Study on Coordinated Governance and Evaluation of Air Pollution in Beijing-Tianjin-Hebei Region

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Abstract. Due to the spatial spillover of air pollution and the regional mobility of polluting enterprises, the territorial governance model is inefficient, and only a regional joint approach can achieve efficient treatment of air pollution. This paper analyzes the current situation of air pollution in Beijing-Tianjin-Hebei, and the problems encountered in the air pollution control in the Beijing-Tianjin-Hebei region. After using the entropy method to measure the annual average of air pollutants, it can more accurately represent the effect of controlling air pollution. Finally, some suggestions for regional air pollution control are provided. Only by working together in the region can air pollution control be more effective.

Keywords: Collaborative governance, air pollution, entropy method.

1. Introduction
Nowadays, environmental problems are becoming more and more obvious in economic development, and directly or indirectly endangering human health. Among them, the problem of air pollution is more prominent. Due to economic system, geographical connection and atmospheric environment, air pollution problems are more serious in Beijing-Tianjin-Hebei. [1]. In September 2013, the State Council issued the “Air Pollution Prevention and Control Action Plan”, proposing the goal of “by 2017, strive to achieve significant improvement in air quality in key areas, a significant decrease in the frequency of heavy pollution, and a decline in fine particulate matter (PM_{2.5}) in the Beijing-Tianjin-Hebei region 25%". The data shows that the first phase of the 2017 Air Pollution Prevention Action Plan (hereinafter referred to as “Atmosphere Ten”) is basically completed, but the national air pollution situation is still grim.

2. The status quo of atmospheric pollution in Beijing, Tianjin and Hebei
Among the smog pollution situation in the country, the Beijing-Tianjin-Hebei region is the most serious. Facing the national economic strategy of the capital economic circle and the integration of Beijing-Tianjin-Hebei, air pollution is clearly the biggest obstacle to development. China monitors six air pollutants including PM_{2.5}, PM_{10}, SO_{2}, NO_{2}, O_3 and CO that reflect air quality. The annual average concentration values of these six air pollutants are summarized separately, as shown in Table 1.
Table 1. Comparison of national pollutant concentrations in 2017 compared with the same period in 2016

| Contaminant | Average concentration in 2016 | Average concentration in 2017 | unit | Change in concentration |
|-------------|------------------------------|------------------------------|------|-------------------------|
| PM$_{2.5}$  | 46.20                        | 44.10                        | (μg /m$^3$) | -4.55%                |
| PM$_{10}$   | 82.20                        | 80.20                        | (μg /m$^3$) | -2.43%                |
| SO$_2$      | 21.80                        | 18.10                        | (μg /m$^3$) | -16.97%               |
| NO$_2$      | 29.50                        | 30.50                        | (μg /m$^3$) | 3.39%                 |
| O$_3$       | 136.00                       | 144.50                       | (μg /m$^3$) | 6.25%                 |
| CO          | 1.02                         | 0.96                         | (mg/m$^3$)  | -6.16%                |

The annual average concentrations of PM$_{2.5}$, PM$_{10}$, SO$_2$, and CO in air pollutants nationwide improved in 2017. However, the situation of NO$_2$ and O$_3$ is not optimistic.

The introduction of "Atmosphere Ten" promoted the coordinated management of air pollution in Beijing-Tianjin-Hebei and surrounding areas, so that the prevention and control of air pollution has changed from the previous "single-play" mode to the joint prevention and control mode. At the end of 2013, 6 provinces, autonomous regions and municipalities and 7 ministries and commissions jointly established the Beijing-Tianjin-Hebei and surrounding areas for air pollution prevention and control cooperation teams; in June 2014, the “Beijing-Tianjin-Hebei and surrounding areas air pollution joint prevention and control joint control 2014 key work” was officially deployed, requiring unified action in all regions to jointly manage regional priorities. Pollution sources, strengthen linkages, simultaneously solve regional common problems, study and formulate public policies, and promote regional air quality improvement; regional cooperation is gradually deepened in 2015; in 2017, for the increase of pollution in autumn and winter, the Ministry of Environmental Protection and other 10 ministries and commissions combined with 6 provinces The People's Government issued the "Action Plan for the Comprehensive Management of Air Pollution in the Autumn and Winter of 2017-2018 in Beijing, Tianjin and the Surrounding Areas" and sent a patrol team.

