The Impact of Water Pollution and Water Control on the Ecological Welfare Economy of the Beijing-Tianjin-Hebei Region from 2010 to 2019

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Abstract. With the rapid economic development and substantial population growth in the Beijing Tianjin Hebei region, the discharge of industrial and agricultural wastes has caused serious water pollution problems. Over the years, the government has attached great importance to water pollution and carried out the scientific treatment, which is of great significance to the development of a green economy and ecological welfare in Beijing, Tianjin, and Hebei. Many academic papers have discussed effective measures to control water pollution. This paper will refer to these academic papers and compare the data to analyse the performance of water pollution control and water resources' ecological welfare. The paper uses the SBM model to do the analysis. The efficiency value calculated by the super efficiency SBM model is relative efficiency, and if the efficiency value is greater than 1, it is relatively effective. Through comparison, the overall characteristics and regional differences in the performance level of water resources' ecological welfare can be analysed. According to the whole region, the average value of water resources' ecological welfare performance in the observation period of the Beijing Tianjin Hebei economic belt is lower than others. According to the provincial level, it has differences in the performance of water resources and ecological welfare among the three provincial units in the Beijing Tianjin Hebei economic belt. The government should be recommended to strengthen and pay attention to the environmental regulation and environment, and be more the importance on "soft construction".

Keywords: Ecological welfare economy · SBM model · Water pollution · Water control

1 Introduction

With the rapid economic development and substantial population growth in Beijing, Tianjin, and Hebei, water pollution problems in Beijing, Tianjin, and Hebei become

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more and more serious. In this case, over the years, the government has attached great importance to water pollution and carried out the scientific treatment, which is of great significance to the development of a green economy and ecological welfare in Beijing, Tianjin, and Hebei. The article is going to research the impact of water pollution and water control on the ecological welfare economy of the Beijing-Tianjin-Hebei region from 2010 to 2019. Based on the serious water pollution problems in the Beijing Tianjin Hebei region, the paper selects Beijing, Tianjin, and Hebei as the research area to discuss the water pollution status and treatment progress in this region from 2010 to 2019. This paper takes 13 prefecture-level cities in the middle reaches of Beijing, Tianjin, and Hebei from 2010 to 2019 as the research sample. The original data are mainly extracted from the statistical yearbooks of provinces and cities. The paper will refer to some academic papers and compare the data and use the SBM model to analyze the performance of water pollution control and water resources' ecological welfare.

There already has been much research about water pollution. Liu and Yan used the Theil index and its decomposition, spatial econometric model, and other methods to analyze the temporal and spatial differentiation pattern and influencing factors of Ecological Welfare performance of 13 cities in Beijing, Tianjin, and Hebei [1]. Yang and Wang took the research on water pollution and protection in the Beijing Tianjin Hebei region as an example to discuss the construction of a legal system related to cross-regional water environment protection in China at the present stage [2]. Based on content analysis, Yang and Chen investigated the changes in water pollution control policy tools in the Beijing Tianjin Hebei region from 2000 to 2019 [3]. Zhang et al. used the generalized least squares method (FGLS) to establish the effect model of water pollution control and analyzed whether the high-quality development of regional economy and water pollution control can be carried out simultaneously under the environmental regulation. Finally, he concluded that it is necessary to formulate a differentiated strategy of water pollution control under the dual effects of economic development and environmental regulation [4]. Ji et al. established a measurement model to fit the environmental Kuznets curve (EKC) of water pollution in Hebei Province and studied it. Finally, it is concluded that the industrial structure of Hebei Province must be optimized and adjusted, the investment in environmental protection technology should be increased, and public opinion should be strengthened to publicize environmental protection knowledge, promote the sustainable development of water resources and social economy in Hebei Province [5].

