Performance Evaluation of Rare Earth Enterprise Based on DEA

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***Abstract*—Based on CCR model of Data Envelopment Analysis (DEA), this paper makes an evaluation on the operating performance of 14 Rare Earth listed companies in 2011. The evaluation includes comprehensive efficiency evaluation, scale efficiency evaluation and projection measure evaluation. Results show that the overall performance of China's Rare Earth listed companies is not ideal. The average performance value is only 0.8157, which is mainly due to the scale inefficiency. According to the ineffective decision making unit for DEA, this paper gives out the adjusted target value of input indexes and output indexes.**

Keywords—DEA; Evaluation; Performance; Rare Earth Enterprise

I. INTRODUCTION

Rare earth, which is one of the most abundant strategic resources in China, is one essential raw material in plenty of high-tech industries and one important basis material in Information Technology, Biotechnology, Energy Technology and some high-tech areas as well as the National Defense construction. Meanwhile, rare earth plays an important role in the reconstruction of some traditional industries, such as agriculture, chemical industry, building materials and etc. [1] The latest statistics of United State Geological Survey (USGS) shows that China's industrial reserves of rare earth account for 30.68% of the world's, while the possible ore accounts for 80%, supplying more than 95% of the world consumption, which gains China a worthy name of Rare Earth Power. Therefore, it is significant to study the improvement of operating performance of China's Rare Earth enterprises and the acceleration of development of China's Rare Earth industry under the background of economic globalization. It makes sense for the improvement of China's Rare Earth enterprise competitiveness as well as the steady development of the whole national economy.

Performance evaluation is the multi-attribute evaluation on how an organization or individual obtains more output results with a relatively fewer input resources, which usually utilizes the "input-output ratio" of "cost benefit analysis" to consider the input attributes and output attributes when the influence on target is negative and positive respectively.

The problem of an enterprise's performance evaluation is to apply scientific methods and adopt specific indicators and standard to study the enterprise internal data and estimate the management process and results of the enterprise, which can be turned into the problem of studying the minimum input and the maximum output. Considering that DEA is an effective quantitative analysis method for enterprise's microeconomic foundation, this paper applies this method to evaluate business performance of China's Rare Earth listed companies and analyzes the technical efficiency and scale efficiency, so as to put forward a series of effective measures to make it reach DEA effective and some policy suggestions to promote the comprehensive development of rare earth enterprises.

II. DEA ANALYTICAL PRINCIPLE

Data Envelopment Analysis method (DEA Model for short), a typical kind of non-parametric method, is a special tool to evaluate relative effectiveness of job performance with the same type organization (or item) based on linear programming. It improved various questions of parametric method, such as the assumption of function form in advance and the effectiveness of parameter estimate, which doesn't need to set the specific function form for production frontier, but to determine production frontier with a large number of practical production points by linear programming [2]. Based on operational research theory, it is gradually formed the method mainly depending on linear programming technology and often used for economic quantitative analysis, which is a kind of effective method applied to unit efficiency evaluation of multiple input multiple output. In the real economic activity, not all the input-output relation can be determined out functional relation, while DEA model provides the tool to evaluate input-output efficiency under the uncertain condition of functional relation.

At present, the most representative classical DEA model contains CCR model[3], BC2 model[4], FG model[5], ST model[6], C2GS2 additive model[7], C2W model[8]with infinitely many DMU semi-infinite programming as well as Comprehensive DEA model[9]and etc., all of which take advantage of DEA method to evaluate the relative effectiveness of Diesel Multiple Units (DMU)[10]. This paper adopts CCR model to evaluate the "validity" of Rare Earth enterprises.

CCR model supposes the constant Return to Scale, which means that the output obtained from each unit input is constant and would not change with the scale.

The basic idea of CCR model is to determine the effective production frontier through the analysis of sample input and output data, and then confirm whether each DMU is DEA effective according to the distance condition of each DMU and production frontier.

