Determination of Economic Optimal Strategy for Increment of the Electricity Supply Industry in Iran by DEA

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Abstract

This paper presents an empirical efficiency analysis approach to analyze the efficiency and performance of utilities to determine the best plants to increase the manpower abilities. In this paper, using Data Envelopment Analysis (DEA) and Most Productive Scale Size (MPSS) notion, optimal strategies are determined. This article uses the above method for increasing the manpower productivity in electricity producers.

Keywords: Data Envelopment Analysis; Efficiency; Multiple Objective Programming; Most Productive Scale Size

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1 Introduction

One of the most important of effective factors on manpower productivity is personnel motion. Unfortunately, up to now, no scientific method is presented to evaluate the personal motion by and creation of facilities in order to its improvement in electricity industry. This research tries to determine the most important effective factors on personal motion and necessary indices for their evaluating. Then the best and most productive producers are distinguished with the view of manpower motion by Data Envelopment Analysis (DEA) and then strongness and weakness points for other producers are determined in comparison with the most productive producer and after it are presented the necessary strategy about this matter.

DEA is a linear-programming methodology, which uses data on the input and output quantities of the utilities to construct a piece-wise linear surface, or efficient frontier over the data points. The efficiency measures are then calculated relative to this frontier in either input-oriented or output-oriented focus. In the input-oriented case, the DEA method defines the frontier by seeking the maximum possible proportional reduction in input usage, with output levels held constant. While, in the output-oriented case, the DEA method seeks the maximum proportional increase in output performance, with input levels held fixed [5].

This paper is set to contain four sections. In the following section, the preliminary definitions of DEA method is described. In Section 3, data are introduced. The fourth section brings some final comments.

2 Preliminary definitions

The seminal work of Charnes, Cooper and Rhodes (CCR) (1978) [3] advanced the methodology of Data Envelopment Analysis (DEA) for the constant returns to scale and since then a broad spectrum of empirical applications has emerged in several areas (see Seiford, 1994). The flexibility of the approach that only assumes piece-wise linearity and convexity of the technology might explain its influential diffusion. The data requirements are restricted to a list of representative inputs and outputs, and it is worth mentioning that no price data is necessary. A first intuition refers to the comparison of virtual output (a linear combination of outputs) with a virtual input (a linear combination of inputs) such that the weights are chosen so as portray each decision making unit (DMU) in the most favorable manner. More precisely, consider a situation where there are m inputs (indexed by subscript i), s outputs (indexed by subscript r) and n DMUs (indexed by subscript j); additionally let $x_{ij} > 0$; $y_{rj} > 0$; respectively, refer to strictly positive values for inputs and outputs of the j th DMU. CCR consider the following fractional programming problem:

$$\begin{aligned}
& \max \frac{\sum_{r=1}^s u_r y_{rp}}{\sum_{i=1}^m v_i x_{ip}} \\
& \text{s.t.} : \frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1, \quad j = 1, \dots, n, \\
& u_r, v_i \geq 0, \quad r = 1, \dots, s, \quad i = 1, \dots, m,
\end{aligned} \tag{1}$$

This problem has to be solved for each DMU. The first constraint indicates that no DMU can operate beyond the efficiency frontier, whereas the second constraint indicates non reactive weights. The solution of those programs allows the generation of relative efficiency scores and there exist two two orientations in DEA analysis. First, one can conceive obtaining the maximum output for given level of input (output orientation) and second it is possible to consider the minimum use of inputs for given levels of outputs (input orientation). The results of the two orientations would be equivalent only in the case of constant returns to scale.

Model (1) is a linear fractional programming problem and can be solved by transforming to a linear programming problem as:

$$\begin{aligned}
& \max \sum_{r=1}^s u_r y_{rp} \\
& \text{s.t.} : \sum_{r=1}^s u_r y_{rj} - \sum_{i=1}^m v_i x_{ij} \leq 0, \quad j = 1, \dots, n, \\
& \sum_{i=1}^m v_i x_{ip} = 1 \\
& u_r, v_i \geq 0, \quad r = 1, \dots, s, \quad i = 1, \dots, m.
\end{aligned} \tag{2}$$

Dual of (2) is as follows:

$$\begin{aligned}
& \min \theta \\
& \text{s.t.} : \sum_{j=1}^n \lambda_j x_{ij} - \theta x_{ip} \leq 0, \quad i = 1, \dots, m, \\
& \sum_{j=1}^n \lambda_j y_{rj} \geq y_{rp}, \quad r = 1, \dots, s, \\
& \lambda_j \geq 0, \quad j = 1, \dots, n.
\end{aligned} \tag{3}$$

