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Determining the Technical Efficiency of Hospitals affiliated with Kashan University of Medical Sciences using Data Envelopment Analysis: 2011-2016

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Abstract
Hospitals, as the biggest and costliest operative units of ministry of health and medical education, have always faced budget deficit. Hence, efficiency scores of hospitals are one of the important criteria that managers and policy makers can use for future planning to improve the performance of the hospitals. This paper presents data envelopment analysis (DEA) to assess relative efficiency of hospitals with multiple inputs and multiple outputs. We use cross-efficiency score for ranking the top hospitals and also Malmquist productivity index for estimating productivity growth. This study evaluates the efficiency of hospitals operated by Kashan University of Medical Sciences from 2011 to 2016, in which input parameters are the number of physicians, nurses and beds and output parameters are the number of discharged patients. GAMS software application was used for data analysis. Based on the results, the average technical efficiency of understudy hospitals was 0.71. On the other hand, inefficient hospitals faced input increase to achieve the same output. The average productivity index at hospitals during study years was 0.909, indicating that the productivity index reduced on average 10% during this time range. Hospitals affiliated with Kashan University of Medical Sciences were technically inefficient. Thus, at these hospitals, technical, pure technical and

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scale efficiency did not follow a fixed trend, changing continually. Moreover, hospitals did not use their resources optimally and encountered decrease in productivity. Therefore, it is recommended that hospitals' functionality be compared with national and international standards.

Keywords: Data envelopment analysis (DEA), Hospital, Pure technical efficiency, Return to scale, Scale efficiency, Technical efficiency.

1. Introduction

Heath care is one of the main needs of every society and paying attention to heath and investing in this field would result in increased workforce productivity and production increase [1]. In fact, efficiency improvement is of the main objectives of health systems [2]. Hospitals, as the biggest and costliest operative units [3] are the locus of more than 50% of health care expenses [4]. Recourse and facility shortage, as a subject of debate over years, imposed hard conditions on economy; therefore, optimum use of facilities, resources, and promotion of efficiency to achieve welfare and health level enhancement have turned to an important issue [4-6]. In Iran, national health expenditure (GDP) has increased since May 2014 by implementing the health evolution program. However, world health organization (WHO), in its last report, announced that the function of Iran treatment and health system ranked the 58th and its overall functionality ranked 93th globally. This waste of resources means that making a distinct level of services and outputs would be even possible by using fewer resources [7].

The first step in evaluating the function of different parts of health system is to evaluate efficiency. Therefore, evaluation and measurement of efficiency can indicate a rational framework of human and financial resource distribution in different parts [2] and assure decision makers regarding optimum productivity of existing resources [5]. The concept of efficiency is concerned with how an organization uses its resources toward production compared with the best function in a given period; in addition,

measuring the efficiency index means calculating the ratio of output resulted from applied input [8]. Regarding the importance of evaluating hospitals' efficiency, Joses et al. (2008) in their study on 28 general hospitals affiliated with Angola municipality showed that an appropriate programming for decreasing surplus expenses helped urban hospitals of this country enjoy an average productivity growth of 5.4% during the study period [9].

Diverse methods have been presented to estimate efficiency. In this line, different studies have been conducted by Gannon (2004) in Ireland [4], Folland and Hofler (2001) in the United States [10], Mortimer (2002) in Australia [11], Somanathan (2000) in Sri Lanka [12], Kakeman (2016), Rezapour (2015) and Sepehrdust in Iran [5,13,6], all of which have used DEA to evaluate the efficiency of hospitals. DEA is a non-parametric method used to calculate the efficiency of homogenous decision maker units. In this pattern, approximation of production function frontier is made using a number of points determined by linear programming. Constant return to scale (CRS) and variable return to scale can be used for determining production function frontier. After optimization, linear programming method determines whether the considered decision maker unit is on the line of efficiency or not; Using this approach, efficient and inefficient units can be distinguished and also inefficient units can be ranked. Moreover, this method helps to apply multi-input multi-output analysis without the need for useful information and measuring their importance in advance [7]. Next, using efficient units, a pattern could be adopted for inefficient units in

order to reach the efficient frontier. Furthermore, the effect of each variable on efficiency can be determined. In this research, an input model with envelopment form is applied. In practice, more than a unit may prove efficient, needing further distinction. In this study, cross-over efficiency method was used as an alternative method of efficiency evaluation and ranking in DEA based on peer evaluation logic. In this method, results of cross-over efficiency matrix and average cross-over efficiency scores of each decision-making unit are used. Considering the time period of study (2011 to 2016), Malmquist production index was applied to assign the progress and regression.

