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A DEA application for analyzing investment activities in higher educational organizations

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Private schools play important role on developing economy especially in rural areas of Iran and when they operate efficiently it can also be considered as a rich source of income. During the past three decades, data envelopment analysis (DEA) has become a popular technique for measuring the relative performance of non-financial units. In this paper, we present an empirical study to measure the relative efficiency of 11 private universities located in region ten of Islamic Azad university. The proposed study of this paper assigns some points for human resources including university professor and regular employees and considers it along with assets as inputs of DEA model. We also consider the number of graduated students and operating profit as output of our proposed DEA model. The implementation of standard BCC method yields 6 efficient units and to have better results we use another DEA technique. The results of this study present some investment opportunities for management of this private university.

1. Introduction

Private schools play important role on developing economy especially in rural areas of Iran and when they operate efficiently it can also be considered as a rich source of income. During the past three decades, data envelopment analysis (DEA) (Charnes et al., 1978, 1994; Andersen et al., 1993) has become a popular technique for measuring the relative performance of non-financial units. Fallah et al. (2011) used DEA analysis on banking sector by considering various financial and non-financial inputs and outputs and measured the relative efficiencies of various branches of banks and analyzed them under different scenarios. Avkiran (2010) studied the relationship between the supper-efficiency estimations and some major important financial ratios for some Chinese banking sector. The survey provided found the inefficient units where there was a low correlation between the supper-efficiency and desirable financial ratios. Staub et al. (2010) studied different factors affecting the relative efficiency of Brazilian banks including cost and technical efficiencies over the period 2000-2007.

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Lin et al. (2009) used different DEA methods for 117 branches of a certain bank in Taiwan and reported an overall technical efficiency of 54.8% among them. Yang et al. (2010) studied bank performance and management planning based on hybrid minimax reference point – DEA approach. Zaheri et al. (2012) investigated customer loyalty and prioritizing based one private bank in Kurdistan province.

In this paper, we present an empirical study to measure the relative efficiency of 11 private universities located in region ten of Islamic Azad university. The organization of the paper first presents details of the propsoed method in section 2. The results are discussed in section 3 and concluding remarks are given in the last to summarize the contribution of the paper.

2. The proposed study

The proposed study of this paper uses DEA as a primary tool for measuring the relative performance of all Islamic Azad university, which are active in region ten and the primary objective is to look for investment activities accomplished during the fiscal year of 2011. Fig. 1 demonstrates the structure of the proposed study of this paper.

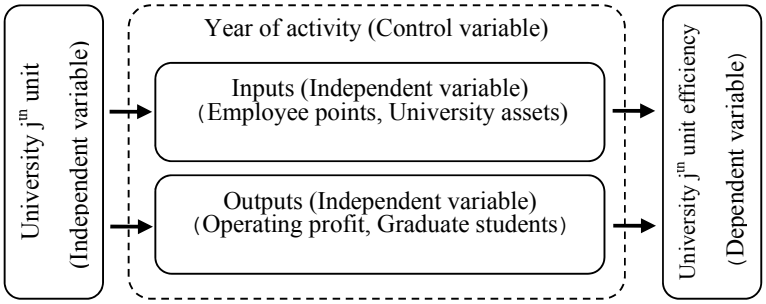

Fig. 1. The framework of the proposed study

The proposed study is considered as an applied research and the purpose of the research is to measure the relative performance of the biggest university units in region 10 in terms of investment activities. Fig. 2 demonstrates details of our proposed study.

