Research on the Impact of Environmental Regulation on Haze Pollution in China

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Abstract: Using spatial exploratory data analysis technology, this paper empirically analyzes the spatial evolution of haze pollution, and examines the impact of environmental regulation on haze pollution based on Spatial Durbin Model in China from 2004 to 2016. The results show that there is a significant spatial autocorrelation for haze pollution in China, and the spatial distribution forms high-haze pollution high-high(H-H) cluster regions and low-haze pollution low-low(L-L) cluster regions. The H-H cluster regions have experienced a change from the central region to the western region and then to the eastern region, and the L-L cluster regions have expanded and shifted to the east. Second, the direct effect of environmental regulation on haze pollution is negative but not significant, while the indirect effect and total effect of environmental regulation on haze pollution are significantly positive, which shows the current environmental regulation has not played a role in suppressing haze pollution. This is inconsistent with the original intention of the government to implement environmental regulation policies and there is indeed a “green paradox” in China. In addition, FDI and population size have aggravate the haze pollution in the region, and the improvement of the industrial structure is conducive to the improvement of haze pollution.

1. Introduction
In recent years, haze pollution has become increasingly serious in China. According to the “Environmental Status Bulletin of China”, there is 145 cities’ air quality fail to meet national standards in 2014, and less than 10% of cities above prefecture level meet the standards in carrying out air quality monitoring activities[1]. Severe haze pollution has caused great harm to economic and social development and the health of residents in China. In the form of serious environmental pollution, the Chinese government’s awareness of environmental protection has continued to increase in recent years, and environmental governance has gradually increased[2]. Do stricter environmental regulation plays an important role in controlling haze pollution? This issue has received extensive attention and heated discussion from the academic circles. Spatial Durbin Model is used to test the relationship between environmental regulation and haze pollution in 30 provinces of China from 2004-2016, it is expected to further test the impact of environmental regulation on smog pollution.

2. Literature Review
How does environmental regulation affect haze pollution? Internationally, scholars have carried out a
series of useful research[3-4]. However, the study is still in early stage in China, and focuses exploring the effect of government administrative control on mitigating regional haze pollution. Wang and Xu (2015) found that the impact of environmental administrative regulations on the decoupling of haze pollution was multiple[3]. Wu (2016) explored that there was a an inverted “U” shape relation between the two[4]. Huang (2016) revealed that environmental regulation could directly and indirectly effects environmental pollution[5]. Liu and Xu (2017) discovered that environmental regulation has dual effects on haze management [6]. Chen and Pan (2017) found that the current environmental regulations of local governments played a positive role in haze governance in China[7]. Zhang and Li (2017) found that current environmental regulations has not effectively promoted haze control level[8]. Wang and Tan (2017) believed that environmental regulations promoted the industries, which was conducive to the realization of haze decoupling targets[9]. Pan, Wu and Zhang (2017) found that Chinese-style decentralization reduced the strictness of local officials in implementing environmental regulatory standards, and made environmental regulations have not achieved the effect of reducing haze pollution[10]. This article intends to explore the spatial spillovers of environmental regulation and haze pollution by using Space Durbin Model, and systematically analyze the relationship between the two to provide beneficial policy recommendations for controlling haze pollution in China.

3. Research Design

3.1. Model Building

According to Anselin (1995), classical spatial metrological model includes Spatial Lag Model (SLM) and Spatial Error Model (SEM). Subsequently, James and Kelly expanded SLM, and put forward Spatial Durbin Model (SDM), which contains both the lagged variable of the explained variable and the lagged variable of the explaining variable. The panel data of this model is set as follows:

$$\ln PM_{10i} = \delta W \ln PM_{10j} + \beta_0 + \beta_1 \ln ER_{it} + \beta_2 \ln FDI_{it} + \beta_3 \ln gdp_{it} + \beta_4 \ln^2 gdp_{it} + \beta_5 \ln IC_{it} + \beta_6 \ln PS_{it} + \theta_1 W \ln FDI_{it} + \theta_2 W \ln gdp_{it} + \theta_3 W \ln PM_{10i}$$

Where, i represents provinces; t represents the period, and lnPM_{10i} denotes haze pollution. lnER represents environmental regulation, population size(lnPS), industrial structure(lnIS), foreign direct investment(FDI), and the level of economic development and its square term are considered in the model as control variables. WlnPM_{10i} is the spatial lag term of the explained variable, and σ denotes the spatial lag coefficients. WlnER_{it}, wlnFDI_{it}, wlnPS_{it}, wln\ gdp_{it}, wlnIC_{it} and wlnPS_{it} are the spatial lag term of explanatory variables.μ_{it}, λ, ε_{it} are the area effect, time effect and random disturbance term respectively. ε_{it} obeys normal distribution. wij is the spatial weight matrix, representing the neighboring relations between the area i and the area j. This paper establishes the spatial weight matrix based on spatial adjacency relation.

