2017 International Conference on Mathematics, Modelling and Simulation Technologies and Applications (MMSTA 2017)
ISBN: 978-1-60595-530-8

DEA Based Research on Investment Efficiency of Power Grid Marketing Project

Jun TONG[1,*], Bin ZHU[1], Ming WEN[2] and Zheng-zhuan MIU[3]

[1]State Grid Zhejiang Electric Power Company Electric Power Science Research Institute, Hangzhou China 310000

[2]State Grid Ningbo Power Supply Company, Ningbo China 315000

[3]State Grid Wenzhou Power Supply Company, Wenzhou China 325000

*Corresponding author

Keywords: DEA, Power grid marketing project, Investment efficiency.

Abstract. This paper combines DEA analysis method with screening index to evaluate the input and output efficiency of power grid marketing project, as well as making empirical analysis on the investment efficiency of power grid marketing project of 11 power companies in a province. The analysis results can be used for performance evaluation of each company, and supporting their management decision on capital allocation.

Introduction

A power grid enterprise is mainly engaged in managing assets related to power transmission, power transformation and power distribution, etc., and it is also responsible for operation of transmission and distribution network. Generally, the analysis on a power grid enterprise is developed from two aspects as distribution network and transmission network. A transmission network mainly undertakes the task of cross-company power transmission where there are huge differences between different companies and difficulties in obtaining detailed data. However, distribution network is closely related to users, and it is the most direct guarantee for providing high-quality power. Therefore, this paper emphasizes on discussing the input and output performance of distribution network. Since the basic management unit of distribution network is municipal or county-level power supply company, this paper will make contrastive analysis on the performance of power supply companies subordinate to power grid enterprise by regarding them as the evaluation objects through applied analysis so as to make model analysis and evaluation from the point of quantitative view. This paper uses Data Envelopment Analysis (DEA) to evaluate the efficiency of marketing project input of all companies through selectively analyzing the input and output indexes so as to support the performance evaluation and management decision on capital allocation of these companies.

Research Methods and Index Data

Basic Theory of DEA

Data Envelopment Analysis (referred to as DEA for short) is a new and multi-disciplinary field, which was put forward by operational researcher, Charnes and Cooper, etc., in 1978. DEA uses mathematic programming model to evaluate the relative efficiency (referred to as DEA efficiency) of “department” or “unit”, which is referred to as Decision-Making Unit (DMU), with multiple inputs, especially multiple outputs. On one hand, DEA method is an important approach to evaluate the relative efficiency of departments or units of the same kind with multiple inputs or multiple outputs. DEA method can evaluate this issue; more importantly, the evaluation result can reflect the result of large-scale social experiments. On the other hand, it has been widely used for efficiency and benefit studies.

If there are n DMU_j(j=1,2,…n) of the same kind, and each DMU has m kinds of "input", which indicates resource consumption of this DMU, and s kinds of "output", which indicates the "efficiency" value of the DMU after consuming the resource, then, the input and output of each DMU can be represented by the vector:

$$X_j = \left(x_{1j}, x_{2j}, \cdots, x_{ij}, \cdots x_{mj}\right)^T \qquad i = 1, 2, \ldots m$$
$$Y_j = \left(y_{1j}, y_{2j}, \cdots, y_{rj}, \cdots y_{sj}\right)^T \qquad r = 1, 2, \ldots s \quad j = 1, 2, \ldots, n$$

For the $j_0\ (1 \le j_0 \le n)$ decision-making unit, DMU_{j0} can formulate two input-oriented and output-oriented linear programming models:

LP1 (input): seek one linear combination for $DMU_j\ (1 \le j \le n)$. It counts minimum input quantity on the premise of keeping the output quantity of DMU_j at least, and inspects whether the input quantity is smaller than original input, with the corresponding model as follows;

$$\min \theta$$
$$\text{s.t} \sum_{j=1}^{n} X_j \lambda_{j0} \le \theta X_{j0}$$
$$\sum_{j=1}^{n} Y_j \lambda_j \ge Y_{j0}$$
$$\lambda_j \ge 0,\ j = 1, 2, \ldots n$$

Obviously, the optimal solution is $\theta' \le 1$. If $\theta' < 1$, it indicates that the input quantity of newly combined DMU is smaller and the original DMU_{j0} is invalid; if $\theta' = 1$, it indicates that the original DMU_{j0} is valid.

