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Comparison of the technical efficiency of the hospital sector: Panel data analysis of the Iranian hospitals using parametric and non-parametric approaches

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ABSTRACT

Background: Health system of Iran is an integrated one in a way that health care delivery and medical education are under the supervision of the Universities affiliated Medical Sciences (UMS). HSTP is a nationwide plan implemented by MHME at the hospital affiliated universities of medical science in line with achieving universal health coverage since May 5, 2014.

Aim: The study aimed to investigate productivity and efficiency linked to the hospitals affiliated Boshehr province before and after the implementation of the HSTP.

Method: This was a descriptive-analytical study conducted by applying panel data for a 5-year time horizon. The study was carried out on eight teaching and non-teaching hospitals of Boshehr Province. An input-oriented DEA technique combined with SFA and Malmquist indices were used to estimate the efficiency and productivity changes. Data were analyzed using Excel.22 and DEA-solver learning version 8 Software.

Result: It illustrated that efficiency and technological changes over the study span were -3% and +17%, respectively. As a result, the Malmquist index has experienced an ongoing trend equaling +14%. In spite of being a progressive trend in technical efficiency based on SFA model, the technical efficiency of the hospitals examined was not favorable.

Conclusion: Estimates on the basis of the Malmquist index revealed that a 5-year average productivity change was +14%. However, the implementation of health system transformation plan (HSTP) has no statistically significant effect on that. So, there is considerable room for improving technical efficiency or cost containment by way of employing unused capacity or expanding outputs.

Keywords: Malmquist index, productivity, DEA and SFA

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INTRODUCTION

Hospitals because of the essential role in providing health care may be entitled as the first place of focus for economic problems within the health sector. Whereas in developing countries, 30-50% of health care expenditures are spent on hospital services,[1] factors like variation in per capita service utilization, population growth and increase in price have led to a growth in hospital expenditures.[2] In a report by Health Affairs, it was estimated that the growth in total hospital expenditure would be 2% higher than that in GDP in 2006-2015.[3] Reports on health expenditure in Iran demonstrated a 2.5 fold increase in per capita expenditure from 2002 to 2014.[4] Increasing health expenditure and limited public budget during the past decades have obliged decision makers to find ways to improve health status.[5] In the current economic space in Iran, it is hard to increase the level of healthcare resources utilized. On the other hand, spending more on health is not always desirable because additional health gain from using more resources, especially at the high level of expenditure, may be too minimal.[6] Thus, the only way for health improvement is the efficient use of existing resources in Iran's health sector. This issue can be a major concern for healthcare managers endeavoring to enhance quality and contain costs.[7] General hospitals efficiency, meanwhile, has received the attention of many scholars and academics because of being absorbed massive health expenditures by this industry.[8,9] According to an initial definition by Farrell, technical efficiency refers to producing a given number of outputs by using the minimum number of inputs; alternatively, delivering the maximum amount of output by a given input.[10] In line with it, two well-known methods, i.e., DEA and SFA have been introduced to measure efficiency. Each way has its pros and cons. In order to make findings robust, both methods were applied to achieve the study purpose.

A firm operating on the frontier is considered technically efficient. In the literature of performance, efficiency, and productivity, these two terms have been used interchangeably, but productivity indicates a broader concept which efficiency measurement is a part of that. Productivity is the ratio of an index of output to an index of inputs employed. Productivity change stems from efficiency change and technological changes.[11,12]

Health system of Iran is an integrated one in a way that health care delivery and medical education are under the supervision of the Universities affiliated Medical Sciences (UMS). These entities are executive bodies to the Ministry of Health policies and plans and entirely 58 UMS located in 31 Provinces in the entire country. In recent years the Ministry of Health and Medical Education (MHME) has implemented several innovative plans including family physician system and health system transformation plan (HSTP) to overcome underperformances in the area of healthcare delivery. The latest project was the "health system transformation plan (HSTP)". This is a nationwide plan which implemented in the governmental hospitals which are affiliated to the UMS. The main objective of the present study is to investigate the productivity of the hospitals affiliated to Boshehr University of Medical Sciences before and after the implementation of the HSTP reform since 2012 to 2016. Indeed, the primary research question examined in this study is ' what is the impact of HSTP on hospital productivity?

