Evaluation and Analysis of Environmental Protection Investment Efficiency in China Based on DEA Model

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Research Article

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Evaluation and Analysis of Environmental Protection Investment Efficiency in China Based on DEA Model

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Abstract: The environmental protection investment aims at protecting the environment, improving the quality of the environment and preventing the deterioration of the ecological environment. A certain amount of capital is put into environmental protection in the form of money, machinery and other elements to form the environmental capital stock. In this study, the DEA model was used to calculate and analyze the input-output efficiency of environmental protection in China from 2001 to 2015. The results show that the overall efficiency of environmental protection input-output in China was low from 2001 to 2015, and the DEA efficiency was not fully achieved in most years, and the contribution of environmental protection investment to the output of environmental protection industry needs to be further improved. Finally, according to the analysis results of DEA model, the countermeasures and suggestions were put forward to optimize the investment structure of environmental protection and promote the rapid economic development from the aspects of broadening the investment channels of environmental protection, actively guiding residents and enterprises to participate in environmental protection undertakings, optimizing the investment mode of environmental protection, vigorously promoting the progress of environmental protection science and technology, adhering to the circular development, and adjusting the industrial structure.

Keywords: environmental protection investment; DEA model; input-output efficiency; efficiency evaluation

1 Introduction

In China, more than 1 trillion yuan is invested in environmental pollution control every year, but at least half of them do not work. By the end of 2018, 97.4% of provincial and above industrial agglomeration areas in China had built centralized sewage treatment facilities equipped with automatic online monitoring devices. 4,332 sewage treatment plants had been built and put into operation in cities and towns of China (Gajdzik and Sroka. 2021), but some of them failed to operate normally or were under load, so the investment had an unsatisfactory benefit. To a certain extent, the total investment in environmental protection reflects the overall level and strength of social environmental protection. As a kind of public welfare investment, environmental protection investment does not pursue the maximization of economic benefits, but is mainly for the purpose of protecting and improving the environment, and promoting the efficient and sustainable development of the economy.

Moreover, investment in environmental protection is an important indicator of the strength of environmental protection in a country, which is the main driving force of ecological restoration, reconstruction and environmental protection. Its investment strength and effect are related to pollution control, environmental construction and ecological protection, the improvement of the quality of ecological environment, and ultimately the guarantee and support of the environment for economic development.

At present, there are few researches on the efficiency of environmental protection investment at home and abroad, mainly using the priority growth model and DEA model. W.WLoontief, an American economist, is the first economist in the world to analyze quantitatively the relationship between environmental protection and economic development. In his opinion, in addition to the consumption of raw materials and labor, the cost of pollution treatment should also be included in the product cost, so he analyzed and studied the impact of environmental economic policies on economic development and the relationship between promoting economic development and protecting and improving the environment. OECD has studied the actual impact of environmental protection expenditure on GNP in its member countries. The results show that environmental protection expenditure has an uncertain actual impact on GNP, and that all environmental protection plans are always conducive to the growth of CNP in the first year, while the impact in the last year is more complex, with positive and negative effects in different countries. But on the whole, environmental protection investment has a very small negative impact. Murgai (2000) used the method of factor analysis to make an empirical study on the relationship between pollution emissions and economic growth, and believed that there is a space for green economic growth. Cairncross (2000) put forward the concept of environment-friendly economic growth, and he believed that almost all economic activities of human society will have an impact on the environment, mainly negative impact, but the transformation of consumption mode and continuous progress of technology can reduce the environmental cost of economic growth, so as to achieve the maximum economic growth with the least environmental cost. Higgins A J, Hajkowicz S and Bui E(Higgins et al. 2008) analyzed the 142,000 ha catchment area in eastern Australia by using the Greedy Randomized Adaptive Search Procedure(GRAP), and concluded that investment in landscape would achieve multiple environmental benefits, and then he searched for the optimal solution with the Pareto front based on this evolutionary programming method . Fullerton D, Kim S R(2008) studied pollution taxes that affect environmental degradation and the cost of restoring natural capital, and found that high demand for public spending could lead to tax distortions or greater increases in pollution taxes.

Li Yining and Zhang Zheng (1993) believed that environmental protection investment mainly involves the following three aspects: investment in environmental pollution control for effective environmental treatment; investment in environmental protection for prevention of environmental pollution; and investment in relevant aspects for development of environmental protection industry. Liu Feng (2012) held that the industrialization of environmental protection investment is an effective way to improve the efficiency of environmental protection investment, and that BOT projects can be used in the economically developed cities at the same time to introduce foreign capital to optimize environmental investment. Xue Shanshan,Pan Zhong and Zhou Lingyun (Xue et al. 2008) firstly collected a large number of water environment protection data of Jiulongjiang River Basin in Fujian Province, and then monetized the income of environmental protection investment through sorting out and using the cost-benefit analysis method, and finally conducted an overall study on the investment of water environment protection, in order to find the optimal strategy that can simultaneously achieve the objectives of

environmental protection investment minimization, pollutant reduction maximization and environmental benefit maximization. Zou Wenjie (2013) applied Malmquist index method of data envelopment analysis to calculate the efficiency of environmental protection investment in Fujian Province from 2004 to 2010, and concluded that the overall efficiency of environmental protection investment in Fujian Province showed a trend of growth, and that the main driving force for the growth of environmental protection investment efficiency was technological progress, while the technological efficiency largely inhibited the growth of environmental protection investment efficiency. Based on the method of non parametric data envelopment analysis (DEA), Xu Hui, Sui Lichun et al. (Xu et al. 2014) conducted an empirical study on the performance of environmental protection investment in Gansu Province from 2002 to 2010, and found that the efficiency of environmental protection investment in Gansu Province fluctuated greatly, and the efficiency in only about 33% of the years reached the best and most effective state in the overall performance level, while that in the rest of the years were still in the non- optimal effective state.