The "Atmosphere Ten" issued by the State Council is the most powerful air management action plan in China's history. For the first time, PM$_{2.5}$ is included in the binding index, and comprehensive control measures are proposed to reduce the emission of various pollutants and improve the environmental quality. The official assessment system was included. The changes in PM$_{2.5}$ in the major cities of Beijing-Tianjin-Hebei in 2015-2017 are shown in Figure 1:
PM$_{2.5}$ in the major cities of Beijing-Tianjin-Hebei region showed a downward trend in 2015-2017, but the cities with more than the national average accounted for the majority, indicating that the pollution of particulate matter and fine particulate matter is still serious. The pollutants in Beijing-Tianjin-Hebei have improved in 2017, but the ozone problem is highlighted and air pollution is still serious.

3. Problems faced by Beijing-Tianjin-Hebei regional pollution control

3.1. Regional public goods issues

Public goods are not exclusive and competitive with respect to private goods. The atmosphere circulating on a global scale belongs to a kind of public goods. The atmospheric environment is a cyclical flow, affecting the whole. Under the influence of the atmospheric circulation, the atmosphere is in constant motion, but under the influence of terrain and latitude. The impact of air flow will be limited to a certain area, but the boundary between the area affected by atmospheric flow and the administrative division cannot be completely coincident [2]. Air pollutants from an administrative division will quickly spread to other adjacent administrative areas under the influence of wind, and atmospheric pollutants will affect any space through which pollutants pass. In this way, between adjacent cities, the atmosphere becomes a common public good, and thus the atmosphere in a certain area composed of adjacent cities is a public good.

Atmospheric environmental capacity resources have the characteristics of non-exclusive and non-competitive in the consumption of regional public goods. Therefore, any administrative division in the region can use the atmospheric environment capacity resources according to their own needs, and according to China's administrative management system, The economic benefits created by enterprises and individuals within the administrative division belong to the administrative district to which they belong, and the environmental capacity cannot participate in the income distribution as a production factor. However, in the context of territorial governance, the strong spillover of atmospheric pollution will cause the regional environment. The definition of responsibility for governance is vague, so even if environmental governance indicators are added to the binding assessment, local governments may still maximize economic growth. This makes local governments naturally have a “free rider” tendency in the process of environmental governance, resulting in inefficiency in environmental governance and difficulties in central government constraints on local governments [3]. The territorial governance model
is inconsistent with the law of atmospheric pollutants diffusion, and it is impossible to avoid cross-contamination and repeated treatment between regions, and it is not enough to mobilize the enthusiasm of all parties to control air pollution.

3.2. The problem of the tragedy theory of the commons
The theory of tragedy of the commons is the theoretical basis for explaining the classics of environmental pollution using the principles of economics. The economic activities undertaken by enterprises will cause different degrees of pollution to the environment, and the environmental capacity is indeed limited. With the expansion of the population, the division of labor in detail, more and more people increase their income through factories and enterprises, which will lead to an increase in pollutant emissions. However, environmental capacity as a public resource can be freely used without the definition of property rights. Benefit from environmental resources, but the cost of environmental pollution is transferred to other people, resulting in negative externalities of the economy.

In order to prevent the occurrence of the "tragedy of the commons" in the field of air pollution control, we must unify all the provinces and cities in the region into the treatment of the atmospheric environment through the joint prevention and control mechanism, and all the administrative districts that cause pollution will bring environmental pollution. The responsibility for governance, the joint prevention and control mechanism must clearly define the different governance responsibilities of each region, and through joint efforts to overcome the negative externalities of the economy, to achieve regional air quality improvement. Only regional linkages and cooperation in the horizontal relationship of administrative divisions can solve the problems caused by the division of administrative divisions to control air pollution under the traditional vertical management mode.

