SETSCI conference proceedings
SETSCI Conference Proceedings
4 (6), 459-461, 2019

4th International Symposium on Innovative Approaches in Engineering and Natural Sciences
November 22-24, 2019, Samsun, Turkey

https://doi.org/10.36287/setsci.4.6.124
2687-5527/ © 2019 The Authors. Published by SETSCI

ISAS WINTER - 2019 ENS

The Malmquist Production Index in determining and improving healthcare productivity in Turkey

Serpil Aydın*

[1]*Department of Statistics/Faculty of Science, University of Ondokuz Mayıs, Samsun, Turkey*
Corresponding author: serpil.gumustekin@omu.edu.tr
+*Speaker: serpil.gumustekin@omu.edu.tr*
Presentation/Paper Type: Virtual / Abstract

Abstract – It is a fact that countries with robust and inclusive health services have a longer life expectancy at birth. Health services aim to improve and maintain health. In order to achieve these objectives, an integrated combination of various activities in which the production of more than one type of output and the consumption of more than one type of resource is aimed is evaluated. In the study, to examine the efficiency of healthcare in Turkey between the years 2010-2014, which is a nonparametric Malmquist DEA method is used. We have used three output variables: life expectancy at birth, health adjusted life expectancy and infant mortality rate and three input variables: number of doctors, number of hospital beds and public health expenditures as percentage of GDP. Findings reveal that there are a number of both developed and developing cities on the efficiency frontier, while the great majority of the cities in the sample are inefficient.

Keywords *– Efficiency, DEA, Health, Malmquist, Productivity*

I. Introduction

One of the most basic needs of people is to provide reliable, quality and stable health services. Health services are all activities carried out by the health sector in order to improve the health of individuals [1]. The Health Transformation Program (HTP) of the Turkish health system, which was initiated in 2003, has shown significant improvements in wider access to health facilities, quality and efficiency [2]. The HTP is designed to advance the primary health outcomes that lag behind comparable countries, improve the quality and efficiency of the health system, increase equal access to health facilities, and achieve universal coverage [3]. The reform combined multiple coverage plans in which different authorization rules had a single Social Security Institution (SSI), where restructuring and redistribution were developed. The expansion was around 7.7%, with healthcare spending well above other OECD countries. Private sector over the past decade, Turkey has developed rapidly, including the less developed regions and currently represents about 18% of hospitals and 36% of all hospital beds.

Life expectancy at birth, infant mortality, maternal mortality and infant mortality are related as shown by the statistics has improved over the last decade in an impressive way in Turkey [4].

The health spending in Turkey is similar to the course of development occurring in the world and is experienced year-over-year increase. During 2000-2016, according to data obtained from TURKSTAT, the average share of total health expenditure in GDP in Turkey is 5%. In addition, there is a steady upward trend in total health expenditures and per capita health expenditures. The average annual increase in total health expenditures was 13.53%. Thus, total expenditure, which was 51 billion in 2007, approached 120 billion in 2016 [5].

Liu and Zhang [6] analyzed provincial government health input dynamic efficiency by Malmquist index method and examined whether there exists convergence of the efficiency of the eastern middle and west provinces. Hadad et al. [7] analyzed the technical efficiency of health production across the OECD countries, using the data envelopment analysis (DEA) method. In their study, Data envelopment analysis (DEA) was utilized to calculate OECD countries' healthcare system efficiency. Life expectancy and infant survival rate were considered as outputs in both models. Healthcare systems' rankings according to the super-efficiency and the cross-efficiency ranking methods were used to analyze determinants associated with efficiency. Gok and Sezen [8] investigated the efficiencies of hospitals in Turkey with respect to their ownerships (i.e. state, education & research, university and private) for the years 2001 to 2006. Gök [9] examined the role of medical technology for improving service quality. For this purpose he empirically analyzed the relationship between the efficiency of medical technology and perceived service quality in Turkish healthcare services. Accordingly, inefficiency causes of medical technology were also discussed in his study. Data Envelopment Analysis (DEA) was applied to analyze the medical technology-based efficiencies of teaching hospitals in Turkey for the study years from 2008 to 2010. Kohl et al. [10] reviewed 262 papers of DEA applications in healthcare with special focus on hospitals and therefore closes a gap of over ten years that were not covered by existing review articles. The aim of this study is to examine to the case of Malmquist indices constructed from nonparametric distance function estimates using data of Turkey's healthcare during the period of 2013 through 2017.

