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Comparative Research on Performance of Feed Companies in China---Based on an OR-DEAE Matrix

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Abstract

Feed manufacturing play a key role in agriculture development and economic growth. The present paper elucidates an operating revenue-DEA efficiency (OR-DEAE) matrix to evaluate both big and strong aspects of feed enterprises in China based on the evaluation measure of Fortune Global 500 and a Data Envelopment Analysis (DEA) method, i.e., super-efficiency CCR model, in order to achieve a healthy and sustainable development in feed manufacturing. Results show that there is a big difference between the performances of feed companies in China. Most of the feed companies are in the question mark quadrant or dog quadrant of the OR-DEAE matrix, showing that their operation levels are relatively low. Only two benchmarking companies were in the star quadrant which reflects they have both big and strong capability. We therefore provide several suggestions for the backward companies to improve their performance.

Keywords: feed companies, China, big and strong, capability, evaluation

1. Introduction

Feed manufacturing which refers to animal feeds is an important part of agriculture. It also contributes to the global food industry by providing production of animal proteins, and then improve the economy and the nutritional wellbeing of people. According to Alltech's annual survey (2017), the global feed production surpasses 1 billion metric tons for first time, and a 3.7% increase in production over 2015. Currently, there are more than 30 thousand feed mills in 141 countries, though with a 7% reduction over 2015. Moreover, Asia still leads the regions around the world, and it is responsible for 36% of the world's total feed production. Among them, China is the world's largest feed producer, with 187 million metric tons of feed production in 2016.

China as a great country in agriculture, ranks first in agricultural population in the world, with 600 million people living in rural areas (China Statistics, 2016). Feed manufacturing which is the highest industrialized industry in China's agriculture, has a close relationship with other industries such as medicine, chemicals and machinery etc. It plays a critical role in China's agricultural development and quality of people's lives. There are more than 7000 feed companies in China. Furthermore, the feed of listed companies, as the industry leaders are important parts of agriculture in China. They are one of the excellent enterprises which represent China's advanced agricultural productivity at the present stage. Based on this, it is important to evaluate their performance to ensure sustainable development.

In the business world, performance management plays an important role in the development of general enterprises (decision making units, DMUs). It includes activities of evaluating both "big and strong" aspects of enterprises in order to ensure that development objectives of the enterprises are consistently being met effectively and efficiently. However, most of current evaluation methods only focus on the "big" aspect of companies. For example, Fortune Global 500 is an annual list published by Fortune magazine that ranks the top 500 publicly and privately held companies in the business world, by using companies' annual revenues. Due to the hugely influential role that these companies play in the world, their management styles and development patterns set up a performance for other companies and offer important insights into the future of commerce, and are drawn the attention for practitioners and researchers. The evaluation method used by Fortune magazine, in fact, can be considered as one of methods for measuring "big" aspect of a company effectively. However, it needs to point out although operating revenue is simple, practical and useful, but it does not reflect operational efficiency, i.e., “strong” aspect, of the company. It is strongly recommended that, enterprises need to be a balance between “big” and “strong”, which refer to the operating revenue and operational efficiency of enterprises respectively, in order to achieve a healthy and sustainable development.

Therefore, the present study constructs an operating revenue-DEA efficiency (OR-DEAE) matrix to evaluate both “big” and “strong” aspects of feed companies in china simultaneously, by using the evaluation method of Fortune Global 500 and the data envelopment analysis (DEA) method. Several basic development paths for the relevant backward feed companies to increase their performance are provided. To the best of our knowledge, there is hardly any publication in the literature that evaluated the performance of the feed industry by using the OR-DEAE matrix to deal with the “big” and “strong” aspects of the feed companies simultaneously.

2. Materials and Methods

2.1 Operating Revenue and Fortune Global 500

Operating revenue consists of primary business revenue and other amounts derived from its primary operations of a company. Usually, it is obtained from selling products or providing services of the company, and can reflect the company’s market share in the industry. In academic literature, operating revenue is also used to express operational results of a company. For examples, operating revenue for measuring effectiveness of service organizations (Gronroos & Ojasalo, 2004), and operating revenue (i.e., operating income which equals net-interest income plus non-interest income in the bank industry) for measuring effectiveness of Indian public sector banks for the financial year 2006/2007 (Kumar & Gulati, 2010).

Operating revenue can also reflect the business scale and is important for a business to remain viable in the business world. In the United States, the Federal Small Business Administration (2012) set a “Table of Small Business Size Standards”, which varies by industry and usually depends on how much operating revenue–not profit the company has or how many employees it has. If a company is in the upper reaches of the size criteria for a certain industry, it is belonged to large and medium-size. In the European Union, mid-size companies are those operating revenue of less than 50 million euros and 50 to 250 employees. In mainland China, operating revenue, or employment, or total asset, is used to classify the business size of the company in various industries (Chinese Ministry of Industry and Information Technology, et al., 2011).

In general, over a small company, a large company in an industry has certain inherent advantages, such as economics of scale that shows the effect of an increased output (e.g., operating revenue) level on unit costs. Stronger product brand recognition: better brand recognition brings more operating revenue and profit; great human resources: the company can arrange its employees to accomplish more work; the company can buy raw materials and produce products in higher quantities at lower unit costs, etc. A large company has such competitive advantages and can become the leader of the related industry.