In his study conducted in Ghana using data envelopment analysis (DEA), Akazili (2008) showed that just 35% of understudy hospitals had complete efficiency [14]. Moreover, Kakeman and et al. (2005) evaluated the efficiency of Tehran hospitals and indicated that just 31.48% of considered hospitals had complete efficiency scoring "one" [5]. In the same line, Ghaderi and et al. (2005) determined the technical efficiency of hospitals affiliated with Iran University of Medical Sciences using DEA. They concluded that the capacity for promoting technical efficiency at hospitals under study was 10%. In this research, constant return to scale was dominant on production process and existence of surplus capacity of productive factors especially human force at hospitals was clear. Therefore, laying off surplus human resources as a comprehensive program helped to decrease hospital expenses [15].

With a population of 300000 people and six hospitals affiliated with Kashan University of Medical Sciences, Kashan is the second biggest city of Isfahan province [16,17]. Considering the limitation in workforce and financial resources and with the aim of helping mangers to decide and use existing resources optimally, this study tried to appoint the efficiency of hospitals affiliated with Kashan University of Medical Sciences using DEA method during a 5-years period, aiding mangers in optimally dedicating resources and making managerial decisions. There are two widely-used frontier methods used in order to evaluate the efficiency of health organizations including accidental frontier analysis. Regarding the ease and usage of several inputs and outputs, DEA was applied to evaluate the technical efficiency of hospitals under study.

In this study, the evaluation method of cross-over efficiency, namely assessment of the function of each units using optimum criteria of other units was applied for ranking the hospitals with the same technical efficiency in a year.

The reasons for applying the input-centered DEA in this article are as follows:

1. People themselves choose the hospitals for their treatment and it is hard to appoint the amount of demands for treatment centers.

2. Hospital managers cannot control their outputs while their hospital inputs (human resources, beds,.) can be under control. Hence, they try to control at least their inputs.

We also evaluate productivity change over time and develop a decomposition of the Malmquist total factor productivity index to estimate productivity growth of the hospitals.

The organization of the paper is as follows. Section II presents a concise review of DEA background. Section III presents the concept of Malmquist productivity index and develop a decomposition of the Malmquist total factor productivity index. Experimental results and discussions are presented in Section IV and finally in Section V, we

conclude with the summary of work.

2. DEA Background

Data envelopment analysis is a non-parametric methodology to measure the relative efficiencies of a set of decision making units (DMUs) that use multiple inputs to produce multiple outputs. Charnes et al. [18] showed that DEA is an effective method for calculating the relative efficiency of peer. In DEA models, it is not needed that analyst pre-specify the functional form of a production function. The production frontier is a convex and piecewise function is constructed using the linear combination of efficient units.

Supposed that there are p DMUs, where each DMU_j $(j = 1, 2, ..., p)$ consume k inputs to produce s different outputs. The observed input and output vectors of DMU_j are called $x_j = (x_{1j}, ..., x_{kj})$ and $y_j = (y_{1j}, ..., y_{sj})$, respectively. Also, it is assumed that all components of vectors x_j and y_j for all DMUs are non-negative, and at the same time, each DMU has at least one strictly positive input and output. The relative efficiency score of DMU_o is defined as follows:

$$\theta_o = \max_{u_r . v_i} \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{k} v_i x_{io}},$$

where u_r and v_i are the non-negative weights associated with output r and input i, respectively. The same weights, when applied to other DMUs, cannot produce any unit with efficiency greater than one [19]. This condition is reflected in the following constraints.

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{k} v_i x_{ij}} \leq 1, \quad j = 1, 2, ..., p.$$

Thus, we can calculate the relative efficiency score of DMU_o by the following linear fractional model.

$$\theta_o^* = \max \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{k} v_i x_{io}} \qquad (1)$$

s.t.

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{k} v_i x_{ij}} \leq 1 \qquad j = 1, 2, ... p,$$

$$v_i \geq \epsilon \qquad i = 1, 2, ..., k$$

$$u_r \geq \epsilon \qquad r = 1, 2, ... s,$$

where $\epsilon > 0$ is a non-Archimedean construct to assure strongly efficient solutions [20]. It should be noted that $0 < \theta_o^* \leq 1$, and DMU_o is efficient if $\theta_o^* = 1$. Each DMU in Model 1 is evaluated by its best weight.

