



Applied Mathematics and Nonlinear Sciences

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Empirical Analysis on Environmental Regulation Performance Measurement in Manufacturing Industry: A Case Study of Chongqing, China

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Submission Info

Communicated by Juan Luis Garcia Guirao

Received December 5th 2019

Accepted January 14th 2020

Available online March 27th 2020

Abstract

In recent years, China's environmental pollution is serious, manufacturing industry has become one of the main targets of government environmental regulation. This paper uses the SBM model to calculate efficiency value of 29 manufacturing industries from 2008 to 2017. The results show that the overall performance of environmental regulation in manufacturing industry is high (the average efficiency value is 0.7806), but it shows a declining trend. The efficiency of environmental regulation also varies widely. The government should consider focusing on the 11 industries with low SBM value in the next step to improve the performance of environmental regulation.

Keywords: manufacturing industry; environmental regulation; performance measurement.**AMS 2010 codes:** 00A71

1 Introduction

In terms of absolute scale, manufacturing industry is still the largest industry in China and an important industry to promote China's economic development. Although China's manufacturing industry has developed rapidly, it is still at the middle or lower end of the industrial chain and the value chain, and it trades for rapid industrial growth at the cost of "high pollution and high energy consumption." At the same time, due to the imperfection of environmental supervision system and mechanism, the problems of ecological damage and environmental pollution in most areas of China are becoming more and more serious. Especially in recent years, environmental pollution incidents keep breaking out, and the public's attention to the ecological environment has increased unprecedentedly. The government frequently issued regulatory policies, using various regulatory

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means to control the impact of industrial enterprises' pollutant emissions on the environment [1]. Chongqing is an important strategic fulcrum for the development of Western China, an important junction of "The Belt and Road" economic belt and the Yangtze river economic belt, as well as an important inland city opening to the outside world. It is also an important ecological barrier and water conservation area in the upper reaches of the Yangtze river. With the rapid economic growth in recent ten years, the discharge of waste water, waste gas and solid waste is also on the rise year by year. Water environment, atmospheric environment and soil environment pollution events occur from time to time. Chongqing, as a miniature of the development of China's manufacturing industry, is also a beautiful city with mountains and rivers. How does it balance the relationship between economic development and ecological environment protection? It is of great significance and popularization value to explore the environmental regulation performance of manufacturing industry in Chongqing. Taking Chongqing as an example, from the perspective of input-output, this paper constructs three input indicators and eight output indicators respectively [2], selects the relevant data of 29 manufacturing industries in Chongqing from 2008 to 2017, and uses the SBM method of unexpected output to measure the effect of environmental regulation performance of manufacturing industry, as well as the difference of regulation performance of various industries, so as to improve the environmental regulation performance of manufacturing industry for the government and to provide a theoretical basis for the improvement of the policy, which has a certain reference value for the environmental pollution control of the global industrialized cities.

2 Data and Methods

2.1 Evaluation Index Selection and Data Processing

The pollutants produced by manufacturing industry are exhaust gas, waste water, noise and solid waste. Because the noise of industrial enterprises can basically meet the discharge standards and is not easy to statistics, the generation and discharge of exhaust gas, waste water and solid waste are considered when national and local environmental data are collected. So when choosing the environmental regulation index of manufacturing industry, this paper mainly chooses three indexes: exhaust gas (SO₂, smoke (powder) dust), waste water and solid waste. Sulfur dioxide, smoke (powder) dust, waste water discharge and solid waste production are regarded as unexpected outputs of environmental regulation. Removal rate of sulfur dioxide and smoke (powder) dust, discharge rate of waste water and comprehensive disposal rate of solid waste are regarded as expected outputs [3]. At the same time, the number of people in environmental protection system is regarded as the human input of environmental regulation, the investment in environmental protection as the financial input of environmental regulation, and the number of waste gas and waste water treatment facilities in manufacturing industry as the material input of environmental regulation [5, 6]. Based on the comprehensive consideration of the selected indexes in other literature and the availability of data, this paper constructs a performance evaluation system of environmental regulation as shown in Table 1. In view of the availability of data, this paper chooses the relevant data of 29 manufacturing industries in Chongqing from 2008 to 2017 (culture, education, art, sports and entertainment manufacturing and metal products, machinery and equipment repair industries were excluded due to lack of data). All the original data in this paper come from Chongqing Statistical Yearbook, Chongqing Environmental Status Bulletin and Chongqing Environmental Statistics Bulletin. The missing individual values in the statistics are smoothed, and the investment in environmental protection is reduced based on 2008 [10].