Since 1995, the annual list of Fortune Global 500 has had its current form, listing the companies in the business world by operating revenue. This ranking is considered to be a piece of information on the productive situation of the companies and a barometer of the economic strength of the country. In 2013, the largest 3 companies are Royal Dutch Shell, Wal-Mart Stores and Exxon Mobil, and their revenue is 481,700, 469,162 and 449,886 million US dollars, respectively. Sinopec Group taking the fourth spot for the first time, its revenue is 428,167 million US dollars. Chinese mainland companies fill 89 places on the Fortune Global 500 list for 2013, increasing 16 companies more than 2012.

2.2 Super-Efficiency (SupPE) CCR Model

Traditionally, efficiency can be regarded as the output to input ratio and focuses on getting the maximum output with minimum resources of an organization (e.g., enterprise, i.e., DMU). It is well known that based on Farrell’s (1957) original work, DEA is a non-parametric approach to efficiency measurement of DMUs with multiple inputs and multiple outputs using a linear programming technique, by Charnes et al. (1978). Returns-to-scale (RTS) reflex the relation between input and output quantities and consider efficiency. Banker et al. (1984) extended the CCR model of constant returns-to-scale (CRS) to the BCC model of variable returns-to-scale (VRS) in its production possibility set (*P*). As results more than 5000 theoretical studies as well as applications in the real world are reported in the literature, such as Cooper et al. (1999), and Emrouznejad et al. (2008, 2010).

DEA CCR model (Charnes, et al., 1978) was a standard efficiency analysis method concerning the ratio of multi-outputs to multi-inputs of using scarce resources to produce valuable DMU’s items subjected to the condition that the similar ratios for all other DMUs be less than or equal to one. The model does not require a priori weights on inputs and outputs.

Suppose there is a set of N DMUs. Each DMUn (n =1, ..., N) produces J different outputs y^n_j (j =1, ..., J) utilizing I different inputs x^n_i (i =1, ..., I); (x^n, y^n) is a positive known input-output vector for the DMUn. There is the fractional programming model (Charnes, et al., 1978; Cooper et al., 1999):

$$FE_t = \max \frac{\sum_{j=1}^{J} u_j y_j^t}{\sum_{i=1}^{I} v_i x_i^t}$$

$$\begin{aligned} s.t. \quad & \frac{\sum_{j=1}^{J} u_j y_j^n}{\sum_{i=1}^{I} v_i x_i^n} \le 1, \quad n = 1,\cdots,N; \\ & v_i, u_j \ge \varepsilon > 0; \quad i = 1,\cdots,I; j = 1,\cdots,J, \end{aligned} \tag{1}$$

where ε is a non-Archimedean infinitesimal; and (v, u) is the variable input-output weight vector; The DMUt (t =1,…, N) is measured for the optimal objective value FE_t with the optimal solution (v^*, u^*) in (1).

It can be proved that the model (1) is equivalent to the linear programming model, i.e., the input-oriented CCR model (2) which assumes the existence of CRS (CRS means that if any input-output vector $(x, y) \in P$, then $(kx, ky) \in P$, where any k >0, and P is the production possibility set, e.g. the set of input-output vectors). The maximum, PE_t (=FE_t) of the objective function given by the CCR model (2) is called relative productive efficiency (PE, or technical efficiency) of DMUt. We have PE ≤ 1.

$$PE_t = \max \sum_{j=1}^{J} u_j y_j^t$$

$$\begin{aligned} s.t. \quad & \sum_{j=1}^{J} u_j y_j^n - \sum_{i=1}^{I} v_i x_i^n \le 0, \quad n = 1,\cdots,N; \\ & \sum_{i=1}^{I} v_i x_i^t = 1, \\ & v_i, u_j \ge \varepsilon > 0; \quad i = 1,\cdots,I; j = 1,\cdots,J. \end{aligned} \tag{2}$$

PE can be decomposed as the product of pure technical efficiency (PTE) and scale efficiency (SE): PE =PTE×SE. See Banker et al. (1984) who extend the CCR model (2) to input-oriented BCC model for obtaining PTE score by assuming the existence of VRS. PE score expresses the global operational efficiency of a DMU, since it takes no count of scale effect, but PTE score expresses the local pure technical efficiency of the DMU under VRS conditions. Input-oriented SE, which is obtained by PE/PTE, expresses the efficiency of operating in productive scale size of the DMU. We have that PE =1 ⇔ PTE=1 and SE=1. Generally, if the efficiency score is equal to value one then the DMU is called efficient relatively, however if the value is less than one then the DMU is called inefficient relatively.

The dual model (3) of the input-oriented CCR model (2) can be written as:

$$PE_t = \min \left\{ \theta - \varepsilon \sum_{i=1}^{I} s_i^- - \varepsilon \sum_{j=1}^{J} s_j^+ \right\}$$

$$\begin{aligned} s.t. \quad & \sum_{n=1}^{N} \lambda_n x_i^n - \theta x_i^t + s_i^- = 0, \quad i = 1,\cdots,I; \\ & \sum_{n=1}^{N} \lambda_n y_j^n - s_j^+ = y_j^t, \quad j = 1,\cdots,J; \\ & \theta, \lambda_n, s_i^-, s_j^+ \ge 0; n = 1,\cdots,t,\cdots,N; i = 1,\cdots,I; j = 1,\cdots,J, \end{aligned} \tag{3}$$

where the optimal objective values of (2) and (3) are equal and the optimal solutions are corresponding to. The dual of BCC model for obtaining PTE can be obtained through the addition of a convexity constraint to the dual of CCR model (3).

