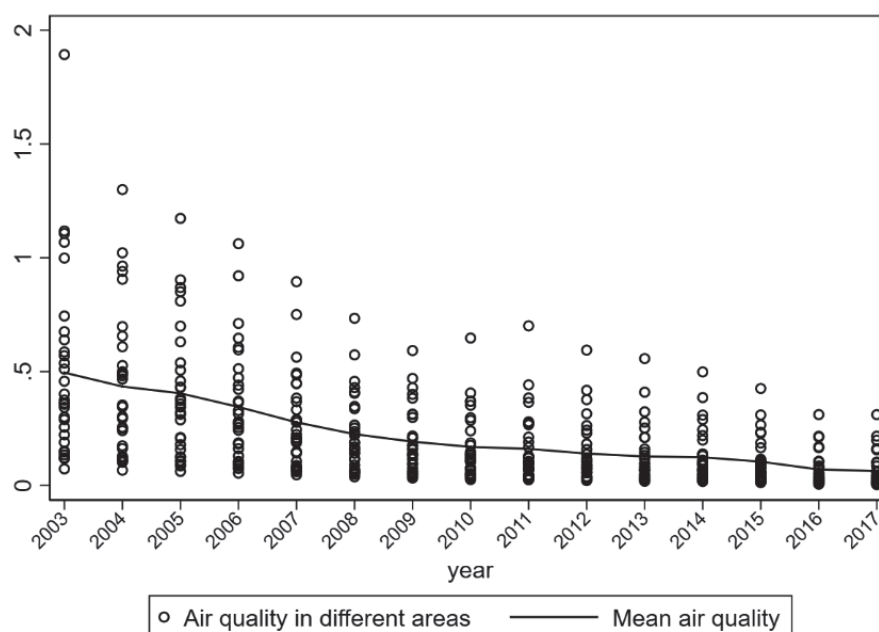


Fig. 1. The pollution in different regions.

to the total word frequency of the full text. However, the term *huanjingbaohu* can not reflect the meanings of *huanjingzhiliang* and *huanjingziyuan*. According to Chen et al. [28], the *huanjingbaohu* is replaced with *huanjing*².

The Level of Economic Development PGDP_{it}

We measure the level of economic development by real GDP per capita. The existing research indicates an inverted U-shaped relationship between the level of economic development and environmental pollution [9]. When the economy is at a low level, the environment will be sacrificed for economic growth. When the economy is at a high level, there will be sufficient funds for pollution control. This paper introduces the square term of the economic development level to verify whether the relationship holds.

Industrial Structure INS_{it}

The ratio of the secondary industry's added value to the GDP is used to measure the industrial structure. The existing researches have different conclusions on the impact of industrial structure on environmental pollution. Wang et al. [30] believe that as the secondary industry's proportion increases, the environment worsens. However, Bai et al. [10] hold the opposite idea that there is a negative relationship between the proportion of the secondary industry and the environment. Existing studies show that the relationship between industrial structure and environmental pollution may not be a simple linear relationship, so the square term of industrial structure is introduced to test.

Foreign Direct Investment FDI_{it}

The existing researches about the impact of foreign direct investment on environmental pollution can be divided into two categories. One is the Pollution Refuge Hypothesis, which believes that foreign direct investment is not conducive to improving environmental quality. The other is Pollution Halo Hypothesis, which believes that foreign direct investment improves environmental quality. Therefore, the direction of the

impact of foreign direct investment on environmental pollution is unclear.

Population POP_{it}

The greater the population size, the greater the demand for public employment. To ease employment pressure, local governments may lower environmental regulations to introduce labor-intensive enterprises. From this perspective, the greater the population size, the more adverse the impact on the air quality.

Environmental Regulation ER_{it}

Local governments can implement environmental regulations on enterprises to internalize the external costs of the environment. Reasonable environmental regulation can regulate the production behavior of enterprises and encourage enterprises to develop environmentally friendly production technologies. We use the ratio of environmental pollution control investment to the GDP to measure environmental regulation. Urban infrastructure construction in environmental pollution investment does not directly affect the behavior of enterprises. If we do not eliminate it, we will overestimate the impact of environmental regulation on enterprises. Therefore, this paper eliminates it.