2.2 Selection of Research Method

According to the current research results, scholars mainly use parametric and non-parametric methods to study environmental efficiency. The parametric method is represented by stochastic frontier analysis (SFA). The core of SFA is to construct a production function. Although it can calculate the technical efficiency value of production unit, the premise is under given production conditions, in which the calculation results will deviate from the actual efficiency value. Based on this, non-parametric method has become the choice for most schol-

Table 1 Evaluation index system of environmental regulation performance of manufacturing industry in Chongqing

Primary Index	Secondary Index	Tertiary Index	
Performance Evaluation Index of Environmental Regulation in Chongqing Manufacturing Industry	Input Index of Environmental Regulation	Number of personnel in environmental protection system	
		Environmental protection investment (RMB 100 million)	
		Number of treatment facilities (sets)	
	Output Index of Environmental Regulation	Expected Output	sulfur dioxide removal rate
			smoke (powder) dust removal rate
			attainment rate of the industrial waste water
			comprehensive utilization rate of solid waste disposal
		Unexpected Output	Sulfur dioxide emissions (tons)
			Nitrogen oxide emissions (tons)
			Discharge of industrial waste water (tons)
			Solid waste production (tons)

ars to study technical efficiency. Non-parametric method is mainly represented by data envelopment analysis (DEA). Linear programming technology is used to construct the best frontier of optimal set representation under the condition of multi-input and multi-output, using input and output data of each decision-making unit. That is to say, the minimum output is used to realize the set of maximum income. Then the inefficiency value is measured by the distance between each decision unit and the optimal frontier. Traditional DEA models [3, 4], such as CCR, BCC, FG, ST and so on, mainly measure efficiency from two aspects: radial (input and output are reduced or enlarged in equal proportion) and angle (input or output angle). They do not take into account the relaxation of input and output [4], which may lead to errors in the calculation of efficiency. Tone (2004) proposed a relaxation variable based SBM model [7]. SBM is a non-radial and non-angular DEA analysis method, which effectively solves the relaxation variables, radial and angular problems in the original DEA model. Considering the existence of unexpected output in the output of environmental regulation, this paper chooses the SBM model to measure the performance of environmental regulation in Chongqing manufacturing industry.

3 Empirical Results

According to the collected data, the performance of environmental regulation of 29 manufacturing industries in Chongqing was measured by Max DEA software, and the SBM efficiency value of environmental regulation of manufacturing industry in Chongqing was obtained. The SBM efficiency value of environmental regulation of manufacturing industry in Chongqing was analyzed from the perspective of the whole industry and the sub-industry respectively. The SBM efficiency value represents the performance level of environmental regulation in Chongqing manufacturing industry, and when the SBM efficiency value is 1, it indicates that the environmental regulation performance of the decision-making unit is effective; when the SBM efficiency value is greater than

or equal to 0.75 and less than 1, the environmental regulation performance of the decision-making unit is a little effective. When the SBM efficiency value is greater than or equal to 0.5 or less than 0.75, the environmental regulation performance of the decision-making unit is weak; when the SBM efficiency value is less than 0.5, the environmental regulation performance of the decision-making unit is invalid.

