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Empirical research of performance evaluation of energy saving and environmental protection enterprise based on DEA

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ABSTRACT

This article builds the performance evaluation model by DEA method for energy saving and environmental protection industry of China. We implemented, according to its input-oriented model, an empirical analysis for energy saving and environmental protection performance of the listed companies in China (2007-2010). From the horizontal, the scores of the relative efficiency of the companies are high, and the overall performance is better. From the vertical, most of the companies' management performance is not stable; however, the industry as a whole shows a more visible growth trend.

Key words: DEA; performance evaluation; energy saving; environmental protection; listed company

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INTRODUCTION

The reduction in energy emissions has become increasingly important as well as an internationally concerned topic. In recent years, China has launched many policies and regulations regarding energy-saving emission and environmental protection. The introduction of policies for energy saving and environmental protection industry has brought an unprecedented opportunity for development. During the period of "Twelfth Five-year" the government will provide support policies about energy saving and environmental protection technologies, equipment and services. They put the energy saving and emissions reduction as an important measure of the transformation of economic development, will promote the sustainable economic and social development.

Enterprise performance evaluation has been the focus of theoretical and practical concerns. In the performance evaluation methods, Data Envelopment Analysis (DEA), a performance evaluation method originating from the banking industry, has been applied in many industries as more and more researchers concern the performance evaluation. Literature on the performance evaluation of energy saving and environmental protection enterprises is limited. Only Li Jian, Hu Haiqing [1] have conducted studies on the environmental protection enterprise performance evaluation system, proposed the construction of balanced score card performance evaluation mechanism of environmental protection enterprises, and evaluated the performance of the environmental protection enterprises with the fuzzy comprehensive evaluation method. This article is based on the energy-saving environmental protection policy environment and prospect of the industry, we use the DEA method for an empirical analysis on energy saving and environmental protection performance of listed companies in China. Through the comparative analysis of the industry development situation on performance, it can more specifically show the status of energy saving and environmental protection industry, and promote sustainable development of this industry.

1 CONSTRUCTION OF PERFORMANCE EVALUATION MODEL BASED ON DEA

1.1 INDEX SELECTION

The principle of the DEA method is to keep the same input or output of the decision-making unit, using mathematical programming and statistical data to determine the relative effective production frontier. The various decision-making units project to the production frontier of the DEA, and to evaluate their relative effectiveness by

comparing the extent of the decision making unit deviates from the DEA frontier. Evaluation is based on the input data and output data of the decision-making unit. The input data consists of resources that a decision-making unit needs to utilize in certain activities such as capital, labor, plants and equipment. Output data are the products of input that are converted after a certain production process, such as the product yield, quality and profits [2].

According to the characteristics of energy saving and environmental protection industry, the selection of input and output indicators are as follows.

1.1.1 Input indicators

Input indicators include total assets, operating costs and total shareholders' equity. Assets reflect the configuration and use of corporate resources, the growth rate of total assets reflects the growth rate of listed companies to some extent. Operating costs is a relative indicator with the prime operating revenue indicator, reflecting the number that must input in order to obtain the corresponding income, and it directly influences on the level of profitability. Shareholders' equity called net assets, on behalf of the shareholders' ownership of the business, reflecting the economic benefits enjoyed by the shareholders in corporate.

1.1.2 Output indicators

Output indicators include net profit, prime operating revenue, earnings per share and patents increase. Net profit reflects the overall profitability of listed companies, is the indispensable condition that the enterprises expand reproduction, reflecting the input-output efficiency of the enterprise and the level of enterprise management. Prime operating revenue can bring a better cash flow for the enterprises, ensuring the normal requirements of cash flow of enterprises, and is the foundation of survival and sustainable development for enterprises. Earnings per share reflect the size of the returns on investment for shareholders of listed companies, reflecting the profitability of listed companies. Patent number reflects the creativity and innovative capacity of a company. It is one of the innovative performances, and the selection of such indicator is consistent with the nature and requirements of energy saving and environmental protection enterprises. Here, patents include those that have already been approved, as well as a patent application that is still under consideration.

1.2 SELECTION OF THE DEA MODEL

According to the performance characteristics of energy saving and environmental protection of listed companies, the controllability of the output indicators is inferior compared to that of the input indicators. Selection follows the two considerations:

The first is to select the input or output model. If the input indicator is not to have a greater change or maintains a basic level, choosing the output-based model is more appropriate. Otherwise, if output indicators would not consist of more major changes as well as stricter limitations, the input model is more appropriate. In this paper, we choose the input-based computing model.