LP2 (output): seek one linear combination for $DMU_j\ (1 \le j \le n)$. It counts the possible maximum output quantity on premise that it is no larger than original input DMU_{j0}, and inspects whether the output quantity is larger than original output, with the corresponding model as follows

$$\max \omega$$
$$\text{s.t} \sum_{j=1}^{n} X_j \lambda_{j0} \le X_{j0}$$
$$\sum_{j=1}^{n} Y_j \lambda_j \ge \omega Y_{j0}$$
$$\lambda_j \ge 0,\ j = 1, 2, \ldots n$$

Obviously, the optimal solution is $\omega' \ge 1$. If $\omega' > 1$, it indicates that the output quantity of newly combined DMU is larger and the original DMU_{j0} is invalid; if $\omega' = 1$, it indicates that the original DMU_{j0} is valid.

Selection of Input-Output Index

It can be classified as per input and output data according to DEA index selection principle. Basis for confirming input or output indexes: the No.j DMU is the valid sufficient condition (X_{j0}, Y_{j0}) for DEA. It is an efficient solution to multi-objective programming issue - Pareto. When using this theory to make evaluation, the smaller input and larger output shall be better. Therefore, when it is used for evaluation, the smaller indexes should be selected as input index and the larger indexes should be selected as output index. This paper mainly uses frequency statistics method, theoretical

analysis method and expert consultation method to select indexes. The frequency statistics method is mainly used to make statistics on existing relevant research reports and dissertations to select those indexes frequently used. The theoretical analysis method is mainly used to classify, compare and integrate connotation, characteristics, basic elements and main issued of indexes to select those indexes with stronger pertinence. The expert consultation method is mainly used to further seek advice from experts on the basis of pointing out evaluation indexes initially to adjust indexes. Comprehensively using three methods mentioned above could obtain general index system.

Use the model to make empirical analysis on the relative performance of power grid enterprises: firstly, use super-efficiency model to analyze data of relevant enterprise on the premise that empirical samples has been confirmed so as count the total vrste of companies respectively, and understand the resource utilization status, improvable direction and improvement magnitude of relatively inefficient enterprises under present operation condition through slack variable analysis.

The comprehensive technical efficiency of an enterprise indicates making minimum input with given output (from the perspective of input) or obtaining the maximum output with the given input (from the perspective of output) on the condition that assuming the return to scale is unchanged. It is an aggregate measurement on the enterprise's ability of allocating resources, resource using efficiency, etc. Comprehensive technical efficiency is the arithmetic product of pure crste and vrste.

Slack variable analysis: for management personnel, they are more interested in how to improve the resource allocation of relatively inefficient company so as to obtain relative efficiency, thus improving management performance. It is possible to make slack variable analysis after understanding all reference sets. For a company with crste of, the target and projection values equal to actual value, indicating that both of its input and output values have been used most efficiently and need not to be improved. However, for a company with the crste being smaller than, it has one input or output at least. In addition, its target value and projection value do not equal to actual value; and the difference between actual value and projection value is the improvable space for resources of relatively inefficient company. Therefore, slack variable analysis can be used to understand the improvable space for resources of a relatively inefficient company, namely, which input could be reduced by what margin when the output is given. Therefore, management personnel of the company could make adjustment as per the input redundancy and output deficiency, and their margins so as to improve operation efficiency.

Table 1. List for evaluation indexes of marketing efficiency.

Indexes	Explanation
Investment amount	All kinds of costs input for power marketing
Power sales	Refers to the actual annual power sales volume of power enterprises
Main business revenue	Refers to the total annual revenue from main business (revenue of power sales) of power enterprises
Power consumption information collection rate:	Refers to the collection accuracy
Meter coverage rate	Refers to the coverage rate of ammeter.

An index system could objectively and truthfully reflect and summarize characteristics of present power grid enterprises from perspectives of service scope, organization scale, production scale and asset scale, etc., which ammeters a solid data foundation for analyzing the efficiency of selected model.

DEA Analysis and Results

According to the selected input and output indexes, it is ultimately confirmed that one input index is selected, namely the investment amount, and 4 output indexes are selected, namely, power sales, main business revenue, power consumption information collection rate and meter coverage rate; where, investment amount data comes from actual revenue of marketing projects, data of power sales and main business revenue comes from annual report statement of State Grid Electric Power Corporation of a province, data of power consumption information collection rate and meter coverage rate are collected from power consumption information collection system of State Grid

Electric Power Corporation of a province. Analyze the actual development situation of marketing projects of all companies in 2016 based on that.

The input-output index data of all companies in 2016 are shown in Table 2:

Table 2. Evaluation index data on investment efficiency of 11 companies in 2016.

