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An Assessment Study on Innovation Ability and Innovation Potentiality for Daqing Oilfield*

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Abstract This paper applies Data Envelopment Analysis (DEA) and Elasticity Analysis to an empirical assessment study on innovation ability and innovation potentiality. According to inputs and outputs data of these innovative enterprises, we build CCR model, BCC model and Elasticity model to measure their innovation ability and innovation potentiality. The results show that innovation ability is varied because of different development focuses. Some innovative enterprises have relatively greater innovative potential than others. Meanwhile, three enterprises are innovative input redundant. Further analysis on innovation ability and innovation potentiality for Daqing Oilfield Limited Company will be illustrated, so as to provide a scientific basis for adjustment and improvement.

Keywords Data Envelopment Analysis (DEA); Elasticity Analysis; Innovation Ability Assessment; Innovation Potentiality Assessment.

1 Introduction

Today, as science and technology changing quickly, scientific and technological innovation and creation is continuously emerging, and the competition of science and technology is increasingly fierce. The ways to sustainable economics are greatly dependent upon the ability of innovation. Since 2008, the Ministry of Science and Technology (MOST), the State-Owned Assets Supervision and Administration Commission of the State Council (SASAC) and the All-China Federation of Trade Unions (ACFTU) have jointly implemented the innovative construction. So far MOST, SASAC, and ACFTU have already chosen and determined 550 pilot innovative enterprises.[1,2] The innovative enterprises construction has achieved remarkable effect. As the most vigorous innovative enterprise cluster, they have continuously strived to raise the innovation ability and increase the contribution to economic development and supported the national competence efficiently.

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Then, the demand for doing research on evaluating innovative enterprises is proposed. The traditional method for innovation assessment is Analytic Hierarchy Process (AHP). [1,2] Combined with qualitative analysis and quantitative analysis, AHP could solve many practical problems which are hard to handle by traditional optimization method. Because it is simple and convenient in practical application, AHP is widely used in various fields. However, it also has some disadvantages and limitations, which could not be neglected. For one thing, the subjective factors of experts have large effects on whole progress which sometimes is hard to accept by decision maker. Due to lack of systemic methods for selecting experts, it will obtain different result by different expert group. And there always has doubt on the fairness of assessment results. For another, the result can hardly give decision maker any information about future improvements and sensitivity analysis for some factors.

In our research, assessment method for innovative enterprises mainly includes Data Envelopment Analysis (DEA), Inverse DEA, and Elasticity Analysis. Data envelopment analysis (DEA), first introduced by Charnes, Cooper and Rhodes in 1978[3], has become a very amateur tool for performance evaluation and benchmarking.[4,5] Compared with other evaluating methods, DEA has three remarkable characteristics: optimality, objectivity and adaptability of complex system for multi-input and multi-output. As for the above advantages, this method is widely applied by enterprises, banks and government departments in performance evaluation and management practice. Inverse DEA method is a complement for the traditional DEA method, which is extremely helpful in sensitivity analysis. Therefore, we adopt Data Envelopment Analysis and Inverse DEA model in our research to assess the innovation ability for nine innovative enterprises.

Further, potential for improving innovation ability is also an important aspect deserving of attention. So we bring in Elasticity Analysis firstly to assess their innovation potentiality.[9] According to Elasticity score, returns-to-scale is more accurately characterized than the previous classification. It is a reasonable evaluating and predicting method for enterprises' future innovation ability. By means of innovation potentiality assessment, decision maker can make investment selection more objectively and scientifically than before.

In the end, analysis on innovation ability and innovation potentiality for Daqing Oilfield Limited Company will be illustrated, so as to provide a scientific basis for adjustment and improvement.

2 Assessment methodology and Modeling

2.1 CCR model and BCC model in DEA

Data Envelopment Analysis (DEA) is a linear programming methodology, particularly adept at estimating the relative efficiency for a group of homogeneous departments (referred to as decision making unit or DMU in DEA terminology) which have multiple inputs and multiple outputs. Over the past three decades, there has been a great variety of applications of DEA for use in performance evaluation in many contexts.[4,5]