To sum up, the efficiency analysis of environmental protection investment has become a hot issue for domestic and foreign scholars. The research results focus on the evaluation index system and methods of environmental protection investment efficiency. However, there is no unified evaluation index system for how to reflect the efficiency of environmental protection investment. In this paper, on the basis of systematically summarizing the relevant research on the efficiency of environmental protection investment, according to the principle of constructing evaluation index system, the total investment in environmental protection was selected as the input index, and the control performance of environmental governance investment in water, gas, solid and other aspects was taken as the output, to build an evaluation index system and an evaluation model of investment efficiency in environmental protection in China based on DEA method(Ferguson et al. 2019), so as to provide reference for environmental protection departments in formulating policies in the environmental protection industry.

2 Current Situation of Environmental Protection Investment in China

2.1 The total amount of environmental protection investment in China is on the rise, but its proportion in GDP is low

According to the experience of developed countries: in a period of rapid economic development, only when the proportion of environmental protection investment in GDP reaches 1% - 1.5%, can environmental pollution be effectively controlled, and only when it exceeds 3%, can environmental quality be effectively improved. Many developed countries, such as the United States, the United Kingdom and Germany, have invested more than 2% of their GDP in environmental protection, and achieved good results in environmental governance.

In recent years, from the perspective of total amount, China's total investment in environmental protection has increased year by year (see Table 1), from 110.67 billion yuan in 2001 to 953.9 billion yuan in 2017, but its proportion in GDP is still low. In 2017, China's investment in environmental pollution control was 953.9 billion yuan, accounting for only 1.15% of GDP. It is observed from Fig. 1, the proportion of China's environmental protection investment in GDP in 2001-2017 is more than 1% but less than 3%, indicating that the environmental pollution in China can be effectively controlled through environmental protection investment, but if the environmental quality needs to be improved, the investment in environmental

protection still needs to be increased.

Table 1 Total investment in environmental pollution control and its proportion to GDP in China

Years	Total investment in environmental pollution control (100 million yuan)	Environmental pollution control investment as a percentage of GDP in the same period (%)
2001	1106.7	1.05
2002	1456.5	1.20
2003	1750.1	1.27
2004	2057.5	1.27
2005	2565.2	1.37
2006	2779.5	1.27
2007	3668.8	1.36
2008	4937.0	1.55
2009	5258.4	1.51
2010	7612.2	1.84
2011	7114.0	1.45
2012	8253.5	1.53
2013	9037.2	1.52
2014	9575.5	1.49
2015	8806.4	1.28
2016	9219.8	1.24
2017	9539.0	1.15

Data sources: *China Statistical Yearbook*, *China Environmental Statistical Yearbook* and *China Environmental Situation Bulletin*

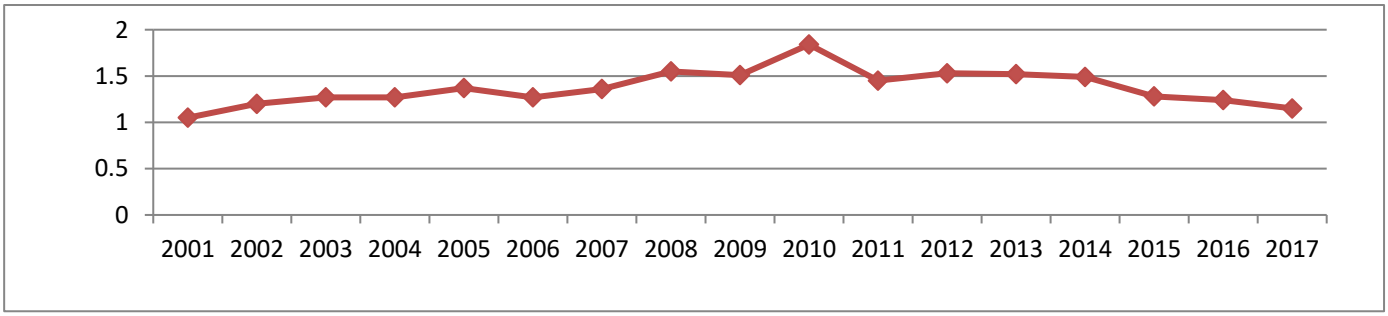

Fig. 1 Proportion of environmental pollution control investment in GDP in the same period (%)

Data sources: *China Statistical Yearbook*, *China Environmental Statistical Yearbook* and *China Environmental Situation Bulletin*

2.2 Current situation of investment in industrial wastewater treatment in China

Since the 21st century, China's economy has grown rapidly, but at the same time, it has also caused some environmental problems, such as the sewage discharge events in Tengger Desert which have caused great harm to the environment. In recent years, with the rapid development of China's environmental protection industry, the total investment in industrial wastewater pollution has shown a rapid growth trend, but the proportion of investment in environmental pollution treatment has been

fluctuating: in 2002-2007, the trend was stable, but it began to decline from 2008 (see Fig. 2), while in 2010-2011, it rose briefly, but in 2011-2015, it still showed a steady annual decline. Therefore, measures such as improving technical equipment, increasing pollution treatment facilities, and improving relevant laws and policies should be taken to reduce industrial wastewater and COD emissions.