Indexes / DMU	(I) Investment amount (0.1 billion Yuan)	(O) Power sales (TWh)	(O) Main business revenue (0.1 billion Yuan)	(O) Power consumption information collection rate (%)	(O) Meter coverage rate (%)
Area 1	3.01	625	331	99.38	99.83
Area 2	1.07	203	109	99.52	99.83
Area 3	1.99	407	221	99.71	99.75
Area 4	2.25	290	155	99.52	99.75
Area 5	0.94	67	21	99.36	99.68
Area 6	2.45	589	328	99.70	99.84
Area 7	0.73	96	47	99.46	99.78
Area 8	1.65	351	192	99.63	99.85
Area 9	1.65	267	129	99.56	99.86
Area 10	2.54	354	191	99.64	99.84
Area 11	0.32	34	22	99.80	99.94

Table 3. Descriptive statistics on performance evaluation index data of State Grid Electric Power Corporations of a province in 2016.

	Investment amount (0.1 billion Yuan)	Power sales (TWh)	Main business revenue (0.1 billion Yuan)	Power consumption information collection rate (%)	Meter coverage rate (%)
Max	3.01	625	331	99.8	99.94
Min	0.32	34	21	99.36	99.68
Average	1.691	298.455	158.727	99.571	99.814
SD	0.848	195.792	108.57	0.14	0.07

To further demonstrate the scientificity of selected indexes when using DEA method, we make further verification through quantitative correlation analysis. It is considered by Reynolds (2002) that scientific and rational index system guarantees that the input index should be remarkably related to at least one output index. Therefore, we make Person correlation coefficient analysis for selected input and output indexes so as to understand whether the selected input and output indexes would define its influence on the operation efficiency of power grid enterprise, and avoid affecting the result accuracy due to inappropriately selected variables. Following Table shows the correlation analysis results between input and output indexes.

Table 4. Correlation statistics on performance evaluation index of State Grid Electric Power Corporations of a province in 2016.

	Investment amount (0.1 billion Yuan)	Power sales (TWh)	Main business revenue (0.1 billion Yuan)	Power consumption information collection rate (%)	Meter coverage rate (%)
Investment amount (0.1 billion Yuan)	1	0.0001	0.0002	0.8023	0.8248
Power sales (TWh)	0.0001	1	0.0000	0.8852	0.8083
Main business revenue (0.1 billion Yuan)	0.0002	0.0000	1	0.7727	0.7475
Power consumption information collection rate (%)	0.8023	0.8852	0.7727	1	0.0520
Meter coverage rate (%)	0.8248	0.8083	0.7475	0.0520	1

Generally, DEA model analyzes the comprehensive benefit of input and output from three aspects of crste, vrste and scale. According to the model analysis result of 2016, it can be seen that investment of Ningbo and Zhoushan is the most efficient DEA and other companies have investment redundancy or output deficiency problem from the aspect of crste. The return to scale of Hangzhou and Lishui keeps decreasing and increasing respectively, and that of the rest companies is unchanged from the aspect of investment scale. Therefore, Ningbo and Zhoushan can be used as reference standards for other companies for investment planning in the future. Specifically, Ningbo can be used as a reference standard for Jiaxing, Jinhua, Lishui, Shaoxing and Wenzhou, Zhoushan can be used as a reference standard for Huzhou, Quzhou and Taizhou to adjust input and output quantity, thus realizing DEA efficiency.

Table 5. Compares ion on efficiency evaluation of State Grid Electric Power Corporations of a province in 2016.

DMU	Crste	Vrste	Scale		peers	
Area 1	0.864	1.000	0.864	drs	1	
Area 2	0.905	0.905	1.000	-	6	11
Area 3	0.880	0.880	1.000	-	11	6
Area 4	0.579	0.579	1.000	-	11	6
Area 5	0.475	0.475	0.999	irs	11	6
Area 6	1.000	1.000	1.000	-	6	
Area 7	0.764	0.764	0.999	-	6	11
Area 8	0.931	0.931	1.000	-	11	6
Area 9	0.736	0.736	1.000	-	6	11
Area 10	0.609	0.609	1.000	-	11	6
Area 11	1.000	1.000	1.000	-	11	