In the model (3), if an optimal solution (θ^*, λ^*, s^{*-}, s^{*+}) of .3) satisfies θ^*=1, and all slack vectors have that s^{*-}= s^{*+}=0, then DMUt is CCR-efficient. Otherwise, the DMUt is CCR-inefficient which the efficiency of input-output vector (x^t, y^t) for DMUt can be improved as CCR-efficient of (X^t, Y^t) through the DMUt's benchmarks, i.e., reference sets (Charnes, et al. 1978; Cooper, et al. 1999), i.e., a formula called the input-oriented CCR projection:

$$X_i^t = \theta^* x_i^t - s_i^{*-} \le x_i^t, (i = 1, \cdots I); \qquad Y_j^t = y_j^t + s_j^{*+} \ge y_j^t, (j = 1, \cdots, J). \tag{4}$$

The formula (4) shows that the input-oriented CCR model (2) or its dual (3) whose objective is to minimize inputs while producing at least the given output levels.

The ranking procedure of PE measures does not yield relative rankings for those DMUs with 100% efficiency. By deleting the inequality constraint where n =t in CCR model (2), Andersen and Petersen (1993) further suggested a model for re-ranking the efficient DMUs, which can be expressed as the following input-oriented SupPE CCR model (5):

$$SupPE_t = \max \sum_{j=1}^{J} u_j y_j^t$$

$$\begin{aligned} s.t. \quad & \sum_{j=1}^{J} u_j y_j^n - \sum_{i=1}^{I} v_i x_i^n \le 0, n = 1, \cdots, t-1, t+1, \cdots, N; \\ & \sum_{i=1}^{I} v_i x_i^t = 1, \\ & v_i, u_j \ge \varepsilon > 0; i = 1, \cdots, I; j = 1, \cdots, J. \end{aligned} \tag{5}$$

The optimal objective value, SupPEt, of (5) is the CCR model's super productive efficiency of DMUt. SupPEt will either equal or greater than 1 in which case DMUt is CCR-efficient or will be less than 1 (the score is the same as the value obtained in (2) or its dual) in which case DMUt is CCR-inefficient. Further studies on the SupPE DEA models with applications can be found, for examples, Zhu (2001), Zhu et al. (2004), Banker and Chang (2006), and Cook et al. (2009).

Based on the previous scholars' work, this paper uses operating revenue and input-oriented SupPE CCR model, respectively, to constructs an OR-DEAE matrix in order to evaluate the big and strong aspects of general enterprises simultaneously.

2.3 Operating Revenue-DEA Efficiency (OR-DEAE) Matrix

In this paper, a two-by-two matrix called the OR-DEAE matrix consists of Y-axis represented by operating revenue that is positive in general, and X-axis represented by the SupPE CCR model in which the outputs involve operating revenue, see Figure 1. The coordinator of the center of the matrix could be chosen as (x0, y0), where x0=1, and y0= ymean, i.e., the mean of operating revenue for the entire sample which can be considered as the average level of the industry which the DMUs belong to. The matrix consists of four distinct quadrants: star (big and strong), sleeper (big but weak), dog (small but strong) and question mark (small and weak), where different profiles of DMUs are likely to exist and be assessed on the matrix analogous to a profitability-efficiency matrix discussed by Dyson et al. (1990) and Boussofiane et al. (1991). From the figure, it is clear that focusing on operating revenue and neglecting DEA efficiency may result in high operating revenue but lacking good operational management. In contrast, focusing on DEA efficiency and neglecting operating revenue may result in low operating revenue.

Note that, the idea of constructing the OR-DEAE matrix came from the work of Dyson et al. (1990) and Boussofiane et al. (1991). Analogously to a famous technique to support strategic option formulation - Boston Consulting Group (BCG) matrix (Boston Consulting Group, 1972), Dyson et al. (1990). and Boussofiane et al. (1991) discussed a profitability-efficiency matrix to assesse on both profitability and DEA efficiency of DMUs which belong to a profit-making sector. Camanho and Dyson (1999) concretely applied the DEA method and the profitability-efficiency matrix to assesse on both profitability and technical efficiency (i.e. productive efficiency in this paper) of Portuguese bank branches in 1996. Further studies on the similar matrix with applications in an organization (e.g. the bank, university, business network and microfinance institution) can be found. See, for examples, Sarrico and Dyson (2000), Mouzas (2006), Kumar and Gulati (2010), and Widiarto and Emrouznejad (2015).

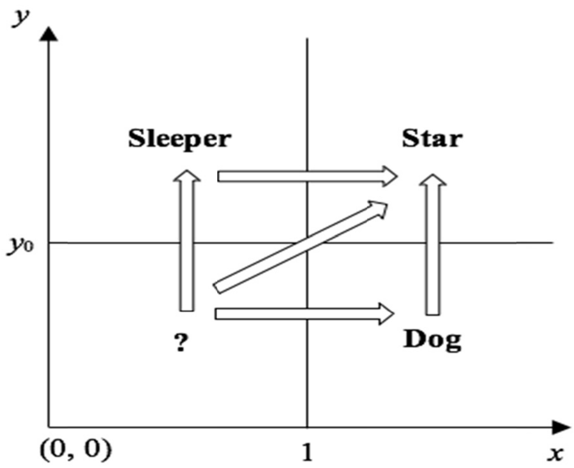

Figure 1. The OR-DEAE matrix

However, it needs to say that in the profitability-efficiency matrix discussed by Camanho and Dyson (1999), the profitability is represented by the profit index obtained dividing the profit before indirect costs by the total interest and non-interest costs, the efficiency is represented by the classical productive efficiency of CCR model (2). In the center (x0, y0) of the matrix, there is x0=0.90, see Figure 1 in the work of Camanho and Dyson (1999). Hence, the DMUs which CCR-efficiency scores are greater than 0.90 but less than 1 located in the star or dog quadrant are not the elements of the reference sets of the CCR model as these DMUs are CCR-inefficient according to the efficiency definition of the DEA method. The matrices and relevant discussions provided by other scholars are the similar, for example, see Figure 4 (in which that x0=0.91 and y0=0.86 are assumed) of Kumar and Gulati (2010).