3.2. Variables Measurement and Data Sources

Haze pollution is measured by PM_{10i}[11]. Total pollution treatment investment reflects the intensity of environmental regulations in a region, which is used to measure environmental regulations, FDI is measured by the total amount of foreign direct investment, the proportion of the secondary industry in GDP represents industrial structure, and total population at the end of the year is used to measure population size[12]. The data in this paper are mainly from the “China Statistical Yearbook” and “China Statistical Yearbook on Environment”. Logarithmic processing is carried out during the analysis process.

4. Results

4.1. Spatial Correlation Test

Table 1 and figure 1 show Moran’s I values and Moran scatterplots of environmental regulation and
haze pollution in China during 2004-2016. The Moran’s I values of the environmental regulation has all passed the test of significance at 10% level and each of its value is positive, except 2010 when its value is negative, there is a robust and obvious spatial dependence and spatial cluster effect.

Table 1. Results of Moran’s I test for environmental regulation and haze pollution in China from 2004 to 2016

| Years | Moran’s I | P value | Moran's I | P value |
|-------|-----------|---------|-----------|---------|
| 2004  | 0.274229  | 0.006   | 0.086288  | 0.149   |
| 2005  | 0.304998  | 0.007   | 0.198794  | 0.027   |
| 2006  | 0.267764  | 0.013   | 0.368157  | 0.002   |
| 2007  | 0.360306  | 0.004   | 0.265727  | 0.010   |
| 2008  | 0.318407  | 0.004   | 0.264442  | 0.003   |
| 2009  | 0.309678  | 0.005   | 0.418052  | 0.001   |
| 2010  | -0.00734655 | 0.340 | 0.352538  | 0.002   |
| 2011  | 0.280807  | 0.009   | 0.334501  | 0.004   |
| 2012  | 0.237635  | 0.020   | 0.364698  | 0.001   |
| 2013  | 0.276908  | 0.009   | 0.347627  | 0.002   |
| 2014  | 0.234737  | 0.023   | 0.497098  | 0.001   |
| 2015  | 0.182135  | 0.032   | 0.505966  | 0.001   |
| 2016  | 0.190547  | 0.036   | 0.523224  | 0.001   |

In other words, the improvement of the level of environmental regulation in the region possible increases the improvement of environmental regulation in the surrounding areas. The Moran’s I values of haze pollution are positive and have reached the significant level of 1%, except for the year 2004. It shows that there is a significant positive spatial correlation for haze pollution in China, and there are significant spatial correlations and cluster characteristics of it. Then, haze pollution in the region possibly spreads to the surrounding areas nearby, and affects the improvement of the environmental quality in the surrounding areas.

4.2. Estimated Results of Spatial Econometric Model

In this paper, the Hausman test is conducted before examining the relationship between environmental regulation and haze pollution. The test results show that the Hausman test value is 29.6328 with a degree of freedom is 13, and the P value is 0.0053. It shows that the fixed-effect Durbin model is superior to the random effect Durbin model. The empirical results are shown in Table 2. From Table 2, it can be
seen that FDI, population size and industrial structure are significant at the levels of 10%, 5% and 5%, respectively, indicating that FDI level, population size and industrial structure are important factors affecting the level of haze pollution. The correlation coefficients of environmental regulation, the first and second terms of per capita GDP are not significant, indicating that they have not significant effect on haze pollution. Judging from the sign of regression coefficient, environmental regulation has a negative impact on haze pollution, and the lagged term of environmental regulation is significant. FDI, population size per capita GDP and industrial structure have a positive impact on haze pollution, and the lagged term of population size is also significant.

| Variables  | Coefficient | Asymptot t-stat | z-probability |
|------------|-------------|-----------------|---------------|
| lnER       | -0.004555   | -0.208053       | 0.835187      |
| lnFDI      | 0.012832    | 1.773443        | 0.095616      |
| lngdp      | 0.410374    | 0.806959        | 0.419690      |
| ln2gdp     | -0.017883   | -0.739162       | 0.459809      |
| lnIC       | 0.082313    | 1.994183        | 0.046132      |
| lnPS       | 0.689170    | 2.489468        | 0.012793      |
| w*lnER     | 0.092910    | 2.067351        | 0.038701      |
| w*lnFDI    | 0.019634    | 0.892636        | 0.372052      |
| w*lngdp    | -0.123953   | -0.165434       | 0.868603      |
| w*ln2gdp   | -0.041520   | -1.141568       | 0.253633      |
| w*lnIC     | 0.000739    | 0.009444        | 0.992465      |
| w*lnPS     | 0.188970    | 2.923858        | 0.003457      |
| W*dep.var. | 0.188970    | 2.923858        | 0.003457      |
| Adjusted R²|             | 0.8719          |               |
| Log likelihood |         | 301.60268     |               |

Note: *****, ** and * indicate the significance at 1%, 5%, and 10% level, respectively.

