Socio-economic factors on haze pollution: based on panel data of 30 provinces in China

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Abstract. Since Reform and Opening-up, China’s economy has been developing rapidly and per capita GDP has been raising. However, along with the rapid development of the economy, the problem of air pollution such as haze becomes increasingly serious, which has seriously affected the health of residents and the sustainable development of the economy. In this paper, we adopt spatial econometrics to explore the relationship between socio-economic factors and haze pollution. Firstly, there is significant spatial autocorrelation in haze pollution. Secondly, population, coal consumption and urbanization have positive and significant impacts on haze pollution. In this regard, governments should coordinate economic growth with environmental protection, balance the relationship between economic growth and environmental pollution.

1. Introduction
In recent years, China’s extensive industry has developed rapidly, and China’s world factory status has been established. However, while GDP per capita is close to 10,000 dollars, China has also entered the peak of environmental pressure. The national haze weather since the winter of 2012 clearly reveals the severity of China’s environmental pollution and the extreme ecological vulnerability. The composite haze with PM10 and PM2.5 as key pollutants not only endangers the health of Chinese residents, but also affects China’s traffic safety, agricultural production and economic growth. It has seriously hindered the sustainable development of China’s economy. The “13th Five-Year Plan” proposes that we should implement the development concept of “green”, and promote the construction of ecological civilization in China. The 19th National Congress points out that it is necessary to promote green development and solve obviously environmental problems. Therefore, it is of great practical significance for the government to make reasonable environmental protection policies and promote the sustainable development of China’s economy and environment to delve into the current situation and related influencing factors of haze pollution in China.

2. Literature review
Studying the formation mechanism, spatial distribution and socio-economic influence factors of haze pollution has always been a key issue for scholars at home and abroad. In recent years, some scholars have begun to change from traditional analytical methods to spatial econometric methods to study the spatial effects and influencing factors of haze pollution. Spatial econometric expert Anselin specifically discussed the importance of spatial factors for environmental economic issues[1]. Then, Rupasingha,
etc., firstly used this method to discuss the relationship between per capita income and air pollution in 3,029 US counties[2]. Hosseini, etc used spatial measurement methods to study the two major air pollutants CO2 and PM10 in Asian countries over the period 1990-2007[3]. It was found that the two pollutants had obvious spillover effects among Asian countries, and the spatial factors could not be ignored. On one hand, some scholars used spatial econometrics to study haze pollution, and pointed out that industrial transfer is an important cause of spatial dependence of haze pollution[4]. On the other hand, other scholars used the spatial limit boundary analysis model to study the spatial correlation and the influencing factors of robustness of haze pollution in China. The result showed that there is a “robustness” spatial spillover effect in China’s provincial haze pollution[5]. In conclusion, most of the research conclusions showed that coal-based energy structure, industrial-based industrial structure, high urbanization level and the improvement of transportation intensity play a significant role in promoting the level of haze pollution. However, based on the differences in selected data and models, there are two controversial conclusions about the impact of economic growth on haze pollution. One is in line with the EKC hypothesis. And the other is that it does not conform to the EKC hypothesis, and that there an obviously U-shaped curved relationship between haze pollution and economic growth.

At present, the researches on the use of spatial econometric methods to study haze pollution in Chinese start late and are relatively few. The number of samples studied is small, and most of them are analyzed from the perspectives of single cities (Beijing, Tianjin, etc), provinces, large regions (such as Beijing-Tianjin-Hebei, Yangtze River Delta, etc). There are few studies on the current situation and influencing factors of haze pollution in China from a nationwide perspective. At this stage, the spread of haze pollution in China is no longer limited to a certain area. In the worst case, half of the provinces are suffering from haze. Only from a global perspective, coordinating collaboration, it can truly play the role and effectiveness of regional joint defense and joint control.

3. Methodology

In general, we think that haze pollution may have the spatial spillover effect, and we utilize the PM2.5 emissions to measure it. First of all, we establish a economic model including the socio-economic factors that may have impact on haze pollution. Then we take the spatial autocorrelation analysis to test whether the spillover effect exists. Finally, we utilize spatial econometric model to estimate the effects of these socio-economic factors and draw the conclusion.