The more general case of variable returns to scale was considered by Banker (1984) [1] and Banker et al. (BCC) (1984) [2] who extended the CCR model by incorporating an additional convexity constraint. The most important result in that context is that the total efficiency (as obtained from the CCR model) can be factored in terms of the technical efficiency (as obtained from the BCC model) and scale efficiency. This model is as follows:

$$\begin{aligned}
 & \min \theta & (4) \\
 & \text{s.t.} : \sum_{j=1}^n \lambda_j x_{ij} - \theta x_{ip} \leq 0, \quad i = 1, \dots, m, \\
 & \sum_{j=1}^n \lambda_j y_{rj} \geq y_{rp}, \quad r = 1, \dots, s, \\
 & \sum_{j=1}^n \lambda_j = 1 \\
 & \lambda_j \geq 0, \quad j = 1, \dots, n.
 \end{aligned}$$

The determination of returns to scale behavior (increasing, constant, or decreasing) from the sum of the optimal weights in the unconstrained problem was first suggested by Banker (1984). However, Banker did not address the possibility of multiple solutions for the weights. Multiple solutions will exist in the unlikely event that the MPSS for the ray in question is not unique. However, the concept of the MPSS is merely one of maximal 'average product', and Banker's criteria are easily modified to take into account the possibility of multiple solutions.

The MPSS for a given input out mix is the scale size at which the output produced per unit of inputs is maximized. In the other word, a production possibility (X_p, Y_p) represents a MPSS, if and only if for all production possibilities $(\alpha X_p, \beta Y_p)$ in production possibility set, we have $\frac{\beta}{\alpha} \leq 1$. Considering the above mentioned definition, Hosseinzadeh et al. [4] suggested the following multi objective linear programming model to determine MPSS's:

$$\begin{aligned}
 & \min(\alpha_1, \dots, \alpha_m) & (5) \\
 & \max(\beta_1, \dots, \beta_s) \\
 & \text{s.t.} : \sum_{j=1}^n \lambda_j x_{ij} \leq \alpha_i x_{ip}, \quad i = 1, \dots, m, \\
 & \sum_{j=1}^n \lambda_j y_{rj} \geq \beta_r y_{rp}, \quad r = 1, \dots, s, \\
 & \sum_{j=1}^n \lambda_j = 1, \\
 & \lambda_j \geq 0, \quad j = 1, \dots, n.
 \end{aligned}$$

In (5), the objective is to minimized inputs and maximized outputs for all DMU possible. To reach the goals in (5), let:

$$\begin{aligned} x_i &= \min(x_{ij}) , \quad j = 1, \dots, n \\ y_r &= \max(y_{rj}) , \quad j = 1, \dots, n \end{aligned} \quad (6)$$

In this case, we are trying to make the distance between x_{ip} , y_{rp} as close as possible to x_i and y_r . Hence the goal of functions α_i and β_r can be considered as $\frac{x_i}{x_{ip}}$ and $\frac{y_r}{y_{rp}}$, respectively. Therefore (5) is transformed to the following linear programming:

$$\begin{aligned} \text{Min} \quad & \sum_{i=1}^m z_i + \sum_{r=1}^s z'_r \\ \text{S.t} \quad & \sum_{j=1}^n \lambda_j x_{ij} \leq \alpha_i x_{ip}, \quad i = 1, \dots, m, \\ & \sum_{j=1}^n \lambda_j y_{rj} \geq \beta_r y_{rp}, \quad r = 1, \dots, s, \\ & \alpha_i - z_i \leq \frac{x_i}{x_{ip}}, \quad i = 1, \dots, m, \\ & \beta_r + z'_r \geq \frac{y_r}{y_{rp}}, \quad r = 1, \dots, s, \\ & \sum_{j=1}^n \lambda_j = 1, \\ & \lambda_j \geq 0, \quad j = 1, \dots, n. \end{aligned} \quad (7)$$

If α^* and β^* are optimal vector for (7) then DMU_p is an MPSS if and only if:

$$\alpha_i^* = 1 \text{ and } \beta_r^* = 1, i = 1, \dots, m, r = 1, \dots, s, \quad (8)$$

otherwise by following transformation that can be made MPSS:

$$\begin{aligned} x_{ip} &\rightarrow \alpha_i^* x_{ip}, i = 1, \dots, m, \\ y_{rp} &\rightarrow \beta_r^* y_{rp}, r = 1, \dots, s. \end{aligned} \quad (9)$$