3.3. The problem of "Prisoner's Dilemma"
Game theory can also be used in the study of the joint action of air pollution prevention and control in the Beijing-Tianjin-Hebei region, as well as the coordination, conflict and cooperation between cities in the region. Here, different cities in the region are regarded as players, if Beijing and Tianjin administrative governments of the various regions within the region have acted in concert to communicate the air pollution control tasks in the region and ultimately improve the overall environmental quality of the Beijing-Tianjin-Hebei region. This is the joint prevention of regional air pollution among the players. Cooperative game in joint control; on the contrary, in the case of increasingly serious air pollution in the Beijing-Tianjin-Hebei region, the administrative regions in the region push the responsibility of governance to other cities in the region, and the governance is insufficient or even untreated. In the long run, the atmosphere of the Beijing-Tianjin-Hebei region environmental quality is deteriorating due to the mutual evasion of governance responsibilities by various provinces and cities. This is the non-cooperative game between the players in the joint control of air pollution in Beijing, Tianjin and Hebei. The "Prisoner's Dilemma" is a typical example of a non-cooperative game. In the joint control of air pollution in Beijing-Tianjin-Hebei, the provinces and municipalities in the region are cooperating with air pollution in the process of coordination, if the administrative regions are asymmetrical due to information in the governance process. Based on opportunistic considerations, the laissez-faire attitude towards air pollution in the region will eventually lead to the dilemma of controlling the air pollution in all cities in the Beijing-Tianjin-Hebei region. Therefore, in the process of coordinating the control of air pollution, Beijing-Tianjin-Hebei should actively invest in the action of air pollution prevention and control to jointly promote the improvement of the overall environmental quality in the region [4].

4. Evaluation of air pollution control in Beijing-Tianjin-Hebei regional
The change of pollutants is the most intuitive manifestation of air pollution control. However, regional atmospheric management needs to reflect the pollutant data of the whole area [5]. Since each city in Beijing-Tianjin-Hebei has different importance to air pollution in Beijing-Tianjin-Hebei, the average air pollutants in the 13 cities of Beijing-Tianjin-Hebei cannot accurately reflect the air pollution status of
Beijing-Tianjin-Hebei. In this paper, the entropy method is used to determine the weight of each city's air pollution to Beijing-Tianjin-Hebei. Using the entropy method to determine the weight can overcome the subjective and random nature of the subjective weighting method.

This paper selects six air pollutants of PM$_{2.5}$, PM$_{10}$, SO$_2$, NO$_2$, O$_3$ and CO that reflect the air quality in China as the evaluation index. The steps to determine the weight using the entropy method are as follows:

1. Establish a matrix of raw data $X_{ij}$:

$$X_{ij} = \begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{bmatrix}$$

2. Dimension the indicators:

Since the units of the indicators selected in this paper are not the same, in order to eliminate the impact of these differences, these indicators need to be dimensionless. Commonly used linear dimensionless methods include standard processing methods, extreme value processing methods, and power factor methods. From the empirical analysis, the data obtained by the extremum method using the extremum method is better than other methods. In this paper, the extreme value method is used to quantify the data. The specific processing methods are as follows:

If the evaluation index $X_j$ is a positive indicator, then

$$y_{ij} = \frac{x_{ij} - m_j}{M_j - m_j} \quad (i = 1, 2, \ldots, n; \ j = 1, 2, \ldots, m) \quad (1)$$

If the evaluation index $X_j$ is a negative indicator, then

$$y_{ij} = \frac{M_j - X_{ij}}{M_j - m_j} \quad (i = 1, 2, \ldots, n; \ j = 1, 2, \ldots, m) \quad (2)$$

among them, $M_j = \max \{X_{ij}\}$; $m_j = \min \{X_{ij}\}$.

After the dimensionless processing, some data may be negative or zero, which will cause the next step to be meaningless when calculating the logarithm, and also need to translate the data, $y'_{ij} = y_{ij} + d$, where $d$ is an integer slightly larger than $\left\lfloor \frac{1}{\ln(n)} \right\rfloor$.

3. Calculate the proportion of the $j$-th indicator under the $i$-th scheme:

$$p_{ij} = \frac{y'_{ij}}{\sum_{i=1}^{n} y'_{ij}} \quad (3)$$

4. Calculate the index entropy value $e_j$ of the $j$-th indicator:

$$e_j = -k \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \quad (4)$$

among them, $k = \frac{1}{\ln(n)} > 0$.

5. Calculate the difference coefficient of the $j$-th indicator:

$$g_j = 1 - e_j \quad (5)$$

6. Calculate the weight of the $j$-th indicator:

$$w_j = \frac{g_j}{\sum_{i=1}^{m} g_i} \quad (6)$$

7. Calculate the composite score of the $i$-th link being evaluated:

$$s_i = \sum_{j=1}^{m} w_j p_{ij} \quad (7)$$

Using the entropy method to calculate the comprehensive scores of air pollution in Beijing and Tianjin by each city is the weight of each city. The greater the weight, the more important the impact on
the air pollution of Beijing, Tianjin and Hebei. The value of atmospheric pollutants in Beijing-Tianjin-Hebei calculated by this method will be more accurate. By comparing the historical data, the effect of air pollution control can be more accurately seen.