On the other hand, the SBM model is widely used in research. Liu improved the traditional energy ecological footprint by integrating it with DEA-SBM to quantitatively measure and analyze the ecological security levels in the eight megacities in the Yangtze River basin of China from 2007 to 2016 [6]. Mahmoudi and Emrouznejad analyzed the performance of Iranian domestic airlines over 8 years from 2013 to 2020 to obtain the deficiencies of each airline and find possible solutions to improve their performance [7]. Siddiqui and Alamhas analyze the efficiency and productivity performance of the 27 health insurance companies from the period 2015 to 2019 using slack-based measurers (SBM) of data envelopment analysis [8]. Xie used the SBM-DEA model to compare and discuss the feasibility and potential of upgrading the standard, recycling water, and sludge disposal methods to improve the environmental performance of sewage treatment plants. Finally concluded that load rate, sewage treatment process, recycling water, and sludge disposal methods have significant effects on environmental performance [9].

Based on the serious water pollution problems of the Beijing-Tianjin-Hebei regions. This paper takes 13 prefecture-level cities in the middle reaches of Beijing-Tianjin-Hebei from 2010 to 2019 as a research sample. The original data is mainly extracted from the Statistical Yearbook of each province municipality. The domestic and industrial sewage is extracted from China Urban Construction Statistical Yearbook, China Economic Development Database, and EPS Data. To eliminate the impact of price factors, the GDP per person is obtained from the average annual population of each city from Hebei Statistical Yearbook, Beijing Statistical Yearbook, and Tianjin Statistical Yearbook from 2011 to 2020.

2 The Experimental Analysis Data and Methodology in the Study

2.1 SBM Model

DEA method is a method to evaluate the relative efficiency of decision-making units. Because this method does not need to set the specific form and estimation parameters of the model in advance, and avoids the subjective impact of artificially determining the weight on the measurement results, it has been widely used in the study of ecological efficiency. But it has a fatal weakness: it is still a radial and angular DEA measurement method in essence. The radial DEA measurement method will cause the "crowding" or "Relaxation" of input elements. When there is non-zero relaxation of input or output, the radial DEA model will overestimate the productivity of the evaluation object. The angle DEA model only focuses on one aspect of input or output, so the calculated productivity results are not accurate.

Super SBM mode is a mode that combines super efficiency and SBM mode. Based on this, it can be said that super SBM is a super-efficient DEA model. Super efficiency DEA is data envelopment analysis. It is a modeling method based on linear programming and distance function. It includes several models such as CCR, BCC, and SBM. The models which apply relative efficiency evaluation of traditional DEA, like CCR and BCC, are difficult to achieve the goal of minimizing input and maximizing output because of undesirable output. Therefore, Tone proposes an SBM model containing undesirable outputs to effectively solve the efficiency evaluation problem under undesirable outputs, which effectively compensates for the shortcomings of the traditional DEA model, that is the problem of relaxing input and output [10]. Therefore, this paper analyses the ecological welfare of water resources by SBM.

It is assumed that there are n decision-making units to be evaluated in the system, and the input index of any decision-making unit (DMU) is m. Desirable and undesirable output indices are expressed by n_1 and n_2 respectively. j is a decision-making unit, and its input is x_{io}, the desirable output is y^g_{ro} and the undesirable output is y^b_{to}. Then, the efficiency of DMUo can be measured by the SBM model.

$$\min \rho_o = \frac{1 - \frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{io}}}{1 + \frac{1}{(n_1+n_2)}\left(\sum_{j=1}^{n_1}\frac{s_j^{G+}}{y^g_{jo}} + \sum_{t=1}^{n_2}\frac{s_j^{B-}}{y^b_{to}}\right)} \tag{1}$$

$$
\text{s.t.}\begin{cases} x_{io} = x_{ij}\lambda_j + s_i^-, i = 1, 2, ..., n \\ y_{ro}^g = y_{rj}^g\lambda_j - s_r^{G+}, r = 1, 2, ..., n \\ y_{to}^b = y_{tj}^b\lambda_j + s_t^{B-}, t = 1, 2, ..., n \\ \lambda_j, s_i^-, s_r^{G+}, s_t^{B-} \geq 0 \end{cases} \tag{2}
$$

In the formula, λ is a constant vector. s_i^- refers to the input redundancy of input indicators, s_r^{G+} and s_t^{B-} respectively represent the deficiency of desirable output and undesirable output. The numerator ρ_o of the expression is input inefficiency and its denominator is output inefficiency if and only if ρ_o= 1. DEA is relatively effective only when there is no redundancy of input and expected output or excess undesired output in DMUo.

