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Analysis of operation efficiency of biomass energy companies in China by DEA model

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ABSTRACT

Biomass is an important source of green energy, but the operation of biomass energy companies is facing barriers in terms of technologies, profit model and many others. To further analyze and evaluate the biomass business performance in recent years, this paper classifies the 16 publically listed biomass energy companies according to production processes to sets up DEA model (BBC model) based on a variable scale, and finds out that in the period of 2008 - 2012, the technology efficiency of the sample companies improves steadily, reaching basically an effective DEA, but due to the fluctuation in scale efficiency, there occurs a widespread ineffective overall efficiency. In light of this, it is believed that there is the presence of scale redundancy with China's biomass energy enterprises and that there is a need of appropriately reducing investment and improving productivity in order to improve business performance and to have firm footing in the market.

KEYWORDS

DEA; BCC; Biomass energy enterprises; Operation efficiency.

INTRODUCTION

In recent years, the production and operation of various types of biomass sources (such as in-depth corn processing), biomass fuels (such as gasoline and ethanol), biomass energy equipment business and biomass power generation companies have gradually developed, but they are still facing a lot of obstacles. Firstly, China does not have sufficient technology and equipment for independent research the development and utilization of biomass energy depends much on imports, resulting in a high cost of biomass energy products. The low-scale development and high risk existing in biomass energy industry, also to a large extent, affects the motivation of enterprises to enter the industry. Thus the number of biomass energy related businesses remain small[3]; Furthermore, as biomass energy industry is not only a labor-intensive industry, but also a capital-intensive one, it is characterized by large-scale investment and long capital payback period and enjoys little price advantage[4], lacking a strong competitive edge compared to traditional energy companies. Therefore, China has enacted various policies and regulations to encourage and support the development of biomass energy enterprises.

Obstacles mentioned above about technology, profit model and other aspects in biomass energy industry are affecting the biomass business performance. Bian Guanghui (2012) found in the research that the cost of biomass power generation enterprises is 50% higher than the cost of thermal power. That is more than 0.8 yuan per kilowatt-hour, with annual profit of 500 million. The need to purchase a range of equipment and fuel, establish collection stations, and the increase of collection area brought biomass power plants widespread losses[5]. Chen Lihui (2011) conducted a detailed cost-benefit study on Changtu Biomass Power Ltd. in 2010 and found that the company suffered from over-expenditures. Its annual loss exceeding ten million, the sales price to power network should reach 0.87 yuan in order to maintain operation by breakeven calculation, much higher than the price at which government currently provides electricity[6]. Seen in this light, the operational efficiency of biomass energy industry is still in a difficult period and the industry needs internal support from the government.

Development of biomass energy has great social significance. Operating biomass energy companies are facing tough challenges, but there are far from enough quantitative research on biomass energy business performance. Therefore, this study will classify bio-energy companies, analyze their operation efficiency with DEA model and finally evaluate their current situation.

DATA ENVELOPMENT ANALYSIS METHOD

Data Envelopment Analysis, referred to as the DEA, is new system analysis method developed in 1978 by the famous operational researchers, A. Charnes, W. W. Cooper and other scholars based on their "Relative Efficiency Evaluation" concept. DEA is a statistical non-parametric estimation method[7], DEA is a statistical non parametric estimation method, using the mathematical programming models (including linear programming, multi-objective programming, with cone structure optimization, generalized semi-infinite programming, stochastic programming etc.) to analyze the evaluation of relative effectiveness of targets, especially suitable for multi input and multi output case.[8]

DEA method contains a variety of models, among which CCR model and BCC model are the two most commonly used ones, with the former takes premise of constant scale returns while the latter proposes a variable scale, taking into account that Technology Efficiency in BCC model can be further broken down into Pure Technology Efficiency and Scale Efficiency, to help determine the specific stage of a given company is in scale efficiency change. Thus in this study, BCC model[9] is chosen. BBC model is divided into two kinds, output-oriented and input-oriented, in which the input-oriented to optimize the number of input to a minimum with output unchanged while the output-oriented to optimize the output to a maximum when the input remain unchanged. For biomass energy companies input factors can be adjusted while output is not easy to be controlled, so for this study input-oriented BBC model is chosen.

