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Environmental performance evaluation of heavy polluting enterprises

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Abstract: *Based on this super-efficiency SBM model, this paper evaluates the environmental performance of heavy polluting enterprises and finds that the overall environmental performance value of heavy polluting enterprises is not good and needs to be improved.*

Keywords: *Environmental performance evaluation; heavy polluting enterprises; super-efficiency SBM model*

1. Background of Research

From the Ministry of Environmental Protection published in 2008 "Listed companies Environmental Protection Verification Industry Classification Management Directory" referred to as "Management Directory", heavy pollution industry includes thermal power, cement, chemical industry and other 14 industries, it can be seen that heavy pollution industry is an important part of the second industry, its output value accounts for more than 60%, The secondary industry contributed 36.8% of China's GDP in 2019. This means that the remediation of pollution industries plays a vital role in the high-quality development of our economy.

Nowadays, corporate environmental performance has become an important component of corporate comprehensive performance. Whether it is due to the mandatory requirements of the state or for the long-term interests of enterprises, enterprises should pay attention to the environmental factors into their strategies and decisions, in order to achieve and promote the long-term sustainable development of enterprises.

In 2019, energy consumption in Sichuan and Chongqing reached 296.8 million tons of standard coal, accounting for 21.12 percent of the western region. In 2017, COD emissions in the region reached 1.493 million tons and sulfur dioxide emissions reached 392,000 tons, accounting for 26.87 percent and 18.22 percent of the western region, respectively. The main cause of air pollution is the discharge of coal, industrial waste gas, automobile exhaust and dust, and the main cause of water pollution is the illegal discharge of heavy polluting enterprises. In September 2020, Sichuan and Chongqing signed the Agreement on Deepening Eco-Environment Co-protection between Sichuan and Chongqing. It can be seen that the pollution in Chengdu-Chongqing area is quite serious, and the government departments of the two places are making efforts to promote the ecological environment governance. As a researcher, the environmental performance research on the major source of pollution -- heavy polluting enterprises can help the heavy polluting enterprises to find a good solution for environmental governance.

2. Literature Review

In the 1960s and 1970s, developed countries encountered serious environmental problems. The traditional industrialization path led by the United Kingdom and the United States, which was pollution first and prevention later, caused extremely serious pollution and destruction to the ecological environment. Under the pressure of environment and the need of human survival and sustainable development, scholars began to discuss environmental performance, hoping to promote environmental governance and improvement through the study of environmental performance.

Environmental performance evaluation research based on data envelopment analysis (DEA), which does not need to set the index weight in advance. DEA is a nonparametric method to judge the relative effectiveness of input-output data [1]. The basic idea is to determine the actual optimal production front by observing the input-output data of the decision-making unit, and obtain the efficiency score of each

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decision-making unit according to its distance from the production front [2]. Xue (2022) takes energy consumption as the main input, with GDP as the ideal output and CO2 emission as the unsatisfactory output. Based on data envelopment analysis, Xue evaluates the environmental performance of different energy consumption sectors in Brazil and finds that the agricultural and electric power industries are still at the low efficiency level even with relatively good environmental performance. It is also believed that providing knowledge and training to cultivate human resources is the best means to achieve performance growth [3]. Therefore, data envelopment analysis is chosen as the research method in this paper.

3. Environmental performance evaluation

3.1 Decision making unit selection

In this paper, 32 heavily polluting listed enterprises in the Shuangcheng economic circle of Chengdu-Chongqing region from 2017 to 2021 are selected as research objects, with a total of 140 samples, including 2 input indicators and 2 output indicators (including expected output and non-expected output). Based on any of the above quantitative principles. The number of decision making units and the number of indicators in this paper meet the requirements of DEA method.

3.2 Construction of evaluation index system

Referring to the commonly used indicators of environmental performance evaluation by previous scholars in this paper, following the aforementioned construction principles of evaluation indicators, and considering the availability and processability of data, this paper selects indicators from the three input perspectives of capital, labor and pollution, as well as from the perspective of economic output. Capital input: net fixed assets. Manpower input: the number of employees. Undesirable outputs as inputs: Pollution composite index. Expected output: revenue.

3.3 Sample selection

This paper chooses to study the heavily polluting A-share listed enterprises in Shanghai and Shenzhen within the Shuangcheng economic circle of Chengdu-Chongqing region from 2017 to 2021. The reason for this study is that the production and operation activities of the heavily polluting listed enterprises are the main cause of environmental pollution, and the pollution emission of the heavily polluting listed enterprises is far more than that of small and medium-sized enterprises. Listed enterprises can better represent the scale and strength of the heavy pollution industry, and can concentrate on the overall development of the heavy pollution enterprises. Moreover, the source, standardization and authenticity of the data of listed enterprises are more reliable. Therefore, the environmental performance evaluation of listed enterprises with heavy pollution can achieve the purpose of promoting the overall development of the heavy pollution industry.

