Research on Resource Efficiency of Companies of Biomass Power Generation Based on Three-stage DEA

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ABSTRACT: From the perspective of resource efficiency of companies, this paper analyzed resource efficiency of companies of biomass power generation by selecting five companies of biomass power generation as sample and employing three-stage DEA method. The results showed that the allocative efficiency of the five companies had generally attained efficient from 2011 to 2013. However, it still remained insufficiency in the aspects of the use of existing technology, the development of new technology and scale efficiency, etc. In view of this, corresponding suggestions were proposed in the paper.
KEYWORD: Companies of Biomass Power Generation; Three-Stage DEA; Resource Efficiency

1 INTRODUCTION

The rapid development of economy and the energy security issues which become increasingly prominent provide a good opportunity for the development of biomass power industry. With the support from government and driven by the market, Chinese companies of biomass power generation have developed to a certain extent and the market demand is constantly growing. However, there still exists the problem of “more than one factories in a place” for the construction of biomass power generation and problems of resource utilization such as difficult access to resources, the rapid rise of resource price, which makes the profit margins of companies of biomass power generation shrink[1]. Faced with both opportunities and challenges, companies of biomass power generation must enhance the efficiency of resource utilization so as to achieve sustainable development. In view of this, from the perspective of the enterprise resource efficiency, this paper attempts to delve into the resource efficiency of companies of biomass power generation by employing method of three-stage DEA, in the hopes to provide suggestions for the companies to improve the resource utilization efficiency.

2 THE BASIC IDEA AND METHOD OF THE STUDY OF COMPANY’S RESOURCE EFFICIENCY

2.1 *The basic idea of the study of company’s resource efficiency*

Company’s resource efficiency is the ratio of outputs and inputs of resource in a given time, which can reflect effectiveness of resource utilization. In the resource ecosystem of the company, resource efficiency, which is considered as measure of the subjects ability of resource utilization and system functioning level, is consist of productive efficiency, allocative efficiency, etc[2]. In the method of DEA, efficiency is composed of allocative efficiency and scale efficiency, etc. Based on the classification of companies efficiency in the resource ecosystem of company, and proper adjustment according to DEA theory, this paper divides the resource efficiency into scale efficiency (SE), productive efficiency (PE) and allocative efficiency (AE).

2.2 *Introduction of three-stage DEA*

In general, evaluating methods of resource efficiency are mostly limited to single output and confuse decision-making unit (DMU) with non-decision-making unit. In contrast, DEA (Data Envelopment Analysis) has absolute advantages in dealing with the issue of multi-input and multi-output. It is a method of system analysis, which is developed on the basis of the concept of the relative efficiency [3]. However, the calculating results from DEA are less

stable, and haven't taken the efficiency deviation resulted from the external factors into account, especially environmental variables such as ownership, government regulations, etc [4-5].

In the basis of DEA, three-stage DEA excludes the environmental variables which affect efficiency. Therefore, it is convenient for companies to compare efficiency with that of other companies in the same industry under the same environmental context by using method of three-stage DEA. Manipulating process of DEA includes three steps. Firstly, assume that there are data on m inputs (i=1,…m) and s outputs (r=1,…,s) for each of N DMU (DMUj, j=1,…,N). For the i-th DMU, Xi and Yi respectively represent input and output; X is the input matrix of m×N, Y is the output matrix of s×N, indicating there are N DMU data. We code DMU to be evaluated with DMU0. Since this research was conducted under conditions of variable returns to scale, it is necessary to introduce BCC model. What's more, to avoid the the situation of infinite solutions coming up, this paper turns fractional programming into multivariate linear programming and introduces slack variables s^-, s^+ according to the principle of duality. Then, the form of equivalent envelope can be expressed as follows:

$$\left.\begin{aligned} &\min\theta \\ &s.t\sum_{j=1}^{N}\lambda_j X_j + s^- = \theta X_0 \\ &\sum_{j=1}^{N}\lambda_j = 1 \\ &\lambda_j \geq 0,\ j = 1,2,\cdots,N \\ &s^+ \geq 0,\ s^- \geq 0 \end{aligned}\right\} \tag{1}$$

Where θ represents integrated technical efficiency, X0 and Y0 respectively demonstrate the value of input and output in the j0-th DMU, λj denotes the weight of a linear combination of several DMU, s^- and s^+ separately indicate input redundancy and output insufficient.