The DEA model results are the determination of those hyper planes that define an envelope surface or Pareto frontier. It should be noted that if a DMU is efficient, it will lie on the Pareto frontier. Model (1) is a linear fractional program that can be transformed into the following linear program by Charnes-Cooper transformation [20].

$$\theta_o^* = \max \sum_{r=1}^{s} u_r y_{ro}$$

s.t.

$$\sum_{i=1}^{k} v_i x_{io} = 1 \qquad (2)$$

$$\sum_{r=1}^{s} u_r y_{ij} - \sum_{i=1}^{k} v_i x_{ij} \leq 0 \quad j = 1, 2, ..., p,$$

$$v_i \geq \epsilon \qquad i = 1., 2, ..., k,$$

$$u_r \geq \epsilon \qquad r = 1, 2, ..., s$$

Model 2 is called CCR model, proposed by Charnes, Cooper and Rhodes. Let $u_r^*(r = 1, 2, ..., s)$ and $v_i^*(1., 2, ..., k)$ be the optimal output and input weights of Model (2) under assessing DMU (DMU_o), respectively. Hence, the best relative efficiency score of DMU_o is measured by $\theta_o^* = \sum_{r=1}^{s} u_r^* y_{ro}$, which is called the CCR-efficiency of DMU_o. If $\theta_o^* = 1$, then DMU_o is CCR-efficient. Otherwise, DMU_o is CCR-inefficient. The cross-efficiency value of DMU_j is obtained by $\theta_{oj} = \frac{\sum_{r=1}^{s} u_r^* y_{rj}}{\sum_{i=1}^{k} v_i^* x_{ij}}$, which reflects the peer evaluation of DMU_o to DMU_j $(j = 1, 2, ..., p, ; j \neq o)$.

Consequently, $p \times p$ matrix can be

obtained in which the diagonal members represent the CCR-efficiency scores of DMUs, and the remaining cells give the cross-efficiency scores. In order to proceed with a cross-evaluation, we can compute the average of cross–efficiency scores in each column and provide a unique ordering of the DMUs [21]. Due to exiting alternatives of optimal input and output weights of Model (2), the cross efficiency matrix may be changed. Hence, the use of cross-efficiency evaluation can be damaged by non-uniqueness of optimal weights. Sexton et al. [22] and Doyle and Green [23] introduced a secondary goal to deal with this issue and obtain a unique efficiency score for DMUs. Doyle and Green [23] presented aggressive and benevolent models. The aggressive model is given as follows:

$$\min \sum_{r=1}^{s} u_r (\sum_{\substack{j=1 \\ j \neq o}}^{p} y_{rj})$$

s.t.

$$\sum_{i=1}^{k} v_i (\sum_{\substack{j=1 \\ j \neq o}}^{p} x_{ij}) = 1 \qquad (3)$$

$$\sum_{r=1}^{s} u_r y_{io} - \theta_o^* \sum_{i=1}^{k} v_i x_{io} = 0$$

$$\sum_{r=1}^{s} u_r y_{ij} - \sum_{i=1}^{k} v_i x_{ij} \leq 0 \quad j = 1,2,\dots.p, \ j \neq o,$$
$$v_i \geq \epsilon \qquad i = 1,2.\dots.k,$$
$$u_r \geq \epsilon \qquad r = 1,2,\dots.s$$

where θ_o^* is the CCR-efficiency of DMU_o derived from model 2.

The benevolent formulation for cross-efficiency evaluation can be achieved by putting max instead of min in the objective function of Model (3).

3. The Malmquist Productivity index

Malmquist index was first introduced by Caves et al. [24] based on an idea of Malmquist [25] in which the evaluation of productivity change over time together with its decomposition into efficiency changes and technology changes. Fare et al. [26] obtained Malmquist productivity index (MPI) between time periods t and $t + 1$ by following the equation.

