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Original Research Paper

Spatial Overflow Effect of Haze Pollution in China and Its Influencing Factors

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ABSTRACT

The influencing factors of haze pollution aggravation were explored to further analyse the spatial distribution and overflow effect of haze pollution in China. The global Moran's *I* of haze pollution distribution was estimated based on the panel data of 30 provinces (including cities and municipalities) in China from 2003 to 2013, and the spatial autocorrelation of haze pollution in these 30 provinces was analysed. An index system of social and economic variables that influence haze pollution in China, which covers economy, population and policy, was established. Subsequently, the spatial correlation of haze pollution in China and its corresponding influencing factors were explored based on the extreme bounds analysis model. An empirical study was then conducted, which found that the global Moran's I fluctuated between 0.4 and 0.5 and achieved a 1% significance level, thereby indicating that haze pollution demonstrated strong spatial correlation. The robustness testing coefficient of the overflow effect (ρ) is relatively large, which shows that haze pollution exhibits a robust spatial overflow effect. Haze pollution in one region is frequently significantly influenced by haze pollution in adjacent regions. Haze concentration occurs in the Beijing-Tianjin-Hebei, Yangtze River Delta and mid-east regions. Industrial structure, energy consumption structure, urban construction architecture, population dimension and car ownership have an anti-interference robustness effect on haze pollution. Conclusions of this study are not only significant for understanding the spatial distribution and spatial overflow effect of haze pollution in China and for identifying its main influencing factors, but can also provide references for the government to formulate haze control policies and enhance joint control of haze-affected regions.

INTRODUCTION

Intensifying air pollution conditions have become a global problem in the 21st century. The sharp deterioration of air quality is doubtlessly the collaborative consequence of natural phenomena and human activities. Volcanic eruptions and earthquakes produce harmful substances. The use of fuel coal and emissions from automobile exhaust and various industries are the main sources of pollution attributed to humans and are expected to worsen pollution in the future. The causes of haze can be generally divided into external and internal causes. External causes mainly refer to climatic factors, including humidity, temperature and wind power. Internal causes mainly refer to human activities that cause pollution. Pollutants do not accumulate in one place because the wind blows them away, thereby reducing the occurrence of haze. Similarly, humidity and temperature influence haze to a certain extent. In addition to the aforementioned causes of pollution, dust is another primary man-made source of air pollution.

The frequent occurrence of haze is mainly caused by human factors. Waste gas produced during social reconstruction and production to satisfy the demands of development exceeds the purification capacity of nature. At present, incomplete energy combustion, industrial waste gas emission and dust in the wind are main causes of air pollution. The proportion of absorbable particles in the air increases with social progress. In urban regions, aerosol pollution is the most important cause of haze. This type of pollution is mainly attributed to human activities. Haze is a weather phenomenon that spreads with atmospheric flow, thereby resulting in regional haze concentrations. Most Chinese enterprises use energy-consuming and high-emission production technologies and equipment. Coal is the main source of energy consumed in most Chinese regions. Coal discharges more pollutants than other energy sources. Therefore, if a region has a high gross domestic product (GDP) growth rate resulting from its development, then its energy consumption is most likely high and it probably suffers from serious haze pollution. Analysing the spatial overflow effect of haze pollution in China and its corresponding influencing factors based on a spatial econometric model will provide effective suggestions for the regional control of haze pollution.