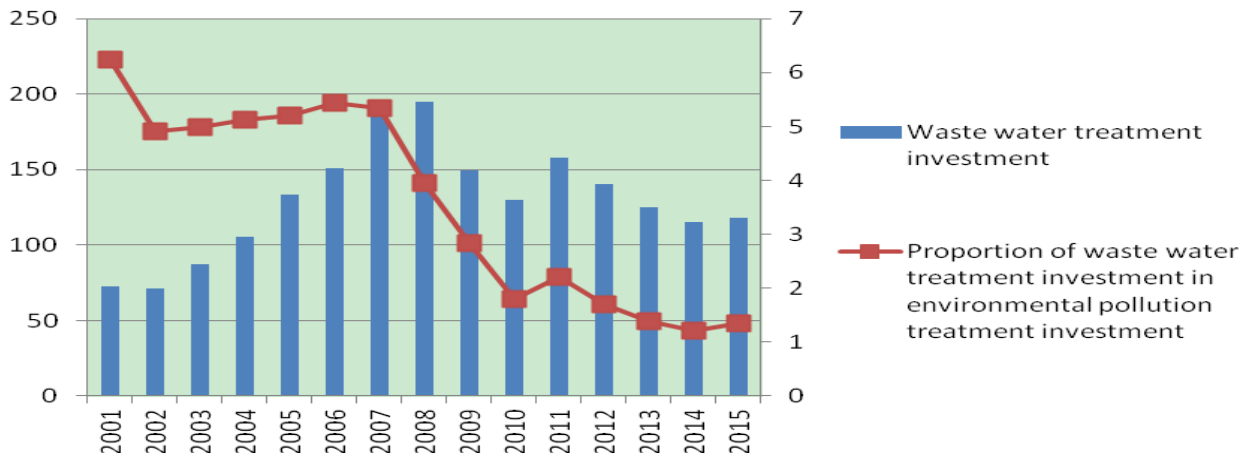

Figure 2 Proportion of investment in industrial wastewater pollution control

Data sources: *China Statistical Yearbook*, *China Environmental Statistical Yearbook* and *China Environmental Situation Bulletin*

2.3 Current situation of investment in waste gas treatment in China

In recent years, China has increased investment in waste gas treatment. In 2014, the investment in waste gas treatment reached 78.94 billion yuan, and the investment in waste gas treatment facilities is increasing year by year (see Fig. 3). However, the technical level of waste gas treatment facilities needs to be improved, and the operation cost of waste gas treatment facilities is high, which leads to low efficiency of waste gas treatment of environmental protection investment, which shows that the development of China's industry is in the transition stage from extensive type to intensive type. In the future, the investment in human resources, capital and energy should be increased while the investment in knowledge and technology should be increased to improve the innovation ability of enterprises.

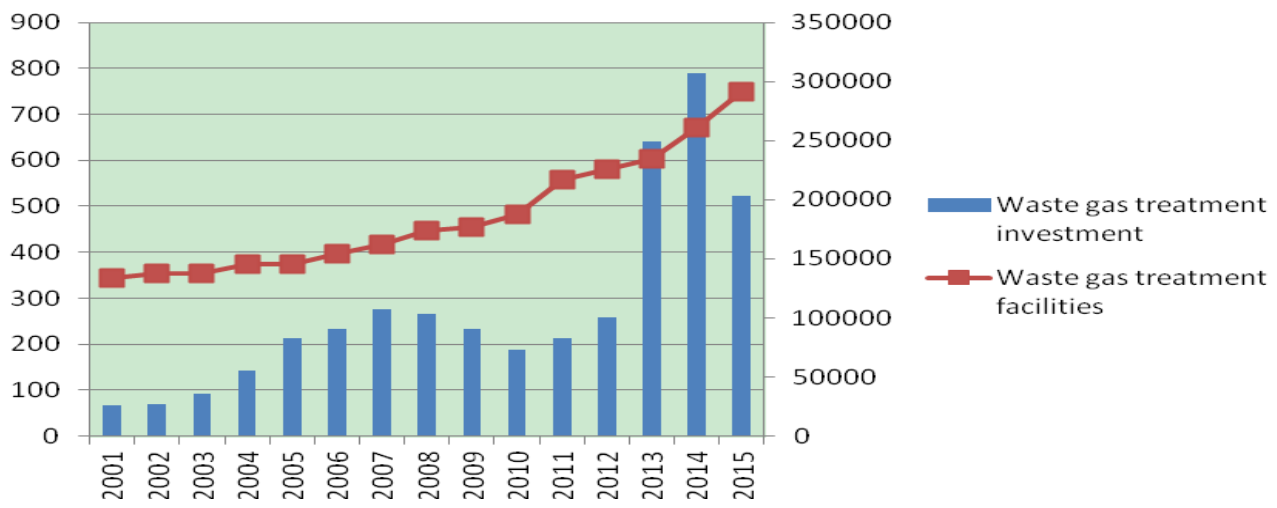

Figure 3 Investment in waste gas pollution treatment and facilities

Data sources: *China Statistical Yearbook*, *China Environmental Statistical Yearbook* and *China Environmental Situation Bulletin*

3 An Empirical Analysis of the Efficiency of Environmental Protection Investment in China

3.1 Research methodology

Data envelopment analysis (DEA) is a method to evaluate the relative efficiency, which was put forward by famous American operational research scientists A.Charnes and W.W.Cooper in 1978(Li and Zhang.1993;Lu.2021).

), and it has been widely used in various fields and departments.DEA model is to evaluate the relative effectiveness of n decision-making units with input-output by establishing linear programming model, and these n decision-making units are comparable. Generally, DEA model is divided into two categories: one is the input-oriented DEA model, that is, the decision-maker pursues the reduction of input under a certain output combination; the other is the output-oriented DEA, that is, the decision-maker pursues the increase of output under a certain input combination.