Suppose there are n decision units (indicated with DMU), and each decision unit has m types of "Input" as well as s types of "Output" respectively indicates the consumption of resources and production results of the unit. x_{ij} is the input of the jth decision making unit to the ith type of input, y_{rj} is the output of the jth decision making unit to the ith type of output, v_i is the weights to the ith type of input and u_r is the weights to the rth type of output. $h_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}$ is defined as the enterprise investment efficiency, and the jth decision unit is relatively effective when $h_j = 1$.

All the values of h_j are limited no more than 1, that is $MAXh_j \le 1$. If $h_k = 1$, the kth enterprise has the highest productivity relative to other enterprises, or this production system is relatively effective. If $h_k < 1$, the production efficiency of the kth enterprise needs to be improved relative to other enterprises, or this production system is ineffective. According to the above assumptions, following fractional programming is established:

$$MAX = \frac{\sum_{r=1}^{s} u_r y_{r_0}}{\sum_{i=1}^{m} v_i x_{i_0}} \qquad (1)$$

$$\text{s.t.} \begin{cases} \dfrac{\sum_{r=1}^{s} u_r y_{r_0}}{\sum_{i=1}^{m} v_i x_{i_0}} \le 1 \quad j = 1, 2, \wedge, n \\ v \ge 0 \quad v = (v_1, v_2, \wedge, v_m)^T \\ u \ge 0 \quad u = (u_1, u_2, \wedge, u_s)^T \end{cases} \qquad (2)$$

To switch the above fractional programming into linear programming through the Charnes-Cooper Transformation and then to make dual will obtain the following programming form:

$$\min \theta$$

$$\text{s.t.} \begin{cases} \sum_{j=1}^{n} \lambda_j x_j + s^- = \theta x_0 \\ \sum_{j=1}^{n} \lambda_j y_j - s^+ = y_0 \\ s^- \ge 0, s^+ \ge 0, \lambda_j \ge 0 \end{cases} \qquad (3)$$

The value of θ calculated by the above model indicates for the operating performance value of Rare Earth enterprise, in which (1) if $\theta^* = 1$, DUM_{j_0} is weak DEA effective (overall); (2) if $\theta^* = 1$, $s^{-*} = 0$ and $s^{+*} = 0$, DUM_{j_0} is DEA effective (overall); (3) if $\theta^* < 1$, DUM_{j_0} is DEA ineffective. The value of s^* is the surplus variable of corresponding index, that is the changeable value. (4) If there exists λ_{j^*} which can make $\sum \lambda^* = 1$ establish, DUM_{j_0} is invariant economies of scale; if λ_{j^*} doesn't exist to make $\sum \lambda^* = 1$ establish and $\sum \lambda^* < 1$, DUM_{j_0} is increasing economies of scale; if $\sum \lambda^* > 1$, DUM_{j_0} is decreasing economies of scale.

III. CASE ANALYSIS

A. Selection of Decision Unit

This paper takes domestic Rare Earth listed company as the research object, in which Rare Earth listed company is engaged in the production and business operation relevant to rare earth. According to "The Industry Classification Guide of Listed Company" constituted by China Securities Regulatory Commission on April 3, 2001, listed companies can be classified as Rare Earth industry only when its operation revenue proportion engaging in Rare Earth is greater than or equal to 50%, or when its operation revenue proportion engaging in Rare Earth is 30% higher than any other business income if its operation revenue of any industries is greater than or equal to 50%.

According to the above principles, this paper selects 14 listed enterprises engaged in the exploitation, process and application of Rare Earth resources as evaluation objects.