EARLIER STUDIES

Considerable research on the overflow effect and the influencing factors of haze pollution has been conducted worldwide. For the overflow effect of haze pollution, Anselin, an authoritative spatial econometrics scholar, discussed the important role of spatial factors on environmental economic studies from multiple perspectives (Anselin 2001). Rupasingha analysed the spatial distributions of atmospheric and water pollutions and found that using spatial variables significantly improved the accuracy of research conclusions (Rupasingha et al. 2004). Maddison used SO_2, NO and other pollutants as measurement indexes of environmental quality and observed significant spatial effects of different forms of pollution and pollution control among different countries (Maddison 2006). Poon analysed atmospheric pollution in China based on SO_2 and some; he concluded that a spatial effect was noted among provinces (Poon et al. 2006). Hosseini analysed two main air pollutants (CO_2 and PM_{10}) in Asia from 1990 to 2007 and pointed out that haze pollution exhibited a spatial effect and spatial factors could not be neglected (Hosseini et al. 2011). Li tested the spatial properties of SO_2 and chemical oxygen demand based on Moran's *I* index, spatial error and the autoregression model; he found that air pollution demonstrated strong spatial dependence (Li et al. 2014). Most studies on the spatial overflow effect of haze pollution have confirmed its spatial correlation. Cross-administrative regional haze pollution occurs, and regions with heavy haze pollution will influence the air quality of its neighbouring regions. Among studies on the influencing factors of haze pollution, Zhao analysed haze pollution in six typical cities in Northern China (Zhao et al. 2006). He believed that particulate matter (PM) was the main pollutant in air and dust was the main source of PM_{10}. Watson analysed PM samples of haze pollution in the Grand Canyon in Colorado and found that local haze pollution was mainly caused by the incineration of crop straw, motor vehicle exhaust and dust. Kim examined haze pollution in Spokane, Washington State and discovered that emissions from plant burning contributed the most to haze pollution (Kim et al. 2003). Chen pointed out that the source of $PM_{2.5}$ would change with time and space; moreover, coal combustion, motor vehicle exhaust, plant burning, soil dust and road dust were the main causes of haze pollution (Chen et al. 2010). Coondoo established panel data to analyse the relationship between haze pollution and economic growth; he found that economic growth was the direct cause of haze pollution (Coondoo et al. 2002). Ang analysed causality among economic growth, energy consumption and pollutant emission in Malaysia for 29 years (Ang 2008). He believed that energy consumption was the main cause of haze pollution. Soytas (2007) analysed the dynamic relationship among energy consumption, economic growth and environmental pollution in the United States and concluded that energy consumption was the most direct influencing factor of environmental pollution (Soytas et al. 2007). Existing research on the spatial distribution, spatial overflow effect and influencing factors of haze pollution have mainly analysed its time and spatial distribution characteristics. However, the research scope is typically limited to a small region within one city, thereby resulting in the poor representativeness of research results. Several scholars have decomposed and reported the chemical composition of haze pollution PM. Others have explored the regional transmission mechanism of haze pollution and secondary pollution processes. As stated earlier, haze pollution exhibits regional concentration. Therefore, analysing the spatial overflow effect and influencing factors of haze pollution based on a spatial econometric model will provide effective suggestions for the regional control of haze pollution.

MODELS AND DATA SPECIFICATION

Models

1. Moran's *I* index model. Moran's *I* index is generally used to measure the spatial autocorrelation (dependence) of haze pollution in one region. Therefore, this index was used to group endogenous regions in the current study.

$$Moran's\quad I=\frac{\sum_{i=1}^{n}\sum_{j=1}^{n}W_{ij}(Y_i-\bar{Y})(Y_j-\bar{Y})}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n}W_{ij}} \qquad ...(1)$$

Where $S^2=\frac{1}{n}\sum_{i=1}^{n}(Y_i-\bar{Y})^2$, $\bar{Y}=\frac{1}{n}\sum_{i=1}^{n}Y_i$ (i denotes the years observed in region Y_i and refers to urban haze quantity $y_{i,t}$ in this study), n is number of provinces and W_{ij} is the binary weight matrix of the adjacent space.

The spatial weight matrix W is defined as

$$W_{ij}=\begin{cases}1; & \text{When the regional i and regional j are adjacent}\\ 0; & \text{When the regional i and regional j are not adjacent}\end{cases} \qquad ...(2)$$

Where $i=1,2,\cdots,n,\ j=1,2,\cdots,m$ and $m=n\ or\ m\neq n$.

