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Study on the Influence of Environmental Regulation on Haze

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Abstract: At present, haze is China's most serious environmental problems, Environmental regulation is a major means of environmental pollution control. This paper uses spatial econometric methods to explore the relationship between environmental regulation and haze using data from 281 prefecture-level cities in China from 2008 to 2015. Precipitation is used as an Instrumental variable for environmental regulation to control endogeneity. The results show that haze presents spatial negative correlation and haze is significantly reduced as the level of environmental regulation increases. Further, environmental regulation affects haze through income effect, competitive effect and technological progress effect. To control haze and promote sustainable economic development, joint governance between regions is imperative. Strictly enforced environmental regulation is the key to achieving a "win-win" situation for environmental protection and economic growth.

Keywords: Environmental regulation; Haze; Spatial econometrics

1. Introduction

In the past 40 years of reform and opening-up, the Chinese economy has entered a new era after experiencing a long-term high-speed growth phase, shifting from GDP first to focusing on the quality of economic growth. The “extensive” development model at the expense of the natural environment has brought serious consequences. Especially in terms of air pollution, haze has become a heart of Chinese residents. Every winter, the central and eastern parts of China are shrouded in haze, and people with low immunity are sick and dwelling. The experience of pollution control in developed countries shows that with the improvement of industrialization level, environmental pollution is first decoupled from industrial development, and then gradually managed. At present, China is in the dilemma of industrial upgrading and environmental pollution deterioration. The main reason is that the environment belongs to public goods. The market lacks sufficient power to achieve green transformation and must rely on the government for environmental regulation. The main reason for this phenomenon is that the environment is a public good, and the market lacks sufficient motivation to achieve green transformation, and must rely on the government for environmental regulation.

In theory, the way environmental regulations reduce haze is as follows: In the short term, enterprises can only reduce production to reduce pollution emissions. At this time, economic growth and environmental protection are mutually exclusive; But in the long run, when it is realized that the relative profit of producing green products is higher, enterprises will turn to green technology innovation, thus changing the industrial structure and technological progress of the region; In addition, when the cost of migration is significantly less than the cost of additional environmental regulations, companies can also choose to relocate to areas with lower levels of environmental regulation. This difference is widespread due to tax competition between local governments.

Spatial factors play an important role in the study of environmental economic issues, including the existence of physical and geographical factors such as water flow and wind direction, as well as human factors such as industrial transfer and trade. Traditional studies assume that the haze among regions is independent and obviously inconsistent with reality.

2. Variable Definition and Data Source

2.1. Explained variable: haze

As the main air pollution problem in China, haze is a general term for the content of various suspended particulates in the atmosphere. Among them, PM2.5 (aerodynamic equivalent diameter of particles less than or equal to 2.5 microns) is considered as the "culprit" of haze. As China began to officially monitor PM2.5 from the end of 2012, the PM2.5 concentration source data used in this paper is from Ma et al. (2016). ArcGIS is used to analyze this raster data into PM2.5 concentration data of 281 prefecture-level cities in China from 2008 to 2015, and the logarithmic value of PM2.5 is used to indicate the degree of haze.

2.2. Explanatory variable: environmental regulation (ER)

According to the theory of new institutional economics, the government can effectively solve the externalities of environmental pollution by formulating clear policies and regulations to define property rights. Reasonable environmental regulations can guide companies to develop clean technologies and improve environmental quality. The common single indicator method is only measured from one aspect of environmental regulation, which is easy to cause deviation of research conclusions. The assignment scoring method has certain people's subjectivity. Based on this, this article refers to Zhong et al. (2015) using the comprehensive index method. Synthetic environmental regulation index by entropy method for industrial smoke and dust removal rate and industrial SO2 removal rate. The data comes from the China City Statistical Yearbook. The calculation steps are as follows: firstly, the standardization processing is performed on each index; secondly, the entropy method is used to determine the index weight; finally, the environmental regulation index is calculated according to the weight and the standardized value. The higher the score, the more stringent the environmental regulations.