B. Selection of Evaluation Index

Considering the research practice from different scholars, the self characteristics of the Rare Earth Industry as well as the scientificity and availability of the data, the input indexes mainly include Total Assets, Operating Costs and Staff Number, while the output indexes include Operation Revenue and Net Margin[11, 12, 13], in which all the data are derived from 2011 annual financial statement of listed company. Among input indexes, Total Assets refers to all the assets able to bring economic interests that one economic entity has or control. It is one economic scale factor for a listed Rare Earth company and the most stable foundation for economic benefit, which can reflect the resource allocation optimizing condition of the listed Rare Earth company. Operating Costs is the input relative to the Operation Revenue, considering from internal management operational efficiency of the listed Rare Earth

company. Staff Number is the creator of the economic benefits of listed Rare Earth company and the most dynamic the source able to create more value. The final purpose for the company's production and management is to make profit, so in output indexes, Operation Revenue refers to the business income obtained from the engagement in some main production and operating activities, which can reflect the size of the company's profit ability. Net Margin, as the output index, reflects the overall profit status of a. The input-output data can be seen in "Table I".

TABLE I. THE INPUT-OUTPUT DATA OF LISTED RARE EARTH COMPANIES

DUM No.	DUM Name	Total Assets (million RMB)	Operating Costs (million RMB)	Staff Number	Operation Revenue (million RMB)	Net Margin (million RMB)
1	Shenzhen Zhongjin Lingnan Nonfemet (NONFEMET)	14042.40	15524.98	9912.00	18634.03	1093.60
2	Advanced Technology & Materials (AT&M)	7173.42	3726.52	3466.00	4530.70	434.34
3	Baogang Rare Earth	14726.63	3137.20	10187.00	11528.26	5608.81
4	Hunan Chenzhou Mining Group	3673.85	2753.87	7750.00	4081.42	540.23
5	Jiangxi Copper Corporation (JCC)	68149.63	106981.00	22500.00	117640.99	6610.48
6	Guangdong Rising Nonferrous Metals Group	2300.90	1695.66	2223.00	2222.13	221.22
7	Guangdong Fenghua Advanced Technology	3309.53	1650.79	7805.00	2081.89	165.06
8	Taiyuan Twin-Tower Aluminum Oxide	1567.75	1017.33	2503.00	1370.22	111.75
9	Minmetals Development	48970.39	158487.67	8492.00	162052.66	554.16
10	Xiamen Tungsten	12655.80	8121.69	9185.00	11910.40	1493.05
11	Zhong Ke San Huan	4969.13	4017.05	5116.00	5695.84	924.94
12	Aluminum Corporation of China (CHINALCO)	157134.16	137790.29	101259.00	145874.43	690.50
13	China Nonferrous Metal Industry's Foreign Engineering and Construction (NFC)	12548.68	8528.63	9177.00	10016.76	488.31
14	Hengdian Group DMEGC	4128.16	2729.56	6522.00	3521.85	90.52

C. The Reckoning based on CCR model

TABLE II. THE PERFORMANCE EVALUATION RECKONING OF RARE EARTH ENTERPRISE

DUM No.	The DEA Evaluation Value of θ^*	Seqencing	$\sum\lambda^*$	s_1^{-*}	s_2^{-*}	s_3^{-*}	s_4^{+*}	s_5^{+*}
1	0.8681	5	0.6569	0	0	2037.439	0	6250.806
2	0.6946	10	0.2383	1067.485	0	0	0	1492.38
3	1.0000	1	1.0000	0	0	0	0	0
4	0.9023	3	0.1972	0	0	5004.919	0	1164.045
5	0.9540	2	2.2090	11514.5	0	0	0	36279.36
6	0.7912	7	0.1086	0	0	663.0702	0	708.9879
7	0.6158	13	0.1292	0	0	3496.125	0	755.6885
8	0.7620	8	0.0729	0	0	1170.123		472.5097
9	1.0000	1	1.0000	0	0	0	0	0
10	0.8248	6	0.6385	0	0	1122.224	0	3593.621
11	0.8953	4	0.2605	0	0	1956.957	0	1427.144
12	0.6941	11	6.2686	0	0	7250.893	0	58825.23
13	0.6807	12	0.5174	0	0	1021.288	0	3754.483
14	0.7372	9	0.1852	0	0	2936.525	0	1407.15
Averafe Value	0.8157							