Recent reforms in Iranian health care system, that is, HSTP is a nationwide plan implemented by MHME at the hospital affiliated universities of medical science in line with achieving universal health coverage since May 5, 2014. This plan includes several executive packages, two of which directly pertained to the hospitals affiliated to MHME. These relevant packages are such as diminishing out-of-pocket payments by 10 percent of total hospitalization expenditure for inpatients in the hospitals affiliated to MHME, improving the quality of care for the hospitals affiliated with MHME, and there are several financing sources associated with HSTP. These sources include increased share of health sector budget (e.g., up to 59 percent in the year 2015 relative to 2014), resources obtaining through the earmarked (targeted) subsidies, and a specific 1 percent added value tax belonging in the health sector.[13]

METHOD

This study is a descriptive-analytical kind conducted in 2017 by employing panel data in a 5- Year time horizon. DEA-Malmquist index is used to evaluate the productivity changes of a DMU from one period to another. This index is equated with the product of "Catch-up" and "Frontier-shift" terms. Catch-up is related to efficiency changes, while frontier-shift is associated with technological alteration. In order to graphically illustrate a DEA - Malmquist model, suppose a DMU with a single input and output as evident in Figure 1.

DMUo in the period of 1 and 2 is located in points p (xo1, yo1) and Q (xo2, yo2), respectively. Catch-up is defined as equation 1:

$$\text{Catch}-\text{UP} = \frac{\frac{BD}{BQ}}{\frac{AC}{AP}} = \frac{\text{The efficiency of point Q relative to the frontier of period 2}}{\text{The efficiency of point P relative to the frontier of period 1}}$$

The Frontier – the shift is calculated based on the following formula (Equation (2) and (3)).

$$\varphi 1 = \frac{AC / AP}{AE / AP} = \frac{\text{The efficiency of point P relative to the frontier of period 1}}{\text{The efficiency of point P relative to the frontier of period 2}}$$

$$\varphi 2 = \frac{BF / BQ}{BD / BQ} = \frac{\text{The efficiency of point Q relative to the frontier of period 1}}{\text{The efficiency of point Q relative to the frontier of period 2}}$$

Then, the frontier-shift effect is measured by the following equation as the geometric mean of φ1 and φ2 as an equation (4):

$$\text{Frontier}-\text{shift} = \sqrt{\varphi 1 \times \varphi 2}$$

Based on the equation (1) and (4), Malmquist index is equal to Catch-up multiplied by Frontier shift as the equation (5):[14]

$$\text{Malmquist index} = \text{Catch up} \times \text{Frontier} - \text{shift}$$

Input and output

The data for this study was extracted from the report issued by the Deputy of Treatment Affairs affiliated to the Boshehr University of Medical Science. The data of 8 hospitals for a five-year period were studied.

The primary goal of For-profit hospitals is to maximize profit for the stockholder. Therefore, they attempt to produce services efficiently. Non-profit hospitals mainly focus on satisfying health care need, expanding into training and re-education of their staff irrespective of profit.[13] In Iran, governmental hospitals are mainly subsidized by the government and may upsize their scale. Because of the importance of higher technical efficiency in governmental hospitals, the sample is composed of 8 governmental hospitals affiliated with the Boshehr University of Medical Science.

Given that private hospitals do run for profit, they put cost containment strategies including operating on efficiency frontier and revenue maximization like marketing and pricing ones on the agenda. In contrast, government hospitals do not involve in for-profit activities; and often operate under a fixed budget. If governmental hospitals are to extend their scale and domains of services that provide, they have no option but to operate efficiently. Henceforth, it seems that efficiency in governmental hospitals is more critical than that of private ones.

Based on data available, three inputs and four outputs were selected. The inputs included a total number of *physician, nurses* and hospital *beds*. The outputs included *Admission per Bed, Occupancy rate, number of Surgeries* and *number of Discharges*. The description of input and output variables are shown in Table 1. The rationale of inputs and outputs was returned to the studies by Ozcan et al., expressing the number of beds acts as a proxy for capital investment, and medical staff does for labor in hospital service production. In the output side, the number of admissions and discharges are typical.[12]

Table 1 Variables and definition

Variables	*Definition and measurement*
Inputs	
Physicians	The number of specialists and general physicians is a major indicator of labor
Beds	The number of beds is an accepted proxy for hospital capitals
Nurses employee	The number of nurses as a member of a medical team
Outputs	
Occupancy rate	Occupancy rate is the suitable measure of capacity for offering health services
Surgery	The number of surgery is a most leading hospital treatment
Discharge	The number of discharges is considered a direct consequence of providing healthcare
Admission per bed	The number of admissions is a widely accepted indicator of a hospital workload

RESULTS

Descriptive statistics of the variables for 2012 and 2016 are shown in Table 2. It shows that there were remarkable changes in the number of both inputs and outputs during the study period. A point merits much attention is a growth in the number of hospital beds by 11 beds (10 %). On the one hand, this slight increase in the number of those might result in a high running cost in organizational infrastructure.

