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Assessing relative efficiency of human force by DEA model

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Abstract

The organizations' managers should assess and measure the operation of the departments under their direction in order to improve their general organization operation. In this study, the relative efficiency of human force was assessed by DEA model; the measurement and cross-sectional method was used to collect necessary data. First, the main input and output variables were selected and then an appropriate Data Envelopment Analysis model was selected (Yield model in proportion to stable criterion) to assess the relative efficiency. By modelling and executing the model in harmony with assessing relative efficiencies of the units, the targeted inputs and outputs were defined by both axial importing and exporting methods in order to make efficient the inefficient ones.

Keywords: Input, output, efficiency, DEA.

Introduction

Organizations' operation assessment plays an important role in managers' decisions; in line with this, the organizations' efficiency and exploitation should be assessed in order to supervise economic growth in future decisions. Nowadays, one of the most important economic goals of countries is to achieve economic growth by exploitation. The organization operation is exploitable when it is efficient and applicable and each one does not indicate individually the exploitation increase. If we measure the favorable use of the inputs in line with improving the outputs production, in fact, we have measured the efficiency rate and having combined both of them, it is possible to have the exploitation signification in a way that how much the organizational goals have been achieved by using the inputs. In this field, one of the appropriate and efficient devices is the Data Envelopment analysis which is used as a nonparametric method to measure the efficiency of the units who decide. Also the efficient paradigms by which the inefficient units were assessed are presented to the inefficient ones. The efficient and inefficient paradigms have the same inputs, but the former are the units who have produced the same outputs or more by using less inputs. The vast variety in the findings has led to use increasingly the technique. That is why the technique has been developed theoretically, too and has become an active branch in operational research science. The efficiency assessment in DEA (Data Envelopment Analysis) is a mathematical program attitude benefiting from different inputs and outputs to measure efficiency; for example, in DEA it is supposed a group of DMUs (Decision maker units) that there are 'n' number of DMU assessed by virtue of the amount of inputs and outputs. Suppose that x_{ij}(i=1,2,….,m) and y_{rj}(r=1,2,..,s) which are the amounts indicating the inputs and outputs in DMU_j(j=1,2,…,n). Intersecting efficiency is often assessed as a two step process. In the first step we measure one of the traditional models of DEA such as CCR of Charnes et al.(1978); especially for each DMU_p the θ_{pp} efficiency is assessed by CCP model as follows:

$$\text{Max } \theta_{pp} = \frac{\sum_{r=1}^{s} urpYrp}{\sum_{i=1}^{m} vipXip}$$

s.t

$$\frac{\sum_{r=1}^{s} urpYrj}{\sum_{i=1}^{m} vipXij} \leq 1, j = 1,2,...,n$$

$u_{rp} \geq 0$, r=1,2,…,s

$v_{ip} \geq 0$, i=1,2,…,m

When v_{ip}(i=1,2,…,n) and u_{rp}(r=1,2,…,s) are the input and output loads given to i^{th} input and output r^{th} the partial theorem known as CCR may be converted to the linear programming theorem.

Research questions and hypothesis

1 - Do the same loads for the inputs and outputs influence the efficiency rate?
2 - What are the advantages and disadvantages of the classification methods?
3 - What are the mechanisms to make efficient the inefficient units?

Definition of key terms

Efficiency: Richard l. Daft states, "Efficiency is the sources used to produce a product " and Konts states , "Efficiency is to achieve goals by the least sources", but by virtue of other offered definitions it is possible to define efficiency as the ratio of real yield to the expected one(Kamal Parhizgar, "Humanistic Relations In Management", 2000).

Input: If this factor increases or other ones remain stable, the efficiency decreases and if it decreases or other ones remain stable, the efficiency increases.

Output: If this factor decreases or other ones remain stable, the efficiency decreases and if it increases or other ones remain stable, the efficiency increases.

Operational significations: DEA is the abbreviation for 'Data Envelopment Analysis of a mathematical program model to assess DMU (Decision maker units) with several inputs and outputs. Researchers have paid attention to efficiency measurement because of its importance in assessing company's or organization's operation. Having used a method similar to efficiency measurement in engineering subjects, Farel (1957) measured the efficiency for production unit; his case for efficiency measurement included one input and one output.