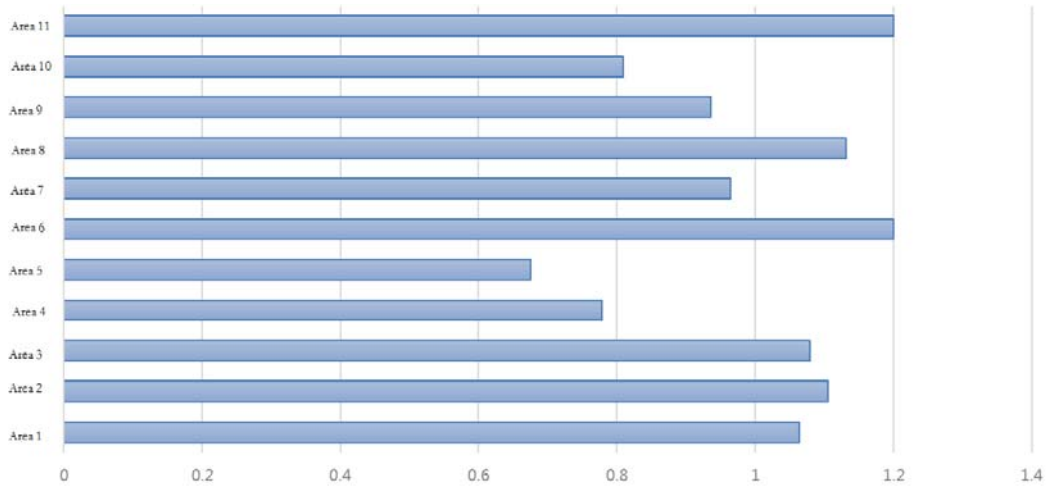

Figure 1. Bar diagram of crste value of all companies in 2016.

For management personnel, they are more interested in how to improve the resource allocation of relatively inefficient company so as to realize relative efficiency, thus improving management performance. It is possible to make slack variable analysis after understanding all reference sets. For an efficient company, the target (projection value) equals to actual value, indicating that both of its input and output values have been used most efficiently and needs not to be improved. However, for a company with relatively lower efficiency, it has one input or output at least. In addition, its target value (projection value) does not equal to actual value; and the difference between actual value and projection value is the improvable space for resources of relatively inefficient company.

Therefore, slack variable analysis can be used to understand the improvable space for resources of a relatively inefficient company, namely, which input could be reduced by what margin when the output is given. Following Table is the slack variables of power enterprise in 2016, which shows the input redundancy and output deficiency of non-efficient companies. Therefore, management

personnel of the company could make adjustment as per the input redundancy and output deficiency, and their margins so as to improve operation efficiency.

According to the result of 2016, it is concluded that, generally, the total marketing input from perspective of input is an important link for improving performance. According to analysis on results, it is concluded that the companies, apart from Area 1, Area 6 and Area 11, need to reduce input amount. Specifically, Area 4 and Area 10 need to reduce total marketing input by a large margin. From the perspective of output, power sales have realized DEA efficiency in 11 regions. The revenue output for main business of Area 5 and Area 9 has relatively large growth space; the accuracy of power consumption information collection system in Area 5 and Area 7 can be further improved, and the meter coverage rate in Area 5 still has the room for improvement.

Table 6. Research on slack variable analysis of State Grid Electric Power Corporations of a province in 2016.

No.	DMU	Excess input	Output deficiency			
		Investment amount (0.1 billion Yuan)	Power sales (TWh)	Main business revenue (0.1 billion Yuan)	Power consumption information collection rate (%)	Meter coverage rate (%)
		S-(1)	S+(1)	S+(2)	S+(3)	S+(4)
1	Area 1	0	0	0	0	0
2	Area 2	0.101	0	6.178	0.250	0.080
3	Area 3	0.238	0	6.654	0.023	0.123
4	Area 4	0.948	0	8.146	0.234	0.144
5	Area 5	0.493	0	19.195	0.434	0.254
6	Area 6	0	0	0	0	0
7	Area 7	0.172	0	9.184	0.329	0.149
8	Area 8	0.113	0	4.778	0.113	0.033
9	Area 9	0.436	0	21.465	0.198	0.038
10	Area 10	0.992	0	7.432	0.102	0.042
11	Area 11	0	0	0	0	0

Main Conclusion and Policy Suggestions

According to aforementioned analysis, it is suggested that when making investment plans for 2018, companies should consider the crste of each company in 2016. Apart from companies in Area 6 and Area 11, the rest ones could reduce investment amount or increase output appropriately, especially companies in Jinhua and Wenzhou, which need to reduce by a large margin. In addition, Area 3, Area 4, Area 5, Area 8 and Area 10 could regard Area 6 as a reference standard, Area 2, Area 7 and Area 9 could take Area 11 as a reference standard to adjust their investment input and output. For example, the revenue output for main business of Area 5 and Area 9 has relatively large growth space; the accuracy of power consumption information collection system in Area 5 and Area 7 can be further improved, and the meter coverage rate in Area 5 still has the room for improvement. It is possible to realize better and more rational investment efficiency of companies through making aforementioned adjustment.

References

[1] Deng Hongbo & Lu Lin, *The Urban Tourism Efficiencies of Cities in Anhui Province Based on DEA Model* [J]. Journal of Natural Resources, February 2014.

[2] Zhao Qi, *DEA Based Empirical Research on Compulsory Education Resource Allocation* [J], Educational Research, March 2015.

[3] Ming Zeng, Zi-zhi Xu, Song Xue, Xiao-li Zhu. Grid project quantities management system based on bill of quantities [J] Electric Power, 2012, 45(2): 70-73.