II. Materials and Method

DEA, as developed by Charnes et al. [11] and extended by Banker et al. [12] is a linear programming technique based on approach for measuring the relative efficiencies. The efficiency of a Decision-Making Units (DMU) is expressed in terms of a set of measures which are classified as DEA inputs and outputs [11]. DEA evaluates the relative technical efficiency with linear programming model by using input and output variables from similar and homogeneous decision making units (DMU). DEA has two key advantages for efficiency analysis: (1) it readily analyzes multiple inputs and outputs at the same time therefore, (2) captures more specific production characteristics of each unit [8].

If there are m inputs and s outputs for each of the n decision-making units in DEA, the i-input amount of the jth decision-making unit is xij ≥ 0 and the r-output amount produced by the j-decision maker yrj ≥ 0.

Input oriented fractional DEA model including:

$$Enb\frac{u_1.Y_{1k}+u_2.Y_{2k}+...+u_s.Y_{sk}}{v_1.X_{1k}+v_2.X_{2k}+...+v_m.X_{mk}} = Enb\frac{\sum_{r=1}^{s}u_rY_{rk}}{\sum_{i=1}^{m}v_iX_{ik}}$$

$$\frac{u_1.Y_{1j}+u_2.Y_{2j}+...+u_s.Y_{sj}}{v_1.X_{1j}+v_2.X_{2j}+...+v_m.X_{mj}} \le 1 \Rightarrow \frac{\sum_{r=1}^{s}u_rY_{rj}}{\sum_{i=1}^{m}v_iX_{ij}} \le 1 \quad ; \quad j=1,...,n$$

$$u_r \ge \varepsilon > 0 \quad ; \quad r=1...,s$$
$$v_i \ge \varepsilon > 0 \quad ; \quad i=1,...,m$$

The DEA relative efficiency measure for a target decision making unit k can be determined by solving the CCR (Charnes, Cooper and Rhodes) or BCC (Banker, Charnes, Cooper) models. CCR model calculates the efficiency ratio for the DMUs based on their inputs and outputs and it is under constant returns to scale (CRS) technology which are inputs and outputs linked in a strictly proportional manner. The others BCC model is under variable returns to scale (VRS) technology and it estimates the pure technical efficiency of a DMU at a given scale of operation. The only difference between the CCR and BCC models is the convexity condition of the BCC model, which means that the frontiers of the BCC model have piecewise linear and concave characteristics, which lead to variable returns to scale [12].

DEA assigns an efficiency score, one to efficient units and less than one to inefficient units. Then, it evaluates the technical efficiency of DMUs but doesn't allow for a ranking of the efficient units themselves. When the data of evaluated DMUs is the panel data containing more than one observed values of time points, the changes in productivity and the respective roles of technical efficiency and technical progress on the productivity changes can be analyzed, which is the commonly-used Malmquist productivity index (MPI). [13] first calculated the Malmquist Index by using the DEA method, and decomposed the Malmquist Index into two aspects of change: one is the change of technical efficiency of the evaluated DMU in two periods; the other is the change of production technology, reflecting the changes of the production frontier in the DEA analysis.