Production function: Production function indicates the relation between the production sources used by a production company (Namely the inputs) and the gained goods or services (Namely outputs) on a defined time without taking into consideration the prices. The mathematical figure of the production function is as follows:

$Y=F(X_1, X_2, \ldots)$

Where:

Y = Output rate (Product)

$(X_1, X_2, \ldots)$ = The rate of production sources and factors (Inputs)

Production border = By virtue of efficiency literature the production function is related to production border; in fact, the latter indicates the maximum product produced by a different amount of the sources …..

Production possibility set: A set of all inputs and outputs together indicating all amounts of the production (Output) for different sources (Inputs); in other words, all possible compounds of inputs and outputs are known as production possibility set.

Production possibility set of 'n' agencies (j=1, 2, ---) with 'm' inputs $x_j = \{x_{1j}, x_{2j}, \ldots\}$ and 's' $\{y_j=\{y_{1j}, y_{2j}, \ldots$ { is defined as follows:

{ The output 'Y' may be created by 'tx' input T - } (X, Y) |

We agree with some principles which are the base of DEA models.

First principle: Observations inclusion: $(X_j, y_j) \in T$, $j=1,\ldots,n$

Second principle: Possibility: If $(X, Y) \in T$, $\bar{X} \leq X$ *and* $\bar{Y} \leq Y$, *then* $(\bar{X}, \bar{Y}) \in T$

Third principle: Yield by stable criterion or ray infiniteness : if $(X, Y) \in T$, *then for each* $\lambda \leq 0$ *and* $(\lambda x, \lambda y) \in T$.

Fourth principle: Convexity: if $(X, Y) \in T$ and $(X', Y') \in T$ and $0 \leq \lambda \leq 1$, then for each $\lambda \leq 0$ and $(\lambda x, \lambda y) \in T$.

Fifth principle: The extrapolation minimum 'T' is the smallest set which is applicable in the first, second, third and fourth principles; all the sets applicable in above principles create the complex 'T_c':

$$T_c = \{(X, Y) \mid X \geq \sum_{j=1}^{n} \lambda_j X_j, Y \leq \sum_{j=1}^{n} \lambda_j Y_j, \lambda_j \geq 0, j = 1,\ldots n\}$$

The complex border is a direct line passing through the origin in a way that T_c is a convex cone including all the units which allow the set to create the CCR model. Likewise, the set to allow the BCC model production is defined as follows: CCR model indicates the yield condition to stable criterion and BCC model indicates the yield to changeable criterion. The CCR and BCC models are described later.

DEA (Data Envelopment Analysis): Charnes, Cooper and Rodenz defined DEA in their article as follows: DEA is a mathematical program model used for the observed data to create a new method to estimate experimentally the efficiency border as production function which is the modern economic base.

DMU definition: DMU is a unit which creates the output vector (For example, $X=(x_1,x_2,\ldots)$) when it receives the input one (For example, $Y=(Y_1,Y_2,\ldots)$). The DMUs are independent units which use similar inputs to create similar output ones. DEA assesses the congruous DMUs' operation; for example, the state hospitals are congruous units which are the inputs including all the nurses, physicians, operating rooms, etc. and the outputs include outpatients treatments, nos. of operations, cured patients, etc.

Input: If this factor increases or other ones remain stable, the efficiency decreases and if it decreases or other ones remain stable, the efficiency increases.

Relative efficiency: DMU_k is dominant on DMU_h, if and only if:

$$\begin{pmatrix} -X_k \\ Y_K \end{pmatrix} \geq \begin{pmatrix} -X_h \\ Y_h \end{pmatrix}$$

And the inequality is at least for one component. Suppose that $0 \in \{1,2,\ldots,n\}$ and DMU_O are relative efficient. If and only if no point is found in the possibility complex dominant on DMU_O.

Materials and methods

This study is cross-sectional- descriptive. Considering the data and when the inputs increase in the health sections the outputs usually increase, too. CCR model which is a model yielding a stable criterion was used. In most of the internal and foreign studies done, this was used to analyze the relative efficiency of the health and treatment sections. The assessment was done by axis input and output CCR model; the findings of both are compared and analyzed.