Table 2 Descriptive statistics from 2012 to 2016 study periods

Variables	2012 Mean (SD[1])	2013 Mean (SD)	2014 Mean (SD)	2015 Mean (SD)	2016 Mean (SD)	2011-2016 % change
Inputs						
Nurse	65.875	66.875	67.25	75.375	75.25	+14
	53.4619	61.8734	58.392	60.3407	59.3122	
Bed	98.625	96.5	98.5	102.62 5	109.25	+10
	87.1477	82.5818	79.3152	80.9539	82.5843	
Doctor	24.75	26.875	31.375	34.375	33.875	+36
	27.22017	29.5864747	34.94974	30.59386	29.78018	
Outputs						
Occupancy rate	40.5	45	45	53.5	52.875	+30
	21.6967	16.598	16.5989	15.1496	20.1646	
Number of surgeries	3424.7 5	3568	3568	3369.25	4203.62	+22
	3828.86	4080.43	4080.43	2998.72	3524.72	
Admissions per Bed	5.5375	6.375	6.375	6.8875	6.875	+24
	3.08864	2.29769	2.29769	2.47669	4.04462	
Number of Discharges	8492.87	8183.25	8183.25	9143.62	10435.1	+22
	7963.1	7080.80	7080.80	7268.73	8248.73	

[1]Standard deviation

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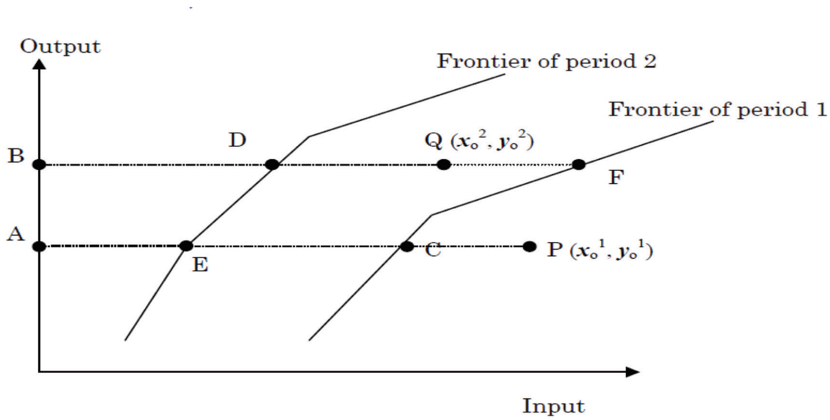