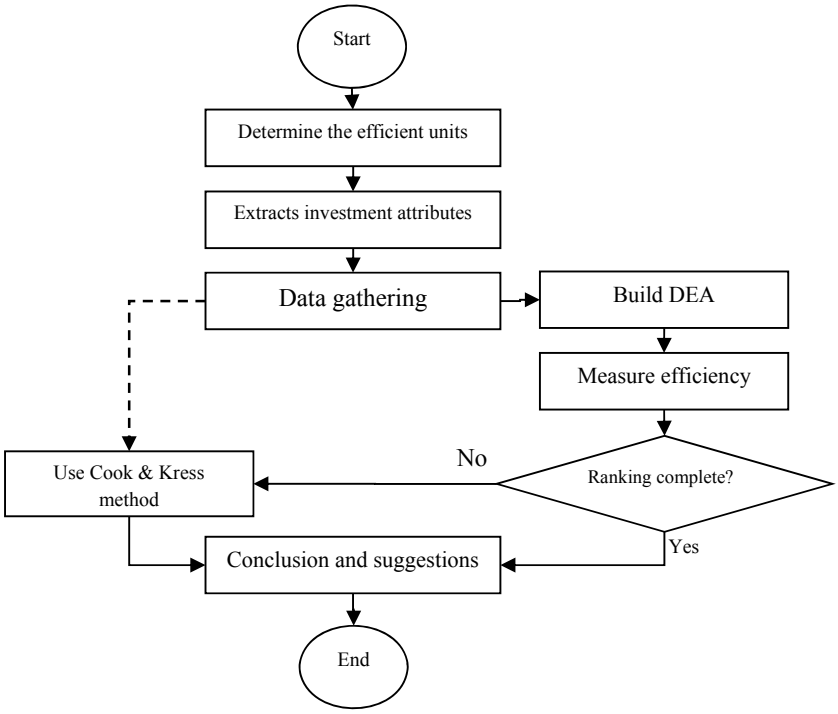

Fig. 2. The procedure of the proposed study

In our study, we investigate whether we could improve the relative efficiency of a particular unit through merging the unit with another unit. We also perform an investigation to detect the best model for measuring the relative efficiency.

Charnes, et al. (1978, 1994) are believed to be the first who introduced the idea of constant return to scale DEA (CCR) as a mathematical technique for measuring the relative efficiency of decision making units (DMU).

It is an easy task to show that DMU works whenever a production function is available. However, in different cases obtaining an analytical form for this function is not practical. Therefore, we form a set of production feasibility, which includes some principles such as fixed-scale efficiency, convexity and feasibility as follows,

$$T_C = \left\{ (X,Y) \middle| X \geq \sum_{j=1}^{n} \lambda_j X_j, Y \leq \sum_{j=1}^{n} \lambda_j Y_j, \lambda_j \geq 0, j = 1, \cdots n \right\}, \tag{1}$$

where X and Y are input and output vectors, respectively. The CCR production feasibility set border defines the relative efficiency in which any off-border DMU is considered as inefficient point. The CCR model is determined in two forms of either input or output oriented.

The input CCR aims to decrease the maximum input level with a ratio of θ so that, at least, the same output is produced, i.e.:

$$\min \quad \theta$$

subject to

$$\begin{aligned} &\theta X_p - \sum_{j=1}^{n} \lambda_j X_{ij} \geq 0, \\ &\sum_{j=1}^{n} \lambda_j Y_{rj} \geq Y_{rp}, \\ &\sum_{j=1}^{n} \lambda_j = 1, \\ &\lambda_j \geq 0, \quad j = 1, \cdots, n. \end{aligned} \tag{2}$$

Model (2) is called DEA form of input CCR where θ is the relative efficiency of the DMU and we can verify that the optimal value of θ, θ^*, is a number between zero and one. We may write the dual of model (2) as follows,

$$\min \sum_{r=1}^{s} u_r y_{r0} + u_0$$

subject to

$$\begin{aligned} &\sum_{i=1}^{m} v_i X_{i0} = 1, \\ &\sum_{i=1}^{m} v_i X_{i0} - {}_{ip} \sum_{i=1}^{m} v_i X_{ij} + u_0 \leq 0, \qquad j = 1, \cdots, n. \\ &u_r \geq 0, \quad r = 1, \cdots, s. \\ &v_i \geq 0, \quad i = 1, \cdots, m \end{aligned} \tag{3}$$

In case we consider the dual fuzzy two-phase BCC form, the first phase is as follows,

$$\max: \ \phi$$

subject to

$$\begin{aligned} &\sum_{j=1}^{n} \mu_j x_{ij} \le x_{i0} \quad , \quad i = 1,\dots,m \\ &\sum_{j=1}^{n} \mu_j y_{rj} \ge \phi y_{r0} \quad , \quad r = 1,\dots,s \\ &\sum_{j=1}^{n} \mu_j = 1 \quad , \quad j = 1,\dots,n \\ &\mu_j \ge 0 \quad , \quad j = 1,\dots,n \end{aligned} \tag{3}$$

