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Research Article

# Benchmarking healthcare systems of OECD countries: A DEA – based Malmquist Productivity Index Approach

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**ABSTRACT**

Along with technological innovations and developments experienced in the second half of the twentieth century, very important changes have occurred in healthcare. Many different, complex and economically expensive services are being tried to be carried out together. For this reason, it is finally crucial that the health services delivered by providers to scarce resources are delivered effectively and efficiently to people without sacrificing quality. Today, the most important problem of the production of healthcare services is the resource shortage as it is in other sectors. Efficiency, quality and competition are important criteria in the production and delivery of health services. Reducing costs in the production of health services is one of the main health policies for many world countries. These policies have made it necessary for international competitiveness, product and service sectors to continually improve their performance. The objective of this paper is to identify the efficiency of healthcare services using the healthcare data of OECD countries through the years 2000 – 2015. Also, this paper examines the fluctuations in total factor productivity, which is obtained by multiplying technical and technological changes in efficiency measurements by years. Using the Malmquist Total Productivity Analysis method, the most efficient healthcare systems are found in Chile, Denmark, Iceland, Israel, Japan, Korea, Mexico, Slovenia, Sweden, and Turkey both technical efficiency and scale efficiency all years.

**Keywords:** DEA, Malmquist, Efficiency, Healthcare, OECD

## 1. Introduction

Healthcare industry, accounting for a massive share of Gross National Income (GNI) of countries continues to face new challenges daily. Majority of the executives have realized that the only way to maintain their profits is to enhance the performance of their facilities, which brought benchmarking, that is, comparative evaluation to the attention. Benchmarking is essential for healthcare sector, particularly now. Studies carried out with data collected in the healthcare industry, along with the interpretations of those studies with field application on mind serve to meet this need. This study aims to bring a new perspective to the notion of performance, going beyond just presenting efficiency results in the field, and providing answers as to the kind of adjustments that are necessary to make within the system in order to optimize expenditure within the healthcare industry, as well as overall impact of other inputs and outputs.

An organization is efficient when it is impossible to generate further output with the available input, or when it is impossible to reduce input utilization without compromising output amount [1]. Organizations aim to maximize revenue and output as a rule. Increase in the cost does not necessarily translate into an increase in revenue due to cost-awareness, rather, it is far more important to increase efficiency. Thus, in those health organizations with efficient management the potential for cost-saving is higher [2]. Indeed, it is assumed that organizations in healthcare sector aim to surpass the limits of their output levels, all the while minimizing their input levels. Therefore, increasing cost-saving potential of healthcare organizations with efficient operation, and maximizing efficiency within hospitals became an increasingly important topic for hospital executives [3]. Ehreth [4] points out that efficiency is the primary indicator of performance of hospitals with regards to evaluating the decisions on the allocation of resources. When there are several alternatives with multiple input and multiple outputs, Data Envelopment Analysis (henceforth referred to as DEA) is the best programming tool that provides multi-criteria comparison and evaluates performance [5]. DEA is a linear programming-based method put forward by Charnes, Cooper, and Rhodes [6] based on [7]. It is a performance evaluation technique for evaluating the relative efficiency of non-parametric mathematical programming and Decision-Making Units (DMU) [8]. It is commonly used for evaluating production efficiency in healthcare organizations [9,10,11,12,13]. It is a widely held view that the inefficiency in healthcare services and healthcare organizations cause the necessity to employ additional healthcare services, which ultimately causes an increase in overall cost. This is because the use of resources increases relative to other efficiently operated healthcare organizations. Therefore, efficiency in healthcare organizations and healthcare services is of utmost importance. DEA is valuable in that it can be used to increase efficiency in healthcare services and carry out benchmarking relative to other healthcare organizations. Having said that, when presented with time-dependent data, we see that research into the use of DEA in benchmarking healthcare services is still lacking. Benchmarking a healthcare organization at specific point in time may be misleading in that, the organization in question may appear to perform well at a certain point, but in the long term it may perform badly overall. When time factor is not considered, the efficiency results derived from a specific period can be biased [14]. Therefore, the efficiency of hospitals should be evaluated over a period. This study evaluates the current state of things and provides suggestions as to how to ensure maximum output with minimum input and aims to provide a broad perspective. Based on the primary outputs and its effects on population over years of healthcare industry that faces many social, economic, political, and even geographical issues, this study is comprised of not only evaluations with numerical data, but also evaluations of system structures as well. This study aims to determine the efficiency of healthcare services in OECD countries with the use of Malmquist Productivity Index and DEA. Using the healthcare data of OECD countries through the years 2000 – 2015, this study aims to examine the fluctuations in total factor productivity, which is obtained by multiplying technical and technological changes in efficiency measurements by years. Using DEA to evaluate healthcare, the relative efficiency of each DMU can be compared to the efficient units. Consequently, it is possible to benchmark the DMUs for the governments, as well as determine the changes required for their effectiveness [15].