Figure 1 Catch-up

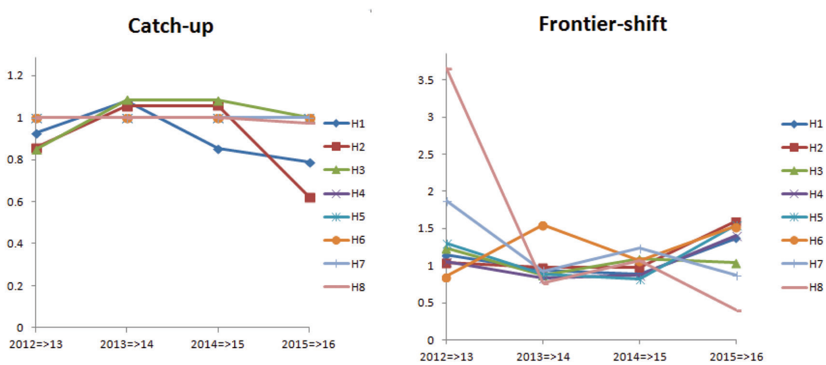

Figure 2 Trend of efficiency and technological changes among DMUs

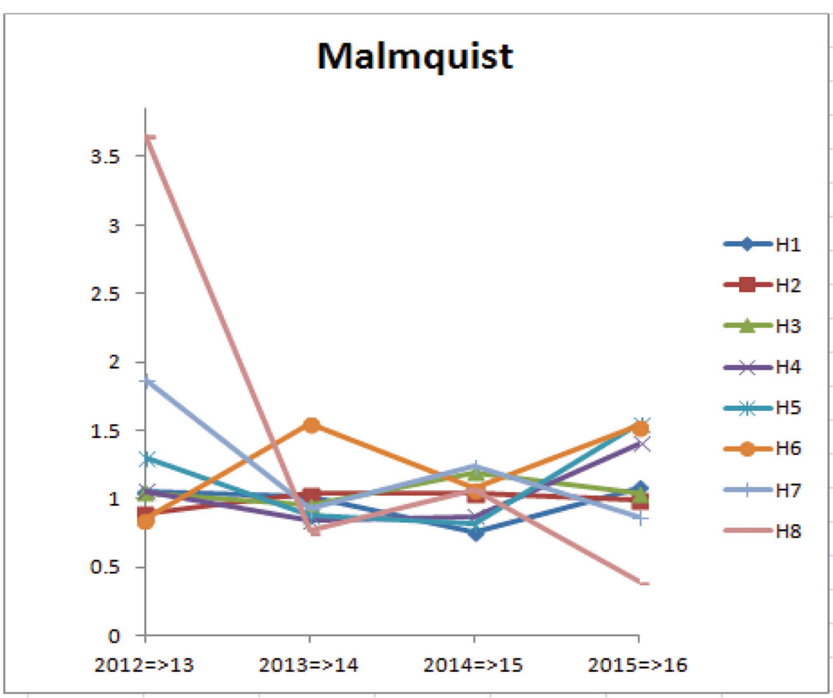

Figure 3 The Malmquist index in DMUs

On the other hand, an expansion in the economic scale is likely to cut unit cost of services.

As to measure technical efficiency, BCC and input-oriented models were used in DEA. Those hospitals having gained score equaling one denote the optimal application of inputs to produce outputs. These decision-making units serve as benchmarks for inefficient peers. In this study, 5 out of 8 hospitals were in the efficient category for the all of the period over 2012-2016. On the whole, the average efficiency score for hospitals was %93, showing %7 inefficiency for them. This is evidence that, on average, the hospitals are likely to use inputs less efficiently. Inefficient hospitals in comparison to efficient ones use 7% more inputs. In other words, inefficient hospitals can reduce their inputs by 7% to reach an efficiency frontier.

The findings illustrate that there were fluctuations in efficiency change (catch- up) among hospitals and also across the years represented in Figure 2. Our results showed that about %62 of the hospitals had remained constant regarding efficiency for all period. No hospital was found to be positive changes in efficiency in all period from 2012 to 2016. As for all hospitals, the results revealed positive, negative or no changes in efficiency. Apart from 2012-13, Average efficiency has a regressive trend over the study period. Furthermore, the 5-year average efficiency for %50 of hospitals has remained constant.

Technology changes from 2012 to 2016 have also been shown in Figure 2. In technological change side, there is a wide variation in efficiency change between 2012-13 and 2013- 14. During 2012-13 all of hospitals but number 6 were operating efficiently by contrast, over 2013-14 hospital 6 was the only one was doing so (see also Figure 3). The analysis illustrates technological changes of 1.52 (geometric mean) during 2012-13, which decreased to %97 in 2013-14. For all of the time period in the study except for 2013-14, on average, the hospitals experienced positive change in technology. We observed no hospital having a continuously positive technology change from 2011 to 2016. However, the 5-year average efficiency changes were positive for all hospitals that expand from 1.04 to 1.25.

Finally, the non-stable trend in productivity was found during the analysis period. The geometric mean of Malmquist index for around %75 of hospitals showed a positive alteration in 2012-2013 while this figure has amounted to about %37. Depending on our findings, there were time periods with a regressive trend and periods with progress in Malmquist index for each hospital. Figure 3 displays changes in the productivity index. A large number (5 Out of 8) of hospitals through the study time frame apart from 2013-14 had a positive change in terms of productivity. The maximum change in Malmquist index attributed to time between 2012 and 2013 with 46% changes. There is a remarkable resemblance between the Malmquist and frontier-shift panel that this could explain technological changes has more impact on Malmquist index rather than efficiency changes.

Generally, based on paired T-test, the implementation of health system transformation plan (HSTP) had no statistically significant effect on the Malmquist productivity index (MI mean before: 1.23, mean after: 1.05 (95% CI: -0.63- 0.28; p=0.4).