ϕ *free.*

In addition, the second phase of fuzzy BCC is as follows,

$$\max: \ w = \sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_r^+$$

subject to

$$\begin{aligned} &\sum_{j=1}^{n} \mu_j x_{ij} + S_i^- = x_{i0}, \qquad i = 1,\dots,m \\ &\sum_{j=1}^{n} \mu_j y_{rj} - S_r^+ = \phi^* y_{r0}, \qquad r = 1,\dots,s \\ &\sum_{j=1}^{n} \mu_j = 1, \qquad j = 1,\dots,n \\ &\mu_j \ge 0, \quad j = 1,\dots,n \qquad S_i^- \ge 0, \quad i = 1,\dots,m \qquad S_r^+ \ge 0, \ r = 1,\dots,s. \end{aligned}$$

One of the issues associated with DEA method arises when some of the dual variables appear to be zero in optimality. In such a case, there are more than one inefficient unit and two units having the same output and different inputs could both be considered inefficient with the ratios. This is not a correct observation since one unit is more efficient that the other one. In such a case we may use an approach developed by Cook and Kress (1990). The model presents the best model for collection ballot voting results and for each candidate, it provides a fair assessment for the first, the second and other candidates. Let y_{rj} be the total number of votes for candidate j^{th} and ε be a small number as a lower bound for decision making unit. For the sake of simplicity we consider d(r, ε)= ε. Therefore we have,

$$max \quad \sum_{r=1}^{s} u_r y_{rO}$$

subject to

$$\begin{aligned} &\sum_{r=1}^{s} u_r y_{rj} \le 1 \quad , \quad j = 1,\dots,n \\ &u_r - u_{r+1} - d(r,\varepsilon) \ge 0 \\ &u_r - d(r,\varepsilon) \ge 0 \end{aligned}$$

3. The results

In this section, we present the results of the implementation of our proposed study. The proposed study of this paper assigns some points for human resources including university professor and regular employees and considers it along with assets as inputs of DEA model. Table 1 demonstrates inputs/outputs of the proposed model.

Table 1
Inputs/outputs of the proposed model

	Inputs		Outputs	
Unit	Assets	Human resource points	Graduated students	Operating profit
Azad shahr (1)	71,689.03	8100	1231	25386
Bandar Gaz (2)	60,203.25	2429	300	-4895
Damghan (3)	119,107.46	10658	984	-14016
Semnan (4)	94,187.98	15228	1860	-31093
Shahrood (5)	123,795.47	24676	1763	-11436
Aliabad (6)	162,375.92	13333	1143	-13490
Gorgan (7)	98,131.66	11886	1407	-34937
Garmsar (8)	145,483.24	18951	1460	-14359
Mahdishahr (9)	8,983.98	2953	100	-2795
Gonbad Kaboos (10)	21,414.07	3262	185	-7478
Minoodasht(11)	12,594.30	2220	213	-4252

Applying DEA method using BCC technique helps determine relative efficiencies of the proposed model summarized in Table 2 as follows.

Table 2
The results of relative efficiency

Unit	1	2	3	4	5	6	7	8	9	10	11
Efficiency	1	1	0.68	1	1	0.68	0.90	0.83	1	0.50	1
Eff./Ineff.	√	√	-	√	√	-	-	-	√	-	√
Rank	1	1	9	1	1	9	7	8	1	11	1

We have calculated how we can improve the relative efficiency of inefficient units to become efficient and the results are summarized in Table 3.

Table 3
The results of necessary improvement required to convert inefficient units to efficient ones

	Present output		Ideal output	
Unit	Graduated students	Operating profit	Graduated students(Gap)	Operating profit(Gap)
Azad shahr (1)	1231	25386	———	———
Bandar Gaz (2)	300	-4895	———	———
Damghan (3)	984	-14016	1457(41%)	5117.58(68%)
Semnan (4)	1860	-31093	———	———
Shahrood (5)	1763	-11436	———	———
Aliabad (6)	1143	-13490	1586(40%)	-5186.46(72%)
Gorgan (7)	1407	-34937	1565(104%)	-4612.53(90)
Garmsar (8)	1460	-14359	1699(43%)	-10976.8(86)
Mahdishahr (9)	100	-2795	———	———
Gonbad Kaboos (10)	185	-7478	359(22)	676.28(52)
Minoodasht(11)	213	-4252	———	———

Table 3 shows the amount of additional output each inefficient unit needs to add to become efficient one. The results also demonstrate the relative gap between actual and desirable outputs. In addition, as we can observe from the results of Table 3, six out of eleven units have become efficient. Therefore, we need to use Cook and Kress (1990) method to rank efficient units and we first report cross DEA for measuring relative efficiency of various units based on BCC method and Table 4 summarizes the results. In addition, Table 5 shows details of ranking based on the results of Table 4.