## 2. Healthcare

The health care sector plays an important role in promoting individual wellbeing and developing a harmonious society. As a fast growing sector, expenditures on the health care are in- creasing for the majority of nations. However, the resources for public sector activities are severely limited. The more resources spent on the health care, the fewer can be spent on other public services, such as education, domestic and international public assistance and aid, and basic social security [16].

Health economics is a branch of economic theory that deals with the efficiency, productivity, values, and behaviors of production and consumption of healthcare services. In broad terms, health economists study the functioning of healthcare systems, and behaviors that have an impact on health. In a sense, healthcare services are a byproduct of healthcare treatment, while productivity refers to the relationship between inputs as resource (costs in the form of workforce, capital, or equipment), outputs as a byproduct (treated patients, time spent waiting, etc.), and ultimate healthcare outputs (lives saved, longevity of life gained, quality of life). Although several estimations use these byproducts as a measurement of efficiency, it may pave the way for suboptimal suggestions as a result of the estimation. Ideal economic assessments should be centered upon final healthcare results [17].

The national healthcare system is a complex, yet extremely important unit for general welfare, seeing as unnecessary focus on policy and a lack of resources are to the detriment of the country, not to mention the adverse effects it will result in on other sectors. In order to ensure proper handling of such disparities, there may be a need for a sort of control switch mechanism, if not other large-scale reforms. Healthcare reform is not a brand-new idea; however, the overarching purpose is to encompass the population, while also ensuring the inclusion of those who cannot afford to pay for their own healthcare needs into the provision for healthcare services. There are 196 countries all over the globe that provide some form of healthcare service. It is crucial to perform analysis on the structure and financing of the healthcare organizational systems, as well as the management of healthcare resources. Countries all over the globe currently adopt the following healthcare system models: The Beveridge Model, the Bismarck Model, the National Insurance Model, and the out-of-pocket model [18], [19], [20], [21]. However, a large majority of countries opt to adopt a mixture of all four models based on their own needs. Therefore, it is of great importance to be cognizant of how some of these countries implemented certain parts of these models in order to better understand how international healthcare systems operate. None of the given health service models are perfect when they are put in practice, and it is crucial to strive for the improvement of the existing healthcare services for everybody regardless of their nationality or ethnic origins. Therefore, examining the health services of each country separately will be beneficial in this respect. Healthcare policies adopted in the OECD countries are idiosyncratic to each country; and the health services are organized on a national level. For example, while the Beveridge health system is being implemented in Spain; Germany, France, Belgium and Netherlands adopt Bismarck system. Consequently, there are huge discrepancies between these countries' practices of health service funding, service delivery, use of human resources, and healthcare regulations such as while

# 3. Methodology

In this section, we provide a brief overview on our methodology. Our method performs analytical approaches to measure the efficiency in healthcare systems at the macro-level (countries) using DEA and Malmquist Productivity Index. The method aims at adding the two contributions to the literature. (i) We consider measuring the efficiency of health services in a certain period, (ii) We suggest proposals for countries that are not productive in health care services to become efficient with the help of reference countries.