The OR-DEAE matrix in the current paper is constructed by operating revenue and the SupPE CCR model (5), and is used to measure big and strong aspects of the DMUs in performance management. Combining DEA theory with the OR-DEAE matrix, the relevant backward DMUs can improve their operational performance through several basic development paths provided by the matrix. In the following section, a case of feed companies operating in China is discussed as an application of the DEA theory and the OR-DEAE matrix.

3. Feed Companies in China

24 feed companies were selected for the study. These companies deal with feed business and their activities are reasonably homogeneous. They were operating and scattered across the country. Other Chinese feed companies that data on some of the inputs and outputs were not available were excluded from our study.

Choosing suitable input and output indexes are an important issue for DEA models. In the study, following the previous scholars' works and combined with the reality of the feed industry, 2 inputs and 2 outputs are chosen, i.e., I=J=2 in model (2).

Choose inputs. Input 1: employees (unit: person). As a business organization, a feed company is a group of people work together to achieve a common goal of the company. Hence, as Camanho and Dyson (1999) and Kumar and Gulati (2010), the (average) number of employees, which stands for human capital, is used as an input index. Input 2: fixed asset (unit: million yuan). The feed industry is a manufacture industry. Fixed asset, which stands for physical capital, is the main asset of feed company's production and operation. It normally includes items such as plant, machinery, farmland, vehicles, buildings, computer and office equipment. Hence, as Kumar and Gulati (2010), fixed asset is used as another input index.

Choose outputs. Output 1: feed revenue (unit: million yuan). Operating revenue consists of feed revenue and other revenue derived from its primary operations of a feed company, which can be collected from its financial statements. Hence, as Kumar and Gulati (2010), feed revenue as the primary business revenue of the feed company is used as an output index. Output 2: other revenue (unit: million yuan). As Kumar and Gulati (2010), other revenue, which is equal to operating revenue minus feed revenue, is used as another output index. Table 1 shows summary statistics for the 24 samples in 2013.

Table 2 shows the Pearson's correlation coefficients between input and output data. The coefficient values close to +1 indicate strong relationships between input and output data.

Table 1. Summary statistics for the input and output from 24 feed companies.

Statistics	Employees	Fixed Asset	Feed Revenue	Other Revenue
	(person)	(million yuan)	(million yuan)	(million yuan)
Max	71848	6305.28	46103.20	23292.04
Min	986	54.85	9.30	2.54
Mean	8276	1350.27	6297.26	2188.37
SD	15413.77	1520.64	10936.20	4598.90

Note. All the data are collected from the annual report of 24 samples.

Table 2. Pearson's correlation coefficients

Inputs	Outputs	
	Feed Revenue	Other Revenue
Employees	0.9631	0.9362
Fixed Asset	0.9661	0.8096

4. Results and Discussions

Firstly, we rank the 24 companies according to their operating revenue which can reflect the "big" aspect of the companies (Fortune rank), see Table 3. DMU1's operating revenue is the biggest that ymax=69395.25 million yuan, and is ranked as the No.1 in the Fortune rank. The mean operating revenue of 24 companies, used to represent the feed industry level, is ymean =8485.62 million yuan. DMU23's operating revenue is the smallest that ymin=451.46 million yuan.

Table 3. DEA efficiencies and ranks for 24 feed companies

DMU	PE	PTE	SE	Ref. set	RTS	SupPE	SupPE rank	Fortune rank
DMU1	1	1	1	1	CRS	1.4119	1	1
DMU2	0.9518	1	0.9518	1;6;11	DRS	0.9518	12	6
DMU3	0.7342	0.7377	0.9952	1;6;11	DRS	0.7342	22	5
DMU4	0.7786	0.8021	0.9707	1;6;11	IRS	0.7786	18	12
DMU5	1	1	1	5	CRS	1.1100	6	9
DMU6	1	1	1	6	CRS	1.2337	2	3
DMU7	0.8531	0.9439	0.9038	5;6;8	IRS	0.8531	15	11
DMU8	1	1	1	8	CRS	1.1868	3	8
DMU9	0.8313	0.9065	0.9171	1;11	DRS	0.8313	16	4
DMU10	0.8838	0.8989	0.9832	1;5;6	IRS	0.8838	14	7
DMU11	1	1	1	11	CRS	1.1315	4	13
DMU12	0.9421	0.9831	0.9583	5;8;17	IRS	0.9421	13	18
DMU13	0.7579	0.7658	0.9896	5;17	IRS	0.7579	21	16
DMU14	0.9541	1	0.9541	5;17	IRS	0.9541	11	19
DMU15	0.9669	1	0.9669	5;8;17	IRS	0.9669	10	20
DMU16	1	1	1	16	CRS	1.1285	5	10
DMU17	1	1	1	17	CRS	1.1014	7	15
DMU18	0.7722	0.8084	0.9552	5;17	IRS	0.7722	19	21
DMU19	0.8265	0.9831	0.8407	11	IRS	0.8265	17	22
DMU20	0.6753	0.8641	0.7815	5;6;8	IRS	0.6753	23	17
DMU21	1	1	1	21	CRS	1.0742	8	23
DMU22	1	1	1	22	CRS	1.0042	9	14
DMU23	0.5361	1	0.5361	5;17	IRS	0.5361	24	24
DMU24	0.7695	0.8548	0.9003	1;6;11	CRS	0.7695	20	2
Max	1	1	1			1.4119		
Min	0.5361	0.7377	0.5361			0.5361		
Mean	0.8847	0.9395	0.9419			0.9423		
SD	0.1271	0.0851	0.1008			0.1987		