2. Extreme bounds analysis (EBA) model. After the 1980s, Levine et al. (1992) proposed the EBA model to show the robustness relationship between variables and economic growth (Levine et al., 1992):

$$\Delta Y=c+\beta_i I_i+\beta_m M+\beta_z Z+\mu \qquad ...(3)$$

Where ΔY is the growth rate of the per capita GDP of a country or region, *I* is the core variable set composed of explanatory variables that are closely related to economic development, *M* is the target variable, *Z* is the conditional variable set composed of explanatory variables that are related to economic growth and μ is a random error term. Changes in and will not directly affect conclusions. Therefore, variables are mainly selected based on existing research results and literature.

Unlike general regression analysis, the EBA model analyses the sensitivity of the target variable regression coefficient through bootstrap alike regression of the conditional variable set and obtains the statistical distribution of coefficient estimation. If the maximum and minimum values of the 90% confidence interval have the same signs and significance, then the target variable is regarded as robust. The EBA model can process multicollinearity adequately, and the conclusion obtained is more convincing than that of general regression analysis. At present, the EBA model applies three main test methods, namely, "strict" EBA test, the big criterion and the Sala-i-Martin criterion. The first two methods are tedious, and their variables exhibit difficulty in passing the significance test. Therefore, the EBA model was tested using the Sala-i-Martin criterion in the current study in accordance with the paper (Ghosh et al. 2004).

3. EBA model based on spatial panel data. The use of spatial factors can significantly increase model accuracy. To test whether haze pollution exhibits the robustness overflow effect in neighbouring regions, the original EBA model should be revised as follows:

$$y = \rho(I_T \otimes W_N)y + \beta_1 pgdp + \beta_Z Z + \mu \qquad ...(4)$$

Where is the column of the explanatory variables, W_N is $n \times n$ the -order spatial weight matrix, $(I_T \otimes W_N)y$ denotes spatial first-order lag dependent variables, ρ is the spatial auto-regression parameter (-1,1) that indicates the degree of influence on neighbouring regions, is the core variable and is the linear combination of three variables that are randomly selected from the target variables for the significance test of haze pollution.

To test the influencing factors for the robustness of haze pollution, the robustness of the target variable for the first step of the significance test of the EBA model is tested as follows:

$$y = \beta X + \beta_M M + \beta_Z Z + \mu \qquad ...(5)$$

Where X is the core variable. If the test confirms the occurrence of the spatial overflow effect of haze pollution, then X contains the spatial lag term of haze pollution. The meanings of the other variables are the same as those in (3).

Data Source and Processing

Haze formation has many influencing factors. After considering data availability, the robustness test of the influencing factors of haze pollution was performed by selecting 15 variables from multiple dimensions. The indexes are listed in Table 1.

In accordance with literature (Engel-Cox et al. 2004), the $PM_{2.5}$ data used in this study were estimated by foreign research institutes based on satellite remote sensing data, which demonstrated high feasibility and reasonable scientific basis. Other data were mainly obtained from the China Statistical Yearbook (2004-2014) and the annual atmospheric pollutant monitoring reports of the Ministry of Envi-

Table 1: Influencing factors of haze pollution.

Category	Influencing factors	Index
Economic factors	Foreign direct investment (FDI)	FDI
	Industry structure (IS)	Proportion of secondary industrial growth in gross regional pro duction
	Industrial upgrading (IU)	Proportion of tertiary industrial output in the second industrial output
	Energy consumption structure (ECS)	Proportion of coal consumption in the primary energy consump tion (standard coal)
	Energy price (EP)	Ex-factory price indexes of industrial products
	Energy efficiency (EE)	Energy consumption for unit GDP
	Urban construction architecture (UCA)	Dust emission of different provinces
Population factors	Population dimension (PD)	Permanent resident population
	Human capital (HC)	Educational background
	Car ownership (CO)	Number of private car owners
	Freight traffic (FT)	Total amount of goods
	Biomass combustion (SY)	Quantity of crop straw combustion
Policy factors	Local financial expenditure (LFS)	Fiscal expenditure
	Industrial pollution control investment (IPCI)	Investments for pollution control
	Cleaning technology level (IWGF)	Industrial waste gas control facilities

(For convenience, all the indexes are expressed by the acronyms in the brackets hereafter.)