The first DEA model is called CCR model.[3] Supposed there are n DMUs, and each $DMU_i (i = 1,...,n)$ has an input vector $X_i = (x_{1i}, x_{2i},..., x_{mi})$ and an output vector $Y_i = (y_{1i}, y_{2i},..., y_{si})$. Compared with other DMUs, the CCR-efficiency of DMU_0 can be calculated by CCR output-orientation model (CCR-O):

$$\max \theta$$
$$\begin{cases} \sum_{i=1}^{n} \lambda_i x_i \leq x_0 \\ \sum_{i=1}^{n} \lambda_i y_i \geq \theta y_0 \\ \lambda_i \geq 0, i = 1, 2, \cdots, n. \end{cases} \qquad (2.1)$$

If an optimal solution (θ^*, λ^*) for CCR-O (1.1) satisfies $\theta^* = 1$ and has no slack $(s^{-*} = x_0 - X\lambda^* = 0, s^{+*} = Y\lambda^* - \theta^* y_0 = 0)$, then the DMU_0 is called CCR-efficient. Otherwise, the DMU_0 is called CCR-inefficient. And CCR efficient frontiers are spanned by the CCR-efficient DMUs. CCR efficient frontiers have constant returns to scale characteristics. That is, if an activity (x, y) is feasible, then for every positive scalar t, the activity (tx, ty) is also feasible.

In 1984, Banker et al. [6] extended CCR model by providing BCC model which built on the assumption of variable returns to scale. The output-orientation of BCC model (BCC-O) is,

$$\max \theta$$
$$\begin{cases} \sum_{i=1}^{n} \lambda_i x_i \leq x_0 \\ \sum_{i=1}^{n} \lambda_i y_i \geq \theta y_0 \\ \sum_{i=1}^{n} \lambda_i = 1 \\ \lambda_i \geq 0, i = 1, 2, \cdots, n. \end{cases} \qquad (2.2)$$

The BCC model (2.2) differs from the CCR model (2.1) only in the adjunction of the condition $\sum_{j=1}^{n} \lambda_j = 1$. Together with the condition $\lambda_j \geq 0$, for all j, this imposes a convexity condition on allowable ways in which the n DMUs may be combined.

If an optimal solution (θ^*, λ^*) for BCC-O (2.2) satisfies $\theta^* = 1$ and has no slack $(s^{-*} = x_0 - X\lambda^* = 0, s^{+*} = Y\lambda^* - \theta^* y_0 = 0)$, then the DMU_0 is called

BCC-efficient. Otherwise, the DMU_0 is called BCC-inefficient. And BCC efficient frontiers are spanned by the BCC-efficient DMUs.

2.2 Returns-to-scale (RTS) and Elasticity model

In the literature of classical economics, returns-to-scale (RTS) has typically been defined on production function only for single output situations. Based on the production function $y = f(x)$ (see Figure 1), returns-to-scale refers to changes in output $\Delta y / y$ resulting from a proportional change in input $\Delta x / x$ (where $\Delta x = x + \varepsilon, \varepsilon > 0$). Then, returns-to-scale is generally classified into these 4 types: [4,6,7,8]

a) If output increases by more than that proportional change, there are increasing returns to scale (IRS), e.g. DMU1 in Figure 1.
b) If output increases by that same proportional change, there are constant returns to scale (CRS), e.g. DMU2 in Figure 1.
c) If output increases by less than that proportional change, there are decreasing returns to scale (DRS), e.g. DMU3 and DMU 4 in Figure 1.
d) If output does not increase, there are Congestion.

Because the real production is difficult to calculate, Banker et al [6] proposed BCC model and adopted the BCC frontier in DEA to approximate the production function. Their models can also identify the returns-to-scale for each DMU. DMU 3 and DMU 4 are identified as decreasing returns to scale. As can be seen in Figure 1, DMU 3 has more grow prospect than DMU 4, and DMU 1 has the greatest growth trend than others. In order to precisely characterize RTS, we bring the Elasticity model to measure this growth potential.