Precipitation is used as a tool variable for environmental regulation. The relationship between precipitation and air pollution is significant. Natural precipitation is used as a tool variable to characterize environmental regulation to overcome endogenous problems. The data comes from the statistical yearbooks of various provinces and Meteorological Administration website in China.

2.3. Control variables

Control variables include economic development (GDP), industrial structure (IS), technology endowment (TEC), and corporate profitability (PRO). The data comes from the China City Statistical Yearbook, and some missing data is filled by interpolation.

Economic development (GDP): Grossman (1992) studies the environmental Kuznets curve (EKC) based on empirical studies of the relationship between per capita GDP and different environmental indicators in several developed and developing countries. When the economy develops to a certain stage, the people's demand for environmental quality is enhanced, environmental protection standards tend to be strict, and industrial restructuring and clean technology advancement and other factors contribute to the economic development and environmental quality into a win-win track. This paper uses the logarithm of GDP per capita after the GDP index has been reduced to characterize the level of economic development.

Industrial Structure (IS): Compared with the primary and tertiary industries, the secondary industry is often more likely to cause environmental pollution problems. For example, Xu and Kong’s research (2014) indicates that the added value of the secondary industry as a percentage of GDP has a significant effect on environmental pollution. This paper also selects the proportion of the added value of the secondary industry to GDP to measure the regional industrial structure.

Technology Endowment (TEC): Technological advancement is the fundamental way to achieve green development. The "Porter Hypothesis" has been supported by many empirical studies. Appropriate environmental regulations will stimulate the green technology innovation of enterprises, thereby compensating the costs of regulation and ultimately achieving A win-win situation between the environment and the economy. This paper uses the logarithmic value of the number of college students per 10,000 people to represent the technology endowment.

Corporate profitability (PRO): Companies with higher profit margins can more rigorously undertake strict environmental regulations, invest capital in green technology innovation to adapt to the increasingly enhanced environmental regulation level, seize the green market, and thus reduce environmental pollution.

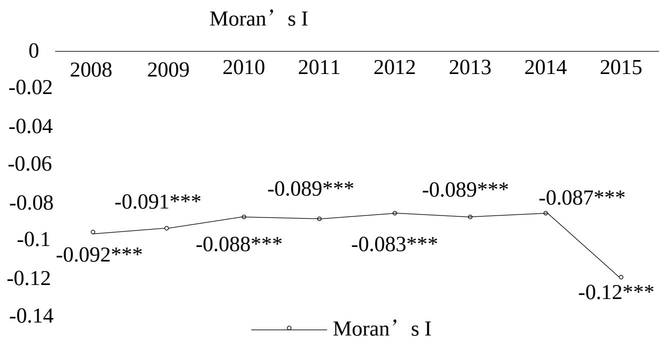
3. Empirical Design

3.1. Spatial correlation test

This paper uses the Moran’s I index to perform a spatial correlation test on the dependent variable. Calculated as follows

$$Moran'sI = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}(Y_i-\bar{Y})(Y_j-\bar{Y})}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}} \tag{1}$$

In equation (1), S^2 is the sample variance, $S^2=\sum_{i=1}^{n}(Y_i-\bar{Y})^2$; n is the number of samples and n=281; Y_i and Y_j are the observation values of the i-th and j-th samples, respectively; $\bar{Y}$ is the average value of the haze of 281 prefecture level city; ω is the spatial weight matrix, and the geographic distance matrix and economic distance matrix are adopted in this paper. The formula for setting the weight element is as follows: $w_{ij}=(1/d_{ij})/[\sum_{i=1}^{N}(1/d_{ij})]$, d_{ij} is the geographical distance between the geographic centers of cities i and j; $w_{ij}=(1/e_{ij})/[\sum_{i=1}^{N}(1/e_{ij})]$, e_{ij} is the per capita GDP difference between the geographic centers of cities i and j. The value range of $Moran'sI$ is -1≤I≤1. When it is close to 1, it means that there is a positive correlation between the regions. When it is close to -1, it means that the space is negatively correlated. When it is close to 0, there is no spatial correlation between the regions. Results are shown in Figure 1. The Moran’s I of haze was less than 0 at the 1% significance level, indicating that the haze was spatially negatively correlated across the country.