CCR method: CCR method is the yield model in stable criterion namely when the input increases the output increases by the same proportion, too. By DEA model having presented the relative efficiency and weak points of the organization are defined and favorable rate of operational indices the organizational policy is promoted to be efficient and profitable. Also, the method defines the efficient paradigms whose inputs are similar to the inefficient ones, but they produce more or the outputs by using less inputs. By virtue of such vast variety of the findings the technique is used increasingly; after the theory, the technique has been used increasingly and has become an active branch of study science in operations. DEA models group the data into two input and output axis groups in view of the improvement direction type. The axis input one emphasizes on decreasing the inputs to become efficient and the axis output ones emphasizes on increasing the data to promote the efficiency of the inefficient units. Some findings from using DEA model are as follows: assessing efficiency of the units and ranking them, defining operational potentials, defining favorable rates in each index and assessing operational growth in different periods.

Ratio analysis method in efficiency measurement: One of the typical methods to measure efficiency is to use the ratios by which a ratio is assessed and analyzed between the items related to numerical data of management. The ratios are used in different economic, financial and industrial fields. The ratio analysis methods are as follows: Trend method, Percent method, Comparison method, and Index method.

Trend method: By the method having taken into consideration a ratio as the base year some ratios are made by next data to be compared with the base one so the growth evolution or rate is shown.

Percent method: By the method different components of a set is taken into consideration as a percent of a general number.

Comparison method: The method compares the ratio between two related components. Such ratios are divided into static and dynamic ones; the static one indicates the ratio between two components in a defined date and the dynamic one indicate exactly the flow ratio and period, but in a more general meaning it is usually the rate due to total assets and sale.

Index method: Index is a statistical measure indicating the changes of one or more interrelated variables in proportion to time, geographical situation or other features such as profession. The method was created by Wall to analyze economic activities of any company to assess its validity; several proportions are converted to a simple index by the method.

Measuring the efficiency of a unit through DEA

There are two principles by which DEA measures the efficiency of a unit:

Borderline random function method: By this method first a special form of the production function is taken into consideration and estimated by a method usual in econometrics. By virtue of the production function definition the units operated in an efficient industry are in accord with the production function. Having the production rates of producing units it is possible to measure and assess the units efficiency and the standard deviation of real or potential production rates estimated by virtue of the production function; the main problem of the method is the production function estimation.

DEA method: The method does not need the production function estimation. Suppose that there are two inputs and one output in an industry. If we show the input and output data for all active producing units in the industry in a double-dimensional space as follows:

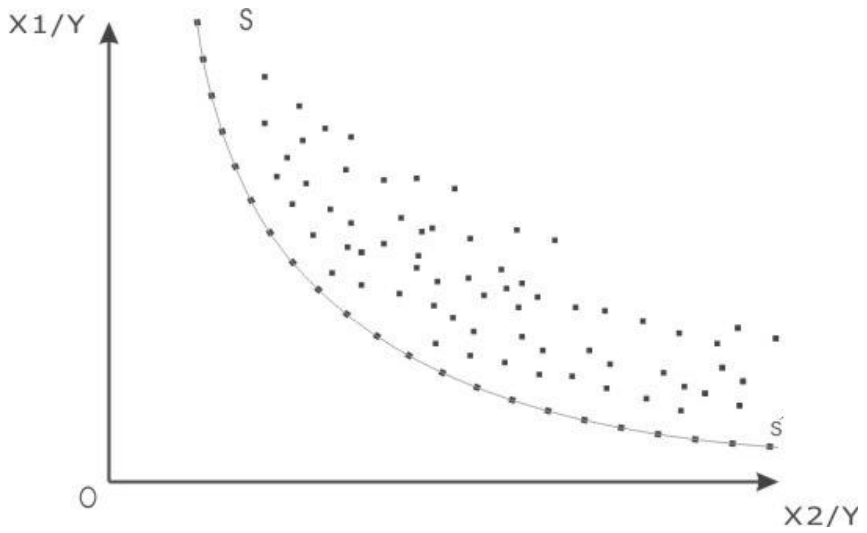

Figure 1: Borderline production curve:

We have a convex function known as borderline (Efficient) production curve by connecting the points near the origin of coordinates. The units above the curve have used more inputs to produce the same products (output). Having compared input and output rates of a producing unit with others, the method indicates if the unit's operation is efficient compared to other ones. In real conditions, where the inputs and outputs are more such computations are done by linear program. The set of the units whose activity has been efficient and is on the borderline production curve is known as reference set.