The second is to select the evaluation computing model. Several models in the DEA, the CCR model is built on the assumption of constant returns to scale for the overall validity of scale efficiency and technical efficiency; C2GS2 model reflects variable returns to scale, but it only evaluates the effectiveness of the techniques; BCC model takes returns to scale into consideration, reflecting the technical validity, the scale validity and the overall validity. So this study selects the BCC model as an analytical model [8].

The following model is the envelope form of the BCC model after introduction of slack (s^+) and surplus (s^-) variables [5].

$$\begin{cases} \min z_0 = \theta - \varepsilon(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+) \\ s.t.\theta x_{i0} = \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^-, i = 1,\mathrm{K}\ , m \\ y_{r0} = \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+, r = 1,\mathrm{K}\ , s \\ \sum_{j=1}^{n} \lambda_j = 1.s_i^-, s_r^+, \lambda_j \geq 0 \end{cases} \quad (1)$$

Z_0 is an arbitrary number, m is the number of input variables, s is the number of output variables, s_i^-, s_r^+ represents respectively the slack variable values of input variables and output variables.

When $\theta^* = 1$ and $s^{*+} = s^{*-} = 0$, the decision-making unit is a technical valid unit, otherwise the non-technical valid. There are three models of income in the BBC model.

$\theta^* = 1$, constant returns to scale;

$\theta^* < 1$ and $\sum_{j=1}^{n} \lambda_j / \theta^* > 1$, decreasing returns to scale;

$\theta^* > 1$ and $\sum_{j=1}^{n} \lambda_j / \theta^* < 1$, increasing returns to scale.

2 EMPIRICAL ANALYSIS

2.1 THE SAMPLE SELECTION AND DATA SOURCES

Follow the following principles in the selected samples.

(1) Excluding the ST*, ST and PT companies;

(2) For ease of comparison analysis and conclusions can be reference, the listed companies selected in the environmental plate are always within the four years (2007 -2010).

Table 1: The distribution table of company efficiency

stock code	Overall efficiency	Pure technical efficiency	Scale efficiency	Returns to scale
000551	0.981	0.988	0.992	Increasing
000544	0.994	0.999	0.995	Increasing
600309	1.000	1.000	1.000	Constant
000811	0.976	0.986	0.990	Increasing
600526	0.968	0.980	0.988	Increasing
600388	0.983	1.000	0.983	Decreasing
000404	1.000	1.000	1.000	Constant
000939	0.936	0.945	0.990	Increasing
600872	0.913	0.944	0.968	Increasing
600363	0.968	0.973	0.995	Decreasing
600133	0.931	0.993	0.938	Increasing
000903	0.901	0.914	0.985	Decreasing
002088	1.000	1.000	1.000	Constant
000685	0.985	1.000	0.985	Increasing
000900	1.000	1.000	1.000	Constant
000619	0.989	1.000	0.989	Decreasing
600649	1.000	1.000	1.000	Constant
600268	0.988	0.993	0.995	Increasing
600261	0.963	0.964	0.999	Decreasing
600846	0.961	0.980	0.981	Increasing
002092	0.922	0.928	0.994	Increasing
600165	0.961	0.971	0.990	Increasing
600855	0.980	0.989	0.991	Increasing
600378	1.000	1.000	1.000	Constant
600566	0.971	1.000	0.971	Increasing
600212	0.926	0.932	0.994	Increasing
600098	0.858	0.892	0.962	Decreasing
002111	1.000	1.000	1.000	Constant
600864	0.884	0.945	0.936	Increasing
000100	1.000	1.000	1.000	Constant
000027	0.879	1.000	0.879	Decreasing
600366	0.955	1.000	0.955	Decreasing
000813	0.999	1.000	0.999	Increasing
600586	0.911	0.930	0.980	Increasing
600481	0.946	0.949	0.997	Increasing
600303	0.964	0.965	1.000	Constant

According to the above principles, finally we select 36 listed companies as the objects of this study from Shanghai stock exchange and Shenzhen stock exchange (including Fujian Longking co., ltd, TCL Group and so on),that is the so-called Decision Making Unit (DMU) in the model. The sample data use averages for four consecutive years (2007-2010) as the input and output data of the model. As the BCC model requires non-negative data, the indicators

of input and output data cannot be guaranteed, so the data need to be normalization processed so that they meet the needs of the model.