The model of DEA is called C^2R for short: n DMU_j s ($j=1,\cdots,n$) are set, the input and output vectors of DMU_j s are respectively

$$x_j=(x_{1j},x_{2j},\cdots,x_{mj})^T>0$$

$$y_j=(y_{1j},y_{2j},\cdots,y_{sj})^T>0$$

For fixed $j_0\ (1\le j_0\le n)$, two linear programming models are established

$$\begin{cases} \max\varpi=\varpi^* \\ \sum_{j=1}^{n}\lambda_j\ x_j+s^-=x_{j0} \\ \sum_{j=1}^{n}\lambda_j\ y_j-s^+=y_{jo}\varpi \\ \lambda_j\ge 0,\quad j=1,2,\cdots,\cdots n \\ \quad s^+\ge 0,\quad s^-\ge 0 \end{cases} \tag{1}$$

$$\begin{cases} \min\theta=\theta^* \\ \sum_{j=1}^{n}\lambda_j\ x_j+s^-=\theta\ x_{j0} \\ \sum_{j=1}^{n}\lambda_j\ y_j-s^+=y_{jo} \\ \lambda_j\ge 0,\quad j=1,2,\cdots,\cdots n \\ \quad s^+\ge 0,\quad s^-\ge 0 \end{cases} \tag{2}$$

To solve the optimal solutions of the two models, if $\theta=1$, $S^+=S^-=0$, the decision-making unit is fully DEA

efficient. If the limited condition $\sum_{j=1}^{n} \lambda_j = 1$ is added to the model, the overall efficiency value calculated in the model is decomposed. Wei Quanling (2004) decomposed the overall efficiency value into pure technical efficiency and scale efficiency, then overall technical efficiency (TE) = pure technical efficiency (PTE) × scale efficiency (SE).

When the value of overall technical efficiency is 1, it indicates that the decision-making unit is DEA efficient, which means that the output has reached the maximum relative to the input, that is, the decision-making unit is already on the curve of the production function. Scale efficiency means that the scale efficiency value is 1, that is, the amount of investment is moderate and the scale return is constant.

3.2 Establishment of index system and data sources

3.2.1 Establishment of index system

The existing researches show that the key of efficiency evaluation is to select reasonable input and output variables, which directly affects the evaluation and analysis results. According to the research of Wei Quanling, Emrouznejad A, Haynes, Amin, etc., in order to ensure the reliability of the model analysis results, the following five principles should be followed in the construction of the index system of environmental protection input-output efficiency: the index system should effectively reflect the DEA efficiency of environmental protection input; the selected index should be representative, covering the overall content of environmental protection; the selected index should be comparable, and the relative index should be used to facilitate the comparison between regions; the input index and output index should be highly correlated; the selected indexes should be oriented and conform to environmental protection policies, which is conducive to better evaluation of environmental protection work oriented by the indicator system.

In this study, on the basis of the previous research results and the current situation of China's environmental protection investment in recent years, following the five principles in selecting indexes, the input indexes are set as: total investment in environmental pollution treatment, investment in wastewater treatment, investment in waste gas treatment, waste gas treatment facilities, solid waste treatment (see Table 2); the output indexes are set as: second industry's contribution to GDP growth, comprehensive utilization rate of solid waste and harmless treatment rate of domestic waste (see Table 3).

Table 2 Index variables of environmental protection input

	I1	**I2**	**I3**	**I4**	**I5**
unit	Billion RMB	Billion RMB	Billion RMB	set	Billion RMB
Input indexes	Total investment in environmental pollution treatment	Investment in wastewater treatment	Investment in waste gas treatment	Investment in waste gas treatment facilities	Investment in solid waste treatment

Table 3 Index variables of environmental protection output

	O1	**O2**	**O3**
Unit	%	%	%
Output indexes	Second industry's contribution to GDP growth,	Comprehensive utilization rate of solid waste	Harmless treatment rate of domestic waste

3.2.2 Data sources

The data are from *China Statistical Yearbook*, *China Environmental Statistical Yearbook* and *China Environmental Situation Bulletin,* see Table 4 and table 5.

Table 4 China's environmental protection input value from2001 to 2015

Years	Total investment in environmental pollution control	Wastewater treatment investment	Waste gas treatment investment	Exhaust gas treatment facility	Treatment of solid waste
2001	1166.7	72.9	65.8	134025	18.7
2002	1456.5	71.5	69.8	137668	16.1
2003	1750.1	87.4	92.1	137204	16.2

2004	2057.5	105.6	142.8	144973	22.6
2005	2565.2	133.7	213.0	145043	27.4
2006	2779.5	151.1	233.3	154557	18.3
2007	3668.8	196.1	275.3	162325	18.3
2008	4937.0	194.6	265.7	174164	19.7
2009	5258.4	149.5	232.5	176489	21.9
2010	7212.2	129.6	188.2	187401	14.3
2011	7114.0	157.7	211.7	216457	31.4
2012	8253.5	140.3	257.7	225913	24.7
2013	9037.2	124.9	640.9	234316	14.0
2014	9575.5	115.2	789.4	261367	15.1
2015	8806.4	118.4	521.8	290886	16.1

Data sources: *China Statistical Yearbook*, *China Environmental Statistical Yearbook* and *China Environmental Situation Bulletin*

Table 5 Output value of environmental protection in China from 2001 to 2015

Years	The pull of the secondary industry on GDP growth (%)	Comprehensive utilization of solid waste	Harmless treatment rate of domestic garbage
2001	0.4	52.1	23.6
2002	0.4	51.9	35.8
2003	0.3	54.8	38.6
2004	0.7	55.7	52.1
2005	0.6	56.1	51.7
2006	0.6	60.2	52.2
2007	0.4	62.1	62.0
2008	0.5	64.3	66.8
2009	0.4	67.0	71.4
2010	0.4	66.7	77.9
2011	0.4	59.8	79.7
2012	0.4	60.9	84.8
2013	0.3	62.2	89.3
2014	0.3	62.1	91.8
2015	0.3	60.2	94.1

3.3 Results and analysis

3.3.1 DEA efficiency analysis

After standardizing the input and output data of environmental protection, DEAP2.1 software was used to calculate the input and output efficiency of environmental protection in China. See Table 6 for the calculation results.