Coal ConsumptionIntensity CI_{it}

Coal consumption is the main cause of air pollution. This paper uses coal consumption per unit GDP to measure the dependence of economic development on coal.

R&D Investment R&D_{it}

The scale and intensity of R&D investment can be used to measure the technical level [10]. Regions with higher R&D intensity may have more advanced and more environmentally friendly production technologies, thereby reducing environmental problems caused by enterprise production.

Data Source

The data of SO₂ and the SD come from the China Environmental Yearbook. The CO₂ can be collected from the China Emission Accounts & Datasets. The GDP, industrial added value, secondary industry added value, government spending, population, foreign direct investment, GDP index, and industrial added value index are from the China Statistical Yearbook, Compilation of Statistical Data for Sixty Years of New China, and Provincial Statistical Yearbook. For the missing industrial added value index, the secondary industry index is used instead because industry is the largest proportion in the secondary industry.

2 The number of occurrences of the following words is subtracted. This is because although these words contain the word „*huanjing*“, they have nothing to do with the ecological environment. These words are as follows: *zhengzhihuanjing*, *jingjihuanjing*, *wenhuanjing*, *touzihuanjing*, *xiaofeihuanjing*, *zhianhuanjing*, *guojihuanjing*, *hepinghuanjing*, *zhoubianhuanjing*, *jiuyehuanjing*, *neiwaihuanjing*, *fazhanhuanjing*, *tizhianhuanjing*, *jinronghuanjing*, *yulunhuanjing*, *fazhianhuanjing*, *chuangxinhuanjing*, *chuangyehuanjing*, *maoyihuanjing*, *xinyonghuanjing*, *jingmaohuanjing*, *lyy-ouhuanjing*, *zhengcehuanjing*, *waibuhuanjing*, *zhiduhuanjing*, *wangluohuanjing*, *wendinghuanjing*, *yingshanghuanjing*, *jingzhenghuanjing*, *yinghuanjing*, *ruanhuanjing*.

Table 1. Definitions and descriptive statistics of variables.

Variable	Definition	N	Mean	Std. Dev.	Min	Max
<i>POL</i>	Air quality	450	0.2222	0.2418	0.0038	1.8927
<i>LGI</i>	Local government intervention	450	0.2102	0.0936	0.0768	0.6269
<i>EPCG</i>	The environmental protection pressure of the central government	15	5.6224	1.3591	3.1421	8.2682
<i>PEP</i>	Public environmental participation	450	6.4929	6.6410	0.0156	42.7435
<i>PGDP</i>	The level of economic development	450	2.5088	1.6197	0.3504	9.0013
<i>INS</i>	Industrial structure	450	0.4668	0.0801	0.1901	0.6148
<i>FDI</i>	Foreign direct investment	450	0.0256	0.0206	0.0004	0.1050
<i>ER</i>	Environmental regulation	450	0.0142	0.0099	0.0015	0.0889
<i>R&D</i>	R&D investment	450	1.3860	1.0961	0.1783	7.4086
<i>CI</i>	Coal consumption intensity	450	1.6462	1.6002	0.0378	8.3457
<i>POP</i>	Population	450	4.4288	2.6625	0.5340	11.1690

R&D expenditure comes from the China Science and Technology Statistical Yearbook. Coal consumption comes from the China Energy Consumption Statistical Yearbook.

Considering that the central government put forward the “Scientific Development Concept” in 2003, it changed the development path of purely pursuing GDP by sacrificing the environment and linked environmental performance assessment with cadres’ promotion. Therefore, the sample period is from 2003 to 2017. Table 1 presents the definitions and descriptive statistics of variables in this research.

Results and Discussion

Spatial Correlation Analysis

We use Moran’s I index to identify whether variables have a spatial correlation. The range of values allowed for Moran’s I index is -1 to 1 . When the Moran’s I index is close to 1 , it explains the strong positive spatial correlation. On the contrary, when the Moran’s I index is close to -1 , it explains the great negative spatial correlation. The greater the absolute value of Moran’s I index, the stronger the spatial correlation of air pollution.