Caves et al. [14] explained the following formula by calculating the total efficiency between two different periods.

$$M\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \left[\frac{D^t\left(x^{t+1}, y^{t+1}\right)}{D^t\left(x^t, y^t\right)} \times \frac{D^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D^{t+1}\left(x^t, y^t\right)}\right]^{1/2}$$

Here, y is the output vector and x is generated using the input vector. The output specifies the process function and the variable describes the efficiency change in the period t and t + 1 under the boundary technology reference for period t. As always, M gives the geometric mean of the period studied and shows the progress or decline in the period of the DMU s boundary value technologies. If M> 1, productivity develops, M = 1 does not change productivity, M <1 decreases productivity. MPI is examined in two parts;

Technical Efficiency Index of Change (TECI): Indicates the change in the proportional efficiency of an DMU for the process t to t + 1.

Technological Change Index (TCI): Explain the technological changes in the boundary between periods in the time period.

MPI is described as follows.

*Malmquist productivity index = TECI * TCI*

While the Technical Efficiency Change Index describes the performance of the decision-making unit in improving its effectiveness, the Technological Change Index is used to explain healthcare efficiency between the two periods and is generally related to health operating technologies [15].

When creating a model, it was taken into consideration that there are homogeneous systems that produce the same outputs with the same inputs and are not affected by external factors in a very different way in accordance with the purpose of the study. For this reason, data were obtained from the Ministry of Health, State Hospitals affiliated to the Ministry of Health were selected for effectiveness measurement, and the major cities and provinces where they were located were accepted as Decision-Making Units (DMU). In the analysis, no distinction was made between the big cities and provinces and the activity scores of the DMUs were listed. From 2010 to 2014, efficiency analyzes of 55 metropolitan and provincial hospitals were conducted with DEA using a non-parametric, input-oriented approach. In this model, total factor productivity model of Malmquist Index was used with the assumption of constant return to scale and the results were evaluated. We have used three output variables: life expectancy at birth (y_1), health adjusted life expectancy (y_2) and infant mortality rate (y_3) and three input variables: number of doctors (x_1), number of hospital beds (x_2) and public health expenditures as percentage of GDP (x_3). Models were analyzed in Max – DEA Ultra program.

III. Results

Table 1 shows the efficiency of DMUs with all variables between 2010 - 2014. The first part of the table shows the efficiency values for all DMUs during the years. If the efficiency score is 1, there is no change in efficiency, if it is below 1, it decreases and if it is above 1, it increases. When the index of change in efficiency is greater than 1, it means that the shift of service production limit is shifted up or new innovations are applied. The scale efficiency (Pure Efficiency Change and Scale Efficiency Change) calculated in the analysis shows that the enterprise provides services at the appropriate scale.

Table1. Analysis results

Period	Efficiency Change	Technical Change	Pure Efficiency Change	Scale Change	Total Factor Productivity
2010/2011	1,1340	1,7100	1,0350	1,2670	1,9380
2011/2012	0,9890	0,8330	1,0340	0,9570	0,8150
2012/2013	0,9230	1,0920	1,0190	0,9150	1,0090
2013/2014	1,1020	0,8550	0,9910	1,1120	0,9420
Mean	**1,0370**	**1,1225**	**1,0198**	**1,0628**	**1,1760**

In the 2010-2011 period, the efficiency values of all DMUs are above one. In 2011-12, a decrease was observed in all values. One of the main reasons for this is health reforms in Turkey. As a result of these reforms, the number of multipliers and the number of physicians and nurses were limited in many public hospitals. When the average of five years is examined in the table, it is seen that all the values of the activity have increased. Efficiency change value increased by 1.98%, technical efficiency changes by 12.2%, pure efficiency change by 6.28%, scale efficiency change by 1.4%, Total Factor Productivity increased by 17.6%. Within the efficiency change, only pure efficiency change has decreased from year to year and there is no efficiency that has increased in all years. Looking at the change in efficiency in the year 2013/2014, a decrease in efficiency changes above 1 in 2012/2013 and an increase in efficiency changes below 1 was observed.