For any economic activity, a series of process is required from "input" to "output" in order to achieve maximum efficiency, thus such unit or department can be called the Decision Making Unit (DMU). The analysis targets of this study are the 16 listed biomass energy companies and they can be seen as 16 same DMU, which share same mission, same goal, in a similar environment and with same input and output. Input indicators and output indicators for each enterprise may constitute respective input matrix X and output matrix Y, as well as their respective weight vectors u and v, after deduction the following linear programming can be obtained[10].

$$\min[\theta - \varepsilon(\hat{e}^T s^- + e^T s^+ 0]$$

$$\begin{aligned} & Y\lambda - s^+ = y_0 \\ & X\lambda + s^- = \theta x_0 \\ s.t., \ & I^T \lambda = 1 \\ & \lambda \geq 0 \\ & s^+ \geq 0, s^- \geq 0 \end{aligned}$$

At this point an optimal solution can be obtained of $\lambda^*, s_n^{-*}, s_m^{+*}, \theta^*$,if $\theta^*=1$ and when $s_n^{-*}=s_m^{+*}=0$ t, DMU is effective, namely technology and scale are both effective; if, $\theta^*=1$ when $s_n^{-*}\neq 0, s_m^{+*}\neq 0$, DMU is weakly efficient, namely technology is effective but scale efficiency is less than 1; and if θ^*<1 when $s_n^{-*}\neq 0, s_m^{+*}\neq 0$, DMU is ineffective, namely both technology and scale are ineffective, then by comparing the value of $\frac{\lambda^*}{\theta^*}$ with 1, determination continue to be done of the stage (returns scale increasing, constant or decreasing) of the scale of a production decision unit.

DATA COLLECTION

Drawing on the previous research using DEA method on operation efficiency of all types of business, with reference to three areas include the Book Value of Fixed Assets, Number of Employees, Main Business Costs, this paper selects Business Investment Scale, Scale of Production and Production Costs as input indicators to reflect the overall situation of investment by the publically listed biomass energy companies in a certain period (where the book value of fixed assets = Original Book Value of Fixed Assets - Accumulated Depreciation - Impairment of Fixed Assets); from the other three aspects of recurrent and major business, Changes in Owners' Equity, Corporate Overall Profit Revenue, this paper takes Business Income, Basic Earnings Per Share, Total Profits and Taxes as output indicators (where Total Profit = Gross Profit + Business Taxes and Surcharges), in order to reflect their overall production status in a given period of time.

Taking into account the integrity and availability of the data, this paper chooses 16 publicly listed companies before 2008 as the analysis target. Specific data on collected input and output indicators are collected from the Annual Reports (source: http://www.cninfo.com.cn) in a five-year period in 2008-2012 and the efficiency of their business operations is analyzed and evaluated by applying the BBC model of DEA method.

RESULT AND DISSCUSS

Overall analysis

Due to limitations in DEA method, normalization of the data is done before setting up the model, through which all the data are transformed into a non-negative value between 0 and 1, by using the following specific formula:

$$x_{ij}^* = \frac{x_{ij} - MIN(x_j)}{MAX(x_j) - MIN(x_j)} \quad i=1,2,...,5 \quad j=1,2,...,16$$

DEAP software is used to conduct an overall analysis on the five-year data of 16 biomass energy companies, the following results are obtained.

TABLE 1 : Average operation efficiency of the 16 companies with data in 2008-2012

	Overall Efficiency	Technology Efficiency	Scale Efficiency	# of Companies with Increasing Scale Returns	# of Companies with Decreasing Scale Returns
2008	0.751	0.889	0.854	8	8
2009	0.760	0.930	0.820	3	7
2010	0.829	0.944	0.876	2	7
2011	0.675	0.920	0.740	1	9
2012	0.815	0.977	0.836	1	10

Overall speaking, the operating efficiency of China's publically listed biomass companies is not ideal with a more common technology ineffectiveness and scale ineffectiveness, in that less than one-third of the enterprises reach an effective DEA. In 2012, the average overall efficiency of the 16 companies is 0.851, the average technology efficiency is 0.977 and the scale efficiency is 0.836. Technology efficiency has a more substantial upgrade in the 5 years, while the fluctuation in scale efficiency causes fluctuations with the overall efficiency and there is not a significant improvement seen. From 2008 to 2012, the number of enterprises at the stage of increasing returns decreases from 8 to 1 while the number of enterprises with decreasing returns increase from 8 to 10, it hasn’t reach a maximization of efficiency with the use of various types of inputs for production, there is a presence of waste and redundancy, a low output efficiency of investment, resulting in the overall operation ineffectiveness. Since there is not a proper match between technical management level and production scale, in

order to avoid excessive impact on production and efficiency by reducing direct investment, possibilities exist with matching the overly-expanded scale by improving equipment performance and the efficiency of human capital and funds.

Categorized analysis

Considering that there is not a clear difference between the results of the analysis on the 16 companies at a same time, taking into account the fact that the DEA efficiency is a "relative efficiency", a categorization into 4 types of biomass energy enterprises is made, as detailed in TABLES based on the position of the enterprises in the industry chain as well as their main business, including Upstream Raw Material Production/Collection (including corn deep-processing, etc.), Biomass Fuel Production (including methanol gasoline and ethanol gasoline, etc.), Biomass Energy Equipment Manufacturing, and Biomass Power Generation, in order to enhance the comparability between enterprises. According to the new classification, again for all types of biomass energy enterprises DEA analysis, shown in TABLE 2.