The statistical formula of Moran’s I index is:

$$I = \frac{n \sum_{i=1}^n \sum_{j=1}^n w_{ij} (POL_i - \bar{POL}) (POL_j - \bar{POL})}{\left(\sum_{i=1}^n \sum_{j=1}^n w_{ij} \right) \left[\sum_{i=1}^n (POL_i - \bar{POL})^2 \right]} \quad (4)$$

n is the number of observations. i and j represent the area i and the area j . w_{ij} is an element of the spatial weight matrix of w . When area i adjacent to area j ,

$w_{ij} = 1$. When area i and area j are not adjacent or $i = j$, $w_{ij} = 0$.

Fig. 2 shows the spatial correlation of POL_{it} from 2003 to 2017. It can be seen from Fig. 2 that the Moran’s I index are all positive and pass the test at the significance level of 5%. It shows that there is a significant positive spatial correlation of pollution. Therefore, spatial factors should be considered in the research.

Empirical Results and Analysis

In order to avoid multicollinearity, this paper calculates the correlation coefficients of each variable. Table 2 shows the correlation coefficients for variables. From Table 2, it can be seen that there is no serious multicollinearity problem between the variables. As indicated in Table 2, the correlation coefficient between local government intervention and pollution is positive. It means that government intervention is not conducive to the improvement of air quality. Otherwise, it also can be seen that the correlation

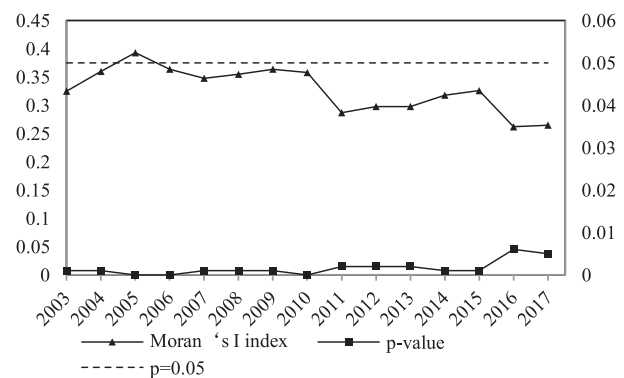


Fig. 2. Global Moran’s I test of China’s pollution integrated index from the year 2003-2017

Table 2. Correlation coefficients.

Variables	<i>POL</i>	<i>LGI</i>	<i>EPCG</i>	<i>PEP</i>	<i>PGDP</i>	<i>INS</i>	<i>FDI</i>	<i>ER</i>	<i>R&D</i>	<i>CI</i>
<i>LGI</i>	0.1808									
<i>EPCG</i>	-0.3038	0.2053								
<i>PEP</i>	-0.2597	-0.0924	-0.0560							
<i>PGDP</i>	-0.5952	-0.132	0.3584	0.4688						
<i>INS</i>	0.0683	-0.2251	-0.1573	-0.0706	-0.1514					
<i>FDI</i>	-0.3152	-0.4186	-0.1100	0.3037	0.2979	0.0110				
<i>ER</i>	0.2402	0.4717	0.1047	-0.0200	-0.1033	-0.1702	-0.2089			
<i>R&D</i>	-0.4015	-0.1915	0.1012	0.4237	0.5997	-0.3169	0.3091	-0.1538		
<i>CI</i>	0.7193	0.2623	-0.1005	-0.2137	-0.3992	0.2484	-0.3820	0.4491	-0.3454	
<i>POP</i>	-0.3011	-0.5296	0.0241	-0.1246	0.0151	0.2743	-0.0470	-0.3842	-0.0030	-0.2887

coefficient of public environmental participation and air pollution is negative. It means that public environmental participation can reduce air pollution. However, how public environmental participation can achieve air pollution reduction needs to be studied further.

Under the appointment system, local governments compete for promotion. Therefore, there are mutual influences between local governments' behaviors, and the influence will inevitably affect air quality. In the process of model selection, in addition to considering the spatial lag effect of air pollution, the spatial effects of other factors need to be considered. Based on this consideration, the SDM model is the first choice for this paper. The regression results are shown in Table 3. The regression coefficient of *EPCG* is the null value. It is because the environmental protection pressure of the central government is measured according to the annual central government work report. All regions face the same pressure from the upper-level government to control pollution. Therefore, considering the direct effect and the indirect effect simultaneously, the problem of complete collinearity appears.