Table 2: Global Moran's *I* of $PM_{2.5}$ emission in 30 provinces (including cities and municipalities). in China from 2003 to 2013.

Year	Moran's *I*	E(I)	Sd(I)	Z	P
2003	0.454	-0.033	0.122	3.893	0.001
2004	0.473	-0.032	0.117	3.706	0.001
2005	0.424	-0.035	0.121	3.850	0.001
2006	0.401	-0.034	0.117	4.212	0.001
2007	0.447	-0.035	0.116	3.700	0.001
2008	0.476	-0.035	0.118	4.259	0.001
2009	0.502	-0.038	0.123	3.860	0.001
2010	0.476	-0.035	0.115	3.592	0.001
2011	0.489	-0.035	0.117	3.943	0.001
2012	0.430	-0.036	0.112	3.921	0.001
2013	0.412	-0.035	0.121	3.960	0.001

ronmental Protection. All data that involved any form of value were converted into constant prices using 2003 as the base period to eliminate the influence of the price factor. Moran's *I* was calculated using ArcGIS and OpenGeoda software, and panel data were processed using Eviews7 software. Spatial panel data were estimated using MATLAB 2012b software.

EMPIRICAL STUDY

Global spatial autocorrelation test: To investigate whether haze pollution exhibits an overflow effect, conducting a Moran's *I* test of the explanatory variables is necessary to determine the occurrence of spatial autocorrelation. If yes, then a spatial econometric model would be established for estimation and testing.

As shown in Table 2, the global Moran's *I* fluctuates between 0.4 and 0.5, and passes the 1% significance level. This result indicates that haze pollution in China exhibits strong spatial correlation. The neighbouring regions of an area with heavy haze pollution have relatively high $PM_{2.5}$ concentration.

Significance test of target variables: The significance test of 15 target variables shall be implemented firstly based on the test principle of the EBA model. If the test result is significant, then the variable passes the first step test of the EBA model. If not, then the variable cannot be used as a conditional variable. The model is expressed as

$$\ln PM2.5 = \alpha + \beta_i \ln PGDP + \beta_M M + \mu \qquad ...(6)$$

For the panel data model, time effect and individual effect should be considered during analysis. This study used short panel data, and thus, time effect could be neglected, and only the model with random and fixed effects was used. The results of the Hausman test are presented in Table 3.

After model type was determined through the Hausman test, regression based on MATLAB software was conducted. The results are shown in Table 4. With the exception of FDI, EP, SY and FT, the remaining 11 target variables passed the first step test of EBA, thereby indicating a significant correlation between these variables and haze pollution.

Robustness test of the overflow effect: Three target variables were randomly selected among those that passed the significance test to form the conditional variable set Z for the robustness test. If a probability of at least 90% to obtain same sign existed and the *t*-test result was significant, then the overflow effect would be significant. The test model is expressed as follows:

$$\ln PM2.5 = \alpha + \rho W \ln PM2.5_{it} + \beta_i \ln PGDP + \beta_Z Z + \mu \qquad ...(7)$$

The spatial lag model was used in this study. The maximum likelihood method was applied considering the autocorrelation and estimation errors of the ordinary least squares method. The estimations based on MATLAB software are presented in Table 5.

As shown in Table 5, the haze pollution in China exhibits a robust spatial overflow effect, and the test coefficient ρ is relatively large, thereby indicating that haze pollution in one region is significantly influenced by haze pollution in neighbouring regions from 2003 to 2013.

Robustness test of the influencing factors: The robustness of the 11 target variables that passed the significance test was tested using the Sala-i-Martin criterion. After several traversal regressions, the regression coefficient, *t*-test value, p value and significance distribution probability of the variables were obtained (Table 6).