Before looking at the average of all DMUs, efficiency scores on the basis of DMUs were also considered. In 30 provinces out of 55, all efficiency exchange scores were over 1. There is no province with all efficiency exchange scores below 1.

IV. DISCUSSION

From 2010 to 2014, 55 provinces and the hospitals of the Ministry of Health in Turkey were measured using Malmquist Total Factor Productivity Index. In the analysis 3 input and 3 outputs and input oriented fixed income model were used. If the MPI scores are less than 1, this does not mean hospital failure. The study showed that hospitals can maximize their technical effectiveness in the health sector if they work effectively using their full potential.

V. CONCLUSION

Health data of provinces in Turkey as the average of the provinces with higher socio-economic level when considered separately, it is seen that the higher service performance. It is possible to develop policies in order to increase the performance of hospitals of other provinces as well, with reference to the activities of fully active hospitals.

As the input and output variables differ in the future studies, the findings will change to a great extent. Therefore, the studies to be performed with different input and output variables can be evaluated by comparing with this study.

ACKNOWLEDGMENT

This paper is presented in the 4th International Symposium on Innovative Approaches in Engineering and Natural Sciences.

REFERENCES

[1] Tunca, Halil (2018), “Türkiye’de İllerin Sağlık Etkinliğinin Belirlenmesi: Bootstrap Veri Zarflama Analizi”, Rating Academy Yayınları, pp.239.

[2] Sulku, S. N. (2011). The health sector reforms and the efficiency of public hospitals in Turkey: provincial markets. The European Journal of Public Health, 22(5), 634-638.

[3] Bump, J. B., and Powers Sparkes, S. (2014). A political economy analysis of Turkey's Health Transformation Program.

[4] Aydın, A., Atila, Ü., and Aydın S. (2018). Use of ANN in Predicting Life Expectancy: The Case of Turkey. Artificial Intelligence Studies, 1(1), 1-7.

[5] Berk, E., & Çerçioğlu, H. (2019). Türkiye’deki Sağlık Hizmetleri Sektörünün Şehirlerin Panel Verilerine Dayalı Olarak Etkinlik ve Verimliliklerinin Ölçümü. Gazi Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi, 34(2).

[6] Liu, Z. M., & Zhang, X. Z. (2012). The Dynamic Efficiency and Convergence of China Government Health Investment—Based on Modified Malmquist Index Method. Soft Science, 26, 50-56.

[7] Hadad, S., Hadad, Y., & Simon-Tuval, T. (2013). Determinants of healthcare system’s efficiency in OECD countries. The European journal of health economics, 14(2), 253-265.

[8] Gok, M. S., & Sezen, B. (2011). Analyzing the efficiencies of hospitals: An application of Data Envelopment Analysis. Journal of Global Strategic Management, 10(1), 137-146.

[9] Gök, M. Ş. (2013). Improving Service Quality In Turkish Healthcare System: The Role Of Medical Technology. International Review of Economics and Management, 1(2), 92-107.

[10] Kohl, S., Schoenfelder, J., Fügener, A., & Brunner, J. O. (2019). The use of Data Envelopment Analysis (DEA) in healthcare with a focus on hospitals. Health care management science, 22(2), 245-286.

[11] Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision-making units. European journal of operational research, 2(6), 429-444.

[12] Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis.Management science, 30(9), 1078-1092.

[13] Malmquist S. Index numbers and indifference surfaces. Trabajos de Estadistica 1953;4:209–42.

[14] Caves, D. W., Christensen, L. R., & Diewert, W. E. (1982). The economic theory of index numbers and the measurement of input, output, and productivity. Econometrica: Journal of the Econometric Society, 1393-1414.

[15] Balıkçı, C. (2016). Türkiye’deki Havaalanlarının 2009–2014 Yılları Arasındaki Etkinliğinin Veri Zarflama Analizi Ve Malmquist Endeks Metoduyla İncelenmesi.