$$MPI(x^{t+1}, y^{t+1}, x^t, y^t)$$
$$= \left[\frac{d_{CRS}^t(x^{t+1}, y^{t+1})}{d_{CRS}^t(x^t, y^t)} \frac{d_{CRS}^{t+1}(x^{t+1}, y^{t+1})}{d_{CRS}^{t+1}(x^t, y^t)} \right]^{1/2},$$

where $d_{CRS}^t(x^t, y^t)$ and $d_{CRS}^{t+1}(x^t, y^t)$ denote the distance functions of the production bundle (x^t, y^t) from the CRS technology frontiers in periods t and $t + 1$, respectively. Also, $d_{CRS}^t(x^{t+1}, y^{t+1})$ and $d_{CRS}^{t+1}(x^{t+1}, y^{t+1})$ show the corresponding distance functions for the production bundle (x^{t+1}, y^{t+1}) from the technology frontiers in periods t and $t + 1$, respectively. The distance functions can be defined as $d_{CRS}^\tau(x^\varphi, y^\varphi) = max\{\theta > 0 : \left(x^\varphi/\theta, y^\varphi\right) \in T_{CRS}^\tau\}$, where $T_{CRS}^\tau =$

$$\left\{ (x^\tau, y^\tau) : \begin{array}{l} \sum_{j=1}^{p} \lambda_j^\tau x_{ij}^\tau \leq x_i^\tau, \ i=1,2,\dots,k, \\ \sum_{j=1}^{p} \lambda_j^\tau y_{rj}^\tau \geq y_r^\tau, \ r=1,2,\dots,s, \\ \lambda_j^\tau \geq 0, \qquad j=1,2,\dots,p, \end{array} \right\}, \quad \text{for}$$

$\tau, \varphi \in \{t, t + 1\}$ which is equal to the reciprocal of the Farell measures of technical efficiency [27]. We can also denote the MPI index defined above as follows

$$MPI(x^{t+1}, y^{t+1}, x^t, y^t)$$
$$= \frac{d_{CRS}^{t+1}(x^{t+1}, y^{t+1})}{d_{CRS}^t(x^t, y^t)} \left[\frac{d_{CRS}^t(x^{t+1}, y^{t+1})}{d_{CRS}^{t+1}(x^{t+1}, y^{t+1})} \frac{d_{CRS}^t(x^t, y^t)}{d_{CRS}^{t+1}(x^t, y^t)} \right]^{1/2}$$

The first term of the above equation can be viewed as Farell technical efficiency measure at period t divided by Farell technical efficiency measure at period $t + 1$ which reflects the efficiency change component in productivity change. Indeed, this term indicates whether the hospital has moved closer to the CRS-frontier. The second term of the above equation describes the geometric mean of the shifts in CRS technology observed at the production bundles (x^t, y^t) and (x^{t+1}, y^{t+1}), respectively. Hence, the MPI index reflects the technological change component in productivity change.

We can also decompose the component of technical efficiency change into pure technical efficiency change and scale

efficiency change. We consider the variable returns to scale technologies T_{VRS}^t and T_{VRS}^{t+1} for the two-time periods $\tau = \{t, t + 1\}$ as follows:

$$T_{VRS}^\tau = \left\{ (x^\tau, y^\tau): \begin{array}{l} \sum_{j=1}^p \lambda_j^\tau x_{ij}^\tau \leq x_i^\tau, \ i = 1,2,\dots,k, \\ \sum_{j=1}^p \lambda_j^\tau y_{rj}^\tau \geq y_r^\tau, \ r = 1, 2, \dots, s, \\ \sum_{j=1}^p \lambda_j^\tau = 1, \\ \lambda_j^\tau \geq 0, \qquad\quad j = 1,2,\dots,p. \end{array} \right\}$$

The corresponding distance functions are defined as $d_{VRS}^\tau(x^\varphi, y^\varphi) = \max\{\theta > 0 : \left(\frac{x^\varphi}{\theta}, y^\varphi \right) \in T_{VRS}^\tau\}$, where $\tau, \varphi \in \{t, t + 1\}$. In this case, MPI equivalently can be written as

$$\text{MPI}(x^{t+1}, y^{t+1}, x^t, y^t)$$
$$= \frac{d_{VRS}^{t+1}(x^{t+1}, y^{t+1})}{d_{VRS}^t(x^t, y^t)} \frac{\frac{d_{CRS}^{t+1}(x^{t+1}, y^{t+1})}{d_{VRS}^{t+1}(x^{t+1}, y^{t+1})}}{\frac{d_{CRS}^t(x^t, y^t)}{d_{VRS}^t(x^t, y^t)}}$$
$$\left[\frac{d_{CRS}^t(x^{t+1}, y^{t+1})}{d_{CRS}^{t+1}(x^{t+1}, y^{t+1})} \frac{d_{CRS}^t(x^t, y^t)}{d_{CRS}^{t+1}(x^t, y^t)} \right]^{1/2}$$

Thus, Malmquist productivity index is equal to the product of three terms representing the changes attributed to pure technical efficiency, scale efficiency and technology. Hence, the *MPI* index values greater than unity are meant to indicate progress whereas values smaller than unity indicate regress. Berg et al. [28] introduced a different way using the so-called base period Malmquist index to calculate technological changes.