As shown in Table 6, IS, ECS and UCA passed the test with significance values of 96.41%, 98.89% and 99.78%, respectively. This result reflects that the overall economic development of a region is closely associated with haze pollution. In the past decade, considerable expansion of the heavy industry and rapid urbanization have provided a strong momentum for the economic growth of China. How-

Table 3: Hausman test results.

Target variable	Chi-SP. Stat.	Chi-Sq.d.f.	Prob.	Model setting
FDI	5.705	2	0.047	Fixed
IS	1.939	2	0.399	Random
IU	0.623	2	0.770	Random
ECS	0.174	2	0.945	Random
EP	1.126	2	0.567	Random
EE	4.224	2	0.121	Random
UCA	19.587	2	0.001	Fixed
PD	9.832	2	0.004	Fixed
HC	0.197	2	0.915	Random
CO	23.544	2	0.001	Fixed
FT	11.138	2	0.004	Fixed
SY	8.134	2	0.020	Fixed
LFS	11.053	2	0.001	Fixed
IPCI	9.176	2	0.009	Fixed
IWGF	8.429	2	0.013	Fixed

Table 4: Basic test results and analysis.

Target variable	β_M	*t*-test probability	Passed or not
FDI	-6.123	0.118	No
IS	3.268	0.004	Yes
IU	-2.394	0.004	Yes
ECS	0.697	0.070	Yes
EP	0.017	0.648	No
EE	0.192	0.034	Yes
UCA	2.524	0.021	Yes
PD	3.926	0.006	Yes
HC	1.091	0.012	Yes
CO	4.224	0.016	Yes
FT	0.012	0.912	No
SY	1.214	0.275	No
LFS	-7.326	0.019	Yes
IPCI	0.761	0.021	Yes
IWGF	0.911	0.001	Yes
IWGF	0.901	0.002	Yes

(Note: The significance level is 10%. "Yes" indicates passing the test, whereas "No" indicates failing the test.)

ever, such extensive economic development was achieved at high costs and resulted in apparent industrial reconstruction and a high combined proportion (79%) of leading building materials, metallurgy, petroleum refining and thermal power in the total industrial output. The total atmospheric pollution emission is considerably higher than the environmental capacity, particularly in the Beijing-Tianjin-Hebei, Yangtze River Delta and the neighbouring mid-east regions, because of the combined influences of high energy demands and the coal-dominated energy consumption structure in China.

The influences of population factors on haze pollution should also not be disregarded. PD and CO passed the significance test (96.79% and 92.89%, respectively). On the one hand, population growth and concentration increase energy demands and car ownership, thereby continuously increasing local energy consumption and motor vehicle exhaust emission. On the other hand, these factors cause land source shortage in urban areas. An extremely high building density can easily cause traffic jam during rush hours and poor ventilation in urban areas, which are conditions for haze occurrence.

In addition, the significance distribution probabilities of IU, EE, HC, LFS, IPCI and IWGF are lower than 90%, i.e. they fail the robustness test. This result may be attributed to following reasons. 1) Although these variables have certain effects on haze pollution, they have limited influences and are easily disrupted by other factors. 2) Several variables have no direct quantitative index. For example, EP, HC and IWGF are represented by approximate variables. Moreover, the explanatory variable $PM_{2.5}$ concentration has been estimated by foreign scholars based on aerosol optical depth. Therefore, the statistical data may be unable to accurately reflect the actual conditions and levels of the research objects. The empirical analysis results may deviate from actual situations.