## 3.1. Data Envelopment Analysis (DEA)

DEA is a non-parametric linear programming tool employed in order to estimate production efficiency, input and output usage, or technical efficiency. [6] introduced this method first and used the term Decision Making Unit (DMU) to refer to the units where efficiency values are calculated. DEA is specifically empowered by its ability to efficiently examine the efficiency of healthcare providers [22]. Sherman [23] was the first to apply the DEA methodology in order to measure the efficiency of seven US hospitals. As for Europe, the first analysis on efficiency was carried out by [24] on Swedish hospitals and, in few years, research on this topic have increased [25].

Data Envelopment Analysis designates the "best" decision making units that produce the most output through the least input. It calculates this based on the relative distance of the efficiency any one decision making unit to the efficient frontier. The line that the best decision-making units draw are used as the reference point. When the radial distance of other decision-making units to the threshold drawn by the best decision-making units are measured, the efficient and inefficient decision-making units are determined. If the efficiency value is equal to 1, then the DMU is efficient. On the other hand, if the if the efficiency value is smaller than 1, the DMU in question is inefficient. All the flexible variables should be equal to 0 for a decision-making unit to be efficient. If the flexible variables are not equal to 0, the decision-making unit is inefficient, in which case it might be possible to render it efficient by way of reducing the number of inputs while increasing the number of outputs whose production were identified to be insufficient. DEA models are characterized by their states – i.e., constant returns to scale, or variable return to scale- and they are assessed by whether they are input-oriented, or output-oriented. The input-oriented models aim to estimate the most appropriate amount of input to be utilized in order to produce a certain amount of output in the most efficient way possible. The output-oriented models aim to estimate the most amount of output that can be produced by a certain amount of input [26].

Practically, we can measure the efficiency of a certain $j_0 - th$ country using the equation proposed by [6] under the assumption that there is no difference in scale among OECD healthcare. Suppose that there are n countries (DMUs) in this study. Each country ($DMU_j$) uses m inputs and s outputs, the total input for $DMU_j$ is Σ $v_k X_{k_{j_0}}$ and the output is Σ $u_m y_{m_{j_0}}$; the efficiency index of $DMU_j$ is defined as ratio of all outputs to overall inputs. The BCC model with variable return to scale can be derived using the following formula to obtain efficiency.

Objective Function: (1)

$$\min \sum_k v_k X_{k_{j_0}}$$

subject to

$$\sum_m u_m y_{m_{j_0}} = 1$$

$$-\sum_m u_m y_{m_j} + \sum_k v_k X_{k_j} \geq 0$$

$$1 \leq j \leq n$$

$$0 \leq u_m , v_k \leq 1$$

where, $u_m$ : weight of m – th output variable; $v_k$ : weight of k – th input variable; $X_{k_j}$: k-th input of j-th country; $y_{m_j}$: m-th output of j-th country and n: number of countries [27].

## 3.2. Malmquist Productivity Index (MPI)

The DEA method allows to calculate the technical efficiency for a period t. To make a dynamic analysis of the behavior of the DMUs in periods t and t+1, an intertemporal model is necessary. When using the DEA model, Malmquist does not require price information. Another advantage of the Malmquist Index is the possibility of decomposing it, providing information about changes in technical efficiency and technological progress. Thus, we chose to use the Malmquist Index to analyze the dynamics of technical efficiency in healthcare efficiency in OECD countries between periods t and t+1 [28]. Malmquist Productivity Index (MPI) was first suggested by Malmquist [29]. Then, MPI was developed by [30]. It is a quantity index that represent an increase in total factor productivity of a decision-making unit and reflects an increase or decrease in productivity over time using multiple inputs and outputs. Malmquist Productivity Index assesses the fluctuation in the productivity of a DMU between two time periods.