The other approach exploited to measure the efficiency of related hospitals was Stochastic Frontier Analysis (SFA). In this model, a production function for ith DMU is defined as follows:

$$Ln\ y_{it} = -_{i} + \sum \dagger_{it} Ln\ X_{jit} + \varepsilon_{it}$$
$$i = 1,2,\ldots,n \quad j\ inputs\ t : period$$

Where:
Ln = Natural Logarithm
y_{it} = Output for hospital i in period t
X_{jit} = jth input for hospital i in period t
ε_{it} = Residual for hospital i in period t

The residual also captures other noise or random effect (e.g., omitted variables, measurement error, etc.). SFA attempts to decompose the error term into efficiency and noise components for each DMUU. The is an identically distributed conventional two-sided error term with zero mean. It stands for random noise, omitted variables, etc. Whereas, u_{it} is for a non-zero mean. It stands for inefficiency. As a result, technical efficiency is calculated by the following proportion:

$$TE = \frac{exp\ y_{it}}{exp\,(\dagger_{it} X_{it} + v_{it})} = \frac{\exp(\dagger_{it} X_{it} + v_{it} - u_{it})}{exp\,(\dagger_{it} X_{it} + v_{it})} = \exp(-u_{it})$$

Average score obtained using four outputs as a dependent variable was considered as a measure of technical efficiency. Based on the parametric model, the annual average efficiencies ranged from 0.17 to 0.70, being lowest for the hospital H8 and highest for the hospital H4. There was an efficiency increase for all hospitals over 2012–2016.

DISCUSSION

As to examine efficiency variability, Malmquist index also was exploited. Average inefficiency in 2012-16 was estimated at 0.30–0.64 with the parametric method and 0.06– 0.08 with the non-parametric method. This finding suggests that improving the efficiency of Boshehr hospitals could dramatically result in input saving or output increasing without creating extra cost. According to DEA and SFA approach, about 35% and 100% of hospitals are operating inefficiently. One possible explanation for this disparity between findings of models is the sensitivity of DEA relative to Sample size. In other words, a large fraction of DMUs will be efficient when sample size would be low. Sahin's study showed that more than 80% of Turkey hospitals were inefficient during the 4-year time span of reform.[15] Their result is consistent with our findings. In spite of being a progressive trend in technical efficiency based on SFA model, the technical efficiency of the hospitals examined was not favorable. In line with this findings, a study by Raei et al. about the efficiency of Yazd hospital showed only one hospital has been operating on efficiency frontier in all years of the analysis.[16] Depending on the 5–year average measures, efficiency, and technological changes were -3% and +17%, respectively, that have caused 14% growth in the Malmquist index during the study span. As evident, a large fraction of productivity changes is attributable to technological changes. Pham and colleagues in a study on efficiency of hospitals in Vietnam noticed that over an 8-year period Hospitals' productivity progressed around 1.4 percent per year, which was mainly due to the technical efficiency improvement.[17] Their result is in contrast with our finding. It seems that such disparity stems from structural change programs in Vietnam that has resulted in restructuring in the hospital sector and managerial regulatory as well as remarkable efficiency improvement. Valdmanis and colleagues carried out a study to examine the performance change by Malmquist approach in Scottish hospitals over 2003–2007. They did not find a constant tendency in Malmquist index, the efficiency index, and the technology change over the time above the horizon. There appears the result of this study confirms to a great extent our study results.[18]

Torabipour et al. in a study conducted in 12 teaching and non-teaching hospitals of Ahvaz County observed that the trend of productivity rate had generally been increasing. But, the hospitals had a decreasing total average of productivity.[19] In sum, the findings suggested that there is considerable room for the efficiency improvement in Iranian hospitals.

Our study is subject to several limitations. Firstly, the sample was limited to the hospitals belonging to one province (Boshehr) so that its generalizability should be conducted with caution. Secondly, It should be taken into account that, due to lack of data, no variables reflected exogenous and qualitative ones having an effect on hospitals performance. Thirdly, the small sample size may biased efficiency scores obtained by DEA model. Further research should aim at a number of unanswered theoretical questions, especially, the appropriateness of SFA or DEA and selection of the type of variables for analysis in the hospital efficiency investigations.

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CONCLUSION

The results of our study indicated that, in spite of being a progressive trend in the performance of hospitals affiliated the Boshehr University of Medical Science, there is considerable room for improving technical efficiency or cost containment by way of employing unused capacity or expanding outputs. It is recommended that healthcare managers should look for practical solutions to improve productivity in these settings.

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CONFLICT OF INTEREST

The authors report that they have no competing interests with regard to this research.

AUTHOR'S CONTRIBUTIONS

All members have contributed in various degrees to the analytical methods used, to the research concept, and approved the final manuscript.

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