Research method

The collected data are about the services presented by affiliated organizations (Civic and rural health centers). In the study, all the rural and civic health centers and their personnel were assessed as the unit to take decisions and city health center; so the operation of each civic and rural unit plays some role in the study conclusion.

Inputs and outputs of the model

The model inputs include two variables: number of the nurse's aides and the family health staff employed in the health centers. Different services are presented in the city health centers; such services including vaccination for under 6 year age (Polio, diphtheria, tetanus, whooping, MMR, etc.), number of the clients referred to the family plan services (Contraceptive pills, etc.), number of pap smears and number of the children aged under 6 under care used as the model output. Meanwhile, considering the units under consideration were congruous it was supposed that other services were presented in other units, too and this feature was mentioned for all the units. The outputs were combined based on the mean time necessary to execute each service; for example, the mean time to distribute contraceptive pills, pap smear and other cares during and after delivery were five, thirty and ten minutes in the family clinic, respectively. So, the 1, 6 and 2 rhythms were calculated for distributing contraceptive pills, pap smear and other familial cares, respectively. The mean of clinical, familial services may be calculated by virtue of the times the services done. In relation to the second variable, the numbers of polio, diphtheria, tetanus, whooping, MMR, etc. are added algebraically. The nurses' aides' and family health employees' work scopes should be defined in the services because the time necessary to do each service is the same so these cases have the same load and also the services presented by nurses' aides and family health employees are not limited to above ones. By virtue of three components used per thousand people the reference coefficient

and mean time to do each service the nurses' aides and family health employees' work scopes were defined; it was 0.16 and 0.60 for nurse's aides and family health employees, respectively with 0.60 was final inputs of the model.

The coefficient indicates the nurses' aides and family health employees spend 0.16 and 0.60 of their time for services, respectively.

The numbers were calculated by Pliver. The statistics concerning above variables were issued by assistance office of Shahid Sodoughi Medical Science and Treatment Services University and the statistic letter was issued by Province Program and Management Organization. Having modeled the case study and defined the input and output variables' rates the decision maker units assessed the efficiency and other dependent variables by PEAOS software which is under web designed by Iranian specialists and having entered above data and selected the model appropriate to analyze the data the relative efficiency of the data is assessed. The calculations were as both input and output axes and then having defined the reference units and coefficients the targeted inputs and outputs were defined to make inefficient units efficient.

The statistics concerning each presented health service are individually shown in Table 1.

These data were raw and used as the model input and output variables.

Table 2 shows the statistics concerning the model inputs and outputs.

Table 3 shows the findings from health centers' efficiency.

As you see Yazd and Meibod health centers were on the efficiency baseline and have higher efficiency than others. With 0.485 efficiency, Mahriz had the least one.

Table 4 shows the reference units for the inefficient ones in order to enable them to reach relative baseline by axis input method; for example, the reference units were Abarkooh, Maibod and Yazd health centers and coefficients of each one were defined by axis input DEA model. For example, the coefficients of Meibod and Yazd centers were 0.304 and 0.031, respectively.

Table 5 shows the targeted inputs and outputs to make the inefficient units efficient by axis input method and targeted outputs to make efficient the inefficient units by axis output method; for example, Abarkooh city should either promote its services to achieve the results in Table 5 for the city outputs, adjust the staff as indicated in the table or increase the services and compensate the staff by a combined method.

The findings indicate that Meibod and Yazd health centers' operations were better than others. As it is clear from table 5, if it is possible that the services increase in Ardakan, they should have 37,082 vaccinations for the children under 6 and approach their rhythmic mean index related to familial clinic services to 23,110; otherwise, they should adjust or transfer their staff to have 21 nurse's aides and familial health personnel 14. The managers of inefficient units may study to find the factors effective on the efficiency and having removed related obstacles they may create the field necessary to increase the services presented in their sections so promote their personnel's efficiency; then the units would not be obliged to adjust their human force.