3.1 Overall Regulation Performance of Manufacturing Industry in Chongqing

Table 2 shows the SBM efficiency value of environmental regulation performance of Chongqing manufacturing industry from 2008 to 2017, and Figure 1 shows the trend of SBM efficiency value. From this, we can see that between 2008 and 2017, the efficiency of environmental regulation performance of Chongqing manufacturing industry is relatively high, with an average value of 0.7806, which shows that the overall regulatory performance of Chongqing is in a little bit effective state. Among them, the efficiency value in 2008 is as high as 0.9366, which is close to the effective state; the efficiency values in 2009–2013 are between 0.75 and 0.9, which is a little effective; the efficiency value in the remaining years is between 0.6 and 0.75, which is in a weakly effective state. The efficiency value is the lowest in 2016, which is 0.6993. From this, we can see that although the overall performance of environmental regulation of manufacturing industry in Chongqing is declining, the decline is not significant, and environmental regulation is in an effective state [8]. In particular, in 2016, the emission of pollutants from Chongqing manufacturing industry declined the most, but the performance of environmental regulation tended to be low. The main reason is that in 2016, Chongqing vigorously strengthened the capacity building of grass-roots environmental protection in villages and towns (streets), and the number of environmental protection systems reached the maximum in 2016, so the efficiency of input and output were relatively reduced [9].

Table 2 Average efficiency and ranking of manufacturing industries in Chongqing from 2008 to 2017

Year	SBM efficiency	Ranking
2008	0.9366	1
2009	0.7896	4
2010	0.7758	6
2011	0.8305	2
2012	0.8042	3
2013	0.7763	5
2014	0.7477	7
2015	0.7368	8
2016	0.6993	10
2017	0.7093	9
Average	0.7806	-

3.2 Environmental Regulation Performance of Manufacturing Industry in Chongqing

Table 3 calculated the mean value of SBM efficiency of environmental regulation performance of manufacturing industries in Chongqing from 2008 to 2017. It can be seen that there are great differences in environmental regulation efficiency between industries. Among them, the environmental regulation performance of waste resources comprehensive utilization industry, textile and apparel industry and clothing industry is the highest, with SBM values as high as 0.953 and 0.932. Furniture Manufacturing, Printing and Recording Media Reproduction, Instrument Manufacturing, Wood Processing and Wood, Bamboo, Rattan, Grass Products, Chemical Fiber Manufacturing, Tobacco Products, Food Manufacturing, Rubber and Plastic Products, Nonferrous Metals Smelting

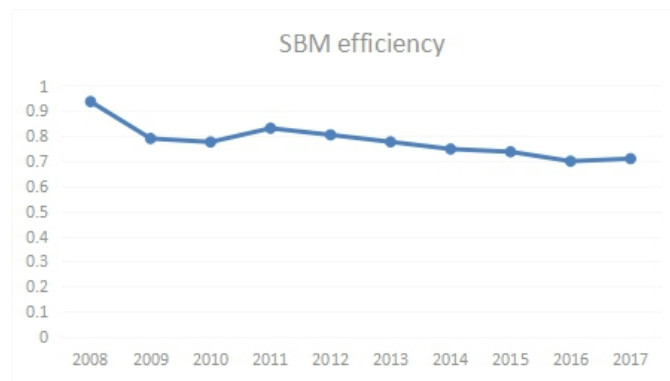


Fig. 1 Trend of overall efficiency value of manufacturing industry in Chongqing from 2008 to 2017

and Calendering, Computer, Communication and other Related Equipment and Electronic Equipment Manufacturing Industry, Paper Making and Paper products industry, Leather, Fur, Feather and its Products and Footwear Industry, Pharmaceutical Manufacturing Industry, Special Equipment Manufacturing Industry, Ferrous Metal Smelting and Calendering Industry, Chemical Raw Materials and Chemical Products Manufacturing Industry, these 16 industries have higher environmental regulation performance. The SBM value ranges from 0.75 to 0.9. Metal Products Industry, Electrical Machinery and Equipment Manufacturing Industry, Petroleum, Coal and other Fuel Processing Industry, Non-metallic Mineral Products Industry, General Equipment Manufacturing Industry, Textile Industry, Wine/Beverage and Refined Tea Manufacturing Industry, Automobile Manufacturing Industry, Agricultural Food Processing Industry, other Manufacturing Industries, Railway, Ship, Aerospace and other Transportation Equipment Manufacturing Industry, the environmental regulation performance of these 11 industries is relatively low, in which the SBM value is between 0.5 and 0.75, among which the environmental regulation efficiency of railway, ship, aerospace and other transportation equipment manufacturing industry is the lowest, in which the SBM value is 0.587 [10].