Table 6 Input and output efficiency of environmental protection in China from 2001 to 2015

Years	crste	vrste	scale	Scale return
2001	0.779	0.975	0.799	drs
2002	0.834	0.946	0.790	irs
2003	1.000	1.000	1.000	-
2004	0.687	0.956	0.66	drs
2005	0.805	0.890	0.72	drs
2006	0.443	0.574	0.25	drs

2007	0.515	0.541	0.28	drs
2008	0.824	0.857	0.71	drs
2009	0.375	0.457	0.17	drs
2010	0.603	0.753	0.45	drs
2011	1.000	1.000	1.000	-
2012	1.000	1.000	1.000	-
2013	1.000	1.000	1.000	-
2014	1.000	1.000	1.000	-
2015	0.793	0.789	0.630	irs
Mean	0.7772	0.849	0.697	

Where, crste represents the technical efficiency without considering the scale benefits, i.e. the overall efficiency. Because crste = crste=scale*vrste, the overall efficiency can be represented by pure technical efficiency and scale efficiency, in which the former represents the efficiency in structure and the latter reflects the efficiency in scale; vrste represents the technical efficiency when considering the scale benefit, i.e. pure technical efficiency; Scale refers to the scale efficiency when considering the scale benefit, i.e. scale efficiency (Bian and Zhao.2019). The last column shows the scale benefit, where irs represents the increase of scale benefit, - represents that the scale benefit remains unchanged, and drs represents the decrease of scale benefit.

From the analysis of the overall efficiency value, the average value is 0.7772, less than 1, which indicates that the scale efficiency of China's environmental protection investment is low and needs to be further improved. The overall efficiency values of China's environmental protection investment in 2003, 2011, 2012, 2013 and 2014 are all 1, indicating that the DEA efficiency of environmental protection investment has been realized in these five years (Zhou.2011;Li.2020), and that the capital utilization ratio of China's environmental protection investment in these five years is relatively high, and the output value of environmental protection industry has produced economies of scale. However, in other years, the overall efficiency value is not up to 1, and DEA efficiency is not realized (Lu et al. 2012), which indicates that the input-output structure is unreasonable or the scale of investment output is not large enough in these years.

From the analysis of pure technical efficiency value, the average value is 0.849, indicating that the input-output structure of China's environmental protection is not reasonable (Wang et al. 2009).The pure technical efficiency values in 2003, 2011, 2012, 2013 and 2014 are all 1, which indicates that the environmental protection investment structure in China is reasonable and in the forefront of production, realizing Pareto optimization. In other years, the pure technical efficiency value does not reach 1, which indicates that the investment structure of environmental protection is unreasonable in these years (Zhu.2014;Du et al.2020;Gajdzik and Sroka.2021).

From the analysis of scale efficiency value, the average value is 0.697, indicating that China's investment in environmental protection still has the potential to improve in terms of total funds and treatment of three wastes (Hu et al. 2008).The scale efficiency value of China's environmental protection investment in 2003, 2011, 2012, 2013 and 2014 is 1, indicating that the best state of scale economy are realized in these five years. In the years when the scale efficiency is not achieved, the technical efficiency is not achieved, which shows that there is the potential to improve the scale economic

efficiency in these years (Ye.2011).

3.3.2 Reason analysis of DEA inefficiency in some years

Except for the five years of 2003, 2011, 2012, 2013 and 2014, the overall efficiency of other years is DEA inefficient, and it is in the stage of decreasing returns to scale in 2001, and from 2004 to 2010, and in the stage of increasing returns to scale in 2002 and 2015.

The pure technical efficiency value and scale efficiency value are lower than 1 in the years of increasing or decreasing scale return, which indicates that the input-output structure and scale of environmental protection are in a non-optimal state in these years. If the scale efficiency is increasing (Yi.2002), the total amount of environmental protection investment is seriously insufficient. The decrease of scale efficiency may be related to the blind increase of total investment, the failure to improve the technical level of equipment invested, or the unreasonable investment structure, which results in the DEA inefficiency of environmental protection investment in these years (Ren.2013;Li.2017).

4 Conclusions and Suggestions

4.1 Conclusions

In this paper, DEA method was used to analyze the efficiency of environmental protection investment in China, and calculate the investment effectiveness in each year, to find out which aspects need to be strengthened, so as to provide decision support for more efficient use of each part of environmental protection funds.(Sun et al.2019)

After the empirical analysis, the following conclusions are drawn:

(1) DEA method has a strong practical significance in the efficiency evaluation of environmental protection investment in China, especially in the overall evaluation and analysis (Ma.2009).

(2) China's investment in environmental protection is of high efficiency in the overall level, but it has not been fully DEA efficient (Hite and Laurent.1972;Barra et al.2019), and there are non-technical and non-scale effectiveness, which indicates that China's supervision and management of environmental protection still needs to be strengthened, and environmental protection problems in various regions should be paid great attention to, so as to improve the scientific and technological content of environmental protection investment.