Secondly, for the deviation may rise when selecting samples and data are continuous variables which have to meet the restricted condition, we introduce Tobit regression equation to deal with the cross-section data. Tobit regression model can determine factors affecting efficiency, which thus tackle with situation when values of the independent variables are cut off [6]. In order to make all the DMU in the same environmental level, the variable value of each DMU is thus adjusted. And the adjusted formula is as follows:

$$y^* = y - \sum_{i=1}^{N}\beta_i \times \left(x_i - x_{i\min}\right) \tag{2}$$

Where y* is the adjusted variable value, y represents the original value of variable, N means the number of environment variable significantly affect efficiency, β is regression coefficient, x is defined as environment variable which have significant impact on efficiency, x min is the worst environment levels[7].

Thirdly, as independent variable, y* is calculated by being re-substituted into the BCC model. Then the data obtained from the calculation will be collected for the analysis.

3 EMPIRICAL ANALYSIS

3.1 *The selection of samples and indicators*

After the aspects of the biomass power industry starting late and problems of information disclosure, this paper finally selected five listed companies of biomass power generation as samples, that are China Huaneng Group, China Datang Corporation, China Huadian Corporation, China Guodian Corporation and China Power Investment Corporation. For the convenient of calculation, these five companies are treated as decision making units, respectively called as Huaneng, Datang, Huadian, Guodian and China Power Investment, and separately coded by 1, 2,3,4 and 5. The related data in this paper are mainly collected from their annual reports of 2011, 2012 and 2013.

Indicators in this paper can be divided into three categories: input indicators, output indicators and environmental variables. Among them, input indicators consist of inventory consumption, business investment and wage payable of employee, respectively coded by I1, I2 and I3. Output indicators incorporate indicators of the main business income and other operating income, separately coded by O1 and O2. Government grants and the projects under construction are selected as indicators of environmental variable, coded by X1 and X2.

3.2 *Test and analysis of operating results of three - stage DEA*

In the first stage, the software of DEAP Version 2.1 is used to calculate results of DEA model based on input-oriented and variable returns to scale (RTS), and account the value of the resource efficiency of biomass power generation companies each year and it's rank (the rank is expressed as R, which has taken the productive efficiency, allocative efficiency and scale efficiency into consideration).

In the second stage, software of Eviews6.0 is used to do regression of input and output variable, as shown in Table 1.

Table 1. Tobit regression results of five companies of biomass power generation from year 2011 to 2013

V	Coefficient	STD. Error	Z-Statistic	PROB.
O1	0.007	0.002	2.686	0.007
O2	0.097	0.052	1.849	0.034
I1	0.012	0.036	0.353	0.024
I2	0.427	0.050	8.475	0.000
I3	0.071	0.045	1.582	0.013
X1	0.053	0.017	3.095	0.002
X2	-0.002	0.006	-0.338	0.035

It is shown from the results that the government subsidies and the project under construction have significant impacts on the input or output at the significance level of 0.05. Specifically, government subsidies and the variables of input or output are positively correlated; yet the project under construction and variables of input or output are negatively related. But the results also show that negative correlation coefficient between the project under construction and input or output is small, indicating the project under construction has little effect on inputs or outputs. As a result, companies of biomass power generation are probably able to eliminate the negative impact on inputs or outputs, as long as the project under construction is properly controlled. From table 1, we also know that the paid-up capital of inputs has little effect on outputs. Even though the result doesn't coincide with the status that Chinese companies of biomass power generation need a lot money, paid-in capital in the financial statements that belongs to equity assets have no relation with main income or other income. Therefore, the regression results fit with GAAP.

In the third stage, the variable values calculated through the fixed formula are substituted into the mode of DEA again. The results are shown in table2.