3.1. Model design

Following an extant literature, we have made some modifications to the STIRPAT model to identify the existence of turning point between economic growth and haze pollution, and get this empirical model as followed:

$$\ln \text{pm25} = \beta_1 \ln \text{pop} + \beta_2 \ln \text{coal} + \beta_3 \ln \text{fdi} + \beta_4 \ln \text{pgdp} + \beta_5 \text{urban}$$

where pm25 measures the concentration value of PM2.5 emissions; pop is the total population in a province; coal represents coal consumptions; fdi is the foreign direct investments in China; pgdp is the level of economic growth measured by GDP per capita and urban is the urbanization rate. The PM2.5 concentration value is based on satellite observations, all data of independent variables come from official data of 30 provincial administrative regions in China, and the selected period is from 2002 to 2013. All of these variables except urbanization

The following table is the result of descriptive statistics. We can see that the annual average concentration of PM2.5 is about 26.84 μg/m³. In some heavily polluted places, haze pollution can even reach 83.09 μg/m³.

| Variables          | Observation | Mean   | Std. Dev | Min  | Max  |
|--------------------|-------------|--------|----------|------|------|
| ln pm25 (μg/m³)    | 360         | 3.29   | 0.62     | 1.56 | 4.42 |
| ln pop (10⁴ peoples)| 360         | 8.93   | 0.76     | 6.27 | 9.27 |
| ln coal (10⁴ t)    | 360         | 13.45  | 0.92     | 5.79 | 10.60|
| ln fdi (RMB 10⁴ yuan) | 360       | 12.08  | 1.65     | 7.62 | 15.09|
3.2. Spatial autocorrelation analysis
Firstly, PM2.5 can spread from one province to another through the air, and areas have significant influences on the surrounding areas. Classic econometrics models ignore the spatial effects of variables, so the estimated results are usually biased. Spatial econometrics takes account of the spatial autocorrelation and spatial heterogeneity, it can better estimate the parameters of variables and reveal the spatial characteristics of data.

Before using spatial econometrics model, we must examine whether the spatial distribution of PM2.5 is uneven. Generally, we are supposed to test global spatial autocorrelation and local spatial autocorrelation. Moran’s I is usually used to test global spatial autocorrelation. To calculate the global Moran’s I (GMI), we must adopt an appropriate spatial weight matrix. In this paper, we consider the impact of geographical adjacency and adopt the first-order binary contiguity matrix with the rook contiguity:

\[
 w_{ij} = \begin{cases} 
 0, & \text{if } i \text{ and } j \text{ are not adjacent} \\
 1, & \text{if } i \text{ and } j \text{ are adjacent} 
\end{cases}
\]

Then the equation for calculating global Moran’s I is as follows:

\[
 I = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} (x_i - \bar{x})(x_j - \bar{x})}{S^2 \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}}
\]

where \( S^2 = \sum_{i=1}^{n} (x_i - \bar{x})^2/n \), \( x_i \) and \( x_j \) present the observation in region \( i \) and \( j \), \( n \) is the total amount of region and \( w_{ij} \) is the elements of spatial weight matrix.

3.3. Spatial econometric model
In terms of different classification criteria, spatial econometrics models are various, and the widely used estimation methods in empirical research are spatial autoregression model (SAR), spatial error model (SEM) and spatial Durbin model (SDM).

According to the viewpoint of Elhorst, if using a spatial econometric model to analyze, it is a better way to adopt an SDM because it could nest both SAR and SEM. The SDM is as followed:

\[
 y = \delta Wy + X\beta + WX\theta + \epsilon
\]

where \( y \) is the dependent variable; \( X \) is the explanatory variables; \( \delta \) is the spatial lag term; \( W \) is the spatial weight matrix; \( \beta \) and \( \theta \) are coefficients of explanatory variables and their spatial lag, respectively; \( \epsilon \) is the random disturbance term.

4. Estimation results and discussion
At first, it’s necessary to test whether spatial spillover effect of haze pollution exists, so I calculate the Moran’s I of PM2.5 from 2002 to 2013. Table 2 reports the results, it shows that spatial autocorrelation is positive and significant at the 1% level, which means that local haze pollution may have impact on the air quality in surrounding province. Therefore, we can adopt the SDM for further analysis.

Table 2. Moran’s I of PM2.5 emissions and its statistical test.

| Year | Moran’s I | z-value | Year | Moran’s I | z-value |
|------|-----------|---------|------|-----------|---------|
| 2002 | 0.6063    | 5.4154  | 2008 | 0.6129    | 5.4392  |
| 2003 | 0.6398    | 5.7385  | 2009 | 0.5864    | 5.2585  |
| 2004 | 0.6271    | 5.5629  | 2010 | 0.5910    | 5.2567  |
| 2005 | 0.5991    | 5.2838  | 2011 | 0.6261    | 5.5947  |
| 2006 | 0.6027    | 5.5042  | 2012 | 0.6110    | 5.4874  |
| 2007 | 0.6286    | 5.6001  | 2013 | 0.6095    | 5.5080  |

Secondly, after the spatial autocorrelation analysis, we adopt SDM to estimate the model (1). Here is the results of direct effects, indirect effects and total effects.
From table 3, we could draw that population has significant positive impact on haze pollution either in local province or surrounding provinces. The concentration of population makes the demand for housing rise sharply, so a large amount of dust is generated on construction sites, and it also causes electrical power. These factors may cause haze pollution.