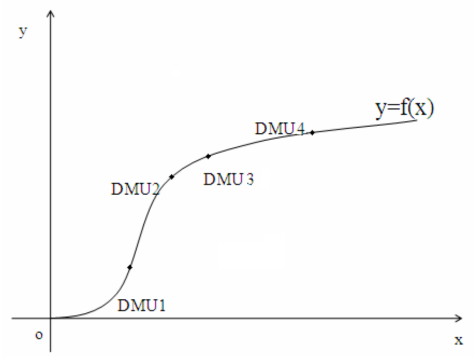

Figure 1: returns-to-scale (RTS) of four DMUs

Elasticity concept is often used economics analysis in single input and single output case. Elasticity of DMU_0 is the ratio of the output's change to the input's change.

$$E_i = \lim_{\Delta \to 0} \frac{\Delta f(x) / f(x)}{\Delta x_i / x_i} = \frac{\partial f(x)}{\partial x_i} \cdot \frac{x_i}{f(x)} \qquad (2.1)$$

In order to handle the case of multiple inputs and multiple outputs, Elasticity concept has been extended to multiple outputs case. Let $\alpha > 1$ represent an arbitrarily proportional inputs increase and β represent the maximum proportional outputs increase. Then activity DMU_0 (X_0, Y_0) is expected to be a new activity $(\hat{X}_0, \hat{Y}_0)$ on production function, where $(\hat{X}_0, \hat{Y}_0) = (\alpha X_0, \beta Y_0)$. It is shown that the proportions in all outputs and inputs are maintained at values β and α. So output and input mixes of the new activity are both preserved. Then the Elasticity of DMU_0 is the maximum of $\frac{\beta - 1}{\alpha - 1}$ to the extent of possible.

$$Max e = \frac{\beta - 1}{\alpha - 1}$$
$$\begin{cases} \sum_{j=1}^{n} X_j \lambda_j \le \alpha X_0 \\ \sum_{j=1}^{n} Y_j \lambda_j \ge \beta Y_0 \\ \sum_{j=1}^{n} \lambda_j = 1 \\ \alpha > 1, \beta \ge 1, \lambda_j \ge 0, j = 1, \dots, n \end{cases} \tag{2.3}$$

Model (2.3) is defined as Elasticity model in our paper. Since returns-to-scale and the Elasticity model are both based on the production function, they can be directly used to identify their growth trend characteristics for efficient DMUs. For inefficient DMUs, the identification of returns-to-scale depends on their BCC projections, and the Elasticity scores are calculated with the projected points on the BCC-efficient frontiers.

3 Assessment on innovation ability and innovation potentiality

3.1 Background of Daqing Oilfield Limited Company

Daqing Oilfield is the largest in China, and also one of the rare giant sandstone oilfields in the world. It was discovered in 1959 and development activities began in 1960. After 49 years of development, cumulative production has exceeded 2 billion tons with 1.6 trillion RMB contributed to the nation.

Daqing Oilfield Limited Company attaches great importance to sustainable development, and their strategic objectives are: stable production, coordinated development, harmonious environment, and the realization of a 100-year oilfield. Therefore, Daqing is do great effort to speed up technological progress and promote innovation, among which are 9 supporting technological research projects, 11 specialized technologies, 6 technologies to explore reserves, 22 major field test projects in five aspects.

3.2 Assessment on innovation capabilities

The data for assessment are collected from 'China innovative enterprises development report 2010'.[1] Here, R&D expenditure (Input 1, unit: 100 million RMB) and R&D personnel (Input 2, unit: 10,000 persons) are two innovation input indicators considered in our evaluation work. Two main economic indicators are Revenue from principal business (Output 1, unit: 100 million RMB) and Value added (Output 2, unit: 100 million RMB), considered as output indicators in our evaluation. Table 1 records the behaviors of nine innovative enterprises.

NO.	Name of Enterprise	Input 1	Input 2	Output 1	Output 2
1	Daqing Oilfield Limited Company	7.80665	0.7169	3020	1970.2749
2	China Petrochemical Corporation (Sinopec Group)	65.6	2.56	13919.5	3879
3	State Grid Corporation of China(SGCC)	51.4	0.48	12495.2	2417.4
4	China National Petroleum Corporation (CNPC)	104.2	2.03	12156.7	5528.4
5	China South Industries Group Corporation	40.2	1.74	1920.9	253.2
6	Baosteel Group Corporation	32.9	0.69	1914.1	425.4
7	China North Industries Group Corporation (CNGC)	24.1	3.51	1618.2	217.4
8	Aluminum Corporation of China Limited (CHALCO)	27.8	0.45	1309	226
9	China Shipbuilding Industry Corporation (CSIC)	71.8	2.98	1188.3	254.1

Table 1: innovation input indicators and main economic indicators of 9 innovative enterprises

CCR model (2.1) and BCC model (2.2) are adopted to evaluate their innovation ability. Table 2 displays their evaluation scores and corresponding ranks. Figure 2 shows the bar graph of innovation ability assessment results.

