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Measuring the relative efficiency of Ilam hospitals using data envelopment analysis

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ABSTRACT

Measuring the relative efficiency is one of the most important issues among hospitals in today's economy. These days, we hear that cost reduction is a necessity for survival of business owners and one primary to reduce the expenditures is to increase relative efficiency. The proposed study of this paper first uses output oriented data envelopment analysis (DEA) to measure the relative efficiencies of nine hospitals. The proposed model uses four types of employee namely specialists, physicians, technicians and other staffs as input parameters. The model also uses the number of surgeries, hospitalized and radiography as the outputs of the proposed model. Since the implementation of DEA leads us to have more than one single efficient unit, we implement supper efficiency technique to measure the relative efficiency of efficient units.

1. Introduction

Today, there is an increasing interest in reducing the cost of services through providing better quality features, increasing the relative efficiency and incorporating advances of information technology. As the population grows in the world, the needs for healthcare systems increases among populated communities. An efficient hospital can provide better services under lower time and expenditures. Many hospitals normally accept medium or low-income patients who cannot afford pay much to receive quality medications. Therefore, it is not possible to increase the cost of services, very easily. On the other hands, many of these hospitals are ruled by non-for-profit organizations or governmental agencies and the sponsor often wish to see they are running on economic scales.

One alternative to encourage such organizations is to allocate budget based on the relative efficiency of the units. There are literally several methods to measure the relative efficiency of operating units

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such as activity based cost, theory of constraints, balanced score card, data envelopment analysis (DEA), etc. DEA has been one of the most popular methods used in different areas of applications (Charnes et al., 1994).

Roghanian and Foroughi (2010) presented an empirical study of Iranian regional airports using robust data envelopment analysis. They performed an empirical analysis on Iranian airports based on DEA methods to measure the efficiencies of various airports. They used a DEA method, which could handle the uncertainty associated with input and output data. The results of this comprehensive study showed that most of the active airlines are practically inefficient and the government could significantly increase the efficiencies of the airports by setting new regulations and rules.

Charnes et al. (1985) are believed to be the first people who introduced DEA method. Data envelopment analysis measures the efficiency of decision-making departments of organization regarding the various inputs and outputs. During the past few years, there have been tremendous efforts on developing various DEA methods. (Andersen & Petersen, 1993). Aryanezhad et al. (2011) presented a BSC-DEA approach to measure the relative efficiency of service industry: A case study of banking sector. They proposed a method to utilize balanced score card (BSC) as a tool for designing performance evaluation indices of an organization.

The integrated BSC-DEA has been applied as an empirical case for a major private bank organization and the results are analyzed. Najafai et al. (2011) in other work presented an integration of BSE with two-stage DEA. The proposed model of this paper implemented various financial and non-financial perspectives to evaluate the performance of decision-making units in various BSC stages. At each stage, a two-stage DEA method is implemented to measure the relative efficiency of decision-making units and the results are monitored using the cause and effect relationships. An empirical study for a banking sector is also performed using the method developed in this paper and the results are briefly analyzed.

Kazley and Ozcan (2009) implemented DEA to investigate the relationship between hospital electronic medical record (EMR) use and efficiency in a national sample of acute care hospitals. Data sources included the American Hospital Association (AHA), Health Information Management Systems Society (HIMSS), and Case Mix Index. They found limited evidence that EMPs could improve hospital efficiency using two research approaches. Small hospitals may benefit in the area of efficiency through EMR use. However, medium and large hospitals generally do not demonstrate such a difference. Likewise, there does not seem to be a substantial increase in efficiency over time associated with EMRs when compared to the efficiency of hospitals without such documentation.

O'Neill et al. (2008) performed a cross-national comparison and taxonomy of DEA-based hospital efficiency studies. They provided the first taxonomy of hospital efficiency studies, which implements DEA and related techniques. They provided a systematic review of 79 such studies published from 1984–2004 representing 12 countries. A cross-national comparison disclosed substantial changes with respect to important study characteristics such as type of DEA model selected and choice of input and outputs. They took a longitudinal perspective, indicated the life cycle of the proposed research, as well as its diffusion across disciplines.

Staub et al. (2010) studied different factors affecting the relative efficiency of Brazilian banks such as cost and technical efficiencies for a time period between the years of 2000 to 2007. They reported that Brazilian banks suffered from low levels of efficiency compared with European or North American banks. They also reported that state-owned banks were significantly more cost efficient than other foreign banks. However, they did not find any evidence to claim that the differences in economic efficiency were due to the type of activity and bank size.

Fallah et al. (2011) examined DEA models for the estimation and improvement of organizational inputs and outputs in order to enhance management and decision making processes. They proposed an empirical DEA analysis on banking sector by considering several financial and non-financial inputs and outputs. The relative efficiencies of various branches of banks were analyzed in different scenarios. The preliminary results indicated that there were some non-financial items, which could change the overall performance of a unit along with other financial items, significantly.

Wei et al. (2011) implemented some DEA models to assess the performance of medical centers in Taiwan, to discover the pseudo-inefficiency. They determined the reason for pseudo-inefficiency by comparing the optimal weight sets of two models. They also validated the proposed DEA model and claimed that it could be a substitutive model for CCR-I to avoid pseudo-inefficiency.