A literature review in the health sector in Greece shows that the method has been used for the assessment of productivity change in hospitals [29,30], hospital clinics [31,32] and dialysis facilities [33].

4. Results

Considering the nature of DEA, i.e. selection of a group of homogeneous data, six hospitals affiliated with Kashan University of Medical Sciences were selected to conduct the study.

By reviewing the previous studies and analyzing the data at statistics and technology center of the University, input and output variables were selected. Therefore, regarding the importance of workforce and capital, two variables of a number of physicians and nurses (as workforce) and a number of active beds (as capital) were considered as input variables and a number of discharged patients as output variables.

Inputs and outputs were descriptively analyzed using statistical software program SPSS; moreover, GAMS software program was used for calculating the Malmquist index, technical efficiency index, scale efficiency, Pure technical efficiency, pure technical efficiency and cross-over efficiency evaluation.

A. Overall Technical Efficiency

In Table I, the technical efficiency of understudy hospitals with distinct inputs and outputs is shown. Hospitals with efficiency coefficient of one and hospitals with efficiency coefficient less than one were considered as efficient and inefficient, respectively. During a five-year period from 2011 to 2016, one (16.6%) hospital in 2011, one hospital in 2012 (16.6%), four hospitals in 2013 (66.66%), two hospitals in 2014 (33.33%), one hospital in 2015 (16.6%) and one (16.6%) hospital in 2016 were technically efficient. In addition, the average technical efficiency with constant return to scale was 0.701, 0.693, 0.955, 0.904, 0.549 and 0.468, respectively, during this period.

TABLE 1. RANKING OF UNDERSTUDY HOSPITALS IN TERMS OF TECHNICAL
EFFICIENCY BY DATA ENVELOPMENT ANALYSIS METHOD

Hospitals	2011	2012	2013	2014	2015	2016	Mean
1	0.455	0.491	0.981	0.75	0.426	0.429	0.588
2	0.998	0.622	1	0.961	0.493	0.467	0.756
3	0.59	0.727	1	1	1	1	0.886
4	0.446	0.573	0.751	0.808	0.349	0.181	0.518
5	0.721	0.749	1	1	0.579	0.421	0.745
6	1	1	1	0.91	0.408	0.307	0.77
Mean	0.701	0.693	0.955	0.904	0.542	0.467	0.71

According to Table I, hospital No. 3 had the highest technical efficiency (0.886) and hospital No. 4 the lowest one (0.518) during this period.

Pure technical efficiency

Based on the results, five hospitals in 2011 (83.3%), five hospitals in 2012 (83.3%), five hospitals in 2013 (83.3%), six hospitals in 2014 (100%), five hospitals in 2015 (83.3%) and four hospitals in 2016 (66.7%) were at best efficiency level and worked with technical efficiency in variable scale of one. The average pure technical efficiency of these hospitals during this period was 0.983, 0.982, 1, 0.998, 0.892 and 0.869, respectively. This indicates that the understudy hospitals do not optimally use their resources, especially human resources.

Scale efficiency

The average scale efficiency of understudy hospitals was 0.715 in 2011, 0.705 in 2012, 0.955 in 2013, 0.906 in 2014, 0.640 in 2015 and 0.575 in 2016. Scale, Pure technical and technical efficiency along with their frequency distribution is shown in Table II. These results indicate that the understudy hospitals did not act optimally in an operative scale.