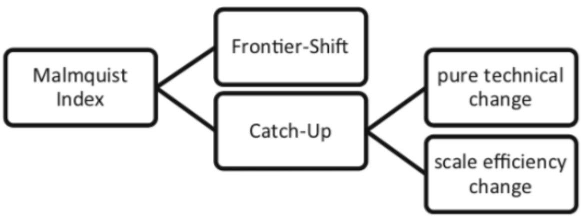


**Figure 1.** Decomposition of Malmquist Index (Source: Kohl et al., 2019)

MPI attributes the cause for the fluctuations in productivity to fluctuations in technical efficiency, and technological efficiency [31]. As Fig.1 shows technical efficiency change (TEC) is means "the effect of catching-up production frontier" (catch-up effect), while technological change (TC) means "shift in the production frontier" (frontier-shift) [32]. These effects in question are the primary elements in total factor productivity and multiplying the change in technical efficiency and technological change produces the amount of change in total factor productivity [33]. The term "catch-up" refers to the angle DMUs take in order to increase its efficiency, while the term "frontier-shift" refers to the change in efficient frontiers around DMUs between two periods of time.

To develop a method for measuring the efficiency change from the time period t to t+1, the efficiency distance functions $D^{t+1}(X_{ik}^{t}, Y_{rk}^{t})$ are defined using the following formula (2) [34]:

$$D^{t+1}(X_{ik}^{t}, Y_{rk}^{t}) = Max\ \theta \quad (2)$$

Subject to $\sum_{j=1}^{n} \lambda_j^{t+1} x_{ij}^{t+1} \leq x_{ij}^{t}$

$\sum_{j=1}^{n} \lambda_j^{t+1} y_{rj}^{t+1} \geq \theta y_{rj}^{t}$

$\lambda_j^{t+1} \geq 0, i = 1, \dots, m, r = 1, \dots, s, j = 1, \dots, n,$

$x_j^{t+1} \geq 0, i = 1, \dots, m, r = 1, \dots, s, j = 1, \dots, n,$

$\theta$ unconstrained

MPI was calculated according to formula (3) [30]:

$$MPI = MPI\left(X_{ik}^{t}, Y_{rk}^{t}, X_{ik}^{rj}, Y_{rk}^{rj}\right) \quad (3)$$

$$= \left[\left(\frac{D^{t}\left(X_{ik}^{t+1}, Y_{rk}^{t+1}\right)}{D^{t}\left(X_{ik}^{t}, Y_{rk}^{t}\right)}\right)\left(\frac{D^{t+1}\left(X_{ik}^{t+1}, Y_{rk}^{t+1}\right)}{D^{t+1}\left(X_{ik}^{t}, Y_{rk}^{t}\right)}\right)\right]^{1/2}$$

## 4. Application

We applied the Input-Oriented Data Envelopment Analysis (DEA) method and the Malmquist Index Model to estimate the efficiency of healthcare systems in OECD countries between the years 2000 and 2015. We assessed the countries' performances through analyses carried out with Max-DEA Ultra program. Decision-making units in DEA should be homogenous. Moreover, the quality of inputs and outputs plays a huge part for the study to achieve realistic and significant results. Table 1 shows a summary of past studies in the field of healthcare that incorporated DEA. We used a data set consisting of 35 OECD countries.

| Year | Author / Authors | Aim of Study | Method | Inputs and Outputs of study |
|---|---|---|---|---|
| 1999 | Al-Shammari | Investigation of 3-year productivity of 15 hospitals in Jordan | Data Envelopment Analysis | Inputs; number of hospital beds, doctors and medical staff.<br>Outputs; the number of days hospitalized, minor surgeries and major surgeries. |
| 2002 | Zavras et al. | The evaluation of the relative activity of 133 primary healthcare facilities in Greece | Data Envelopment Analysis | Inputs, number of staff working in the health institution and patients covered by the health institution<br>Outputs; number of pensioners registered with the health institution |