IV. RESULT ANALYSIS

A. Comprehensive Efficiency[14] Analysis

According to the reckoning of "TABLE II", the average efficiency of 14 listed Rare Earth companies is 0.8157, and there is 18.43%upside potential. Only the Comprehensive Efficiency of Baogang Rare Earth and Minmetals Development arrives strong DEA effective, the ideal state, which is "to obtain the maximum output with existing input" and "to make the minimum input with existing output", while the rest of the 12 enterprises are invalid in CCR model. There are only two out of 14 selected listed Rare Earth companies in the comprehensive efficiency effective frontier, accounted for only 14.2% of the total amount. The reckoning shows that the comprehensive efficiency of listed Rare Earth companies is lower, and the selected enterprises have great differences in comprehensive efficiency, in which the comprehensive efficiency of Guangdong Fenghua Advanced Technology is the minimum of only 0.6158.

B. Scale Efficiency Analysis

According to the value of $\sum \lambda^*$, among those DEA ineffective enterprises, Scale Efficiency of JCC and CHINALCO are decreasing, that is to say the increasing rate of output is less than the input. The Scale Efficiency of other rest 10 enterprises are increasing, that is to say the increasing rate of output is greater than the input. As far as the selected decision unit is concerned, 85.7% of the enterprises are scale inefficient.

C. Projection Analysis

Through calculating the indexes' projection values as well as the difference between the actual value and projection value of input and output of each DEA ineffective company, the ineffective companies can obtain the capable economical input and the output target would be achieved after improvement.

For the DEA ineffective DMU, it can be known from the DEA theory that $x_0^* = \theta^* x_0 - s^{*-}$ and $y_0^* = y_0 - s^{*+}$ can be used to adjust the DEA ineffective DMU into effective [15]. According to above analysis and combining with TABLE II, the DEA ineffective DMU can be adjusted into effective through the adjustment of each index, which can be seen in "Table III".

There exist excess DEA ineffective companies among the selected companies and insufficient output. Take DUM1, Shenzhen Zhongjin Lingnan Nonfemet (NONFEMET), as an example, the primary Total Assets was 14042.40 million RMB, the Operating Cost was 15524.98 million RMB and the Staff Number was 9912, which was a redundant input. After the adjustment, the Total Assets turns into 12189.89 million RMB, the Operating Cost is 13476.88 million RMB and the Staff Number reduces to 6567, from which the Net Margin changed from 1093.60 to 7344.40 million RMB. This adjustment can make the DEA ineffective DUM1 DEA effective.

TABLE III. THE PROJECTION RECKONING ADJUSTMENT OF EACH DEA INEFFECTIVE INDEXES

DUMNo.	Total Assets (million RMB)	Operating Costs (million RMB)	Staff Number	Operation Revenue (million RMB)	Net Margin (million RMB)
1	12189.89	13476.88	6567	18634.03	7344.40
2	3915.01	2588.35	2407	4530.70	1926.72
4	3315.07	3137.20	1988	11528.26	5608.81
5	53500.61	2484.93	21465	4081.42	1704.28
6	1820.50	102060.44	1096	117640.99	42889.84
7	2037.85	1341.62	1310	2222.13	930.21
8	1194.56	1016.48	737	2081.89	920.75
10	10438.08	775.16	6453	1370.22	584.26
11	4448.76	158487.67	2623	162052.66	554.16
12	109060.44	6698.50	63029	11910.40	5086.67
13	8541.41	3596.39	5225	5695.84	2352.08
14	3043.11	95634.65	1871	145874.43	59515.73

V. CONCLUSION

Results show that the overall efficiency of China's listed Rare Earth companies is not high, for which the average comprehensive efficiency is just 0.8157, and there exists significant difference in efficiency. From the perspective of scale efficiency, China's listed Rare Earth enterprises perform not well, among which scale benefits of most companies are increasing. For the DEA ineffective enterprises, this paper calculates out the target of reducing input redundancy and increasing output. If those enterprises improve management standards and control the appropriate development scale, they would become DEA effective.

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