Policy Suggestions

Reasonably adjust the industrial structure and promote its upgrading: Attention should be directed to industry transformation and upgrading given the excess production capacities and low industrial levels in China. Backward productivity should be eliminated continuously to optimize local industrial structures. The government should release a series of tax preferences and subsidies in favour of enterprise transformation and upgrading. Such move will encourage enterprises to increase investment for production research and development as well as to reduce energy consumption per unit product. The government should also enhance the formulation of related laws and regulations, including mandating enterprises to abolish backward productivity that is not eliminated based on current requirements and meting out the corresponding punishment, as well as mandating enterprises to transform and upgrade from the side. Moreover, the government should set up an industrial structural transformation foundation to support enterprises with the intent to transform but without a capital. Embezzlement and misuse of funds should be strictly prevented, and a faultless supervision mechanism should be simultaneously established. From the perspective of society and industries, it will attract social capitals for the transformation and upgrading of enterprises with excess productivity and offset governmental fiscal shortage with social capitals. Particular attention should be directed to the con-

Table 5: Overflow test results of overall effect.

Test coefficient	Maximum	Minimum	Mean	Significance distribution probability (%)	Passed or not
ρ	10.246	-0.456	5.142	93.874	Yes

Table 6: Robustness test result of the influencing factors.

Target variables	βm-max	*t*-Stat.	Prob.	βm-min	*t*-Stat.	Prob.	Significance distribution probability (%)	Passed or not
IS	87.480	6.674	0	12.389	1.788	0.073	96.41	Yes
IU	-2.197	1.655	0.097	-7.651	-6.506	0	84.86	No
ECS	14.402	8.479	0	2.319	1.331	0.067	98.89	Yes
EE	-1.006	-1.679	0.084	-6.259	-6.497	0	60.56	No
UCA	9.511	9.653	0	4.068	4.851	0	99.78	Yes
PD	5.687	10.282	0	0.798	1.647	0.099	96.79	Yes
HC	3.972	5.620	0	1.115	1.662	0.096	81.53	No
CO	8.990	6.151	0	2.900	1.985	0.047	92.89	Yes
LFS	7.872	0.014	0	0.211	0	0	53.61	No
IPCI	3.676	3.504	0.001	0.008	1.789	0.073	55.83	No
IWGF	8.350	5.237	0	1.944	1.645	0.099	81.39	No
IWGF	8.479	5.239	0	1.978	1.647	0.097	81.39	No

siderable reform and reconstruction of state-owned enterprises in China. The reform of state-owned enterprises is one of the key factors that influences haze pollution control in China. Introducing social or private capitals at the appropriate time plays an important role in solving problems regarding the reform of state-owned enterprises and haze pollution. Similarly, attention should be directed to preventing the loss of state-owned capitals and receiving national benefits through illegal means. Different industrial criteria should be established. Industry associations should guide their respective industries to improve their product level and quality. They should establish detailed emission standards for different types of pollution and regularly release authoritative haze pollutant emission data by cooperating with universities and environmental assessment organizations in society. In addition, they should expose substandard enterprises and report them to concerned government departments (e.g. the Ministry of Environmental Protection) to enforce reforms.

Increase investment for haze pollution control and enhance haze control efforts: Haze pollution has only occurred in China in recent years, and thus, no adequate investment has yet been made for haze control. The characteristic of 'public goods' for haze pollution control requires the government to play an important role in such investments. All investments are made for the use of enterprises. In this process, the government should strengthen legislation and formulate special laws and regulations for haze pollution control. Unlike the previous *Law of Atmospheric Pollution Control*, these special laws and regulations should emphasize actual operability and suitability. Various emission taxes should be imposed to enterprises with different types of $PM_{2.5}$ emissions to expand the financial sources for haze pollution control of the government. The government should supervise the installation and usage of $PM_{2.5}$ processing instruments in executive enterprises and mete out punishments to those who did not install and use such instruments according to regulations. It can even order the closure of enterprises that seriously violate such regulations. All fines should be allotted to the government fund for haze pollution control. The government should provide enterprises with fiscal subsidies and tax preferences for PM2.5 processing instruments encourage enterprises to install and use such instruments, strictly control capital flow and establish a fixed sum for fixed purposes. The government should build a real-time monitoring network for testing pollutant emissions based on the Internet. Enterprises should install $PM_{2.5}$ processing instruments by strictly following laws and should keep such instruments running throughout production, which can reduce influences to the atmospheric environment. Government subsidies and tax preferences should be used strictly to control waste gas production, and enterprises should cooperate with government departments in tracing related expenditures. Moreover, enterprises should develop more effective $PM_{2.5}$ processing instruments to reduce production cost and relieve haze pollution in the entire society, thereby demonstrating the social responsibility of enterprises. They should report $PM_{2.5}$ emission and processing conditions to the Ministry of Environmental Protection and to civil society, invite the society and the public to monitor their production and management activities as well as pay taxes for $PM_{2.5}$ emission according to tax laws.