Note. Max—maximum, Min—minimum, SD—standard deviation.

By using the input-oriented DEA method, we get the CCR-efficiency including productive efficiency (PE), pure technical efficiency (PTE) and scale efficiency (SE) of 24 companies. Then we get the super-productive efficiency (SupPE) and according to the efficiency scores to rank the companies which could reflect the "strong" aspect of the companies. The scores of PE, PTE and SE, CCR-reference set, CCR-returns-to-scale (RTS) characteristics of each company, the scores of SupPE, and SupPE's rank are also listed in Table 3. There are three kinds of RTS on VRS (Cooper et al., 1999): constant returns-to-scale (CRS), decreasing returns-to-scale (DRS) and increasing returns-to-scale (IRS). DRS means if output increases by less than that proportional change in inputs. IRS means if output increases by more than that proportional change in inputs.

In Table 3, 9 companies are CCR-efficient, such as DMU1, DMU5 and DMU6. The other 15 companies are CCR-inefficient relatively. The relationship among the PE, PTE and SE is that 0.8847= 0.9395× 0.9419. The mean PE is 0.8847, and the mean PTE (0.9395) is smaller than the mean SE (0.9419), which can reflect that the lower PTE has a little bit more influence on the feed industry's CCR-efficiency.

Figure 2 shows the OR-DEAE matrix for 24 companies where x coordinate stands for the super-efficiency and y coordinate stands for the operating revenue. The four quadrants are separated by value 1 of efficiency score and the mean operating revenue, and (x0, y0) = (1, 8485.62) is the center of the matrix. All of 24 DMUs are located in the four-quadrant grid, offering a compact picture of their strengths and weaknesses. A diamond in Figure 2 is a DMU which represents the OR-DEAE relationship. The situation of 24 DMUs in the OR-DEAE matrix is shown in Table 4.

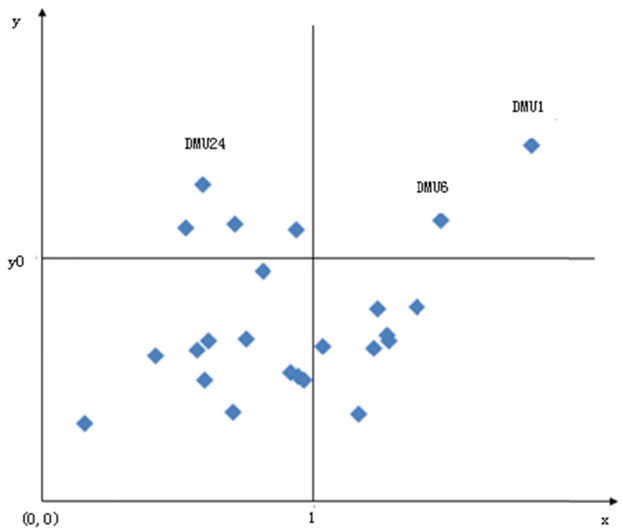

Figure 2. The OR-DEAE matrix of 24 companies

Table 4. 24 companies in the OR-DEAE matrix

Quadrant	Feature	DMU	No.
Star Quadrant	Big and strong: the operating revenue higher than the industry level and the SupPE score is larger than 1	DMU1, DMU6	2
Sleeper Quadrant	Big but weak: the operating revenue higher than the industry level but the SupPE score is smaller than 1	DMU2, DMU3, DMU9, DMU24	4
Dog Quadrant	Small but strong: the operating revenue lower than the industry level but the SupPE score is larger than 1	DMU5, DMU8, DMU11, DMU16, DMU17, DMU21, DMU22	7
Question Mark Quadrant	Small and weak: the operating revenue lower than the industry level and the SupPE score is smaller than 1	DMU4, DMU7, DMU10, DMU12, DMU13, DMU14, DMU15, DMU18, DMU19, DMU20, DMU23	11

5. Development Paths for Feed Companies to Improve Performance

The companies could learn from the role models by using the matrix, and find the proper development paths to improve their competitiveness. In the following, several basic development paths for the feed companies are provided and discussed, respectively.

5.1 Star Quadrant→Star Quadrant

As see in Figures 1 and 2. DMUs located in the star (big and strong) quadrant are benchmarks of the best operational practice for other DMUs already. Big: their operating revenues are above the average level of the industry which the DMUs belong to, that means those DMUs have large market share, large amounts of cash flow and large business sizes (employees, asset, revenue, etc.) in the industry; and strong: their operations are CCR-efficient, i.e., both the BCC-efficient and scale efficient relatively. Those DMUs need to create effective, efficient management plans and keep their competitive advantage, retain the benchmarks and leaders of the industry through a balanced approach.