TABLE 2. SCALE, PURE TECHNICAL AND TECHNICAL EFFICIENCY
OF THE UNDERSTUDY HOSPITALS FROM 2011 TO 2016

Years	Efficiency	Mean	Median	Maximum	Minimum	SD
	Technical	0.701	0.655	1	0.446	0.251
2011	Pure TE	0.983	1	1	0.899	0.041
	Scale	0.715	0.695	1	0.446	0.254
	Technical	0.693	0.674	1	0.491	0.178
2012	Pure TE	0.982	1	1	0.895	0.042
	Scale	0.705	0.711	1	0.491	0.174
	Technical	0.955	1	1	0.751	0.1
2013	Pure TE	1	1	1	1	0
	Scale	0.955	1	1	0.751	0.1
	Technical	0.904	0.935	1	0.75	0.104
2014	Pure TE	0.998	1	1	0.992	0.003
	Scale	0.906	0.939	1	0.75	0.105
	Technical	0.549	0.459	1	0.393	0.23
2015	Pure TE	0.892	1	1	0.601	0.173
	Scale	0.64	0.539	1	0.392	0.281
	Technical	0.468	0.425	1	0.188	0.279
2016	Pure TE	0.869	1	1	0.462	0.222
	Scale	0.575	0.524	1	0.187	0.328

B. Cross-Over efficiency

According to Table I, one out of six understudy hospitals had the highest efficiency level, namely technical efficiency of one, during 2011, 2012, 2015 and 2016. As several hospitals were of technical efficiency level of one in 2013 and 2014, cross-over efficiency index was applied for ranking the hospitals of the highest technical efficiency level (technical efficiency of one). Based on this index, hospital No. 3 acquired the highest

efficiency score out of six hospitals; furthermore, hospitals No. 3, 5, 2 and 6 with 0.981, 0.975, 0.956 and 0.951 scores, respectively, ranked as first to four. Moreover, fifth and third hospitals with 1 and 0.972 scores, respectively, ranked as first and second in 2014.

Table III showed that hospitals No. 6 ranked as first twice and hospital No. 3 ranked as first three times based on cross-over efficiency ranking from 2011 to 2016.

TABLE 3. RANKING OF UNDERSTUDY HOSPITALS BASED ON CROSS-OVER EFFICIENCY METHOD

years	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6
2011	Hospital 6 (1)	Hospital 2 (0.944)	Hospital 5 (0.56)	Hospital 3 (0.527)	Hospital 1 (0.453)	Hospital 4 (0.342)
2012	Hospital 6 (1)	Hospital 3 (0.65)	Hospital 2 (0.602)	Hospital 5 (0.596)	Hospital 1 (0.49)	Hospital 4 (0.439)
2013	Hospital 3 (0.981)	Hospital 5 (0.975)	Hospital 2 (0.956)	Hospital 6 (0.951)	Hospital 1 (0.944)	Hospital 4 (0.422)
2014	Hospital 5 (1)	Hospital 3 (0.972)	Hospital 2 (0.948)	Hospital 6 (0.892)	Hospital 1 (0.741)	Hospital 4 (0.737)
2015	Hospital 3 (1)	Hospital 5 (0.579)	Hospital 2 (0.492)	Hospital 1 (0.425)	Hospital 6 (0.407)	Hospital 4 (0.392)
2016	Hospital 3 (1)	Unit 2 (0.427)	Unit 1 (0.399)	Unit 5 (0.394)	Unit 6 (0.29)	Unit 4 (0.182)
2016	Pure TE	0.869	1	1	0.462	0.222
	Scale	0.575	0.524	1	0.187	0.328

C. Decreasing Input and Increasing the Output

In order for inefficient hospitals to become efficient, they must considerably economize in their resources and inputs and increase their outputs as well. Table IV

shows that inputs are in need of decrease.

According to Table IV, in 2016, for example, the number of physicians, nurses and beds should be reduced to 117, 291 and 449, respectively, to achieve efficiency.

TABLE 4. OVERALL NEEDED DECREASE IN INPUTS TO MAKE HOSPITALS EFFICIENT

Years		Input		
		Physicians	Nurses	Beds
2011	Actual Value	201	518	630
	Target Value	141	363	442
	Difference	60	154	188
2012	Actual Value	202	550	630
	Target Value	140	381	437
	Difference	62	168	193
2013	Actual Value	209	565	825
	Target Value	200	540	788
	Difference	9	25	37
2014	Actual Value	212	590	831
	Target Value	192	534	752
	Difference	20	56	79
2015	Actual Value	217	556	834
	Target Value	119	306	458
	Difference	98	250	375
2016	Actual Value	221	548	846
	Target Value	103	257	396
	Difference	117	291	449

D. Malmquist Productivity Index

To analyze productivity changes from 2011 to 2016, Malmquist productivity index was used in which 2011 was considered as the base year. Results shown in Table V indicate that Malmquist productivity index shows an average 10% decrease during this period. While technology changes increased by 14%, technical efficiency decreased by 6%. As a result, decrease in technical efficiency resulted in decrease in overall productivity index. Productivity index of understudy hospitals was above one in just two years (2014 and 2015), indicating increased productivity in hospitals affiliated with Kashan University of Medical Sciences.