2.2 Metric Selection and Data Sources

This paper puts forward the specific indicators of the United Nations Development Agency, including the total number of people in school and the average number of people in education, as well as the average life expectancy of human resources per region. The indicators are selected according to the systematisms, feasibility, and rationality of the index system. The per capita wastewater discharge includes domestic wastewater discharge and industrial wastewater discharge, and the per capita chemical oxygen demand discharge includes chemical oxygen demand in domestic wastewater and chemical oxygen demand in industrial wastewater. The per capita wastewater discharge is selected to measure the wastewater discharge. The purpose of selecting per capita wastewater chemical oxygen demand is to measure the degree of water resources pollution. To eliminate the scale effect, the selected indicators are divided by the resident population to obtain the per capita indicators, to more truly reflect the actual situation. The specific indicators are shown in Table 1.

This paper selects the data of the Beijing, Tianjin, and Hebei economic belt for empirical research to calculate the sustainable development level of water resources in Beijing, Tianjin, and 11 cities in Hebei Province. The original data are mainly from the 2012–2020 China Urban Yearbook, China Environmental Statistics Yearbook, and the statistical yearbooks of corresponding provinces and cities. Other missing data are mainly from China's economic and social development statistical database and ESP database.

Among them, because the average life expectancy is not a statistical index required by the state, there is only the average life expectancy in 2010 in the 2011–2020 Yearbook. From the relevant data released by the world bank, China's overall life expectancy at birth has increased linearly since 2003. This paper uses the processing methods of Xu Yudong and others for reference to supplement the missing data of each province according to the natural growth rate [11]. The per capita regional GDP is subject to constant price treatment. Using the GDP reduction index of provinces and cities, the regional GDP with the constant price is calculated based on 2010 and then divided by the permanent resident population.

Table 1. Specific Index

Type	Primary indicator	Secondary indicator	Index
Input	Resource Consumption	Water Consumption	Per Capita Water Consumption
Undesirable Output	Environmental Pollution	Wastewater Discharge	Per Capita Wastewater Discharge
		Water Pollution Degree	Per Capita COD Emissions
Desirable Outputs	Welfare Level	Economic Level	Per Capita GDP
		Educational Level	Number of students in institutions of higher learning per 10,000 people
		Health Level	Life Expectancy

Table 2. DUM of the Beijing, Tianjin, and Hebei regions from 2010 to 2019.

DMU	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Baoding	0.74	0.73	0.76	1.00	1.00	1.00	1.00	0.62	0.92	0.63
Beijing	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cangzhou	1.00	0.87	0.78	0.74	0.78	0.55	1.00	0.43	0.51	0.42
Chengde	0.44	1.00	1.00	1.00	1.00	1.00	1.00	0.66	0.66	0.73
Handan	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hengshui	0.44	0.49	1.00	0.87	0.76	0.46	0.59	1.00	1.00	1.00
Langfang	0.65	0.68	0.63	0.66	0.65	1.00	0.80	1.00	1.00	1.00
Qinhuangdao	1.00	0.52	0.70	0.79	1.00	1.00	1.00	1.00	1.00	0.64
Shijiazhuang	1.00	1.00	0.86	0.86	1.00	0.72	1.00	1.00	1.00	1.00
Tangshan	0.34	0.42	0.37	0.52	0.66	0.55	0.54	0.45	0.45	0.62
Tianjin	0.72	1.00	1.00	1.00	0.93	0.74	1.00	1.00	1.00	1.00
Xingtai	0.43	1.00	1.00	0.81	1.00	1.00	1.00	1.00	1.00	1.00
Zhangjiakou	1.00	1.00	1.00	1.00	0.97	1.00	1.00	1.00	1.00	1.00

3 Results and Discussion

From the perspective of the whole region, the average value of ecological welfare performance in the Beijing, Tianjin, and Hebei Economic Belt during the observation period is 0.8556, and the overall level is low. On the annual average, only the average performance level in 2016 reached 0.917. On the whole, there is no year with a performance level exceeding 1 in ten years, so it is relatively effective and achieves the optimal allocation.