2.2 THE HORIZONTAL ANALYSIS

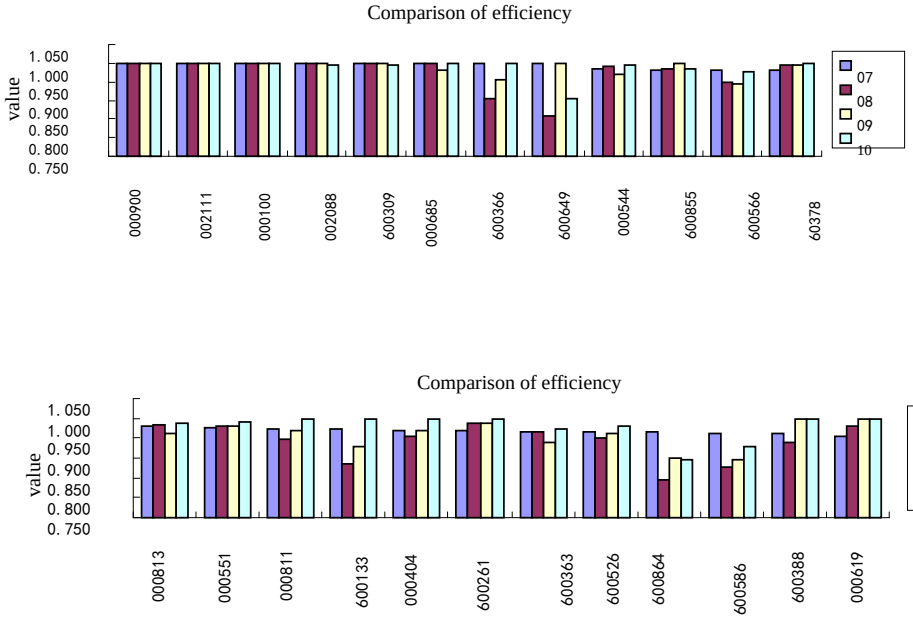
By comparing the data of four consecutive years (2007-2010) can reflect the state of development of the industry. The mean data dealt input the BCC model of the DEAP software, and the results of efficiency score are shown in Table 1.

Table 1 shows that the overall efficiency values of the samples are between 0.858 and 1, and the overall difference is not too large. It indicates that the efficiency of development of the overall industry is better. Yantai Wanhua co., ltd, Huayi compressor co., ltd, Luyang incorporated company, Xiandai investment co., ltd, Chengtou holding co., ltd,Sichuan Tianke co., ltd, Weihai Guangtai co., ltd and TCL Group eight companies' overall efficiency, pure technical efficiency and scale efficiency is 1.They are in the efficient frontier, showing that the resource utilization of these enterprises reaches to be optimal in terms of technology or scale.

Judging from the returns to scale, there are nineteen companies in increasing state, there are eight companies in decreasing state, and the scale efficiency of nine companies is 1.This shows that in the stage of increasing returns to scale companies account for 53%, more than half of the total number of DMU, and in the stage of decreasing returns to scale companies is the least. Most of the sample companies can be considered to expand the scale and enjoy the economies of scale.

2.3 THE VERTICAL ANALYSIS

The vertical analysis evaluates the development of the environmental protection of listed companies from the perspective of time, focusing on the company's continued ability to operate and grow. The analysis of the efficiency and ranking of companies can reflect the development situation of the companies and development trend of the industry during four years, and can reflect which company is stable, which company is more volatile. In order to more clearly analyze the comparison of each company each year, we make a chart about the overall efficiency, shown in Figure 1.



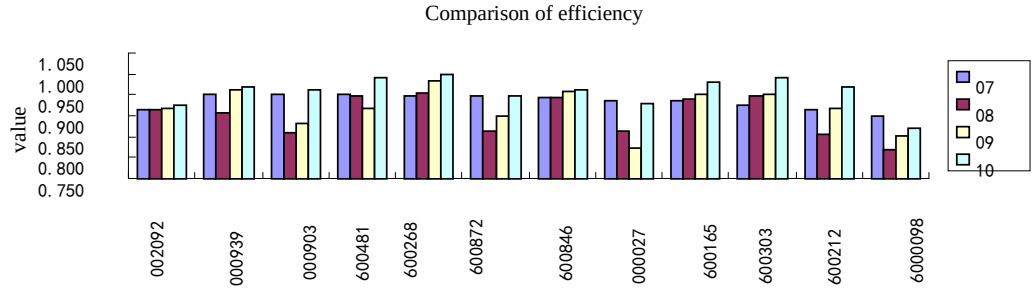


Figure 1 The comparison of efficiency of each company

Through the analysis and comparison of the data of each year from 2007 to 2010, we know:

(1) In comparison of 2008 and 2007, achieving the efficiency progress has twelve companies; seven companies' efficiencies do not change, while the rest regress. In comparison of 2009 and 2008, twenty-three companies attain the efficiency progress; five companies keep the efficiency, and the rest reduce. In comparison of 2010 and 2009, achieving the efficiency progress has twenty-six companies; four companies do not change, while the rest reduce. Seen from the contrast and analysis of the four consecutive years, the total number of companies that can maintain the existing high-efficiency and efficiency progress are more and more, the number of companies of efficiency decreasing is fewer and fewer. It indicates that the industry is in the process of development and the prospect is good, which consistent with the results of four horizontal mean data analysis.

(2) The four-year vertical results also demonstrate that the operating efficiency of the majority of companies is not stable. Comparison of the four-year efficiency, Xiandai investment co., ltd, Weihai Guangtai co., ltd and TCL Group are the most stable operational companies, the rankings of the three companies in four years reach to be optimal. The other thirty-three companies are not stable, Shanghai Chengtou holding co., ld and Wuhan east lake co., ltd are the least stable companies.

(3) From 2007 to 2010, there are 24 companies that the efficiencies of 2010 reach to be optimal, showing a more obvious growth trend.

CONCLUSION

The paper uses the DEA method to conduct an empirical analysis on the performance of the 36 energy saving and environmental protection of listed companies, the conclusions as follows:

(1) The overall performance of the industry is good and on the rise, the gap of efficiency in the industry is not big. The overall efficiency of each company is between 0.858 and 1, and the comprehensive efficiency score of the energy saving and environmental protection industry is 0.961, which is in the efficient frontier.

(2) The invalid reasons of DEA of the industry are complex. Some due to pure technical invalid, some due to an invalid size, and most companies are the two reasons. For pure technical invalid company you can see through the distribution of the slack variable, the main problems of cost control is not ideal and inputs of productivity is not high. From the perspective of scale efficiency, the gap between the numbers of companies in the different returns to scale stage is large, the largest percentage is in the increasing stage. This shows that most of the companies in the sample can be considered to expand the scale.

(3) The operating performance of most of the companies in the industry is not stable. Four-year vertical comparison shows that Xiandai investment co., ltd, Weihai guangtai co., ltd and TCL Group are the most stable operational companies, and the rankings of the three companies in four years have reached to be optimal. The three companies can be referenced by other companies. The companies should refer to the three companies to analyze the reasons of inefficiencies and operational instability and improve.

RECOMMENDATIONS

For the status of energy saving and environmental protection industry and the above conclusions, we put forward the following Suggestions.

(1) Relying on technological innovation, improving the R&D capabilities

The independent R&D capabilities of energy saving and environmental protection enterprises in recent years have

been significantly improved. Overall, the capacity of technological innovation and the development of scale are still incompatible, a number of key and core technologies still rely on imports. Lacking of technological innovation has become the bottleneck of the sustainable development of energy saving and environmental protection industry. Therefore, enterprises must place enhancing technological innovation capacity in a prominent and central location, and implement the innovative strategies. We should gradually establish and improve the independent innovation capability and mechanisms, continue to increase the investment in research and development and train innovative talent team, strengthen the infrastructure construction of innovation [3].

(2) Relying on the professional skills, low-cost operation

As the requirements and characteristics of the innovative technology of energy saving and environmental protection industry, it is difficult to control and reduce costs, and this is one of the defects of this industry. But if you consistently reduce the costs to ignore technological innovation and upgrading, it is not desirable, and cannot adapt to the tough competitive environment. So we should control costs with professional skills and adjust the strategy to achieve low-cost operation. We should adjust the product structure, improve the added value and technical content, adjust the industrial structure and improve the enterprise's value chain and industrial chain [6, 11].

(3)Strengthening management, enhancing the core competitiveness of enterprise

Management is the basis for achieving sustainable development, and establishing the way conforms to the characteristics of enterprise and highly efficient management is helpful to form the core competitiveness of the enterprise. Energy saving and environmental protection industry of China starts late, the time of development is short. However, foreign countries have had a mature and viable management system for energy saving and environmental protection industry, so we can learn from the excellent management model. We can create and implement quality, environmental and occupational health and safety integration management system, create energy saving and environmental protection enterprise cluster management model according to national circumstances, using the advantages of groups and geography forms strong and sustainable competitive strength [4].

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