3.4 Measures of environmental performance

The most classic model in DEA method is the CCR model proposed by Charnes, Cooper and Rhodes (1978) and the BCC model [4] proposed by Banker, Charnes and Cooper (1984). Both models have been named by the initials of the researchers. The former is based on the assumption of Constant Returns to Sale (CRS), while the latter is a model designed by considering the situation of Variable Returns to Scale (VRS). If the decision-making unit is on the effective production front, its efficiency value is 1, and it is called DEA effective. If the decision-making unit is not on the effective production front, the value calculated by the model is between 0 and 1, that is, DEA is invalid.

Suppose there are n decision units in the CCR model, and DMUj represents the JTH decision unit (j=1,2... n), each decision making unit has m inputs and s outputs. xij (i=1,2... ,m) represents input i, yrj (r=1,2... ,s) represents the output of item r, and vi and ui represent the weights of input and output of item i and item r.

CCR model is as follows:

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$$h_o = \max \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}$$

$$\text{s.t.} \quad \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1,$$

$$u_r, v_i \ge 0,$$

$$\text{i} = 1, 2, ..., m,$$

$$j = 1, 2, ..., n,$$

$$r = 1, 2, ..., s$$

BCC model is as follows:

$$\min \theta$$

$$\text{s.t.} \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta_j x_{ij}, i = 1, \cdots, m,$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rj},\ r = 1, \cdots, s,$$

$$\sum_{j=1}^{n} \lambda_j = 1,\ j = 1, \cdots, n,$$

$$\lambda_j, s_i^-, s_r^+ \ge 0,$$

The traditional DEA model represented by CCR and BCC can effectively distinguish decision making units (DUS) from non-effective DUS, but can only sort the invalid DUS, and cannot distinguish the decision making units (effective DUS) on the front plane (efficiency value is 1). Therefore, Andersen and Petersen (1993) [5] proposed a super efficient DEA model based on the CCR model, which could calculate the efficiency value of the effective decision making unit greater than 1 and then sort it, but it still failed to solve the problem that the traditional DEA model did not consider relaxation improvement. At the same time, the traditional DEA model requires that input-output variables of non-effective decision-making units must change in the same direction and in the same proportion. However, in reality, not all input-output variables will be operated in proportion [6].

In the super-efficiency SBM[5] model, it is assumed that there are n decision units, and DMUj (j=1... , n), according to each decision making unit m items for expected output and the expected output, vector $x \in R^m$, $y^d \in R^{s_1}$, $y^u \in R^{s_2}$; X、Y^d and Y^u are matrices greater than 0, $X = [x_1 \cdots x_n] \in R^{m \times n}$, $Y^d = [y_1^d \cdots y_n^d] \in R^{s_1 \times n}$, $Y^u = [y_1^u \cdots y_n^u] \in R^{s_2 \times n}$. The super efficiency SBM model constructed with non-radial, non-oriented and non-expected output is as follows:

$$\min \rho = \frac{1 + 1/m \sum_{i=1}^{m} \left(s_i^- / x_{ik} \right)}{1 - 1/\left(s_1 + s_2\right) \left(\sum_{p=1}^{s_1} s_P^{d^+} / y_{pk}^d + \sum_{q=1}^{s_2} s_{\text{q}}^{u^-} / y_{qk}^u \right)}$$

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$$\text{s.t.} \sum_{j=1,\neq k}^{n} x_{ij}\lambda_j - s_i^- \leq x_{ik} \quad i = 1,\cdots,m$$

$$\sum_{j=1,\neq k}^{n} y_{pj}^d \lambda_j + s_p^{d^+} \geq y_{pk}^d \quad p = 1,\cdots,s_1$$

$$\sum_{j=1,\neq k}^{n} y_{qj}^u \lambda_j - s_q^{u^-} \leq y_{qk}^u \quad q = 1,\cdots,s_2$$

$$1 - 1/\left(s_1 + s_2\right)\left(\sum_{p=1}^{s_1} s_P^{d^+} / y_{pk}^d + \sum_{q=1}^{s_2} s_{\text{q}}^{u^-} / y_{qk}^u\right) > 0$$

$$\lambda_j \geqslant 0\,; j = 1,\cdots,n; s^{d^+} \geq 0; s^{u^-} \geq 0; s^- \geq 0$$

3.5 Environmental performance evaluation of heavy polluting enterprises

Based on the above environmental performance evaluation index system and evaluation model, this section will use Matlab2019 software to carry out static environmental performance evaluation on the heavily polluting enterprises in the Chengdu-Chongqing economic circle, and calculate the relative efficiency values of the environmental performance of the sample enterprises during the five years from 2017 to 2021, as shown in table 1 below.