Note: *** indicates significant at 1% level

Figure 1. Moran's I

3.2. Econometric model

This paper intends to use the spatial econometric method that considers spatial correlation between regions to examine the effects of environmental regulations on haze, including spatial autoregressive models (SAR) and spatial error models (SEM). The formula is as follows:

$$HAZE_{it} = \alpha_{it} + \rho\omega HAZE_{it} + \delta ER_{it} + \sum X_{it}\delta_r + u_{it} \quad (2)$$

$$HAZE_{it} = \alpha_{it} + \delta ER_{it} + \sum X_{it}\delta_r + u_{it}$$

$$u_{it} = \varphi\omega u_{it} + \varepsilon_{it} \quad (3)$$

Formulas (2) and (3) are SAR and SEM models, respectively. In the formula, $HAZE_{it}$ is the haze of the i-st region in t period; ER_{it} is the environmental regulation level of the first city in t period; ω is the spatial weight matrix mentioned above; φ is the spatial error coefficient; ρ is the spatial autocorrelation regression coefficient, what indicates the impact of haze in neighboring prefectures on haze in the region; X is the control variable described above. a_{it} is the intercept term; u_{it} is a random disturbance.

4. Empirical Results

4.1. Model estimation and result analysis

With reference to Dong and Wang (2019), the effect of environmental regulation on haze using two-stage least squares method is shown in Table 1. The regression results of the first stage is also listed in Table 1. It is found that the regional precipitation has a significant negative relationship with the environmental regulation indicators and the F value is much larger than 10, excluding the weak instrumental variables. According to Hausman Test, the test results of SAR and SEM models all show the null hypothesis that the random effect is rejected at 5% confidence level. Therefore, this paper uses the fixed effect model for empirical analysis and uses the clustering robust standard error to model the model.

Table 1. Spatial panel model regression results

	SAR Wd	SAR We	SEM Wd	SEM We
ER	-0.10***	-0.11***	-0.11***	-0.12***
GDP	-0.25***	-0.25***	-0.27***	-0.26**
IS	0.27***	0.29***	0.27***	0.29***
ST	-0.07**	-0.07**	-0.07***	-0.07**
PRO	-0.08***	-0.08***	-0.08***	-0.08***
ρ	0.19***	0.13***	/	/
λ	/	/	0.20***	0.13***
Adjusted R2	0.49	0.48	0.47	0.47
Log likelihood	1993.19	1993.19	1992.25	1992.48
First-stage regression results				

JS：0.3293（1.3113）		F：39.25***	P：0.0000
Spatial correlation diagnostic test			
LM-lag	Robust LM-lag	LM-error	Robust LM-error
165.73***	123.42***	33.06***	1.67

Note: ***, **, and * represent the significance level less than 0.01, 0.05 and 0.1, respectively; "/" means that the item is empty; the spatial interaction coefficient of the control variable in the SDM model is not reported in this table. The spatial correlation diagnostic test of this table is the result of the geographic distance matrix.

Optimal Model Selection and Space Spillover Effect. Anselin (2005) gives a selection mechanism for cross-sectional data models. The first step is to determine whether the model needs to introduce spatial variables through Moran's I. In the second step, observe LM-lag and LM-error, where LM-lag is used to test the SAR model, and LM-error is used to test the SEM model. If only one of them passes the significance test, then the selection model is directly selected. If both pass the test, continue to look down on Robust LM-lag and Robust LM-error. Similarly, Robust LM-lag corresponds to the SAR model, and Robust LM-error corresponds to the SEM model. It is worth noting that both of them pass the saliency test, otherwise it is necessary to re-examine the model settings. Based on this, this paper chooses the SAR model. The ρ of model 1 is significantly greater than 0, indicating that the haze exhibits a spatial spillover effect.