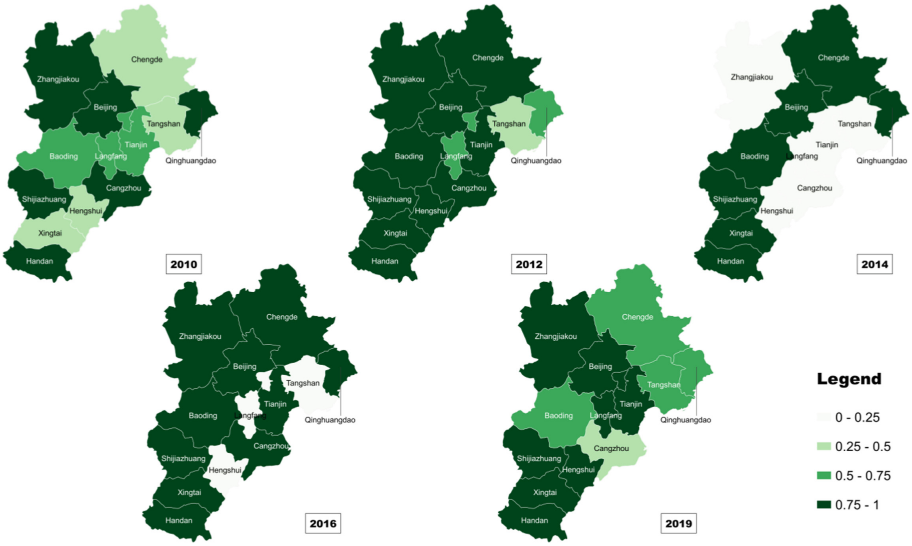

Fig. 1. Resources Ecological Welfare Performance from 2010 to 2019

Most of the years from 2010 to 2015 were inefficient, but from the changing trend of ecological welfare performance, it is not difficult to find that the overall performance level is fluctuating and rising. Among them, 2014–2016 was fluctuating, and 2017–2019 showed a slight fluctuating downward trend, but overall it was relatively stable (Table 2).

From the provincial level, the ecological welfare performance of three provincial units in Beijing, Tianjin, and the Hebei Economic Belt are different. During the observation period, the average ecological welfare performance in Beijing is the highest, followed by Tianjin, and the lowest in Hebei Province. It can be seen from the data that Beijing has maintained an ecological performance benefit greater than or equal to 1 from 2010 to 2019, and has always maintained an effective ecological welfare state. This is probably related to Beijing's strict pollution discharge standards and active water pollution control. Except for 2010 and 2014, Tianjin maintained good ecological performance in other years. This is partly due to the active governance policy. Compared with Beijing and Tianjin, the two economically developed areas, the welfare performance level of Hebei Province is low, which may be due to the following three reasons. First, to pursue economic development one-sidedly, the local government may vigorously develop high-energy and extensive enterprises, which leads to an insignificant water pollution control effect. Secondly, because industrial enterprises have invested too much and have not been strictly regulated by the environment, the effect of water pollution control is not good. Thirdly, Hebei Province is close to Beijing and Tianjin, and its environmental cost is low. Therefore, it has undertaken the transfer of industries with high pollution and energy consumption from economically developed areas (Fig. 1).

Generally speaking, there are significant regional differences in welfare performance brought by water pollution control in Beijing, Tianjin, and Hebei region from 2010 to

2019, especially in economically developed areas such as Beijing, but not in economically underdeveloped areas. In pursuit of high-quality economic development, economically developed areas invest heavily in technological innovation, make use of leading scientific and technological research and development achievements to drive industrial structure adjustment, and rationally allocate resources to green and clean energy industries [12]. However, compared with economically developed areas, economically underdeveloped areas lag in scientific and technological innovation ability, and the level of economic development can't meet people's increasingly high demand, so they try to drive water pollution control through urbanization development. However, its problems of insufficient scientific and technological innovation ability, inadequate industrial transformation and unreasonable resource allocation lead to the suppression of water pollution control effect. The economic development of underdeveloped areas depends on the level of urbanization to a great extent, and the blind pursuit of economic benefits will lead to the inability of underdeveloped areas to carry out water pollution control simultaneously because of urbanization. Because economically underdeveloped areas can't implement environmental regulations, the effect of water pollution control is not ideal.