Firstly, we estimate Equation (3) without considering the spatial effects (Model 1). Secondly, the estimation results of the SDM are shown in Model 2. The spatial correlation coefficient ρ in model 2 does not pass the test of 10% significance ($p = 0.1084$), which means that there is no spatial spillover effect of the pollutant itself. The major reasons for this situation are as follows. First of all, the pollutants selected in this paper are measured from industrial enterprises' pollutant discharge outlets, not the pollutant concentration in the air. Therefore, these pollutant data do not be affected by transboundary spillovers. Secondly, generally speaking, there is a competitive relationship between industrial enterprises in the same region. The competitive relationship among industrial enterprises in different regions is relatively weak. Therefore, there may not be direct imitation between industrial enterprises in different regions.

We believe that explanatory variables mainly cause the global spatial correlation of air pollution. Therefore, we choose the spatial SLX to test the above hypotheses. Because the explanatory variables of the SLX model do not include the spatial lag of the explained variable, the estimation technology of the ordinary panel model is still applicable to the SLX model. In order to correct for panel heteroscedasticity, the model is estimated using the econometric technique advocated by Beck and Katz [31]. The results are reported in Table 3 (Model 3).

Moreover, this paper takes one period of lag on local government intervention, central government pollution control pressure, and public environmental participation to avoid reverse causality. From model 1 to model 3, we can see that local government intervention is not conducive to air quality. The results show that the direct effect of government intervention on air pollution is positive and pass the test at the significance level of 1% (the direct effect of *L.LGI* is 0.7218 and $p < 0.01$). It indicates that the excessive intervention of local governments is not conducive to air quality. And this kind of intervention has a spatial spillover effect. The local government intervention from neighboring regions will also inhibit the improvement of local air quality (the indirect effect of *L.LGI* is 1.0744 and $p < 0.01$).

The results show that the coefficient of *L.PEP* does not pass the test at the significance level of 10%. It indicates that it is difficult to form effective constraints on air pollution, relying on the public's power alone. Simultaneously, the coefficient of *L. (LGI*PEP)* is 0.0111 and does not pass the test at the significance level of 10%, indicating that local governments do not respond to public environmental demands when making relevant decisions. The coefficient of *L.(PEP*EPCG)* is -0.0012 and pass the test at the significance level of 5%. It shows that public participation can significantly force enterprises to reduce pollution emissions under the central government's pollution control pressure. Otherwise, under the combined pressure of public environmental participation and central government

environmental pressure, the adverse impact of local government intervention on the air quality is restricted (the coefficient of $L.(LGI * PEP * EPCG)$ is -0.0227 and $p < 0.05$). It shows that under the environmental protection pressure of the central government, public environmental participation can effectively restrain the adverse impact of local government behavior. Moreover, the indirect effect of $L.(LGI * PEP * EPCG)$ passes the test at the significance level of 5%. The indirect impacts of $L.(PEP * EPCG)$ and $L.PEP$ do not pass the test at the significance level of 10%. The indirect impacts of $L.PEP$ and $L.(LGI * PEP)$ are positive. It means that public environmental participation can not form a positive demonstration effect by their strength.

The Direct Effects of Control Variables

The coefficients of the economic development level ($PGDP$), foreign direct investment (FDI), environmental regulation (ER), coal consumption structure (CI), and population (POP) are statistically significant and have the expected signs (note that a negative sign indicates that the variable can improve the air quality, as the dependent variable captures the level of pollution).

Without considering the spatial spillover effect, there is a nonlinear relationship between industrial structure and air pollution (see Model 1). When considering the spatial spillover effect, although the impact of the secondary industry's square term on air quality is no longer significant, it is still positive (see Model 3). It may be because when the secondary industry accounts for a relatively low proportion, the improvement and sharing of clean technology will be realized as the secondary industry increases. However, when the secondary industry accounts for a relatively high proportion, it is difficult for the government to determine who is responsible for the pollution discharge due to a large number of polluting enterprises. Enterprises are prone to pollution mimicry.