| | | | | |
|---|---|---|---|---|
| 2008 | Li & Ilacqua | Effectiveness of OECD countries health services between 1997 and 2001 | Data Envelopment Analysis | Inputs; purchasing power parity, Number of beds per thousand people, health expenditure per capita. Outputs; life expectancy, infant mortality rate. |
| 2010 | Caballer-Tarazona et al. | Investigation of efficiency assessment in three health services of 22 hospitals in Eastern Spain and taking necessary measures to increase efficiency | Data Envelopment Analysis and Discriminant Analysis | Inputs; number of doctors, number of beds Outputs; weighted patient admissions, number of consultations, the treated consultation, Number of surgical procedures |
| 2013 | Varabyova & Schreyögg | Comparing the technical efficiency of the hospital industry using unbalanced panel data from OECD countries during the period 2000–2009 | Two stage Data Envelopment Analysis and Stochastic Frontier Analysis | Inputs; The number of hospital beds, The number of employees at the hospital, number of doctors, number of nurses Outputs; Hospital discharges, average mortality rate |
| 2013 | Moran &Jacobs | Investigation of the potential use of inpatient mental health services to examine hospital technical efficiency in 32 OECD countries in 2010 | Bootstrap Data Envelopment Analysis and Cluster Analysis | Inputs; number of doctors, The number of hospital beds, average hospital stays Outputs; Hospital discharges Environmental variables; alcohol consumption, income, education, unemployment |
| 2014 | Popescu et al. | Evaluation of Romanian Health System and European Health Systems in terms of efficiency | Data Envelopment Analysis | Inputs; immunization rate, health spending Outputs; adult survival rate, tuberculosis rate |
| 2014 | Asandului et al. | Evaluation of the performance of public health systems of 30 European countries for 2010 | Data Envelopment Analysis | Inputs; number of doctors, the number of hospital beds, share of health spending in GDP. Outputs; life expectancy at birth, waighted life expectancy, infant mortality rate |
| 2015 | Daştan & Çetinkaya | OECD countries, United States and Turkey 's changes in health spending between the years of 1980-2012. And what share of spending in GDP to examine whether the expenditure is financed. | Data Envelopment Analysis | Inputs; life expectancy at birth, infant mortality rate Outputs; access to health services, equity in accessing health services |
| 2015 | Bekaroglu | Examining the healthcare activities of 34 OECD countries in terms of production and consumption between 2000 and 2011 | Multi Stage Data Envelopment Analysis | Inputs; the number of patients examined, the number of patients discharged, days hospitalized Outputs; life expectancy, life expectancy at 65, infant mortality rate |
| 2016 | Berenguer et al. | Experimental investigation of the main productivity factors of country programs related to reproductive health in Sub-Saharan African countries supported by international fund organizations | Three stage Data Envelopment Analysis and Stochastic frontier analysis | Inputs; access to healthcare costs Outputs; procurement time, frequency of contraceptive use |
| 2016 | Campos et al. | Examining the efficiency of public resources invested in regional management of the health system in Spain | Data Envelopment Analysis and Super efficiency | Inputs; public health spending, health labor costs Outputs; hospital admission rate, rate of health services, medical health service and nurse rates |
| 2016 | Öztürk | Examining the differences between the health systems performance levels of OECD countries between 2000 and 2014 | Data Envelopment Analysis | Inputs; public health spending, private health spending, gross domestic product and number of doctors Outputs; life expectancy and baby survival rate |
| 2017 | Kara et al. | A comparison of different research conducted on Turkey in 2010- effectiveness analysis in healthcare in 2017. | Data Envelopment Analysis | Input and output variables differ in studies. |

| | | | | |
|---|---|---|---|---|
| 2018 | Herwartz & Schley | Examining how socio-economic factors affect regional efficiencies in the provision of health services | Stochastic frontier analysis | Inputs; number of staff working in the health institution, number of doctors, The number of hospital beds<br>Outputs; standardized mortality rate, female life expectancy, male life expectancy. |
| 2020 | Zhong et al. | Estimating the factors affecting the efficiency of Primary Healthcare Institutions in the Hunan Province of China and making feasible suggestions to increase efficiency. | Data Envelopment Analysis and Malmquist Productivity Index | Inputs; number of health technicians, The number of hospital beds and equipments<br>Outputs; the number of outpatients, the number of emergency visits and the number of patients discharged |