Table 1: Operational statistics of city health centers in Yazd province

	Abarkouh	ARDA KAN		Taft	Khatam	Saduq	Tabas	Mehriz	Meibod	Yazd
Number of Behvarzes	31	30	41	98	29	36	49	44	25	37
Number of Health Personnel	8	21	16	16	9	8	13	18	15	102
Vaccination under 6 years	10880	17830	14382	9453	7710	6085	18893	11007	19929	183,571
Polio vaccine	3898	6141	4965	3258	2704	2167	6592	3878	6798	63695
Vaccine MMR	1152	1895	1936	1152	1025	827	2099	1322	2173	19399
DTP Vaccine	3423	5144	4583	2963	2563	2157	5467	3522	5813	49404
BCG vaccine.	371	983	434	289	131	10	1071	351	984	14212
Vaccine against hepatitis	2036	3667	2464	1791	1287	924	3664	1934	4161	36861
Refer to family c	57529	19746	601 93	54037	50669	395 60	42523	58367	121 311	5864 08
Tablet	15700	10934	10957	9431	17395	5985	18299	8530	15737	71993
Condoms	8810	17613	14876	12943	8718	16111	18492	18371	37563	164,747
IUDs	6453	21323	8991	8001	6924	5072	940	11467	16640	101,383
Other	26566	29876	25369	23662	17632	12392	4801	19999	51371	248,285
The number of pap smears	1839	360	1163	1448	1084	659	3568	3129	1814	2780
Under 6 years of care	3154	4804	2804	2065	2345	1146	3127	3395	4678	24983

Table 2: Nos. of DEA model inputs and outputs

Health Center	Total tunable vaccination and care under 6 years	Weighted average of the Family Clinic	Number of Health Workers	Number of Staff
Abarkouh	14034	7794	31	8
ARDAKAN	22634	14502	30	21
Bafg	17186	8639	41	16
Taft	11518	7910	98	16
Khatam	10055	6848	29	9
Saduq	7231	5078	36	8
Tabas	22020	4184	49	13
Mehriz	14402	9877	44	18
Meibod	26607	16669	25	15
Yazd	208,554	86725	37	102

Table 3: Relative efficiency of city health centers in Yazd province

City health centers	
Abarkouh	0.931
ARDAKAN	0.628
Bafg	0.544
Taft	0.427
Khatam	0.740
Saduq	0.548
Tabas	0.805
Mehriz	0.485
Meibod	1
Yazd	1

Table 4: Defining reference units and their coefficients based on axis input method for inefficient health centers:

Center	Reference Unit 1	Reference Unit 2	coefficients unit1	coefficients unit2
Abarkouh	Meibod	yazd	0.304	0.031
ARDAKAN	Meibod	yazd	0.750	0.023
Bafg	Meibod	yazd	0.232	0.055
Taft	Meibod	-	0.475	-
Khatam	Meibod	-	0.411	-
Saduq	Meibod	-	0.305	-
Tabas	yazd	-	0.106	-
Mehriz	Meibod	-	0.593	-
Meibod	Meibod	-	1	-
Yazd	yazd	-	1	-

Table 5: Targeted inputs and outputs to make efficient the inefficient units:

	Targeted inputs to make efficient the inefficient units by axis input method		Targeted inputs to make efficient the inefficient units by axis output method	
Health center	Nos. of nurse's aides	Nos. of family health employees	Times of vaccinations & cares under age 6	Mean rhythmic services by family clinic
Abarkooh	19	8	15079	8374
Ardakan	21	14	37082	23110
Bafgh	28	9	31565	15868
Taft	33	7	27341	18521
Khatam	21	6	13670	9260
Sodough	34	5	13670	9260
Tabas	34	11	27351	11373
Mahriz	26	9	30075	20373
Meibod	27	15	24607	16669
Yazd	40	102	208,554	86725

Conclusion

By virtue of the study findings, it is concluded that the cities with rural and especially younger population have less efficiency and the cities with more civic population and lack of personnel increase are the most efficient.

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