DEA has also been used in educational systems, for instance, Gharakhani et al. (2011) used a robust this technique for measuring the relative efficiency of Iranian high schools. They presented an empirical study on a set of high schools located in Tehran, which is the capital city of Iran. The study used uncertain data for input/output information and the results are compared with an existing parametric stochastic frontier analysis (SFA). The preliminary results indicate that the robust DEA approach is relatively a reliable method for efficiency estimating.

2. Problem statement

Let x_{ij} be the inputs for a decision unit with *i=1,…,m* and y_{rj} be the outputs with *r=1,…,s* and *j=1,…,n.* Let u_i and v_j be the dual variables associated with x_i and y_j, respectively. An output oriented DEA model is formulated as follows,

$$\begin{aligned} \min \quad & \theta - \varepsilon\left(\sum_{\mathrm{i}=1}^{\mathrm{m}} s_i^- + \sum_{\mathrm{r}=1}^{\mathrm{s}} s_r^+\right) \\ \text{subject to} \quad & \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta x_{i\circ}, \ \mathrm{i}=1,2,...,\mathrm{m} \\ & \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = \mathrm{y}_{r\circ}, \quad \mathrm{r}=1,2,...,\mathrm{s} \\ & \lambda_j, s_r^+, s_i^- \geq 0 \end{aligned} \tag{1}$$

In model (1) when $\theta^* = 1$ then we have $s_r^{+*} = s_i^{-*} = 0.$ Model (1) is the basis of traditional DEA and it is solved *j* times to determine the relative efficiencies of various units. Note that the first constraint also becomes linear using a simple manipulation.

Problem (1) has been widely used for the past three decades and the results are commonly accepted as a tool to measure the relative efficiency of different units. However, when there is uncertainty with the inputs and the outputs, one may use different techniques to make sure that a small change on input/output data does not change the output rankings.

In many cases, we have more than one single efficient unit and in this case we can run the model proposed by Anderson and Peterson (Andersen & Petersen, 1993) among efficient units to find the relative efficiency of these units. The model is as follows,

$$\begin{aligned} &\min \ \theta^s \\ &\text{subject to } \sum_{j=1,\, j\neq o}^{n} \lambda_j x_{ij} \le \theta^s x_{io}, \quad i=1,...,m \\ &\sum_{j=1,\, j\neq o}^{n} \lambda_j y_{rj} - y_{ro} \ge \circ, \quad r=1,...,s \\ &\lambda_j \ge 0, \quad j=1,...,n, \quad j\neq o \end{aligned} \tag{2}$$

In model (2), θ^s measures the relative efficiency of the efficient units.

3. The proposed model

The proposed model of this paper used DEA technique to measure the relative efficiencies of nine hospitals located in the province of Ilam, Iran. Table 1 shows the input/output data used for the proposed model of this paper.

Table 1
The input/output of DEA implementation

Hospitals	Inputs				Outputs		
	Specialist	Physicians	Technicians	Others	Surgery operations	Hospitalized patients	Radiography
1	20	120	35	38	1747	15610	5608
2	25	83	42	50	6407	13162	7586
3	6	45	30	35	0	467	0
4	5	13	19	9	191	596	6463
5	7	26	10	12	726	1556	4575
6	6	35	15	13	1246	2823	11769
7	6	26	14	12	242	1554	5691
8	6	30	15	15	776	2565	8914
9	6	45	16	18	760	2824	8815

We have implemented the proposed model of this paper using the information of nine units and Table 2 shows details of our survey.

Table 2
The relative efficiency of nine hospitals using model 1 and 2

Hospitals	θ_o^*	θ_o^{s*}	Rank	Slack variables of inputs			Slack variables of outputs		
				s_1^{-*}	s_2^{-*}	s_3^{-*}	s_1^{+*}	s_2^{+*}	s_3^{+*}
1	1	1.561	3	0	0	0	0	0	0
2	1	2.169	1	0	0	0	0	0	0
3	0.099	0.099	9	0	0.90	1.95	52.27	0	167.77
4	1	1.479	4	0	0	0	0	0	0
5	0.723	0.723	7	1.814	2.58	0	0	30.48	0
6	1	1.634	2	0.060	0	0.74	449.06	0	0
7	0.680	0.680	8	0	0	0	0	0	0
8	0.955	0.955	5	0	0	1.25	376.17	0	0
9	0.891	0.891	6	0	8.75	1.64	23062	0	0

According to the results of Table 2, the implementation of the first model yields 4 efficient units while the implementation the second model considers the second unit as efficient one. The optimal values of $\theta_o^{s^*}$ help us find out how much of the input resources are wasted. For instance, unit five wastes about 1-0.723=0.277 or approximately 28 percents of 3 inputs. We may also use $\theta_o^{s^*}$ to calculate the amount of required reduction on inputs. For example, for the second input of unit 5 we have 0.7225×26-2.58=16.21, which means we have to reduce the number of physicians from 26 to 16 to increase the level of efficiency. We may similar approach to find out how much reduction we need to increase the level of efficiency of inefficient units. One obvious observation is that most of the hospitals compete with each other tightly.

4. Conclusion

In this paper, we have presented an empirical study to measure the relative efficiencies of nine hospitals located in the province of Ilam, Iran. The proposed model of this paper used DEA model with three inputs and three outputs. The inputs include all human resources and the outputs covers different kinds of patients hospitalized. The implementation of traditional DEA yielded more than one efficient units and we used an extended DEA model to locate the super efficiency among four units. The proposed model of this paper can be extended for a more comprehensive study where all hospitals of the province have been taken into consideration and we leave it for interested researchers as future research.

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