Research on spillover effect of industrial agglomeration and haze pollution in China

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Abstract: Based on the samples of 31 provinces (cities, autonomous regions) in China from 2000 to 2016, this paper studies the correlation and spillover of industrial agglomeration and haze pollution. The results show that: (1) the spillover effect of industrial agglomeration and haze pollution is obvious. Haze pollution is mainly high-high agglomeration and low-low agglomeration, showing stability. (2) Haze pollution is also more serious in areas with high industrial concentration, and the two show correlation and consistency. Based on this, This paper suggests that the complementary mechanism of haze prevention and control should be improved to better strengthen regional cooperation and achieve the best effect of coordinated management of regional joint prevention and control.

1. Introduction
The generation of haze pollution is the result of many factors, but the reason lies in the unreasonable industrial structure and energy efficiency caused by the extensive development of China's economy. As a special form of industrial organization, the impact of industrial agglomeration on haze pollution cannot be ignored. Therefore, it is of practical significance to clarify the distribution of industrial agglomeration and haze pollution to select to locate industrial agglomeration and give full play to the scale effect of industrial agglomeration to lessen haze pollution. Based on the statistical data of 31 provinces (cities, autonomous regions) in China from 2000 to 2016, using the global and local Moran's I, the cold hot spot analysis method to study the spatial correlation and spillover of industrial agglomeration and haze pollution.

2. Literature review
2.1. Spillover effect of industrial agglomeration
Chen et al. (2020) used Dubin model to study the relationship between industrial agglomeration, pollution and ecological efficiency. The results show that industrial agglomeration and pollution have significant spatial spillover effects, and the relationship between them is inverted U-shaped. Zhang L et al. (2018) studied the relationship between industrial agglomeration and carbon emissions and found that the spatial spillover of industrial agglomeration is of great significance to reduce carbon emissions, and its joint effect with urbanization helps to reduce carbon emission intensity. Cohen jp and Paul CJM (2005) studied the spatial agglomeration of food manufacturing industry and agriculture in the American States, and found that the domestic industrialization will also be affected by the supply side agglomeration effect of neighboring countries, and the marginal cost of industries with high
agglomeration degree is smaller.

2.2. Spatial spillover effect of haze pollution

Yan et al. (2018) found that PM2.5 concentration had spatial and temporal differences when studying the characteristics of haze evolution in Beijing, Tianjin and Hebei, i.e. it was higher in winter than other seasons, higher in northwest than in southeast, and there was significant spatial spillover effect. Wu et al. (2018) studied the time characteristics and source analysis of PM2.5 in 367 cities in China, and found that there was a regional transmission effect of haze pollution. Haze pollution not only came from the exhaust gas from fossil energy combustion, but also from the impact of neighboring areas. Sulong NA et al. (2017) studied the sources and health risks of haze in Malaysia and Kuala Lumpur. It was found that smoke generated by Sumatra fire activities would be transported to Kuala Lumpur along with the air mass, causing harm to the health of local residents.

Through combing the above literature, we can find that the spatial spillover effect of industrial agglomeration and haze pollution has attracted the attention of experts and achieved corresponding research results, but there are relatively few literatures that put industrial agglomeration and haze pollution into the unified analysis framework, so the contribution of this study is to use the data of 31 provinces (cities and autonomous regions) in China from 2000 to 2016 to study the spatial correlation and spatial spillover between industrial agglomeration and haze pollution. The data of haze pollution in this paper comes from the center for social and economic research and application of Columbia University, and the data needed for industrial agglomeration comes from the China Statistical Yearbook and the statistical yearbooks of various provinces and cities.