(3) It is observed from the analysis results that the increase of environmental protection investment in China is due to the insufficient total amount of environmental protection investment. The reasons for the decline of scale return lie in the unreasonable investment structure, the non-optimal output scale and the low technology level of environmental protection industry.

4.2 Suggestions

(1) Investment channels for environmental protection should be broadened. In recent years, there are still problems such as relatively less total investment in environmental protection, relatively low investment efficiency (Qiao.2014), unreasonable investment structure and relatively single investment benefit in China. At present, China's investment in environmental

protection mainly comes from the government, financial institutions, the private sectors and enterprises themselves. The government should encourage qualified local financing platform companies to expand investment and financing channels for environmental protection by direct and indirect financing. During period of the 11th Five Year Plan, government regulation and market mechanism were combined (Dai.2010). With the improvement of market mechanism and the development of environmental protection, according to the principle of "polluter pays", enterprise investment is still an important source of pollution prevention and control. At the same time, securities, funds and some foreign financing institutions pay more and more attention to environmental protection and begin to involve in environmental protection investment and financing. In addition, a diversified financing mechanism for environmental protection has been gradually established in China (Environmental Protection 2020).

Although China has an increasing total investment in environmental governance year by year, its proportion in GDP is still low. According to the report of the 18th National Congress of the Communist Party of China (Song and Wu.2012), the construction of ecological civilization should be vigorously promoted, the basic state policy of saving resources and protecting the environment should be adhered to, the deterioration trend of ecological environment should be reversed from the source, a good production and living environment should be created for the people, and a contribution should be made to global ecological security. Environmental protection departments have played an increasingly important role in pollution reduction and improvement of environmental quality. Have received the attention and support of governments at all levels in Heilongjiang Province, according to the principle of "polluter pays", the proportion of enterprises' self-financing funds has been increased.

(2) Residents and enterprises should be actively guided to participate in environmental protection. The government should actively guide residents to consciously abide by environmental laws and regulations and fulfill their obligations of environmental protection. Although the public awareness and knowledge of environmental protection in China have been improved to some extent, there are still problems of poor public initiative and participation in environmental protection. Therefore, environmental publicity and education work should be strengthened, with organization, measures, levels and emphasis, so that residents care about environmental protection and their ability to participate in environmental protection can be improved. The publicity and education of environmental protection awareness of local governments and enterprises should be carried out to strengthen the initiative investment awareness of environmental protection of enterprises(Li and Zhang.1993). The government should guide the enterprises to understand the environmental protection investment correctly, and promote them to take the initiative in environmental protection investment by improving the economic benefit consciousness of environmental protection investment. Enterprises shall increase investment in equipment and facilities for environmental protection, introduce high-tech decontamination equipment, and effectively recycle sewage and sewage. Banks and financial institutions shall provide preferential credit for environmental protection investment of enterprises, and encourage them to invest in environmental protection with low interest and high amount. The local environmental standards of each region should be improved to promote the upgrading of industrial technology. With the development of social economy, the existing local environmental standards should be improved; the charging system for pollution discharge and treatment should be established and improved; new emission standards should be issued; clean production technologies should be used to improve the quality of ecological environment in pharmaceutical, brewing, chemical industries to

strengthen the support of scientific and technological innovation, promote the upgrading of industrial technology, and improve market competitiveness (Zhang .2019).

(3) The subsidy of public finance to direct environmental protection investment should be increased. The government should combine the innovation of foreign financing with the promotion of industrial structure adjustment, actively strive for the fund loan for clean development mechanism in China, support the work of energy conservation and emission reduction, and promote the adjustment of industrial structure. China's non direct environmental protection investment mainly comes from public finance. It is suggested to increase subsidies for direct environmental protection investment in public finance to ensure the emission reduction needs of major pollutants in China. In 2014, in deepening economic reform, the state clearly proposed that the central government should continue to expand investment in environmental protection industry, and that energy conservation and environmental protection is not only a means but also a purpose to promote the upgrading of industrial structure so that the industry will take the lead in achieving performance and leading the overall economic growth under the direct support of finance for energy conservation and environmental protection.

(4) The investment mode of environmental protection should be optimized, and the progress of environmental protection technology should be greatly promoted. When the environmental protection investment has a low proportion in GDP, the pollutant emission reduced by the progress of environmental protection science and technology is far greater than that brought by it. Each industrial enterprise should adopt new technology to control pollution in its production process and end treatment. The government should encourage industrial enterprises to establish their own technology and R & D center, and constantly improve environmental protection technology. At the same time, enterprises should increase investment in environmental protection research funds. The government should carry out the educational policy of promoting the training of environmental protection professionals, introduce and absorb scientific and technological talents, so as to continuously improve the professional and technical level of environmental protection industry team.

Environmental protection investment can not only achieve environmental effects and accelerate the development of environmental protection industry through the promotion of environmental technology, but also bring potential social and economic effects. The way of environmental protection investment directly affects the efficiency of environmental protection investment. Chinese environmental protection department should formulate corresponding industrial organization policies and objectives in line with the industrial development, and the government should provide various economic subsidies to increase support for enterprise environmental protection projects(Li et al.2020;Wei et al.2020).