3.3 Changing Trend of Environmental Regulation Performance of Manufacturing Industry in Chongqing

Table 4 shows the comprehensive efficiency value of environmental regulation performance of manufacturing industries in Chongqing, from which we can see the changing trend of environmental regulation performance of various industries from 2008 to 2017 [11]. Among them, the SBM efficiency of food manufacturing, textile and apparel, clothing industry, instrument manufacturing industry and waste resources comprehensive utilization industry in 2008 and 2017 are all 1. Although there are some fluctuations, the average SBM efficiency is above 0.88, and the overall performance of environmental regulation is in the state of effectiveness and a little bit effectiveness. The SMB efficiency values of furniture manufacturing, automobile manufacturing, railway, ship, aerospace and other transportation equipment manufacturing industries in 2017 are higher than those in 2008, and the SMB efficiency values of these three industries have increased first and then decreased, and all of them have peaked in 2011. Furniture manufacturing industry as a whole has high SBM efficiency, which is in a little effective and effective state of environmental regulation performance. The SBM efficiency of automobile manufacturing industry and railway, ship, aerospace and other transportation equipment manufacturing industry is on the low side as a whole and in a weak effective state. Meanwhile, it is worth noticing that the SBM efficiency of these two industries is below 0.5 from 2008 to 2010, which is in an invalid state of environmental regulation performance. This is in line with Chongqing's vigorous development of supporting the automobile manufacturing industry at that time. The number of automobile manufacturing enterprises was relatively large. It may be difficult for the government to manage in the process of environmental regulation. At the same time, there were some policy biases, so the performance was relatively poor. The SBM efficiency values of the other 22 industries in 2017 are lower than those in 2008, declining in fluctuation, which is consistent with the trend of the overall efficiency values of manufacturing industry [12]. The SBM efficiency values of other manufacturing

Table 3 Average integrated technical efficiency of various industries, 2008-2017

Industry	SBM value
Waste Resources Comprehensive Utilization Industry	0.9532506
Clothing and Apparel Industry	0.9334731
Furniture Manufacturing Industry	0.8853607
Printing and Recording Media Reproduction Industry	0.8839425
Instrument Manufacturing Industry	0.8816577
Wood Processing and Wood, Bamboo and Grass Products Industry	0.8751221
Chemical Fiber Manufacturing Industry	0.8720931
Tobacco Products Industry	0.867389
Food Manufacturing Industry	0.866314
Rubber and Plastic Products Industry	0.8384345
Nonferrous Metals Smelting and Calendering Industry	0.8257309
Manufacturing of Electronic Equipment for Computers, Communications and Other Related Equipment	0.8166281
Paper Making and Paper Products Industry	0.7821013
Leather, Fur, Feather and its Products and Footwear Industry	0.7733928
Pharmaceutical Manufacturing Industry	0.7705146
Special Equipment Manufacturing Industry	0.7607089
Ferrous Metal Smelting and Calendering Industry	0.751305
Manufacturing of Chemical Materials and Chemicals	0.7492757
Metal Products Industry	0.7330558
Electrical Machinery and Equipment Manufacturing Industry	0.7306378
Petroleum, Coal and Other Fuel Processing Industry	0.7204917
Non-metallic Mineral Products Industry	0.7156119
General Equipment Manufacturing Industry	0.7117027
Textile Industry	0.6975907
Wine/Beverage and Refined Tea Manufacturing Industry	0.6904077
Automobile Manufacturing Industry	0.6742629
Agricultural Food Processing Industry	0.6503488
other Manufacturing Industries	0.6407483
Railway, Ship, Aerospace and other Transportation Equipment Manufacturing Industry	0.5864064

industries decreased from 1.0 in 2008 to 0.3 in 2009 and 0.2 in 2010, and the SBM efficiency values of the remaining years were all around 0.7, the difference was too large, probably due to the statistical error of the original data.