The technical level measured by $R\&D$ is not conducive to the improvement of air quality. This conclusion is consistent with Bai et al. [10]. Technologies can be divided into production technologies and pollution emission reduction technologies. The former mainly affects factor productivity, and the latter affects mostly pollution intensity. This paper's results indicate that $R\&D$ investment may be used more to promote the progress of production technology rather than the progress of "green" technology, leading to the expansion of production scale and showing a certain increase in air pollution. This reminds us that if we want to use technology to improve air quality, it is particularly important to guide $R\&D$ investment towards pollution reduction technologies effectively.

The Indirect Effects of Control Variables

The level of the economic development level ($PGDP$), environmental regulation (ER), $R\&D$

investment, and population (POP) are statistically significant, and the signs are consistent with the direct effects. This shows that there are competing imitations among local governments. The indirect effects of industrial structure (INS) and FDI are not statistically significant. The indirect effect of coal consumption intensity (CI) is significantly negative. One possible reason is that because coal resources are limited, increasing coal consumption in neighboring areas will inevitably lead to a decrease in local coal consumption.

Robustness Test

To verify the robustness of our key conclusions, we re-estimate the SLX model in two ways.

Firstly, in order to eliminate occasional factors that cause the annual abnormal fluctuations in government spending. We use the 3-year moving average instead of the current year's value. For example, in 2003, the average value from 2001 to 2003 is used, and in 2004, the average value from 2002 to 2004 is used. The results are reported in Table 4 (Model 1).

Secondly, we use the principal component analysis (PCA) to construct an air pollution index. Before constructing the air pollution index, we standardize the data and use the Kais-Meyer-Olkin (KMO) Test and the Bartlett Ball Coefficient Test to examine the applicability of principal component analysis. The results show that the KMO Test value is 0.697, which is greater than 0.5. The P -value of the Bartlett test is 0.000, which is significant at the 1% level. The KMO test and Bartlett test results show that the principal component analysis method is suitable for air pollution. The characteristic value of the first principal component extracted from it is 2.607, which is greater than 1, indicating that the information obtained by this component should be retained. At the same time, the cumulative contribution rate of the first principal component is 86.92%, which mostly reflects the information of the original variables. Therefore, the first principal component is used to construct a comprehensive air pollution index. The results are reported in Table 4 (Model 2).

According to Table 4, the relationship among public participation in environmental protection, local government intervention, and air pollution are similar to our analysis above.

Further Analysis

In the previous analysis, we constructed a comprehensive pollution index to measure air quality. In this part, we separately study the impact of public participation and government intervention on each pollutant. The results are shown in Table 5. The explained variable of Model 1 is SO_2 . The explained variable of Model 2 is CO_2 . The explained variable of Model 3 is SD .

It can be seen from the regression results that the direct and indirect effects of government

Table 3. Effects of public participation and government intervention on air pollution.

