Research on the causes of smog and the effect of spatial spillover

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Abstract: This paper uses the method of spatial measurement to explore the interaction of smog pollution between local and remote areas in 31 provinces in China and the impact of economic changes. Global spatial correlation analysis shows that there is significant spatial positive correlation of smog pollution, and local spatial correlation shows that the high concentration of pollution is distributed in Beijing-Tianjin-Hebei and adjacent Shandong, Henan, Liaoning, based on environmental Kuznet The curve (also known as the EKC curve) found that smog pollution is closely related to the growth of the main business income, and the inverted U-shaped relationship between smog pollution and economic growth does not exist or has not yet appeared. That is to say, with the growth of the main business, the pollution level is rising continuously. The comprehensive empirical analysis shows that the spatial spillover effect of smog pollution is particularly obvious. The high pollution concentration area is affected by the neighboring areas, and it is difficult to obtain all the benefits from the implementation of environmental regulation. It is imperative to control smog and strengthen inter-regional joint defense.

1. Introduction

In recent years, due to environmental pollution and other problems, air quality has continued to deteriorate, smog weather has increased, and the damage has intensified, which has had a great impact on people's production and life. In addition, smog has become a foreign investment for foreign investors in China. As well as the important obstacles for tourists, especially the impact on the image of international metropolises such as Beijing, far exceeds the loss of economic interests. This paper attempts to use the spatial panel metrology model to discuss and analyze the smog pollution based on the environmental Kuznets curve. Foreign scholars have studied the spatial spillover effects and EKC curves of air pollution. Rupasingha, A. et al studied the relationship between per capita income and air pollution in 3,029 counties in the United States, and found that the influence of adding spatial factors can improve the accuracy of the model. [1], Maddison conducted research on European countries, and concluded that the spillover effect of air pollution between countries does exist [2]. Poon et al. found that there is a significant spillover effect between China's provinces and cities by studying the impact of energy traffic and foreign trade on China's air pollution. Early scholars have learned from experience that environmental quality is deteriorating with economic growth. However, there is no empirical analysis [3]. In 1991, American economists Grossman and Krueger first discussed the impact of North American free trade on the US domestic environment. The relationship between environmental quality and per capita income was empirically studied with four pollutants [4]. It was found that per capita income and environmental quality showed an inverted U-shaped curve. The turning point occurs when per capita income reaches $8,000. The EKC curve reveals that environmental quality is degraded as the
economy grows, but when income reaches a certain level, the income increases and improves. The existing literature on smog research focuses on industrial agglomeration, the relationship between energy structure and smog, and foreign scholars have rarely systematically studied the spillover effects between various provinces and cities in China. This paper attempts to pass provincial and municipal panel data. The province is a sample to study the influencing factors and spatial spillover effects of haze.

1.1 Data source and processing instructions
This paper mainly studies the composition of smog PM10. The average annual concentration of PM10 is from the “Resources and Environment” in China Statistical Yearbook. The average annual concentration of PM10 and SO2 in 2013-2015 is calculated by area weighting. Correlation Data processing and plotting in the analysis were performed by the Keyoda version 1.8 software. The spatial econometric regression analysis was calculated by Matlab software.

2 China's smog pollution space autocorrelation test

2.1 Global Spatial Autocorrelation
The global spatial autocorrelation is to study whether the regional distribution has agglomeration characteristics, reflecting the similarity of adjacent spaces. Usually measured by the Moran’I index, the Moran index is the standardized spatial auto-covariance. Assuming a vector X = [ x1, x2, ... xn], the global Moran'I index is expressed as follows:

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

\[ s^2 = \sum_{i=1}^{n} (x_i - \bar{x})^2 \]

Among them, \( x_i \) is the annual average concentration of air pollutants in i province, the unit is micrograms per cubic meter. \( w_{ij} \) is a spatial weight matrix. The value of Moran’I is generally between -1 and 1, and a value greater than 0 indicates a positive correlation, that is, regions of the same attribute value are gathered together, and less than 0 indicates a negative correlation, that is, regions having different attribute values are gathered together. A value close to 0 indicates that the attributes are randomly distributed, and \( w_{ij} \) selects a spatial neighboring matrix. The principles set are as follows:

\[ W_{ij} = \begin{cases} 1 & \text{if } i \neq j \\ 0 & \text{if } i = j \end{cases} \]

Table 1-1. Moran’I of PM10 Annual Concentration in 31 Provinces and Cities in China, 2006-2015

| year | Moran’I | E (1) | Mean | Sd | Z-value | P-value |
|------|--------|------|------|----|---------|--------|
| 2006 | 0.254389 | -0.0333 | -0.0259 | 0.1127 | 2.4860 | 0.0160 |
| 2007 | 0.188535 | -0.0333 | -0.0308 | 0.1145 | 1.9153 | 0.0370 |
| 2008 | 0.138982 | -0.0333 | -0.0283 | 0.1161 | 1.4403 | 0.0900 |
| 2009 | 0.238473 | -0.0333 | -0.0327 | 0.1166 | 2.3248 | 0.0140 |
| 2010 | 0.204861 | -0.0333 | -0.0324 | 0.1087 | 2.1813 | 0.0190 |
| 2011 | 0.175615 | -0.0333 | -0.0285 | 0.1110 | 1.8386 | 0.0390 |
It can be seen from Table 1-1 that during the period of 2006-2015, the global Moran'I index of annual average PM10 concentrations in 31 provinces and cities in mainland China was positive, and the Moran'I index test was tested on the assumption of normal distribution. The results are also highly significant. During 2006-2015, there was a significant and positive spatial autocorrelation of the average PM10 concentration in 31 provinces of mainland China. It indicates that the haze pollution has obvious agglomeration characteristics.