NO.	Name of Enterprise	CCR Score	CCR Rank	BCC Score	BCC Rank
1	Daqing Oilfield Limited Company	1	1	1	1
2	China Petrochemical Corporation (Sinopec Group)	0.7197002	4	1	1
3	State Grid Corporation of China(SGCC)	1	1	1	1
4	China National Petroleum Corporation (CNPC)	0.7340198	3	1	1
5	China South Industries Group Corporation	0.1580931	8	0.1909285	8
6	Baosteel Group Corporation	0.2209027	5	0.2258753	7
7	China North Industries Group Corporation (CNGC)	0.1735693	7	0.2466231	6
8	Aluminum Corporation of China Limited (CHALCO)	0.1846295	6	1	1
9	China Shipbuilding Industry Corporation (CSIC)	0.0553241	9	0.0853694	9

Table 2: innovation ability assessment of 9 innovative enterprises

State Grid Corporation of China (SGCC) and Daqing Oilfield Limited Company are two CCR-efficient enterprises. It means that these two enterprises achieve the maximum output-input ratio compared with others. China Shipbuilding Industry Corporation (CSIC) is the last in CCR Rank, and has the relatively weak innovation ability.

State Grid Corporation of China (SGCC), Daqing Oilfield Limited Company, China National Petroleum Corporation (CNPC), and Aluminum Corporation of

China Limited (CHALCO) are four BCC-efficient enterprises. China National Petroleum Corporation (CNPC) and Aluminum Corporation of China Limited (CHALCO) only achieve BCC-efficiency (not achieve CCR-efficiency). It indicates that these two enterprises are on the production function (i.e. on the BCC frontiers). So they are just technical efficient, not scale efficient. There is some redundancy or limitation in their input scale. And their urgent task is to adjust their innovation input scale.

Aluminum Corporation of China Limited (CHALCO) has relative high BCC Score but relative low CCR Score. It suggested CHALCO should take a great adjustment in input scale (R&D expenditure and R&D personnel).

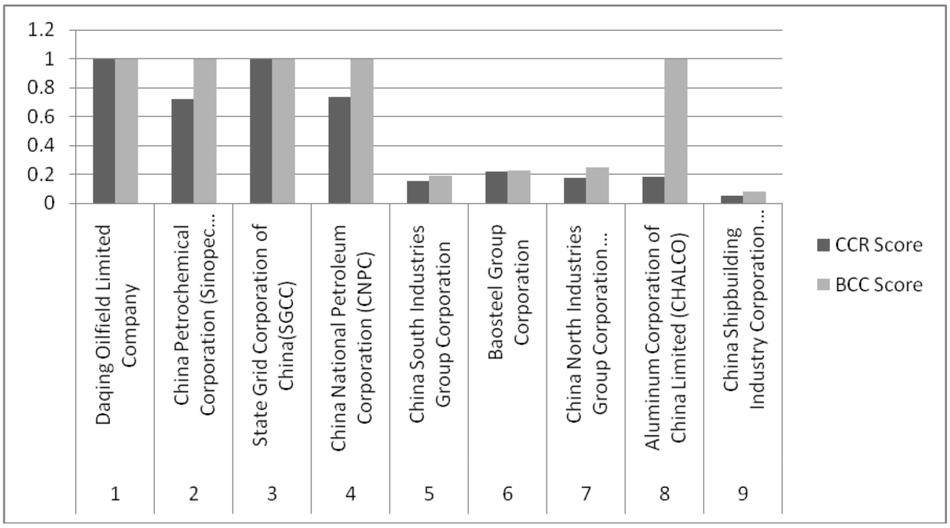

Figure 2: bar graph of innovation ability assessment results

3.3 Assessment on innovation potentiality

Further, innovation potentiality assessment for these nine innovative enterprises uses model (2,3). Results of innovation potentiality assessment are showed in Table 3. Bar graph assessment results can be seen in Figure 3.

Aluminum Corporation of China Limited (CHALCO) gets the highest Elasticity Score, which reflects that CHALCO has the greatest growth prospect. CHALCO is increasing return-to-scale, which suggested CHALCO should enlarge its innovative inputs. Compared with other enterprises, CHALCO has to adjust its innovative inputs urgently, because current small-scale is inhibit or restrain its development.