3. Spatial correlation analysis of industrial agglomeration and haze pollution

3.1. Spatial correlation analysis of industrial agglomeration

This paper chooses location entropy as the main explanatory variable of the follow-up empirical analysis. The formula is as follows:

\[ \text{Agg} = \frac{\sum X_{ij}}{\sum \sum X_{ij}/X_{ij}} \]

\[ X_{ij} \text{ represents the output value of i industry in j region. This paper chooses the output value of the secondary industry as the research object. When the Agg value is greater than 1, it indicates that the industrial agglomeration degree of j region is better than the national average level. Based on the output value data of the secondary industry, the corresponding location entropy is calculated as shown in table 1:} \]
Table 1 The description of the location entropy statistics

| Province         | Mean | Std. Dev | Min  | Max  | Province         | Mean | Std. Dev | Min  | Max  |
|------------------|------|----------|------|------|------------------|------|----------|------|------|
| Beijing          | 0.516| 0.069    | 0.468| 0.749| Hubei            | 1.087| 0.132    | 0.888| 1.346|
| Tianjin          | 1.181| 0.060    | 1.077| 1.275| Hunan            | 0.934| 0.119    | 0.774| 1.098|
| Hebei            | 1.178| 0.046    | 1.100| 1.246| Guangdong        | 1.122| 0.068    | 0.994| 1.206|
| Shanxi           | 1.153| 0.128    | 0.949| 1.326| Guangxi          | 0.902| 0.151    | 0.706| 1.111|
| Inner Mongolia   | 1.038| 0.202    | 0.747| 1.259| Hainan           | 0.421| 0.069    | 0.316| 0.537|
| Liaoning         | 1.123| 0.082    | 0.915| 1.226| Chongqing        | 0.944| 0.155    | 0.709| 1.171|
| Jilin            | 1.047| 0.156    | 0.864| 1.276| Sichuan          | 0.968| 0.131    | 0.822| 1.170|
| Heilongjiang     | 1.114| 0.209    | 0.708| 1.458| Guangxi          | 0.902| 0.151    | 0.706| 1.111|
| Shanghai         | 0.969| 0.091    | 0.801| 1.073| Guangdong        | 1.122| 0.068    | 0.994| 1.206|
| Jiangsu          | 1.173| 0.039    | 1.117| 1.265| Hunan            | 0.421| 0.069    | 0.316| 0.537|
| Zhejiang         | 1.151| 0.018    | 1.120| 1.190| Tibet            | 0.192| 0.015    | 0.169| 0.224|
| Shanghai         | 1.087| 0.071    | 0.934| 1.212| Shaanxi          | 1.034| 0.173    | 0.762| 1.239|
| Fujian           | 0.973| 0.197    | 0.671| 1.200| Shandong         | 0.922| 0.079    | 0.766| 1.000|

Data sources: China statistical yearbook

It can be seen from table 1 that the location entropy of most provinces in the eastern and middle China is greater than 1, indicating that the degree of agglomeration of the secondary industry in these regions is better than the national average level, and the location entropy of the western region is generally less than 1, indicating that the level of industrial agglomeration is in a relative disadvantage in the country. The fluctuation of location entropy of most provinces in the central and western regions is higher than that in the eastern regions. As a whole, the secondary industry shows a trend of agglomeration from the eastern to the central and western regions.

The commonly used indicators to analyze the spatial correlation and degree of industrial agglomeration are global spatial relevance and local spatial relevance. The formula of global Moran's I is as follows:

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

Where \(I\) is Moran's I, \(X_i\) is the industrial agglomeration value of the \(i\)th region, and \(W_{ij}\) is the spatial weight matrix. When Moran's I is greater than 0, it indicates that there is a positive spatial autocorrelation in the industrial agglomeration. The formula of local Moran's I is as follows:

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

The meaning of each variable is the same as that of formula (2). In this paper, we use the local Moran's I to depict the Lisa maps of the local industrial agglomeration in China in 2000, 2008 and 2016, as shown in figure 1-3:
From the analysis of figure 1-3, it can be seen that Hebei, Shandong, Henan, Jiangsu are areas with better industrial agglomeration than the national average level, and the surrounding areas also show the relative advantages of industrial agglomeration, that is, the "high-high" type of agglomeration, which is also consistent with the fact that China's secondary industries are mostly concentrated in the east and the middle. The industrial agglomeration in Xinjiang, Yunnan, Sichuan is inferior to the national average level. Beijing and Shanxi are characterized by "low-high" agglomeration.