TABLE 5. SUMMARY OF MALMQUIST INDEX BASED ON ANNUAL AVERAGE

Years	Total factor productivity change	Scale efficiency change	Pure technical efficiency change	Technological change	Technical efficiency change
2011	1.017	0.838	0.999	1.017	0.851
2012	1.405	0.730	1.018	1.379	0.661
2013	0.946	1.084	0.998	0.947	1.026
2014	0.576	1.906	0.877	0.656	1.099
2015	0.793	1.141	0.956	0.828	0.905
Mean	0.947	1.140	0.970	0.966	0.909

E. Discussion

Based on the result, the average technical efficiency of understudy hospitals was 0.71 based on DEA with constant return to scale. Furthermore, hospitals affiliated with Kashan University of Medical Sciences were not efficient in term of technical efficiency from 2011 to 2016, during which just 16.6%, 16.6%, 16.6%, 33.3%, 16.6%, and 16.6% of hospitals, respectively, were efficient in terms of technical efficiency, indicating that hospitals were in need of efficiency improvement. According to a study conducted in Tehran, the average technical efficiency of hospitals affiliated with Tehran University of Medical Sciences was 0.59 [34]. Moreover, the average technical efficiency in other studies conducted by Azar and colleagues (2013) in Tehran, Akbari and colleagues (2012) in Azerbaijan, Eel Beigi and colleagues (2012) in Khorasan Razavi and Saleh Zadeh and colleagues (2011) in Qom was 0.86, 0.984, 0.823 and 0.825, respectively, not conforming to the results of the present study [35]. In another study done by Kia Daliri and colleagues (2013), the average technical efficiency of hospitals in Iran was evaluated as 85%, indicating that the technical efficiency of hospitals studied in the present study was considerably lower compared with that of the average technical efficiency of national hospitals [36]. In Kenya and Nigeria, the average technical efficiency of hospitals was 65% and 59.4%, respectively, which is not consistent with present study [37,38].

In addition, Ram Jat's study (2013) in India showed an average technical efficiency of 79% [39], nearly conforming to the results of this study. Another study conducted in Ireland and India indicated an average technical efficiency of 95% and 84%, which do not conform to the results of the present study [40]. In a study done in the Netherlands, it was shown that the average inefficiency for domestic hospitals was 16%, indicating nearly 1.5 billion Euro wasted [38]. In this study, the hospitals' productivity was under efficiency frontier, indicating that they do not use their resources optimally and must improve their functionality; these results conformed to those of the study conducted in Tehran hospitals assessing 70% of hospitals as inefficient [5].

Based on the results of this study, the average scale efficiency in understudy hospitals was 75% and the highest amount of scale efficiency was 0.955 and 0.96 in 2014 and 2015, respectively. In the study administered by Rahimi and colleagues in Azarbajan (2011), the average scale efficiency was reported as 0.771 [35]. Moreover, the average scale efficiency was 72% in Sierra Leone and 70% in Kenya, which was in line with that of the present study [41]. Furthermore, the average scale efficiency in Akbari and colleagues' study (2012) in East Azarbaijan, in Eel Beige and colleagues' study (2012) in Khorasan Razavi, in Sales Zadeh and colleagues' study (2011) in Qom and in Mahani and colleagues' study (2009) in Kerman was 0.957, 0.881, 0.95 and 0.918, respectively [35]. In Nigeria and India, the average scale efficiency was 82.7% and 88%, which is not consistent with that of the present study [37,39]. As a result, the trend of scale efficiency changes (SEC) shows an increase from 2012 to 2013 followed by a decrease from 2014 to 2016. This indicates that the understudy hospitals must review their favorable operative scale.