Variable	(1)	(2)	(3)	
	FE	SDE	SLX	
			DIRECT	DIRECT
<i>L.LGI</i>	0.3568**	0.6940***	0.7218***	1.0744***
	(0.0190)	(0.0000)	(0.0000)	(0.0013)
<i>L.EPCG</i>	-0.3499***		-0.7684***	
	(0.0000)		(0.0000)	
<i>L.PEP</i>	-0.0003	0.0005	0.0006	0.0007
	(0.7106)	(0.5241)	(0.4244)	(0.6175)
<i>L.(LGI*PEP)</i>	0.0004	0.0109	0.0111	0.0339**
	(0.9664)	(0.2062)	(0.1474)	(0.0446)
<i>L.(LGI*EPCG)</i>	-0.1465***	-0.1354***	-0.1331***	-0.1439
	(0.0040)	(0.0047)	(0.0068)	(0.1044)
<i>L.(PEP*EPCG)</i>	-0.0006	-0.0009	-0.0012**	-0.0027
	(0.4419)	(0.1663)	(0.0434)	(0.1118)
<i>L.(LGI*PEP*EPCG)</i>	-0.0139	-0.0227**	-0.0227**	-0.0458**
	(0.1878)	(0.0154)	(0.0193)	(0.0310)
<i>PGDP</i>	0.1020***	0.1169***	0.1196***	0.2039***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
<i>PGDP²</i>	-0.0052***	-0.0069***	-0.0071***	-0.0119***
	(0.0088)	(0.0005)	(0.0001)	(0.0010)
<i>INS</i>	-0.7014***	-0.6391***	-0.6024***	0.0331
	(0.0000)	(0.0000)	(0.0000)	(0.8575)
<i>INS²</i>	2.1908***	0.7227	0.6955	2.2546
	(0.0009)	(0.2437)	(0.2036)	(0.1153)
<i>FDI</i>	0.1275	0.7241**	0.6898**	-0.7588
	(0.7270)	(0.0325)	(0.0176)	(0.2571)
<i>L.ER</i>	-1.4555***	-1.2663***	-1.3362***	-1.8221*
	(0.0029)	(0.0026)	(0.0043)	(0.0750)
<i>R&D</i>	0.0418**	0.0200	0.0248*	0.0974***
	(0.0260)	(0.2478)	(0.0686)	(0.0022)
<i>CI</i>	0.0664***	0.0447***	0.0433***	-0.0639**
	(0.0000)	(0.0000)	(0.0038)	(0.0251)
<i>POP</i>	0.1493***	0.1654***	0.1713***	0.0979***
	(0.0000)	(0.0000)	(0.0000)	(0.0046)
<i>C</i>	1.4913***		2.2541***	
	(0.0000)		(0.0000)	
ρ		0.1186		
		(0.1084)		
<i>N</i>	420	420	420	

Note: The time effect and the individual effect are controlled. The p-values are reported in parentheses. ***, ** and * are significant at the 1%, 5%, and 10% levels. Due to space limitations, the model SDM does not report the coefficients of $d'_i z_{jt}$ and $d'_i x_{jt}$.

Table 4. Robustness test.

Variable	(1)		(2)	
	Direct	Indirect	Direct	Indirect
<i>L.LGI</i>	1.1169*** (0.0000)	0.9719*** (0.0036)	2.8687*** (0.0000)	4.5959*** (0.0003)
<i>L.EPCG</i>	-0.7515*** (0.0000)		-2.9923*** (0.0000)	
<i>L.PEP</i>	0.0008 (0.2391)	0.0008 (0.5698)	0.0024 (0.3673)	0.0043 (0.4446)
<i>L.(LGI*PEP)</i>	0.0076 (0.3306)	0.0256 (0.1384)	0.0370 (0.2196)	0.1358** (0.0348)
<i>L.(LGI*EPCG)</i>	-0.1770*** (0.0005)	-0.1586* (0.0940)	-0.5614*** (0.0040)	-0.5587* (0.0917)
<i>L.(PEP*EPCG)</i>	-0.0013** (0.0249)	-0.0027 (0.1269)	-0.0048** (0.0412)	-0.0136** (0.0308)
<i>L.(LGI*PEP*EPCG)</i>	-0.0243** (0.0151)	-0.0442** (0.0480)	-0.0904** (0.0201)	-0.1878** (0.0169)
<i>PGDP</i>	0.1169*** (0.0000)	0.1854*** (0.0000)	0.4347*** (0.0000)	0.7811*** (0.0000)
<i>PGDP²</i>	-0.0063*** (0.0003)	-0.0088*** (0.0086)	-0.0255*** (0.0002)	-0.0444*** (0.0010)
<i>INS</i>	-0.5987*** (0.0000)	-0.0427 (0.8130)	-2.2696*** (0.0000)	0.1820 (0.7913)
<i>INS²</i>	0.7272 (0.1702)	1.5457 (0.2663)	2.4171 (0.2294)	10.0371* (0.0605)
<i>FDI</i>	0.5308* (0.0596)	-0.8504 (0.2010)	2.6746** (0.0168)	-2.9289 (0.2498)
<i>L.ER</i>	-1.4731*** (0.0011)	-2.3375** (0.0208)	-4.9703*** (0.0046)	-6.5923* (0.0864)
<i>R&D</i>	0.0227* (0.0914)	0.0703** (0.0144)	0.1124** (0.0273)	0.4317*** (0.0005)
<i>CI</i>	0.0453*** (0.0005)	-0.0800*** (0.0036)	0.2034*** (0.0008)	-0.2959*** (0.0066)
<i>POP</i>	0.1851*** (0.0000)	0.0857** (0.0142)	0.6415*** (0.0000)	0.3758*** (0.0034)
<i>C</i>	2.2993*** (0.0000)		7.8257*** (0.0000)	
<i>N</i>	420		420	