In the case of the feed industry, only 2 companies are located in the star quadrants: DMU1 and DMU6, which feed revenue is 46103.20 million yuan and 16877.20 million yuan, up to 66.44% and 94.13% of its operating revenue 69395.25 million yuan and 17930.41 million yuan, the total feed market share is 30.50% and 11.17%, the number of employees is 71848 million yuan and 9634 million yuan, the fixed asset is 6305.28 million yuan and 2706.79 million yuan, respectively. Their operating revenues are above the feed industry level 8485.62 million yuan, and operations are CCR-efficient. They perform best in the “big and strong” aspects of overall performance management, and are the benchmarks in the feed industry discussed.

Interestingly, DMU1 is No.1 in the Fortune rank (the largest operating revenue) and has the highest SupPE score 1.4119 by using the biggest employees and largest fixed asset among 24 companies, see Tables 1, 3 and Figure Note that if the fixed asset index as an input index is replaced by the total asset index, DMU1 also has the highest SupPE score. In fact, DMU1 was established in 1982 and it is one of the key enterprises of the national-level agricultural modernization. It is a big private company which net profit is 2491.4 million yuan in 2013. The feed business is kept a fast growth and developed in the foreign operations quickly. DMU6’s performance is also very good. Those companies need to keep their competitive power in the feed industry.

5.2 Sleeper Quadrant→Star Quadrant

If DMUs are located in the sleeper (big but weak) quadrant of the matrix and wish to be the leaders in the industry, they could choose “sleeper quadrant→star quadrant” as their development paths to enhance their competitive power. DMUs located in the sleeper quadrant have large operating revenues which are above the industry level, yet their operations are CCR-inefficient relatively. For overcoming the weak aspect of the DMUs, the performance improvement for them are increasing their CCR efficiencies through their reference sets consisted of CCR-efficient DMUs which are located in star and dog quadrants. Suppose (x, y) are the original input-output vectors, and (X, Y) are the improved input-output vectors, by using CCR projection formula (4), there are $\sum_{j=1}^{J} Y_j \geq \sum_{j=1}^{J} y_j > y_{\text{mean}}$. Through benchmark learning, those CCR-inefficient DMUs could reduce theirs inputs while producing at least the given output levels, which could make those DMUs move into the star quadrant, and become not just big but also strong companies.

For example, DMU24, located in the sleeper quadrant, is the second biggest company listed in the Fortune rank in Table 3. It is a big private company and operating in China, and its parent company is in Thailand. The feed revenue is 26807.70 million yuan, up to 79.97% of its operating revenue 33520.95 million yuan, the total feed market share is 17.74%, the number of employees is 36000. DMU24 could choose the development path of “sleeper quadrant→star quadrant” to increase its competitive powers. After learning from CCR-efficient DMU1, DMU6 and DMU11 (see Table 3) and using formula (4), the original inputs (employees, fixed asset): (36000, 4992.21) of DMU24 could be reduced to (27704, 3841.74), but the outputs are the same as original outputs (feed revenue, other revenue): (26807.70, 6713.25), and there is 26807.70+6713.25=33520.95>8485.62.

5.3 Dog Quadrant→Star Quadrant

DMUs located in the dog (small but strong) quadrant could keep their previously operational patterns. However, if they want to be the leaders in the industry, they could choose “dog quadrant→star quadrant” as their development paths. Although the operating revenues of those DMUs are below the industry level, but all of those DMUs are CCR-efficient, i.e., BCC-efficient and scale-efficient, and are in CCR-CRS status. Hence, for those DMUs that want to move into the star quadrant from the dog quadrant, they need to implement plans for increasing their input amounts so that all output amounts are increasing by that same proportional change as all inputs change since if $(x, y) \in P$, then $(kx, ky) \in P$, where any k >0 and P is the production possibility set, see models (1) and (2) with the CRS assumption. Suppose (x, y) is the original input-output vector of the CCR-efficient DMU, the positive value of k needs to guarantee that the sum of the output amounts is above the industry level, $k\sum_{j=1}^{J} y_j > y_{\text{mean}}$.

Use DMU8 as an example. It is located in the dog quadrant, the feed revenue is 2715.22 million yuan, up to 72.90% of its operating revenue 3724.76 million yuan, the total feed market share is just 1.80%, the number of employees is 2101, and the fixed asset is 1109.72 million yuan. However, DMU8 is CCR-efficient and SupPE score is 1.1868. If it wants to be the leaders in the industry, DMU8 just needs to increase its inputs (employees, fixed asset) 2.5 times, 2.5× (2101, 1109.72) =(5253, 2774.29) so that its outputs (feed revenue, other revenue) are increasing 2.5 times, 2.5×(2715.22, 1009.54)=(6788.05, 2523.86). The k is choosing as 2.5 to guarantee the improved operating revenue of DMU8 is above the feed industry level, 6788.05+ 2523.86=9311.91> 8485.62.

5.4 Question Mark Quadrant→Star Quadrant

Finally, we are discussing the case that DMUs are located in the question mark (small and weak) quadrant. If DMUs are located in the question mark quadrant, the operating revenues of those DMUs are below the industry level, that means those DMUs hold small percentages of feed market share, do not produce much cash and have small business sizes (employees, asset, revenue, etc.) in the industry. At the same time, their operations are CCR-inefficient, i.e., BCC-inefficient, or scale-inefficient, or both. On the performance improvement for those DMUs that want to change their development patterns and move into the star quadrant, three basic development paths are suggested for those DMUs to choose.