Using the above method, according to the data of China Monitoring and China Ecological Environment Status Bulletin, the annual average values of atmospheric pollutants in Beijing, Tianjin and Hebei in 2016 and 2017 are calculated as Table 2:

|       | PM$_{2.5}$ | PM$_{10}$ | O$_3$ | SO$_2$ | NO$_2$ | CO  |
|-------|------------|-----------|-------|--------|--------|-----|
| 2016  | 71         | 118       | 172   | 31     | 49     | 3.2 |
| 2017  | 64         | 113       | 193   | 25     | 47     | 2.8 |

In 2017, PM$_{2.5}$ and PM$_{10}$ decreased by 9.9% and 4.2% respectively compared with 2016, and SO$_2$ and NO$_2$ decreased by 19.4% and 4.1% respectively compared with 2016. Through the analysis of pollutants, it can be seen that the air pollution control of Beijing-Tianjin-Hebei has achieved certain effects, but compared with the national average, there is still a certain gap, and air pollution control is still facing severe challenges.

5. Beijing-Tianjin-Hebei policy recommendations for air pollution control

1. Strengthen the unified law enforcement construction in the Beijing-Tianjin-Hebei region

The Beijing-Tianjin-Hebei regional legislation provides the basis for the unified law enforcement of the three places. "There are laws to follow and law enforcement must be strict." Strict law enforcement is the key to ensuring perfect legislation. Fair law enforcement is also an effective way to establish legal credibility. In order to effectively overcome the "free rider" phenomenon in some areas of air pollution prevention and control, and the blind spots in the air pollution control across administrative areas, the unified law enforcement construction in the Beijing-Tianjin-Hebei region should be strengthened, and environmental protection at different levels in each administrative region should be continuously strengthened. Cooperation between departments, and cooperation between the environmental protection department and other departments with responsibility for air pollution control, multi-sector joint law enforcement to ensure the smooth completion of air pollution prevention and control work in the Beijing-Tianjin-Hebei region [6].

2. Establish a sound ecological compensation mechanism

The ecological compensation mechanism is an effective form to realize the coordination of interests by means of economy and technology. It is the use of environmental resources or the beneficiaries to pay certain economic compensation to environmentalists in order to achieve the coordination of interests with environmental resource protectors. With the development of the system, technical support has also become a form of ecological compensation [7]. The differences in administrative divisions in the Beijing-Tianjin-Hebei region require us to improve the ecological compensation mechanism in the process of air pollution control in Beijing, Tianjin and Hebei. The Beijing-Tianjin-Hebei coordination of air pollution requires the participation of the two provinces and one province. In the process of air pollution control, the only way to prevent the "tragedy of the commons" in the process of regional environmental governance. Balancing the ratio of interests between the three places, achieving a relatively fair distribution of governance tasks, under the principle of relative justice, can effectively promote the joint action of the three places and jointly manage the serious air pollution in the Beijing-Tianjin-Hebei region.

3. Reasonable allocation of responsibility for each region

The formation of a long-term mechanism for joint control of air pollution prevention and control in Beijing, Tianjin and Hebei must clarify the responsibilities of the provincial and municipal administrative departments in the region. The regional environment is a whole. The responsible parties
in the region work together to finally achieve the improvement of the atmospheric environment. However, the responsibility can only be guaranteed to the implementation of the corresponding responsibilities. In the process of regional air pollution control, responsibility should be assigned according to the model of the beneficiary area and the resource development and utilization area sharing the obligation of governance.

6. Conclusion

With the development of regional economic integration, the Beijing-Tianjin-Hebei region has gradually broken the restrictions of administrative divisions and achieved unity in many fields. Environmental governance is the first problem that needs to be solved in the economic and social harmonious development of the Beijing-Tianjin-Hebei region. This requires the three governments to work together in the air pollution control of Beijing-Tianjin-Hebei. The regional characteristics of air pollution determine the integrity of regional environmental governance. The complexity of pollution determines that regional air pollution cannot be treated separately, which requires multiple levels of government and multiple departments in multiple regions of the region to work together.

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