(5) Equal attention should be paid to the development of circular economy and optimization of industrial structure. The upgrading and optimization of industrial structure plays a positive role in the improvement of the environment. Adhering to circular development is the internal demand of adjusting industrial structure and accelerating industrial transformation and upgrading. According to the principle of "polluter pays"(Battese and Coelli.1995), the pollution caused by production and operation should be directly reduced or the relevant environmental losses should be compensated, and the residents should be properly guided to consciously abide by the environmental laws and regulations and fulfill the environmental protection obligations. The modern service industry should be vigorously developed, the economy of saving and environmental protection should be developed, and the new industrialization road should be taken. The government should formulate

relevant policies to fully support the industrial enterprises to extend the industrial chain, develop downstream products, and change the extensive industrialization mode at the cost of resource consumption and environmental pollution, so as to realize the improvement of industrial quality and efficiency, and improve the efficiency of economic growth in China. The government should combine the advantages of Chinese industries with the basis of development, focus on the development of circular economy, actively guide traditional enterprises to reform the old technology, build a product R & D and production circular industrial chain, abide by the principle of "reduction, reuse and recycling" of circular economy, reasonably make use of resources, so as to achieve less or even zero emissions.

Declarations

Not applicable

Ethical Approval

Not applicable

Consent to Participate

Yes

Consent to Publish

Yes

Authors Contributions

Guiyan Zhao put forward research ideas and design research schemes,Jilan Bian and Yao Shan responsible for conducting experiments and analyzing data,Guiyan Zhao,Jilan Bian and Yao Shan responsible for paper drafting.

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Competing Interests

No conflict of interests

Availability of data and materials

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Figures

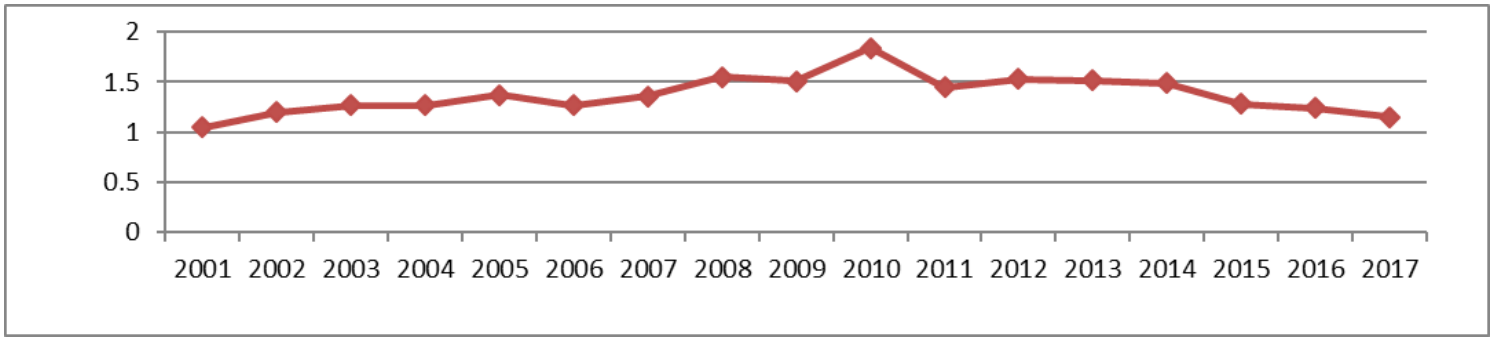

Figure 1

Proportion of environmental pollution control investment in GDP in the same period (%) Data sources: China Statistical Yearbook, China Environmental Statistical Yearbook and China Environmental Situation Bulletin