4 The Policy Recommendation

4.1 Overall Development

Strengthen the dual functions of environmental regulation and economic development. To harmonious development of economic growth and green development, the government should try to put an end to the phenomenon of pollution smuggling and pollution transfer in pursuit of economic aggregate. At the same time, the paper should not blindly pursue the standard of environmental regulation and suppress the development of the local economy. The paper should increase private investment and attract foreign investment, and encourage all regions to carry out scientific and technological research and development and equipment renewal. On the other hand, the government should reduce the preferential treatment and subsidies for economically underdeveloped areas, encourage high-tech R&D personnel to stay in the local area to carry out technological innovation and avoid the situation of lack of adventurous spirit due to low survival pressure.

4.2 Local Conditions

The government should pay attention to regional differences and implementation effects of environmental regulations. According to the economic differences, resource endowment characteristics, scientific and technological R&D capabilities, urbanization level, etc. of various provinces and cities, the paper should reasonably formulate differentiated environmental regulations. For example, areas with poorer economic standards should adopt more relaxed environmental regulations and incentives. Because there may be insufficient innovation ability and the cost of environmental regulation is too high to meet the requirements of environmental regulation.

4.3 Soft Construction

The government should pay attention to the importance of "soft construction", intensify the development of economically developed areas that pursue high-quality development, and upgrade its green technology competitiveness promotes the green development of other regions through the "demonstration effect" and increases the control of pollution-intensive enterprises.

4.4 Accelerate Industrial Transformation

In Hebei, the water demand of the secondary industry is large, and the pollutants produced at the same time are numerous and difficult to treat, which has a great negative impact on the quality of water resources. Therefore, it is urgent to speed up the industrial transformation and promote the current industry from energy consumption and pollution-intensive to environment-friendly and technology-intensive. This can optimize the industrial structure, and then reduce the discharge of pollutants to achieve the effect of improving water pollution control. However, depending on the market mechanism alone, the industrial structure can hardly be actively adjusted, and it must rely on the leading role of the government. Therefore, the government should formulate relevant policies to guide the industrial transformation. For example, vigorously support high-tech industries and subsidize specific industries.

4.5 Intra-regional Exchanges and Cooperation

The natural environment is a whole, and if the local water pollution in each city is not treated in time, the upstream and downstream will likely be polluted simultaneously [4]. Therefore, the local government should strengthen supervision, and supervise the highly polluting enterprises in the region to do a good job in matters related to pollutant discharge and treatment. To some extent, avoid pollution transfer and shirk responsibility. At the same time, exchanges and cooperation between cities should be strengthened to share the experience of water pollution control. Areas with low governance efficiency can learn more advanced and mature governance policies from areas with good governance effects. Only cooperation and common improvement can promote the healthy development of the whole region.

5 Conclusion

Based on the ecological welfare performance indicators calculated by the SBM model in Beijing, Tianjin, and Hebei regions from 2010 to 2019, it is concluded that the overall welfare performance indicators are low, the regional development is unbalanced, and the effects of water pollution control results are different between economically developed areas and economically underdeveloped areas. By examining the relationship between regional economic development and water pollution control, it is concluded that economically developed areas have the advantage of resource allocation while economically underdeveloped areas have the insufficient environmental regulation ability, which leads to poor water pollution control effect. Therefore, the policy suggestions of this paper are to strengthen the communication and cooperation within the region, the government should specify environmental regulations according to local conditions, strengthen the supervision of sewage discharge, speed up the transformation of industries to environment-friendly, and technology-intensive, and strengthen soft construction. Finally, realize the harmonious and overall development of economic growth and green development.

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