China Petrochemical Corporation (Sinopec Group), China National Petroleum Corporation (CNPC), and China Shipbuilding Industry Corporation (CSIC) are three decreasing return-to-scale innovative enterprises. Their Elasticity Scores are 0. It indicated that innovative inputs scale (R&D expenditure and R&D personnel) of these three innovative enterprises is redundant. They are suggested to reduce R&D expenditure or cut down staff.

NO.	Name of Enterprise	CCR Score	BCC Score	RTS	Elasticity Score
1	Daqing Oilfield Limited Company	1	1	Constant	0.1462554
2	China Petrochemical Corporation (Sinopec Group)	0.7197002	1	Decreasing	0
3	State Grid Corporation of China(SGCC)	1	1	Constant	0.0263047
4	China National Petroleum Corporation (CNPC)	0.7340198	1	Decreasing	0
5	China South Industries Group Corporation	0.1580931	0.1909285	Constant	2.4572546
6	Baosteel Group Corporation	0.2209027	0.2258753	Constant	1.8696006
7	China North Industries Group Corporation (CNGC)	0.1735693	0.2466231	Constant	1.7410106
8	Aluminum Corporation of China Limited (CHALCO)	0.1846295	1	Increasing	22.1905
9	China Shipbuilding Industry Corporation (CSIC)	0.0553241	0.0853694	Decreasing	0

Table 3: innovation potentiality assessment of 9 innovative enterprises

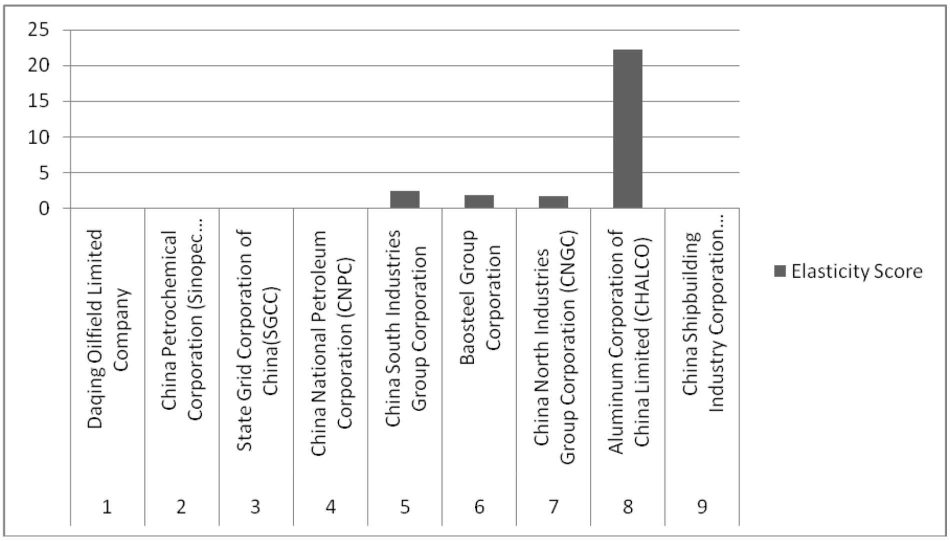

Figure 3: bar graph of innovation potentiality assessment results

Daqing Oilfield Limited Company has high innovation ability but relative less competitive in innovation potentiality assessment. The present development of a enterprise must provide a foundation with greater potentials and a wider space for future development. According to the innovation potentiality assessment results, future innovation trend of Daqing Oilfield Limited Company is probably slower than other innovative enterprises, which presently deserves to be attached importance to. It requires some adjustments in innovative input scale for Daqing Oilfield Limited Company. And it is better for Daqing Oilfield Limited Company to take appropriate measures to reduce redundant employees and unnecessary expenses to a certain extent. Proper adjustments are conductive to the long-term innovation development of Daqing Oilfield Limited Company.

4 Conclusion

This paper applies Data Envelopment Analysis (DEA) and Elasticity Analysis to an empirical assessment study on innovation ability and innovation potentiality.

According to inputs and outputs data of these innovative enterprises, we build CCR model, BCC model and Elasticity model to measure their innovation ability and innovation potentiality. The results show that innovation ability is varied because of different development focuses. Some innovative enterprises have relatively greater innovative potential than others. Meanwhile, three enterprises are innovative input redundant. Further analysis on innovation ability and innovation potentiality for Daqing Oilfield Limited Company has been illustrated, which can provide a scientific basis for adjustment and improvement.

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