The empirical results of direct effect, indirect effect and total effect of Spatial Durbin Model are shown in Table 3. As shown in Table 3, the direct effect of environmental regulation on haze pollution is negative and does not pass the test of significance, indicating that environmental regulation in the region is beneficial to the control of haze pollution, but this effect is not significant. The possible reason is that the implementation of environmental regulation is high cost and low yield for insufficient regulatory efforts and inadequate market mechanisms, resulting in the actual effects of environmental regulation has not been achieved. At the same time, industrial structure and population size also have significant impact on haze pollution in the region, however, this factors cannot be fundamentally changed in a short period of time, and prevents the role of environmental regulation in the control of haze pollution.

Then, the indirect effect of environmental regulation on haze pollution is positive and passes the test of significance at the level of 5%, indicating that the intensity of environmental regulation in the region has a significant impact on haze pollution in the surrounding regions, and the spatial diffusion effect of environmental regulation is significant. The key reason lies in that, under the background of centralized political power, the relativity of the government’s environmental performance assessment has caused local governments to pay closely attention to the environmental regulatory actions of competitors, and the environmental regulation policies and measures taken by the local governments have a significant impact on the environmental regulation behavior of the surrounding regions. When the environmental regulation in the region is enhanced and the environmental governance input is increased, the haze pollution in the area has been improved, and if no action is taken in the surrounding areas, the haze pollution in the surrounding areas will be relatively deteriorated. This phenomenon explains that the indirect effect of environmental regulation on haze pollution is positive, means that the improvement of environmental regulation in this region will lead to relatively serious haze pollution in the surrounding
What is more, from the point of total effects, the impact of environmental regulation on haze pollution is positive, and passes the test of significance at the level of 10% level. This shows that the current environmental regulation does not play a role in suppressing haze pollution as a whole, which is inconsistent with the original intention of the government to implement environmental regulation policies, indicating that there is indeed a “green paradox” in current environmental regulation in China. In addition, the direct effect between population size, industrial structure, FDI and haze pollution are significant and pass significance test at 10% level, which shows that smog pollution level in a region is significantly affected by population size, industrial structure and FDI of the area. From the sign of the regression coefficient, population size and FDI have significantly aggravated pollution pollution in the area, and industrial structure helps to reducing smog pollution. The direct and indirect effects of GDP and its square terms on smog pollution are not significant, both of which do not pass the test, and it shows that the relationship between smog pollution and economic development is not significant.

Table 3. Direct effect, indirect effect and total effect of Spatial Durbin Model

| Variables | Direct effect | Indirect effect | Total effect |
|-----------|--------------|----------------|-------------|
| lnER      | -0.000367    | 0.108389**     | 0.108021*   |
| lnFDI     | 0.014192*    | 0.026604       | 0.040796    |
| lngdp     | 0.397215     | -0.055679      | 0.341537    |
| ln^2gdp   | -0.019458    | -0.053611      | -0.073069   |
| lnIC      | -0.082585*   | -0.023482      | -0.106068   |
| lnPS      | 0.704403**   | 0.344132       | 1.048534*   |

Note: ***, ** and * indicate the significance at 1%, 5%, and 10% level, respectively.

4.3. Robustness test

In order to test the stability of the relationship between environmental regulation and haze pollution, this paper uses PM2.5 as the alternative variable of haze pollution to conduct empirical analysis again based on the data during 2004-2012, and the estimation results are listed in Table 4. As shown in Table 4, the robustness test results generally support the above empirical results.

Table 4. Robustness test results

| Variables | Direct effect | Indirect effect | Total effect |
|-----------|--------------|----------------|-------------|
| lnER      | 0.979534*    | 6.272420**     | 7.251954**  |
| lnFDI     | 0.790718*    | 1.709685       | 2.500403    |
| lngdp     | -15.535096   | -16.819626     | -32.354722  |
| ln^2gdp   | 0.689539     | 0.428744       | 1.118283    |
| lnIC      | -5.999453**  | -44.571313***  | -50.570766***|
| lnPS      | -11.505568*  | -29.672956     | -41.178525  |

Note: ***, ** and * indicate the significance at 1%, 5%, and 10% level, respectively.

5. Conclusions

Based on the panel data of 30 provinces in China from 2004 to 2016, this paper uses the Spatial Durbin Model to analyze the influence of environmental regulation on haze pollution. The results show that there is a significant positive spatial correlation for haze pollution in China, and haze pollution in the region possibly spreads to the surrounding areas nearby, and affects the improvement of the environmental quality in the surrounding areas. The spatial distribution forms high haze pollution high(H-H) cluster regions and low haze pollution low-low(L-L) cluster regions. The H-H cluster regions have experienced a change from the central region to the western region and then to the eastern region and the L-L cluster regions have expanded and shifted to the east. Second, the direct effect of environmental regulation on haze pollution is negative but not significant, while the indirect effect and total effect of environmental regulation on haze pollution are significantly positive, which shows the current environmental regulation has not played a role in suppressing haze pollution. In addition, the
direct effect of FDI, population size and industrial structure on haze pollution are significant, indicating that FDI, population size and industrial structure in the region have important impact on haze pollution in the region.

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