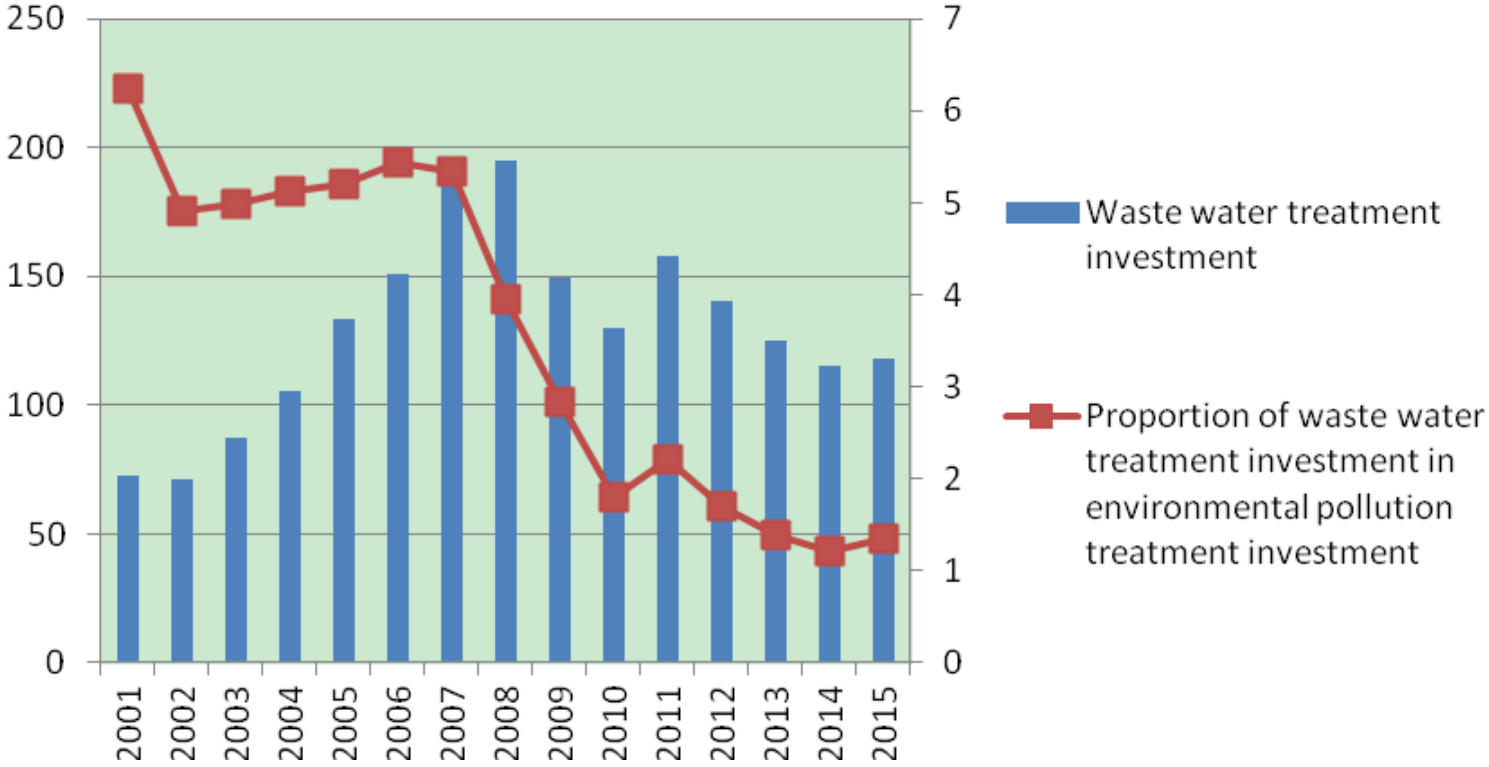

Figure 2

Proportion of investment in industrial wastewater pollution control Data sources: China Statistical Yearbook, China Environmental Statistical Yearbook and China Environmental Situation Bulletin

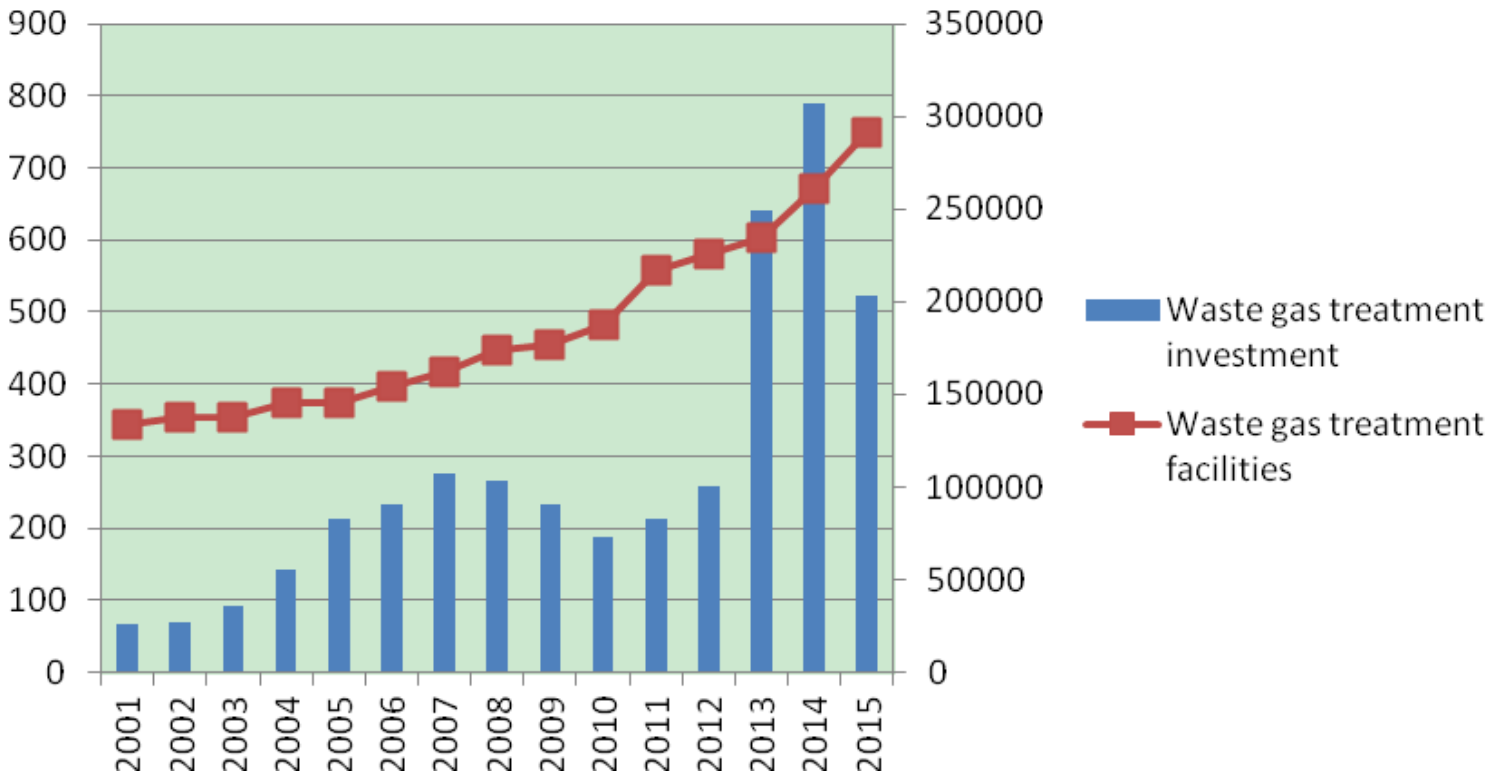

Figure 3

Investment in waste gas pollution treatment and facilities Data sources: China Statistical Yearbook, China Environmental Statistical Yearbook and China Environmental Situation Bulletin