Environmental regulation has a significant negative impact on haze. In the short term, environmental regulation can directly limit pollution emissions; in the long-term environmental regulation, the relative profit of green products will be improved, enterprises will adopt greener technology with R&D, and finally achieve cleanliness. produce. The level of economic development has a significant negative impact on haze, indicating that as the level of economic development increases, the threat of environmental pollution to people's health rises, the opportunity cost of environmental pollution increases, and people are willing to sacrifice some economic growth for environmental protection. speed. The industrial structure has a significant positive effect on haze. Most polluting industries are included in the secondary industry. China has entered the late stage of industrialization, and pollution is shifting from the developed region to the less developed region. The technology endowment has a significant negative impact on haze. Higher technology endowments mean higher technological innovation capabilities, and green technology advancement is the fundamental way to haze control. The profit rate of enterprises has a significant negative impact on haze, indicating that enterprises with higher profit margins have more funds for equipment transformation and green technology innovation, thus reducing haze.

4.2. Further research

How does environmental regulation reduce haze? Grossman (1991) pointed out that as the economic grows, people's demand for environmental quality will rise, we call it the income effect. Konisky (2007) believes that due to the administrative division of local governments and the competition among regional economic competitions, when backward industries migrate from developed areas to backward areas, there is a "race to bottom" between local governments, which exacerbates haze, we call it the competitive effect. Porter (1995) believes that reasonable environmental regulation will force enterprises to carry out green technological innovation and achieve win-win results in environmental protection and economic growth; Acemoglu (2012) further proposes that environmental regulation can improve the relative profits of green technology, and thus achieve environmental protection, we call it the technological progress effect. This paper introduces the interaction between environmental regulation and per capita GDP, industrial structure, technological endowment and enterprise profit margin to test income effect, competition effect and technological progress effect, respectively. The results are shown in Table 2.

Table 2. Results of further studies

	SAR Wd	**SAR We**	**SEM Wd**	**SEM We**
EGDP	-0.02***	-0.03***	-0.03***	-0.03***
EIS	0.10***	0.10***	0.10***	0.10***
EST	-0.02 *	-0.02 *	-0.02*	-0.02*
EPRO	-0.03***	-0.03***	-0.03***	-0.03***
ρ	0.19***	0.13***	/	/
λ	/	/	0.18***	0.12***
Adjusted R2	0.45	0.44	0.42	0.43
Log likelihood	1987.54	1987.79	1985.71	1986.60

From the results of Table 2, it can be seen that the interaction between environmental regulation and per capita GDP has a significant negative impact on haze, indicating that the income effect is conducive to haze control, just as the labor supply curve bends backwards, when the income level reaches a certain level, the opportunity cost of environmental damage has increased, people have begun to pay attention to environmental protection. The interaction between environmental regulation and industrial structure has a significant positive impact on haze, indicating that one of the main causes of current haze is industrialization, local governments have intensified haze for GDP to compete for industrial output. The interaction between environmental regulation and technology endowment and corporate profit rate has a significant negative impact on haze, indicating that the technological progress effect is conducive to haze control.

5. Conclusion

This paper introduces spatial effects into the study of environmental pollution and economic growth, and uses spatial measurement methods to test the effects of environmental regulations on haze. The results show that: first, the haze in various regions of China has negative spatial autocorrelation and the correlation is stable for a long time; second, environmental regulation has effectively reduced haze, including the income effects brought about by economic development and the technological progress effects brought about by corporate's green technology innovation, but the competitive effect of the secondary industry between cities has intensified haze.

The analysis conclusions of this paper have important policy implications: first, strengthen the coordinated management of regional ecological environment, including cultivating regional environmental common market, strengthening environmental information disclosure and sharing, and improving market-oriented ecological compensation mechanism. In combination with China's actual situation, environmental performance should be reasonably incorporated into official assessment standards to prevent environmental standards from “race to bottom"; second, developed regions must establish strict environmental regulations to stimulate green technology innovation, and thus fundamentally achieve a "win-win" for environmental protection and economic growth. In the backward areas, it is necessary to set an appropriate level of environmental regulation to balance economic growth and environmental protection.

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