TABLE 2 : Operation efficiency of the 4 types of biomass energy enterprises in 2008-2012

		Upstream Raw Material Production/Collection	Biomass Fuel Production	Biomass Energy Equipment Manufacturing	Biomass Power Generation,
Overall Efficiency	2008	0.7103	0.6446	0.8650	0.8380
	2009	0.7198	0.6814	0.7560	0.8187
	2010	0.8883	0.7454	0.7670	0.8898
	2011	0.7328	0.6101	0.6320	0.7285
	2012	0.8568	0.8314	0.7560	0.7718
Technology Efficiency	2008	0.8375	0.8010	1.0000	0.9693
	2009	0.8840	0.8839	0.9530	0.9682
	2010	1.0000	0.9055	1.0000	0.9773
	2011	1.0000	0.8613	1.0000	0.9723
	2012	0.9900	0.9623	1.0000	0.9967
Scale Efficiency	2008	0.8723	0.8382	0.8650	0.8559
	2009	0.8178	0.7860	0.7933	0.8386
	2010	0.8883	0.8263	0.7670	0.9066
	2011	0.7328	0.7324	0.6320	0.7403
	2012	0.8646	0.8689	0.7560	0.7743

Overall efficiency

The overall efficiency of the 4 types of biomass energy companies in the five-year period is generally in fluctuating form but in a state of having an in effective DEA. In 2008, the overall efficiency of the upstream enterprises in raw material production/collection and biomass fuel production is significantly lower than that of the enterprises in biomass energy equipment manufacturing and biomass power generation and is below 0.75, but gradually increases afterwards till an overtake in 2012. The main reason is that the technology efficiency of the former has been improved significantly in the five years while the scale efficiency of the latter decreases significantly. At the same time it is clear that the year of 2011 is the bottom of all biomass energy sectors and there is a rebounding phenomenon in 2012.

Technology efficiency

The technology efficiency of the four categories of biomass energy companies enjoys varying degrees of increase in the 5-year period of 2008-2012, among which the technology efficiency of the enterprises in biomass energy equipment manufacturing and biomass power generation has remained at a high state and reached an effective DEA until 2012, while the upstream enterprises in raw material production/collection and biomass fuel production is at a lower stage in 2008, has a significant steady increase afterward and reaches an effective DEA till 2012. This means that biomass energy enterprises has reached the best condition with their current level of technology through introducing foreign advanced technologies and equipment and conducting a certain level of independent research and development.

Scale efficiency

The Scale efficiency of four types of biomass energy enterprises is ineffective and has different degrees of “W-type” fluctuations in the five-year period. In 2008, the scale efficiency is found during the investigation quite even among all of the enterprises in each category and the scale efficiency of the enterprises in biomass energy equipment manufacturing and biomass power generation significantly decreased, and till 2012, nearly 50% of the upstream enterprises in raw material

production/collection and biomass fuel production as well as all enterprises in biomass energy equipment manufacturing and biomass power generation are in a state of diminishing scale returns. This means that there exists the phenomenon of a widespread scale redundancy with biomass energy enterprise, even more serious with biomass energy equipment manufacturing enterprises. This is mainly because the upstream companies in raw material production/collection and biomass fuel production are relatively small scale with the advantages of flexible to make adjustments, easy to update equipment and change production plans, while the enterprises in biomass energy equipment manufacturing and biomass power generation have large number of huge equipment, which has a longer update cycle, higher costs to update, thus it is difficult to adjust their production scale in a short time.

CONCLUSIONS

Despite the fact of continuously introducing foreign advanced technologies and equipment as well as actively conducting independent research and development, the operation performance of biomass energy companies in China is largely inefficient due to scale redundancy and the entire sector is at the stage of descending from scale efficiency increase to scale efficiency decrease. In the period 2008-2012, the technology efficiency of the four types of biomass energy companies was almost enhanced till the level of being effective, but the scale efficiency was in fluctuations, especially overall scale efficiency was obviously reduced of the enterprises in biomass energy equipment manufacturing and biomass power generation. This led directly to China's overall efficiency of biomass energy business not being ideal, although there was significant improvement in the overall efficiency of the enterprises in upstream raw material production/collection and biomass fuel production.

Given the development of biomass energy companies in China is still not mature enough and requires longer payback period and the market is facing great challenges, enterprises should be take appropriate measures to reduce inputs, adjust the scale, especially with the biomass energy companies depending on introducing foreign technologies and equipment, leading to higher costs, it is believed that the biomass energy companies strengthen internal control, reduce energy consumption by use of advanced equipment and to improve efficiency in use of raw materials in order to improve operation efficiency and increase returns.

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