4 Conclusions

From 2008 to 2017, the overall environmental regulation performance of manufacturing industry in Chongqing was in a little effective state, with the average SBM efficiency value of 0.7806. Although the efficiency value is high, it cannot be ignored that the overall performance of environmental regulation in Chongqing's manufacturing industry is declining, especially in recent years. The government should pay great attention to it and take effective measures to curb the decline of environmental regulation performance [13]. The efficiency of envi-

Table 4 Comprehensive efficiency value of manufacturing industry in Chongqing from 2008 to 2017

Industry	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Agricultural Food Processing Industry	0.79	0.6	0.56	0.7	0.7	0.67	0.65	0.61	0.61	0.62
Food Manufacturing Industry	1	1	0.9	0.83	0.82	0.79	0.77	0.76	0.8	1
Wine/Beverage and Refined Tea Manufacturing Industry	0.94	0.74	0.76	0.7	0.7	0.67	0.64	0.6	0.58	0.58
Tobacco Products Industry	1	1	1	0.88	0.89	0.86	0.77	0.8	0.8	0.69
Textile Industry	0.96	0.77	0.74	0.7	0.7	0.67	0.64	0.6	0.58	0.6
Clothing and Apparel Industry	1	0.85	0.77	1	1	0.93	1	0.77	1	1
Leather, Fur, Feather and its Products and Footwear Industry	1	0.85	1	0.78	0.77	0.69	0.66	0.61	0.6	0.76
Wood Processing and Wood, Bamboo, Rattan, and Grass Products Industry	1	0.82	1	1	1	0.9	0.84	0.74	0.73	0.73
Furniture Manufacturing Industry	0.7	0.57	1	1	1	0.94	0.9	1	0.74	1
Paper Making and Paper Products Industry	1	0.83	0.79	0.72	0.77	0.74	0.79	0.68	0.78	0.72
Printing and Recording Media Reproduction Industry	1	0.77	0.77	1	1	0.94	1	1	0.71	0.65
Petroleum, Coal and Other Fuel Processing Industry	1	0.77	0.8	0.7	0.7	0.68	0.67	0.66	0.61	0.62
Manufacturing of Chemical Materials and Chemicals	0.97	0.85	0.78	0.74	0.73	0.67	0.68	0.6	0.77	0.71
Pharmaceutical Manufacturing Industry	1	0.89	0.8	0.81	0.81	0.69	0.65	0.59	0.81	0.67
Chemical Fiber Manufacturing Industry	1	0.85	1	0.79	0.81	0.92	1	0.81	0.81	0.74
Rubber and Plastic Products Industry	0.97	1	1	0.9	0.88	0.84	0.77	0.69	0.69	0.65
Non-metallic Mineral Products Industry	0.93	0.8	0.76	0.74	0.73	0.7	0.68	0.61	0.65	0.56
Ferrous Metal Smelting and Calendering Industry	0.96	0.85	0.77	0.72	0.72	0.74	0.69	0.61	0.74	0.73
Nonferrous Metals Smelting and Calendering Industry	1	1	0.84	1	0.73	0.7	0.65	0.59	1	0.74
Metal Products Industry	0.97	0.82	0.8	0.85	0.86	0.67	0.64	0.6	0.58	0.54

General Equipment Manufacturing Industry	0.98	0.83	0.82	0.7	0.7	0.67	0.64	0.61	0.58	0.58
Special Equipment Manufacturing Industry	1	0.86	0.76	0.7	0.7	0.67	0.65	1	0.58	0.68
Automobile Manufacturing Industry	0.5	0.4	0.43	1	0.85	0.8	0.77	0.69	0.69	0.61
Manufacturing of Railway, Ship, Aerospace and Other Transportation Equipment	0.49	0.4	0.39	0.7	0.7	0.67	0.64	0.67	0.6	0.61
Electrical Machinery and Equipment Manufacturing Industry	1	0.78	0.68	0.71	0.7	0.67	0.64	1	0.58	0.54
Manufacturing of Electronic Equipment for Computers, Communications and Other Related Equipment	1	0.85	0.78	1	0.9	1	0.76	0.76	0.58	0.54
Instrument Manufacturing Industry	1	0.84	0.8	1	0.77	0.96	0.85	1	0.59	1
Other Manufacturing Industries	1	0.3	0.2	0.7	0.7	0.67	0.65	0.72	0.74	0.72
Waste Resources Comprehensive Utilization Industry	1	1	0.77	1	1	1	1	1	0.76	1