Results of this study indicate that the average managerial efficiency of understudy hospitals was 0.954 in the study period, i.e. the understudy hospitals can acquire the same amount of output by saving 0.5 on inputs resources and dedicating health care service resources to more patients. The highest and lowest average pure technical efficiency were 1 and 0.895 observed in 2014 and 2016, respectively. The average pure technical

efficiency in Akbari et al.'s (2012) in East Azerbaijan, in Eel Beigi et al.'s study (2012) in Khorasan Razavi and in Mahani et al.'s study (2009) in Kerman was 0.984, 0.871, 0.931 and 0.993, respectively [35]. These values are in line with the results of the present study. Nevertheless, the average pure technical efficiency in Rahimi et al.'s study (2012) in West Azerbaijan and SalehZadeh et al.'s study (2011) in Qom was 0.782 and 0.862. These values do not conform to the results of this study [35]. Furthermore, the average pure technical efficiency in studies conducted in India and Nigeria was 0.95 and 0.728 [38,39]. The former is in accordance with the results of the present study while the latter is not.

Results showed that different kinds of efficiency such as technical, pure technical and scale efficiency do not follow a fixed and distinct trend and are continually changing. Based on the results, the potential of saving on resources was calculated; for example, surplus of physicians, nurses and beds for inefficient hospitals in 2016 was calculated as 117, 291 and 449, respectively. Considering the waste of input resources, the potential to improve the efficiency of understudy hospitals is high; using this high amount of resources, hospital output can be improved and in input resources can be economized. Moreover, it is possible to allocate this saving to other health care sectors so that patients can be provided with more services and a higher level of health care justice can be met. Findings of Farziyanpour and colleagues' study (2012) also indicated the abundance of resources such as nurses in Tehran University of Medical Sciences [42]. In addition, Ram Jat et al.'s study (2013) in India showed that inefficient hospitals must decrease the number of physicians, nurses and beds by 22%, 27% and 51.82% to get the same output level. As shown, the surplus of

human resources is more than capital resources; therefore, the number of human resources and beds must be consistent. This is possible through modifying the overall structure of hospitals [39]. This conforms to the results of the present study. Sherman (1984) believes that the existence of additional beds in health care centers is a key factor affecting efficiency decrease [43]. Awareness of existence of abundant resources with low outputs in hospitals allows the mangers and policy makers to make decisions so as to move toward improvement by decreasing the expense and inefficiency and facilitate improvement by strategic orientation and making designs.

Total factor productivity index (TFPC)

Total factor productivity index of the hospitals studied was 0.909 during the study period. From 2014 to 2015, TFPC was larger than one, indicating productivity growth of hospitals and, in 2012, 2013 and 2016, it was less than one, indicating productivity decrease. In other studies, Malmquist index for hospitals in Greece [44], Canada [45] , Utopia [46] and Taiwan [47] was 0.985, 0.988, 0.986, 0.964 and 0.977, respectively, conforming to the results of this study. Contrary to the average productivity growth of Kashan hospitals, studies conducted in some countries showed that productivity growth index of their hospitals was more than one, indicating productivity growth; for example, productivity growth was 1.209 in Brazil Federal University hospitals [48] and 0.028 in Ireland [49] hospitals.

Average technical change

In this study, the average technical change was 1.14, indicating that the trend of technical change for understudy hospitals rose from 2014 to 2016, which happened at the same time of enforcement of health system evolution program at

hospitals of Ministry of Health and Medical Education in Iran. Increased technical change starting in 2014 contributed to the overall productivity index increase at understudy hospitals. In his study in China, NG (2011) stated that the observed productivity growth from 0.68 to 0.94 is due to using modern technology in patient treatment [50]. Furthermore, Cheng's study (2015) in China showed that technical changes increased during study years [51].

By increasing pure technical and scale efficiency changes from 2012 to 2013, technical efficiency change was enhanced as well, however, technical changes experienced a decrease during this period. Therefore, considering the decrease in overall productivity index change from 0.851 to 0.661, it can be concluded that technical change has contributed to this decrease. Comparing the calculated geometric mean and considering that productivity index decreased by 10% and technical efficiency change decreased as 6% while technological changes increased by 14% during the study period, it can be concluded that technical efficiency changes significantly influenced the productivity growth decrease.

5. Conclusion

The understudy hospitals were not efficient and their activity was lower than efficiency frontier. This indicates that these hospitals did not use their resources optimally. Considering the waste of input resources, the potential exists to improve the efficiency of understudy hospitals. Using a particular amount of resources, either hospitals' output can be improved or input economization can be guaranteed. This way, saved resources can be applied to other health care sectors for providing more people with services and eliminating injustice. Awareness of existence of abundant resources with low output in hospitals allows the mangers and policy makers to make decisions to move toward

improvement due to decreased expenses and inefficiency. Thus, proper strategic orientation and decision-making will lead to improvement.

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