(1) "Question mark quadrant→sleeper quadrant→star quadrant", see Figure 1. If a DMU is located in the question mark quadrant, there may be two stages for the DMU to move into the star quadrant. At the first stage, increase the operating revenue. Firstly, the DMU chooses the path of "question mark quadrant→sleeper quadrant" by suitably increasing its input amounts in order to raise the operating revenue and move into the sleeper quadrant. We know that models (1) and (2) have the CRS assumption: if $(x, y) \in P$, then $(kx, ky) \in P$, that means the output increases by that same proportional change as all inputs change, where any k >0. Hence, this small DMU needs to make a plan to increase its operating revenue that satisfies $k\sum_{j=1}^{J} y_j > y_{\text{mean}}$, and the improved input-output vector to be (kx, ky) where (x, y) is the original input-output vector. Note that this improved DMU is still CCR-inefficient with the same CCR-inefficiency score as the original DMU at the question mark quadrant, but has moved into the sleeper quadrant. Then at the second stage, as path B analysis, the CCR-inefficient DMU can choose the path of "sleeper quadrant→star quadrant" to increase its CCR efficiency and move into the star quadrant finally.

Path (1) may be suitable for the DMUs that have certain improvement conditions and plan firstly to increase the operating revenue and enhance the "big" aspect, then to increase the CCR-efficiency and enhance the "strong" aspect of the DMUs. Path D-1 may also be suitable for a CCR-inefficient DMU in IRS status.

DMU7 is used as an example. Its feed revenue is 1395.66 million yuan, up to 67.15% of its operating revenue 2078.40 million yuan, the total feed market share is just 0.92%, the number of employees is 1748, and the fixed asset is 491.36. DMU7 also has CCR-inefficiency score 0.8531, and it is in IRS status. If it wants to be the leader in the industry, at the first stage, DMU7 can choose the path of "question mark quadrant→sleeper quadrant" by increasing its inputs (employees, fixed asset) 5 times, 5 ×(1748, 491.36) =(8740, 2456.78) so that its outputs (feed revenue, other revenue) are increasing 5 times, 5×(1395.66, 682.74)=(6978.29, 3413.72). The k is choosing as 5 to guarantee the increased operating revenue is above the feed industry level, 6978.29+ 3413.72=10392.01> 8485.62. The improved DMU7 located in sleeper quadrant is still CCR-inefficient with the CCR-inefficiency score 0.8531 as the original DMU7 at the question mark quadrant. Then at the second stage, as path B analysis, the CCR-inefficient DMU7 will choose the path of “sleeper quadrant→star quadrant” to increase its CCR efficiency and move into the star quadrant finally.

(2) “Question mark quadrant→dog quadrant→star quadrant”, see Figure 1. If a DMU is located in the question mark quadrant, there may be another two stages for the DMU to move into the star quadrant. At the first stage, the DMU can move through the path of “question mark quadrant→dog quadrant”. The performance improvement for the DMU is firstly increasing its CCR efficiency through its reference sets. Through benchmark learning, the DMU could become CCR-efficient and move into the dog quadrant, as a result the original input-output vector (x, y) is improved as (X, Y) by using formula (4). At the second stage, the CCR-efficient DMU will choose the path of “dog quadrant→star quadrant”. As path C analysis above, the final improved input-output vector of the CCR-efficient DMU could be (kX, kY), where k>0 and guarantees the sum of the improved output amounts is above the industry level, $k\sum_{j=1}^{J} Y_j > y_{\text{mean}}$.

Path (2) may be suitable for the DMUs that have certain improvement conditions and plan firstly to enhance the CCR-efficiency and improve the “strong” aspect, then increase the operating revenue and improve the “big” aspect of the DMUs; or may be suitable for the DMUs that are in CRS or DRS status.

(3) “Question mark quadrant→star quadrant”, see Figure 1. Path (3) is also named “great-leap-forward development” in China. If a DMU is located in the question mark quadrant but its position is very close to the star quadrant, there may exist a development path for the DMU to directly move into the star quadrant from the question mark quadrant. The reason is based on the input-oriented CCR projection (4), after learning from the reference set consisted of CCR-efficient DMUs, the CCR-inefficient DMU can improves its overall operation efficiently, at the same time its operating revenue produced may be above the industry level.

The DMUs located in the question mark quadrant have the potential for both operating revenue and CCR-efficiency, and should study their benchmarks in the industry, and choose the correct path for healthy and sustainable development of the DMUs.

6. Conclusion

Feed industry plays an important role in China’s economic development and living standards of people. The feed listed company is an important part of Chinese agricultural industry chain, and it is also an important form of modernization of agricultural industry. Moreover, its operation levels affect the development of the whole Chinese feed industry directly. In order to ensure their healthy and sustainable development, our work constructed an OR-DEAE matrix to evaluate both “big” and “strong” aspects of feed companies simultaneously.

Results in our study showed that there was a big difference between those feed of listed companies’ performances in China. Most of those companies are in question mark quadrant and dog quadrant, which reflected their operation levels were low and competitive capability was weak. Only two benchmarking companies were in the star quadrant, and had good lead over other companies.