Note: The time effect and the individual effect are controlled. The p-values are reported in parentheses. ***, ** and * are significant at the 1%, 5%, and 10% levels.

Table 5. Effects of public participation and government intervention on different pollutants.

Variable	(1)		(2)		(3)	
	Direct	Indirect	Direct	Indirect	Direct	Indirect
<i>L.LGI</i>	1.1226***	1.4397***	8.6155***	23.8440***	0.5778***	0.8201**
	(0.0000)	(0.0034)	(0.0019)	(0.0004)	(0.0049)	(0.0398)
<i>L.EPCG</i>	-1.0349***		-8.9575***		-0.7289***	
	(0.0000)		(0.0000)		(0.0000)	
<i>L.PEP</i>	0.0016	0.0033	0.0042	0.0260	0.0000	-0.0012
	(0.1310)	(0.1319)	(0.7218)	(0.3536)	(0.9867)	(0.5203)
<i>L.(LGI*PEP)</i>	0.0118	0.0658***	-0.0169	0.3118	0.0158*	0.0204
	(0.3503)	(0.0094)	(0.9113)	(0.3319)	(0.0741)	(0.3128)
<i>L.(LGI*EPCG)</i>	-0.2815***	-0.3468***	-1.7869	-0.2314	-0.0495	-0.0517
	(0.0004)	(0.0068)	(0.1079)	(0.8740)	(0.3858)	(0.6320)
<i>L.(PEP*EPCG)</i>	-0.0035***	-0.0074***	-0.0004	-0.0811***	-0.0001	0.0010
	(0.0007)	(0.0031)	(0.9732)	(0.0013)	(0.8692)	(0.6534)
<i>L.(LGI*PEP*EPCG)</i>	-0.0404**	-0.0970***	-0.2258	-0.4645	-0.0139	-0.0193
	(0.0144)	(0.0013)	(0.2984)	(0.1654)	(0.1967)	(0.4650)
<i>PGDP</i>	0.1332***	0.3004***	0.8012*	1.7885***	0.1425***	0.1878***
	(0.0000)	(0.0000)	(0.0535)	(0.0065)	(0.0000)	(0.0002)
<i>PGDP²</i>	-0.0072***	-0.0153***	-0.0467*	-0.0958*	-0.0089***	-0.0126***
	(0.0038)	(0.0036)	(0.0914)	(0.0910)	(0.0001)	(0.0037)
<i>INS</i>	-0.4928***	0.0248	-7.8638***	2.0219	-0.7669***	0.0162
	(0.0004)	(0.9263)	(0.0000)	(0.5022)	(0.0000)	(0.9434)
<i>INS²</i>	1.0485	3.6360*	-0.8726	55.1223**	0.8038	1.2580
	(0.1489)	(0.0671)	(0.9221)	(0.0107)	(0.2782)	(0.4922)
<i>FDI</i>	0.5951	-0.7205	10.7881**	-10.9027	0.8376**	-0.8829
	(0.1675)	(0.4879)	(0.0341)	(0.3106)	(0.0146)	(0.2654)
<i>CI</i>	0.0192	-0.1116***	1.8106***	-1.7949***	0.0437**	-0.0245
	(0.4277)	(0.0073)	(0.0000)	(0.0012)	(0.0107)	(0.4732)
<i>L.ER</i>	-2.1705***	-2.7641*	-5.8133	-4.6630	-1.2723*	-1.9050
	(0.0011)	(0.0684)	(0.5395)	(0.7821)	(0.0579)	(0.1286)
<i>R&D</i>	0.0408**	0.1347***	0.6506***	2.5313***	0.0127	0.0665*
	(0.0319)	(0.0045)	(0.0041)	(0.0001)	(0.4582)	(0.0622)
<i>POP</i>	0.2221***	0.1341***	0.1379***	0.9749*	0.1795***	0.0982**
	(0.0000)	(0.0058)	(0.0001)	(0.0867)	(0.0000)	(0.0393)
<i>C</i>	2.8441***		30.3087***		2.1999***	
	(0.0000)		(0.0000)		(0.0000)	
<i>N</i>	420		420		415	