Considering the coal consumption, coefficient is also positive and significant at 1% level. This may be because coal combustion can produce a large amount of volatile pollutants such as PM2.5, and these pollutants are easily spread through air. In daily life, household coal can not be effectively desulfurized and denitrified, resulting severe air pollution. However, domestic coal consumption on haze pollution in neighboring provinces is not significant. It may be beacuse that coal consumption in different provinces is self-sufficient.

The coefficients of foreign direct investments and economic growth are negative, both of them are significant at 5% level or less for direct effects, indicating they can reduce the domestic haze pollution. As China’s economy grows, people’s life is getting better and better, so they put forward to higher requirements for living environment. Meanwhile, foreign companies may share technology with Chinese companies to obtain policy support and divends.

| Variables | Direct effects | Indirect effects | Total effects |
|-----------|----------------|-----------------|---------------|
| ln pop    | 0.3442***      | 0.6146**        | 0.9588***     |
|           | (4.2313)       | (2.1366)        | (2.6864)      |
| ln coal   | 0.1177***      | 0.1817          | 0.2993**      |
|           | (2.9754)       | (1.4451)        | (2.0773)      |
| ln fdi    | -0.0739**      | 0.0181          | -0.0558       |
|           | (-2.0871)      | (0.1258)        | (-0.3240)     |
| ln pgdp   | -0.5278***     | 0.1465          | -0.3813       |
|           | (-3.9040)      | (0.3490)        | (-0.7726)     |
| urban     | 0.0287***      | 0.0400**        | 0.0687***     |
|           | (6.7017)       | (2.2550)        | (3.4289)      |

Third, urbanization can also increase haze pollution. With the advancement of urbanization, buildings are more and more, causing urban heat island phenomenon. In addition, industrial structure, energy consumption, and the number of cars are also a reflection of the degree of urbanization. These factors may cause the deterioration of haze pollution.

Finally, considering the total effects, due to the insignificant indirect effects of foreign direct investments and economic growth, only population, coal consumption and urbanization could exacerbate air pollution.

5. Conclusion and policies
Based on the study for social economic factors on haze pollution in China, we can draw the following conclusions.

First of all, Moran’s I denotes that there is obvious spatial autocorrelation of PM2.5 emissions. In other words, domestic haze pollution could spillover from locality to surrounding provinces, it may be caused by the physical characteristics of PM2.5 particles.

Second, spatial econometric model demonstrates all of the independent variables have significant impacts on PM2.5 emissions for local provinces. Among them, population, coal consumption and urbanization could increase haze pollution. Meanwhile, foreign direct investments and economic growth exhibit an inhibitory effect on haze pollution.

Third, on the whole, population aggregation, coal burning and unrestrained urbanization expansion will make the environment quality worse and worse. Impacts on foreign direct investments and economic growth are less obvious on air quality.

Therefore, local governments need to find the balance point between haze pollution and urbanization, and it’s necessary to provide policy support to enterprises that develop new energy technologies. Residents should also establish a sense of environmental protection and earnestly implement a garbage
classification system.

References
[1] Anselin, L. (2001) Spatial effects in econometric practice in environmental and resource economics. American Journal of Agricultural Economics, 83: 705-710.
[2] Rupasingha, A., Goetz, S.J., Debertin, D.L., Pagoulatos, A. (2004) The environmental kuznets curve for US counties: A spatial econometric analysis with extensions. Papers in regional Science, 83: 407-424.
[3] Hossenei, H.M., Rahbar, F. (2011) Spatial environmental kuznets curve for asian countries: study of CO2 and PM10. Journal of environmental studies, 37: 1-14.
[4] Ma L., Zhang, X. (2014) Spatial effects of regional air pollution and the impact of industrial structure. China Population Resources & Environment, 7: 157–164.
[5] Wang L., Chen, J. (2016) Socio-economic influential factors of haze pollution in china: Empirical study by eba model using spatial panel data. Acta Scientiae Circumstantiae, 36: 3833–3839.
[6] Elhorst, J.P. (2014) Spatial econometrics: from cross-sectional data to spatial panels. Springer, Berlin.