Table 4
The summary of relative efficiency using Cross DEA using BCC technique

Unit	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1)	100	-	74.788	55.351	33.952	60.406	68.921	43.373	-	-	-
(2)	30.335	100	21.852	18.279	11.077	18.087	21.441	13.593	63.333	58.686	86.885
(3)	81.529	-	67.56	45.526	27.889	49.185	56.334	35.479	-	-	-
(4)	-	-	-	100	61.256	-	-	77.002	-	-	-
(5)	-	-	-	-	100	-	-	-	-	-	-
(6)	93.419	-	69.786	51.85	31.792	67.56	64.437	40.561	-	-	-
(7)	-	-	84.526	68.235	41.614	69.197	90.09	51.557	-	-	-
(8)	-	-	91.475	73.142	44.648	74.742	87.72	82.64	-	-	-
(9)	-	-	-	-	-	-	-	-	100	-	-
(10)	36.462	64.913	24.295	25.424	15.157	21.081	26.995	17.349	45.726	49.5	67.854
(11)	-	83.334	-	-	-	-	-	-	-	-	100

Table 4
The summary of ranks of various units using Cross DEA using BCC technique

Unit	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1)	1	–	3	4	5	4	3	4	–	–	–
(2)	5	1	7	8	9	7	7	8	2	1	2
(3)	3	–	5	6	7	5	5	6	–	–	–
(4)	–	–	–	1	2	–	–	2	–	–	–
(5)	–	–	–	–	1	–	–	–	–	–	–
(6)	2	–	4	5	6	3	4	5	–	–	–
(7)	–	–	2	3	4	2	1	3	–	–	–
(8)	–	–	1	2	3	1	2	1	–	–	–
(9)	–	–	–	–	–	–	–	–	1	–	–
(10)	4	3	6	7	8	6	6	7	3	2	3
(11)	–	2	–	–	–	–	–	–	–	–	1

Finally, we summarize the frequencies of six efficient units compared with eleven units and Table 5 demonstrates the results of our survey.

Table 5
The frequency of ranks in different cities

Unit	1	2	3	4	5	6	7	8	9	10	11
Azad Shahr	1	0	2	3	1	0	0	0	0	0	0
Bandar Gaz	2	2	0	0	1	0	3	2	1	0	0
Semnan	1	2	0	0	0	0	0	0	0	0	0
Shahrood	1	0	0	0	0	0	0	0	0	0	0
Mehdi Shahr	1	0	0	0	0	0	0	0	0	0	0
Minodasht	1	1	0	0	0	0	0	0	0	0	0

Now we can use Cook and Kress (1990) technique to find the relative ranking and Table 6 summarizes the results of our survey.

Table 6
The results of the BCC and Cook & Kross techniques and final ranking

	BCC		Cook and Kress		
Unit	Efficiency	Rank	Efficiency	Rank	Final rank
Azad shahr (1)	1	1	1	1	1
Bandar Gaz (2)	1	1	1	1	1
Damghan (3)	0.68	9	–	–	9
Semnan (4)	1	1	0.7491	3	3
Shahrood (5)	1	1	0.4987	5	5
Aliabad (6)	0.68	9	–	–	9
Gorgan (7)	0.9	7	–	–	7
Garmsar (8)	0.83	8	–	–	8
Mahdishahr (9)	1	1	0.4987	5	5
Gonbad Kaboos (10)	0.5	11	–	–	11
Minoodasht(11)	1	1	0.4994	4	4

As we can observe from the results of Table 6, two cities, Azad shahr and Bandar Gaz, are the best candidate for investment followed by Semnan, Minoodasht, Mahdishahr.

4. Conclusion

In this paper, we have presented an empirical investigation to measure the relative efficiency of 11 private universities located in region ten of Islamic Azad university. The proposed study of this paper assigned some points for human resources including university professor and regular employees and considered it along with assets as inputs of DEA model. We have also considered the number of graduated students and operating profit as output of our proposed DEA model. The implementation of standard BCC method yielded 6 efficient units and to have better results we have used another DEA technique. The results of this study presented some investment opportunities for management of this private university.

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