In terms of scale efficiency, the Huaneng, Huadian and Guodian reached effective scale in 2011, while Datang and China Power Investment were still in the stage of scale increase, that means the two companies can improve productivity by increasing scale. In 2012, Huaneng, Datang and Guodian maintained a constant state of scale, while Huadian was in the stage of decreasing scale. Thus, Huadian shouldn't expand the scale, otherwise it would reduce productive returns. In contast, China Power Investment needed to continue to expand business scale and benefit in the case of the limitation of technical level. By 2013, all the enterprises except Guodian attained the effective scale. Although Guodian was in a state of decreasing scale, it's ability of increasing output at given input and technological progress was strong after removing scale efficiency.

Table 2. Values of resource efficiency and rankings of five companies of biomass power generation from year 2011 to 2013 after adjusted

DMU	year	PE	AE	SE	RTS	R
1	2011	0.983	1.000	1.000	—	3
2	2011	1.024	1.000	0.872	irs	5
3	2011	0.984	1.000	1.000	—	2
4	2011	1.040	1.000	1.000	—	1
5	2011	1.098	1.000	0.836	irs	4
1	2012	0.983	1.000	1.000	—	4
2	2012	1.024	1.000	1.000	—	3
3	2012	0.984	1.000	0.854	drs	5
4	2012	1.040	1.000	1.000	—	2
5	2012	1.098	1.000	0.993	irs	1
1	2013	0.983	1.000	1.000	—	4
2	2013	1.024	1.000	1.000	—	2
3	2013	0.984	1.000	1.000	—	3
4	2013	1.040	1.000	0.938	drs	5
5	2013	1.098	1.000	1.000	—	1

In terms of productive efficiency and allocative efficiency, the productive efficiency of China Power Investment, Guodian and Datang have been the top three for the three years, indicating that the three companies have made prominent achievements in using existing technology or technological improvement. But these companies has no change in allocative efficiency, which demonstrats that the arrangements for division of input components, products prices and capacity of production technology under the guidance of the government is reasonable.

In terms of changes in ranking, Huaneng and Guodian are in a decline trend. Huaneng declined marginally, dropping from the third to the fourth. While the ranking of Guodian is in a fast and unsteady trend of decline, droping from the first to the fifth. Rankings of Datang and China Power Investment have risen with an extent from big to small. Ranking change of Huadian is U-shaped with a relatively large and unstable extent.

4 CONCUSIONS AND SUGGESTIONS

In this paper, method of three-stage DEA is employed to eliminate the impact on the resource efficiency from environment variable, through which the actual resource efficiency of companies of biomass power generation is obtained. Tobit regression analysis shows that government grants positively affect the resource efficiency of biomass power generation companies. The project under construction has little but negative effects on the resource efficiency of these companies. The results

from the three-stage DEA demonstrate that allocative efficiency of companies of biomass power generation has generally attained effective. Productive efficiency of Datang, Guodian and China Power Investment is relatively high; however Huaneng and Huadian need to strengthen efforts of using existing research & technology and developing new technology. Except Huaneng, there is still large improvement room for companies of biomass power generation in scale efficiency.

Combing the empirical results with characteristics of biomass power generation companies, this paper proposes several suggestions concerning the enhancement of resource efficiency of these companies. Firstly, companies of biomass power generation should reasonably control their development scale. On one hand, it is determined by principle of diminishing returns to scale, which demonstrate that bigger size of the company is not equal to better performance. On the other hand, Instead of simply expanding business scale according to the market demand, companies should also take the status such as raw material dispersion and a limited geographical scope into consideration when make decisions on the scale of biomass power generation companies.

Secondly, companies should continue to increase the investment of scientific research & application in the field of biomass power generation. In the first place, foreign advanced technology and equipment should be introduced to make up technological backwardness of biomass power generation business. Then, companies are encouraged to implement policy of the combination of producing, studying and researching, and promote cooperation of research institutes, universities and biomass power plants.

Thirdly, the utilization efficiency of government grants should be enhanced and the proportion of investment in the project under construction business in the current period be adjusted. For one thing, companies ought to make reasonable arrangements in the government subsidies and improve the utilization of government grants by strengthening the management of production and distribution of raw materials and streamlining channels of production. For another thing, the supervision on business investment in the project under construction should be strengthened so as to eliminate its negative impact on resource efficiency.

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