As discussed above, we provide several development paths for feed companies which in sleeper quadrant, dog quadrant and question mark quadrant to improve their performance to move into the star quadrant. In particular, feed companies in the question mark quadrant has three development paths for different improvement conditions of companies, and these development paths can guide them to enhance their efficiency and operating revenue. For a sustainable development, those backward companies need to set up benchmarking program and learn form the excellent enterprises to make themselves big and strong. Through benchmark learning, those backward companies could reduce theirs inputs while producing more outputs, which could make them move into the star quadrant, and become big and strong.

Further, operating revenue and productive efficiency are main terms in assessing business performance. Based on the previous scholars’ work, this paper absorbs the both advantages of the evaluation measure of Fortune Global 500 and DEA methods, and constructs an OR-DEAE matrix to evaluate big and strong aspects of general enterprises simultaneously. The matrix evaluation measure can be regarded as an extension method of the Fortune Global 500. As an application, the performance of the feed companies operating in China is discussed through the balanced approach. Exploring successful development paths for general enterprises has both theoretical and practical significance. As all the DEA efficiencies discussed are calculated in the input-oriented measure, the output-oriented measure or mix could be useful to study. As the applications, the evaluations for performance management of the different kinds of companies with involved industries need to be investigated.

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References

Andersen, P., & Niels C. P. (1993). A procedure for ranking efficient units in data envelopment analysis. *Management science, 39,* 1261-1264. http://dx.doi.org/10.1287/mnsc.39.10.1261

Alltech. (2013). *Global Feed Summary*. Retrieved from http://www.alltech.com/home

Banker, R. D., & Chang, H. (2006). The super-efficiency procedure for outlier identification, not for ranking efficient units. *European Journal of Operational Research, 175,* 1311-1320. https://doi.org/10.1016/j.ejor.2005.06.028

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management science, 30,* 1078-1092. http://dx.doi.org/10.1287/mnsc.30.9.1078

Boston Consulting Group. (1972). *Perspectives on Experience* (1st ed.). Boston.

Boussofiane, A., Dyson, R. G., & Thanassoulis, E. (1991). Applied data envelopment analysis. *European Journal of Operational Research, 52,* 1-15. https://doi.org/10.1016/0377-2217(91)90331-O

Camanho, A. S., & Dyson, R. G. (1999). Efficiency, size, benchmarks and targets for bank branches: an application of data envelopment analysis. *Journal of the Operational Research Society, 50.* 903-915. https://doi.org/10.1057/palgrave.jors.2600792

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2,* 429-444. https://doi.org/10.1016/0377-2217(78)90138-8

Chinese Ministry of Industry and Information Technology et al. (2001). *Small and medium-size enterprises classification standards*. China.

Cook, W.D., Liang, L., Zha, Y., & Zhu, J. (2009). A modified super-efficiency DEA model for infeasibility. *Journal of the Operational Research Society, 60,* 276-281. https://doi.org/10.1057/palgrave.jors.2602544

Cooper, w.w., Seiford, L.M., & Tone, K. (1999). *Data Envelopment Analysis, a comprehensive text with models, applications, references and DEA-solver software.* Boston: Kluwer Academic Publishers.

Dyson, R.G., Thanassoulis, E., & Boussofiane, A. (1990). Data envelopment analysis. *Operational research tutorial papers*, 13-28.

Emrouznejad, A., Parker, B. R., & Tavares, G. (2008). Evaluation of research in efficiency and productivity: A survey and analysis of the first 30 years of scholarly literature in DEA. *Socio-economic planning sciences, 42,* 151-157. https://doi.org/10.1016/j.seps.2007.07.002

Emrouznejad, A., & Witte, K. D. (2010). COOPER-framework: A unified process for non-parametric projects. *European Journal of Operational Research, 207,* 1573-1586. https://doi.org/10.1016/j.ejor.2010.07.025

Farrell, M.J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society. Series A (General), 120,* 253-290. https://doi.org/10.2307/2343100

Fortune Magazines. (2013). Retrieved from http://fortune.com/

Gronroos, C., & Ojasalo, K. (2004). Service productivity: Towards a conceptualization of the transformation of inputs into economic results in services. *Journal of Business Research, 57,* 414–423. https://doi.org/10.1016/S0148-2963(02)00275-8

Kumar, S., & Gulati, R. (2010). Measuring efficiency, effectiveness and performance of Indian public sector Banks. *International Journal of Productivity and Performance Management, 59,* 51-74. http://dx.doi.org/10.1108/17410401011006112

Mouzas, S. (2006). Efficiency versus effectiveness in business networks. *Journal of Business Research, 59,* 1124-1132. https://doi.org/10.1016/j.jbusres.2006.09.018

Sarrico, C. S., & Dyson, R. G. (2000). Using DEA for Planning in UK Universities-An Institutional Perspective. *The Journal of the Operational Research Society, 51,* 789- 800. https://doi.org/10.2307/253960

U.S. Small Business Administration. (2012). *Table of Small Business Size Standards*. Washington.

Widiarto, I., & Emrouznejad, A. (2015). Social and financial efficiency of Islamic microfinance institutions: A Data Envelopment Analysis application. *Socio-Economic Planning Sciences, 50,* 1-17. https://doi.org/10.1016/j.seps.2014.12.001

Zhu, J. (2001). Super-efficiency and DEA sensitivity analysis. *European Journal of Operational Research, 129,* 443-455. https://doi.org/10.1016/S0377-2217(99)00433-6

Zhu, N., Zhuo, X., & Dong, Y. (2004). A case study of the efficiency of China's national commercial banks and the reform strategy. *Management World, 2,* 18-26. (Chinese paper)

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