2.2 Local spatial autocorrelation

2.2.1 Moran’I scatter plot of PM10 average annual concentration

The first quadrant of Moran scatter plot is the diffusion effect zone, the second quadrant is the polarization effect zone, the third quadrant is the transition zone, and the fourth quadrant is the low-speed growth zone. In the Moran scatter plot, the objects are represented by provinces. For example, the annual average concentration of PM10 in 2015 is the first provinces corresponding to the provinces of Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Shandong, Henan, Hubei, Hainan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang.

\[
I_i = \frac{(x_i - \bar{x})}{s} \sum_j w_{ij}(x_j - \bar{x})
\]

2.2.2 Local Moran index

The local Moran index is used to test the aggregation of observations in local areas. The Local Moran'I statistic can measure local area correlation. Its expression is:

\[
I_i = \frac{(x_i - \bar{x})}{s} \sum_j w_{ij}(x_j - \bar{x})
\]
3.1 Model setting

In order to verify the relationship between air pollution and manufacturing, the relationship between China's environmental quality and manufacturing development is judged by analyzing the environmental primary and secondary factors by referring to the environmental Kuznets curve and using multiple regression methods. So create the following model:

$$Y_{it} = \beta_0 + \beta_1 \ln MN_{it} + \beta_2 (\ln MN_{it})^2 + \beta_3 PC_{it} + \beta_4 RN_{it} + \beta_5 RB_{it} + \mu_{it}$$

$Y_{it}$ indicates the concentration of PM10 in year $t$ of $i$ province, $MN_{it}$ indicates the main business income of industrial enterprises above the scale of $i$ provinces, $PC_{it}$ indicates the private car ownership of $t$ provinces in $i$ province, $RN_{it}$ indicates the rainfall of the province in $t$ years, $RB_{it}$ indicates the amount of waste incineration in the year $t$ of the province.

The spatial lag model mainly investigates the influence of the behavior of adjacent areas directly on the behavior of samples in the region. Its measurement formula is:

$$Y_{it} = \beta_0 + \beta_1 \ln MN_{it} + \beta_2 (\ln MN_{it})^2 + \beta_3 PC_{it} + \beta_4 RN_{it} + \beta_5 RB_{it} + \rho \sum_{j=1}^{n} w_{ij} Y_{jt} + u_{it} + \epsilon_{it}$$

The spatial error model is mainly used to study the relationship between the inter-regional relationships through the correlation between the error terms. The spatial effect is reflected in the error term. The measurement expression is:

$$Y_{it} = \beta_0 + \beta_1 \ln MN_{it} + \beta_2 (\ln MN_{it})^2 + \beta_3 PC_{it} + \beta_4 RN_{it} + \beta_5 RB_{it} + u_{it} + \epsilon_{it} + \delta_{it}$$
3.2 Empirical Analysis Based on Different Spatial Matrices

Table 3-1. Comparison of regression analysis based on spatial neighboring binary matrix PM10

|                  | Panel Model | Spatial lag panel data model | Spatial error panel data model |
|------------------|-------------|-----------------------------|------------------------------|
|                  | Model 1     | Model 2                     | Model 3                      |
|                  | Model 4     | Model 5                     | Model 6                      |
|                  | OLS         | Fixed effect                | Random effect                |
|                  |             | Fixed effect                | Random effect                |
|                  |             | Fixed effect                |                              |
| $P$              |             | 0.3529***                  | 0.3440***                   |
|                  |             | (0.0000)                   | (0.0000)                     |
| $\lambda$        |             |                             | 0.3474***                   |
|                  |             |                             | (0.0000)                     |
| C                |             | 53.6681**                  | 66.3246*                     |
|                  |             | (0.04489)                  | (0.0511)                     |
| $\ln(MNl_t)$     |             | -3.6884**                  | -0.7709                     |
|                  |             | (0.0349)                   | (0.6851)                     |
| ($\ln(MNl_t)^2$ |             | -0.6671*                   | 0.2001                      |
|                  |             | (0.07554)                  | (0.7021)                     |
| $PC_i$           |             | 0.0399***                  | 0.0273**                    |
|                  |             | (0.00004)                  | (0.0243)                    |
| $RN_i$           |             | -0.030***                  | -0.0110**                   |
|                  |             | (0.0000)                   | (0.0359)                    |
| $RB_i$           |             | -0.0244                    | -0.0500**                   |
|                  |             | (0.1036)                   | (0.0138)                    |
| $R^2$            |             | 0.3138                      | 0.0368                      |
|                  |             | 0.6756                      | 0.7088                      |
|                  |             | 0.6761                      | 0.6613                      |
| Hausman          |             | 0.9858                      | 0.0175                      |

Table 3-2 SAR and SEM panel estimation model judgment test

|                        | LM lag | Robust LM lag | LM error | Robust LM error |
|------------------------|--------|---------------|----------|-----------------|
| probability            | 0.000  | 0.000         | 0.000    | 0.974           |

The test result is selected by the model, and the spatial lag model (SAR) is superior to the spatial error model (SEM). It can be seen that PM10 has spatial lag correlation. The fixed effect model is then selected by the spatial Hausman test. Therefore, the optimal model is model 4. From the regression results of model 4, it is known that the factors affecting PM10 concentration mainly include private car ownership. The effect of rainfall on PM10 concentration is not significant, but the spatial spillover effect is particularly obvious, indicating pollutants. The transfer between regions has spatial and temporal externalities. The concentration of PM10 in the study subject will be affected by the neighboring provinces and cities. For every 1% increase in PM10 concentration in the surrounding area, the PM10 concentration in the region will increase by 0.3440%. The main business income and the squared
The coefficient did not pass the significance test. It shows that the environmental Kuznets curve does not exist in the relationship between China's economic development and the environment.

References:
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