Table 1: Environmental performance of heavy polluting enterprises

Number	Enterprise code	2017	2018	2019	2020	2021	Mean	Rank
1	300194	0.280	0.278	0.340	0.413	0.332	0.329	17
2	300363	0.205	0.197	0.238	0.312	0.257	0.242	25
3	600438	0.150	0.213	0.254	0.333	0.385	0.267	22
4	600678	1.020	0.438	0.433	0.411	0.419	0.544	11
5	603077	3.054	3.184	4.943	3.365	2.170	3.343	1
6	000510	0.177	0.201	0.187	0.248	0.381	0.239	26
7	000568	0.278	0.264	0.318	0.393	0.410	0.333	16
8	000688	1.361	1.262	1.309	1.051	1.194	1.235	4
9	000731	0.394	0.289	0.363	0.372	0.431	0.370	14
10	000858	0.219	0.194	0.222	0.347	0.382	0.273	21
11	000935	1.299	1.384	1.407	1.554	1.606	1.450	3
12	002004	0.283	0.479	0.433	1.034	0.740	0.594	8
13	002246	0.215	0.189	0.175	0.286	0.264	0.226	27
14	002258	0.236	0.234	0.269	0.368	0.375	0.296	19
15	002386	0.242	0.183	0.205	0.304	0.276	0.242	24
16	002422	1.129	1.103	1.142	1.116	0.891	1.076	5
17	002466	0.153	0.203	0.179	0.259	0.234	0.206	28
18	002507	0.711	0.603	0.425	0.418	0.749	0.581	10
19	002539	0.306	0.272	0.328	0.367	0.316	0.318	18
20	002742	0.195	0.173	0.196	0.323	0.363	0.250	23
21	002749	0.265	0.217	0.237	0.383	0.336	0.288	20
22	002773	5.221	3.881	1.006	1.005	1.120	2.446	2
23	002798	0.580	0.370	0.485	0.432	0.329	0.439	13
24	002907	1.001	0.260	0.299	0.393	0.281	0.447	12
25	600132	1.001	0.486	1.004	0.321	0.266	0.616	7
26	600779	0.309	0.702	0.554	0.900	0.477	0.588	9
27	603027	0.676	0.659	1.005	1.008	1.272	0.924	6
28	300194	0.330	0.294	0.330	0.363	0.359	0.335	15
	Mean	0.760	0.650	0.653	0.646	0.593	0.661	/

Pure technical efficiency (PTE) is calculated by taking into account the fact that not all enterprises can achieve the optimal scale production in reality, and eliminating the influence of enterprise scale effect, the change of resource allocation ability and scale factors from the comprehensive efficiency. It mainly

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reflects the comprehensive ability of enterprises such as management level and technology level. The pure technical efficiency of the sample enterprises is shown in Table 1.

In general, during the sample period, the average pure technical efficiency of the heavily polluted sample enterprises in the Chengdu-Chongqing Shuangcheng economic Circle is 0.661, the maximum value of pure technical efficiency is 5.221, and the minimum value is 0.150, with a large efficiency gap (5.071), indicating a large difference in the management level and technical level of the sample enterprises. Among the 28 enterprises, the number of enterprises that reach the average value of pure technical efficiency is 5, which are as follows: Sichuan Jinding (3.343), Guoguang Stock (2.446), Wuliangye (1.450), Luzhou Laojiao (1.235) and Tianyuan Stock (1.076) accounted for 17.88% of the sample enterprises, indicating that there is still a large space for the green development of sample enterprises. There were 6 enterprises that exceeded the average pure technical efficiency of the sample (0.661). In addition to the above 5 enterprises with pure technical efficiency and effectiveness, there were also Shui Jing Fang (0.924), indicating that only 21.43% of enterprises reached the average level of the sample in terms of management and technical level.

4. Conclusion

Based on the panel data of 28 heavily polluting enterprises in Shuangcheng Economic Circle in Chengdu-Chongqing area, this paper calculates the static environmental performance of sample enterprises in 2017-2021 by using the super-efficiency SBM model containing unexpected output, and draws the following conclusions:

The average pure technical efficiency was 0.661 during the calculation period, and the average of each year ranged from 0.593 to 0.760, and reached the average of 0.760 in 2017.There were 8, 5, 7, 7 and 5 enterprises that realized DEA effectiveness each year, and the average number of enterprises that reached pure technology effectiveness in 5 years was 5, which were Sichuan Jinding, Guoguang Co., LTD., Wuliangye, Luzhou Laojiao and Tianyuan Co., LTD. In a word, efficiency needs to be further improved, and policy makers should take positive measures to achieve the best efficiency state.

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