ronmental regulation varies greatly among manufacturing industries [14]. The highest SBM value is in waste resources comprehensive utilization industry and the textile and apparel industry, in which the performance of environmental regulation is close to the effective state. Furniture Manufacturing, Printing and Recording Media Reproduction, Instrument Manufacturing, Wood Processing and Wood, Bamboo, Rattan, Grass Products, Chemical Fiber Manufacturing, Tobacco Products, Food Manufacturing, Rubber and Plastic Products, Nonferrous Metals Smelting and Calendering, Computer, Communication and other Related Equipment and Electronic Equipment Manufacturing Industry, Paper Making and Paper products industry, Leather, Fur, Feather and its Products and Footwear Industry, Pharmaceutical Manufacturing Industry, Special Equipment Manufacturing Industry, Ferrous Metal Smelting and Calendering Industry, Chemical Raw Materials and Chemical Products Manufacturing Industry, these 16 industries have high environmental regulation performance and are in a little effective state. Metal Products Industry, Electrical Machinery and Equipment Manufacturing Industry, Petroleum, Coal and other Fuel Processing Industry, Non-metallic Mineral Products Industry, General Equipment Manufacturing Industry, Textile Industry, Wine/Beverage and Refined Tea Manufacturing Industry, Automobile Manufacturing Industry, Agricultural Food Processing Industry, other Manufacturing Industries, Railway, Ship, Aerospace and other Transportation Equipment Manufacturing Industry, the environmental regulation performance of these 11 industries is relatively low and is in a weak effective state. Therefore, the government should consider the next step to focus on environmental regulation measures in the 11 industries with low SBM value in order to improve the performance of environmental regulation. From 2008 to 2017, the trend of environmental regulation performance of different industries is not consistent. Overall, food manufacturing, textile and apparel industry, clothing industry, instrument manufacturing industry, waste resources comprehensive utilization industry and other four industries basically maintain a fairly high level, the overall performance of environmental regulation is in an effective and a little effective state. Furniture manufacturing, automobile manufacturing, railway, shipping, aerospace and other transportation equipment manufacturing industries are rising in fluctuation, and they are in the more effective and weak state of environmental regulation performance respectively. The SBM efficiency values of the other 22 industries are declining in fluctuation, which is consistent with the change trend of the overall efficiency values of manufacturing industry. It indicates that the government's environmental regulation measures and efforts vary from industry to industry [15].

Based on the empirical results, we can find the main direction of future policies. First, we should give full play to the positive externality of environmental regulation and further enhance the intensity of environmental regulation, thus strengthening the competitive advantage of the industry. Special attention should be paid to the 11 industries with relatively low performance of environmental regulation. Environmental regulation should be strictly protected from the perspective of legalization and institutionalization, environmental related law enforcement procedures should be strictly standardized, law enforcement intensity should be improved, and illegal costs should be greatly increased. The second is to flexibly use environmental policies and innovate the organic combination of environmental regulation and manufacturing agglomeration. As different industries will also have different degrees of environmental pollution, differentiated measures should be taken according to specific conditions. For example, for monopoly industries and capital-intensive industries, strict environmental regulation policies can be implemented to keep pollution discharge activities out of the threshold, and environmental pollution can also be improved by exerting industrial agglomeration effect. When formulating environmental protection policies, full consideration should be given to whether it can promote scientific and technological innovation and industrial structure upgrading, so that it can really play a role in controlling environmental pollution [16]. The third is to further improve relevant policies and enhance the technological innovation capability of Chongqing's manufacturing industry. Manufacturing occupies a dominant position in Chongqing's economic system and is the key to promote the sustained and healthy development of the local economy. Intelligent manufacturing should be taken as the main direction of future industrial upgrading, efforts should be made to promote the application of new technologies, new formats and new modes, and key industries should be encouraged to upgrade and replace key core equipment. Support small and medium-sized micro-enterprises to develop characteristic products and cultivate independent intellectual property rights and brands [17]. At the same time, taking the construction of parent factories of large enterprises as the starting point, we will cultivate a number of key industry flaunt enterprises based on the development of new formats, technologies and modes. Comprehensive use of subsidies, government procurement and other forms to encourage large enterprises to provide technical support and services to small and medium-sized enterprises in the region and the supply chain, to form an ecosystem with overall improvement of technological capabilities.

Funding: This work was sponsored in part by National Social Science Foundation of China (19XMZ095).

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