Promote improvement of the energy consumption structure and direct attention to the regional integrated control of haze pollution: One of important causes of serious haze pollution in China is the presence of numerous enterprises with high energy consumption, such as the thermoelectricity and smelting industries. Therefore, energy conservation and emission reduction policies have to focus on adjusting the energy consumption structure and using clean energy sources. Both the government and enterprises should exert positive efforts. The government should enhance the development of new energy sources and increase funds for the development of nuclear energy, solar energy, tidal energy, wind energy, bioenergy and hydropower, to realize transition from heat power to electricity. In particular, the government should attract social capitals to finance the input, increase conversion efficiency of research results and establish related standards. It should mandate enterprises to eliminate backward equipment (e.g. boiler), provide related enterprises with subsidies to purchase new energy equipment (this measure is particularly important for smelting enterprises, where the use electric furnace instead of the original coal blast furnace is suggested). The government should set new prices for different forms of energy, increase the price of raw coal appropriately, provide more price subsidies to new sources of energy, reduce usage cost and encourage the use of new sources of energy instead of fossil fuels. Moreover, the comprehensive use of gas boiler for heating should be achieved among enterprises during winter to reduce the use of highly polluting fuels such as coal as well as decrease smoke and dust emissions. Simultaneously, the government should build a regional office for environmental pollution control that will be responsible for implementing and explaining specific laws and regulations. An administrative organization that corresponds to regional haze pollution control regulations should be established, and related government departments in different administrative districts in the region should cooperate to set up a haze pollution control office that will be tasked to make overall and contingency plans for haze pollution control in the regions. A regional joint law enforcement mechanism that will be responsible for invoking the cooperation of environmental monitoring agencies of different administrative districts should be created. To increase the utilization of funds, the funds for haze pollution control should be budgeted by the haze pollution control office in the region, and the procurement of funds should be determined by regional financial sectors based on industrial economic development and then distributed uniformly according to haze pollution conditions.

CONCLUSIONS

Haze pollution has increased accordingly with the rapid industrialization and urbanization, along with the increasing energy consumption, in China. Influencing factors are explored to further analyse the spatial distribution and overflow effect of haze pollution in China. The global Moran's I is estimated based on panel data for 30 provinces (including cities and municipalities) in China from 2003 to 2013. An index system for the social and economic variables of haze pollution, which covers economic, population and policy factors, is established. The spatial correlation and influencing factors of haze pollution in China are discussed based on the EBA model. An empirical study shows that the global Moran's I fluctuates between 0.4 and 0.5 and passes the 1% significance test, thereby indicating that haze pollution exhibits strong spatial correlation. The correlation coefficient ρ is relatively large, which implies the robust spatial overflow effect of haze pollution. Haze concentration is observed in the Beijing-Tianjin-Hebei, Yangtze River Delta and mid-east regions. Industrial structure, energy consumption structure, urban construction architecture, population dimension and car ownership exhibit anti-interference robustness effect on haze pollution. This study considers only 15 influencing factors of haze pollution. However, haze pollution has many influencing factors and not all of them can be included in this study because of limitations in research perspective, data availability and other aspects. Future studies can consider as many correlated variables as possible to form the conditional variable set and discuss the correlation of haze pollution among regions with different economic developments as well as the cross-administrative regional control for haze pollution.

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