3 Data

In this study, we consider decision making units as the heat power stations in throughout of Iran. They are including the power stations in form of vapory, gas and compound cycle. There is a lot of indices about evaluation of man-power's motivation in heat power station. Given this, the following indices

have determined after consulting with experts of power stations and managers of Tavanir Company:

the number of technical and executive staff, the staff of security units, health cost, overtime work cost, duty cost, reward and payment for new year, working period right, transfer payments, rent and freight, clinic cost, other costs related to staff information about management, oldness, years of working, years of management, education course, and so forth- the number of damaged individuals in separately of kind and cause of accident, the number of resulted to death, the paid damaged to accidents and satisfaction of the staff.

In order to determination of the above indices quantity in different power stations was needed two kinds of data as follows:

1. The data that must got from different power stations, such as information about management and so forth for this purpose an information form designed.
2. The data that must got from the staff such as effectiveness of security unit, environment health. Therefore a questionnaire designed and completed by 20 percent of the personnel in the power stations at random. This study preformed on the basis of received data from 10 power stations.

To reduce the complexity, the following inputs and outputs that have obtained from combination of above indices is determined.

Inputs	Outputs
1. Work safety and per capita cost	1. Personnel's motivation
2. Per capita cost	
3. Education and experiment of managers	

Table 1. Inputs and outputs

The above data is related to the heat power stations in throughout of the country in 1999 year.

4 Conclusion and propositions

With attention to chosen indices and composition of them, the calculated inputs and outputs on basis of the questionnaires and information forms is as table 2.

DMU	Input1	input2	input3	Output
01	0.28762	0.46317	0.96654	0.89557
02	0.34050	0.48369	0.98980	0.88241
03	0.72310	0.34632	0.97640	0.89214
04	0.20873	0.54484	0.95277	0.99311
05	0.55511	0.69094	0.92339.	0.86285
06	0.13038	1	0.95390	1
07	0.26621	0.57672	1	0.90473
08	1	0.43292	0.84319	0.95466
09	0.00490	0.44820	0.98153	0.92252
10	0.07151	0.83123	0.95258	0.87404

Table 2. Inputs and outputs

Obtained results are explained in the table 3.

DMU	CCR	composition coefficients
01	0.92	L3=0.36, L4=0.44, L8=0.15
02	0.93	L4=0.11, L6=0.03, L9=0.80
03	1.00	L3=1
04	1.00	L4=1
05	0.86	L4=0.12, L6=0.35, L8=0.41
06	1.00	L6=1
07	0.86	L4=0.85, L6=0.01, L8=0.05
08	1.00	L8=1
09	1.00	L9=1
10	0.92	L6=0.49, L9=0.42

Table 3. Efficiencies by CCR model

In table 3, columns 1,2,3 are denoted to power station code, obtained efficiency of CCR's model and and composition coefficients, respectively. As seen, power stations 04,05,06,08 and 09 have the most production scale size. In other, to arrive the most production scale size for the units that is not laid in MPSS's domain, optimal strategy for inputs and outputs are determined as table 4.

DMU	Input1	input2	input3	Output
01	0.27850	0.44850	0.93600	0.94290
02	0.33688	0.47854	0.97927	0.93873
05	0.54249	0.67524	0.90240	0.98051
07	0.25158	0.54503	0.94506	0.99421
10	0.07230	0.74146	0.96305	0.96048

Table 4. New inputs and outputs

The obtained results from performance of model 7 have arrived in table 5. In this table, the columns 1,2,3,4,5 are showed power station code, α_1 , α_2 , α_3

and β_1 . It is mentionable that, due to each power station have tree inputs and outputs; consequently there is necessitated tree α and one β .

DMU	α_1	α_2	α_3	β_1
01	0.0170	0.9677	1.0155	1.0299
02	0.1439	0.9266	0.9916	1.0455
03	0.0678	1.2942	1.0053	1.0341
04	0.0235	0.8226	1.0302	0.9289
05	0.0088	0.6487	1.0630	1.0692
06	0.0376	0.4482	1.0290	0.9225
07	0.0184	0.7772	0.9815	1.0197
08	0.0723	0.8000	1.1580	0.9345
09	1	1	1	1
10	0.0685	0.5392	1.0304	1.0555

Table 5. The optimal vale of α and β

With attention to table 5, we find that power station 09 has the most production scale size and other power stations can transformed to a MPSS with exerting of obtained coefficient on basis of relation 8. The table 6 shows the calculated quantities for transformation to the most production scale size for all studied power stations.

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