Note: The time effect and the individual effect are controlled. The p-values are reported in parentheses. ***, ** and * are significant at the 1%, 5%, and 10% levels.

intervention on the three pollutants are positive. All three pollutants are reduced under the pressure of the central government to control pollution. However, it is difficult for the public to improve air quality directly, and it cannot restrain the adverse effects of government intervention on the pollutants. Under the pressure of the central government's willingness to control pollution, public environmental participation can reduce SO_2 , and the improvement effect is significant. But the improvement effects of CO_2 and SD are not statistically significant.

We believe that the following reasons cause this situation. Firstly, as far as CO_2 is concerned, CO_2 is a colorless and odorless gas. It is difficult for the public to judge whether it exceeds the standard. Therefore, the improvement effect of public environmental participation on CO_2 is limited. Secondly, SO_2 has always been a pollutant that is clearly required to be reduced in the five-year plan. But SD is not a binding emission reduction pollutant stipulated by the central government. This may lead to insufficient incentives for local governments to reduce SD. Simultaneously, local governments also lack responses to public complaints about SD, resulting in the insignificant effect of public environmental participation in reducing SD emissions.

Conclusions

Improper intervention by the local government is one of the reasons for the deterioration of China's air quality. We investigate the impact of public environmental participation and local government intervention on air pollution using provincial data from 2003 to 2017 in China. Because there is competition among local governments for promotion, the traditional panel data model will lead to estimation bias. Compared with the non-spatial panel data model, the spatial panel data model considers spatial effects and can avoid bias. Therefore, this paper adopts a spatial measurement model to analyze the relationship between public environmental participation, government intervention, and air pollution. The main findings are robust, as indicated by a robustness test.

According to our empirical results, some main conclusions can be drawn. Local government intervention is not conducive to environmental improvement. Moreover, the adverse effects of government intervention on the environment have spatial spillover effects. Although the public's role is being valued in the current environmental governance process, the research results show that it is difficult for the public to restrain corporate pollution by their strength and restrain the adverse effects of local government intervention on the environment. However, under the central government's pressure to control pollution, the active role of public environmental participation has been brought into play. And the improvement effect of

public environmental participation is significant for SO_2 but not significant for CO_2 and SD.

The conclusions show that in the process of environmental governance, the government-led multi-governance model has shortcomings. The effect of public environment participation is highly dependent on the central government. It indicates that under the performance-based appointment system, local governments are mainly accountable to the central government. Therefore, from the perspective of the central government, this paper puts forward some policy recommendations on how to play the role of public environmental participation and restrain local governments' environmental negligence.

The central government can restrict local government behavior from three aspects. Firstly, the central government should regulate the functions of local governments to avoid environmental deterioration caused by the excessive intervention of local governments on enterprises. Secondly, the central government can alter the incentive structure to guide local governments to perform environmental protection responsibilities actively. Finally, the central government should improve the top-level design of the environmental management system to correct the local government's dereliction of duty in environmental protection from the institutional level.

In guiding the public to participate in environmental protection, on the one hand, the central government should enrich the channels for public environmental participation to avoid the lack of public environmental participation caused by the single channels of public environmental participation. On the other hand, the government's imperfect response mechanism is one of the cruxes that plague the Chinese public's effective participation in environmental protection. The government cannot respond to public environmental complaints in a timely and effective manner, resulting in a mere formality in China's public environmental participation. Therefore, the central government should improve government response mechanisms and enhance government environmental public service quality.

Conflict of Interest

The authors declare no conflict of interest.

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