3.2. Spatial correlation analysis of haze pollution

In this paper, the global Moran's I is used to test the spatial correlation of PM2.5. According to formula (2), Moran's I = 0.295812 in 2000, Moran's I = 0.353179 in 2008, Moran's I = 0.403587 in 2016, indicating that there is a positive spatial correlation between the haze pollution in each region. Moran's I increased year by year in 2000, 2008 and 2016, indicating that the spatial agglomeration effect of PM2.5 is increasing. At the same time, the spatial distribution of haze pollution is described with the help of Moran scatter plot. The spatial homogeneity of the first and the third quadrants is large, and the spatial difference of the second and the fourth quadrants is large. The results are shown in figure 4-6.

It can be seen from Moran scatter figure 4-6 that in 2000, 2008 and 2016, most regions in China were located in the first or third quadrant, i.e. high-high concentration and low-low concentration, which are the main forms of haze pollution in China. Specifically, 20 provinces (cities, autonomous regions) have not changed, showing the spatial stability of haze pollution. Beijing and Shanghai transferred from LH area to HH area, and Ningxia and Shaanxi from HH area to LL area, indicating that the spatial concentration characteristics of haze pollution are more obvious.

In order to better observe the distribution of PM2.5 in China, ArcGIS is used to analyze the local spatial evolution characteristics of haze pollution. figure 7-9 shows the distribution of PM2.5 in the 31 regions in 2000, 2008 and 2016. On the whole, the annual average of PM2.5 in 31 regions of China in 2000, 2008 and 2016 shows an increasing trend year by year, indicating that the haze pollution in
China is increasingly serious. The hot spots of haze pollution are mainly concentrated in Beijing-Tianjin-Hebei and the Middle East, the spatial concentration trend is obvious, and the sub hot spots are mainly concentrated around the hot spots, which shows that the spatial spillover effect of haze pollution is obvious. In recent years, with the gradual transfer of eastern enterprises to the central and western regions, the trend of haze pollution transfer from the east to the central and western regions is more obvious.

4. Conclusions and policy implications
This paper studies the spatial correlation and spatial spillover of industrial agglomeration and haze pollution. The results show that: (1) The main ways of industrial agglomeration in China are high-high agglomeration and low-low agglomeration, and with the development of time, the scale of agglomeration is expanding. (2) The global Moran's I of haze pollution is greater than 0 and increases year by year, indicating that the positive spatial agglomeration effect of haze pollution is increasing.

4.1. Give full play to the agglomeration effect and improve the complementary mechanism of haze prevention and control
The spatial spillover of haze pollution makes the prevention and control of a single area have little effect. Therefore, local governments should encourage the aggregation of high-tech industry and public service industry, and give full play to the collective effect to reduce haze pollution. At the same time, when the western region develops industrial agglomeration according to local conditions, it should also appropriately undertake the industrial transfer of the eastern and central regions, promote the development of complementary industries, and provide basic guarantee for pollution control and emission reduction with its unique resource endowment advantages.

4.2. Strengthen regional cooperation and improve regional coordination and governance mechanism
For enterprises, we should strengthen cooperation and dialogue with forward and backward enterprises, cooperate in research and development of clean production technology, and jointly discuss and implement emission reduction plans. For the government, on the one hand, it is necessary to establish a long-term mechanism to encourage enterprises to strengthen the research and development of new energy and new technology. On the other hand, we should strengthen cooperation with neighboring areas, accelerate the establishment of regional environmental monitoring platform, information sharing platform, joint law enforcement platform and unified planning platform, and avoid the strip distribution of haze control. In view of the imbalance of regional development, haze management should also be adapted to local conditions.

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