**Table 1.** Summary of past studies using DEA

We drew and collected the data from OECD Health Statistics, World Health Organization's annual statistics, and Turkish Statistical Institute (TSI) statistics published between the years 2000 – 2015. One of the most important stages in estimating the efficiency of a certain decision-making unit in studies carried out with DEA is the selection of inputs and outputs. Following other studies on performance of healthcare systems [35,38,39,40,42], number of doctors, number of nurses, number of hospitals, number of hospital beds and healthcare expenditures were used as a measure of input. Output was represented by life expectancy at birth for both sexes and baby survival rate [44,47]. The panel data on input and outputs covered the period between 2000 and 2015 inclusive. Table 2 shows the input and output variables we used in this study.

| **Inputs** | **Description** |
|---|---|
| Number of doctors | number of doctors per 1000 population |
| Number of nurses | number of nurses per 1000 population |
| Number of hospitals | number of hospitals per one million population |
| Number of hospital beds | number of hospital beds per 1000 population |
| Healthcare expenditure | the share of healthcare expenditure in relation to GDP of each country |
| **Outputs** | **Description** |
| Baby survival rate | baby mortality rate subtracted from 1000) divided by (baby mortality rate) |
| Life expectancy rate | life expectancy at birth |

**Table 2.** Input and output variables in this study

## 4.1. Results

Table 3 includes the efficiency scores of healthcare in the OECD countries generated by Banker Charnes Cooper (BCC) between 2000 – 2015. As shown in Table 3, the TE of healthcare in OECD countries increased from 0.8593 in 2000 to 0.9036 in 2006 and increased slightly in 2008 after a small decline in 2007. Among the countries with effective TE, there were at least 9 countries in 2000, 2001 and 2011, and the most in 2007 when there were 14. In 2000–2015 there were about 9 –14 countries whose SE operated at the best level, with an SE score of 1.000. The average SE's range was 0.9314 – 0.9669. During the period from 2000 to 2010, BCC – I increased from 0.8952 to 0.9400. After a decrease in 2011, it increased again in 2014. The number of effective countries fluctuated between 12 and 17.

| | *TE*[1] | | *TE<sub>VRS</sub>*[2] | | *SE*[3] | |
|---|---|---|---|---|---|---|
| **Year** | **Mean** | **Efficient Country** | **Mean** | **Efficient Country** | **Mean** | **Efficient Country** |
| 2000 | 0,8593 | 9 | 0,8952 | 12 | 0,9590 | 10 |
| 2001 | 0,8698 | 9 | 0,9198 | 13 | 0,9454 | 9 |
| 2002 | 0,8740 | 11 | 0,9140 | 15 | 0,9565 | 11 |
| 2003 | 0,8861 | 10 | 0,9280 | 14 | 0,9548 | 11 |
| 2004 | 0,8944 | 12 | 0,9261 | 15 | 0,9649 | 12 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2005 | 0,8993 | 12 | 0,9382 | 17 | 0,9587 | 12 |
| 2006 | 0,9036 | 13 | 0,9340 | 17 | 0,9669 | 14 |
| 2007 | 0,8955 | 14 | 0,9312 | 16 | 0,9589 | 14 |
| 2008 | 0,9061 | 12 | 0,9388 | 16 | 0,9645 | 13 |
| 2009 | 0,8958 | 11 | 0,9402 | 16 | 0,9536 | 11 |
| 2010 | 0,9049 | 13 | 0,9400 | 17 | 0,9619 | 13 |
| 2011 | 0,8645 | 9 | 0,9279 | 14 | 0,9314 | 9 |
| 2012 | 0,8652 | 10 | 0,9129 | 13 | 0,9448 | 11 |
| 2013 | 0,8862 | 12 | 0,9269 | 14 | 0,9544 | 12 |
| 2014 | 0,9023 | 12 | 0,9341 | 14 | 0,9635 | 12 |
| 2015 | 0,8953 | 12 | 0,9273 | 14 | 0,9623 | 12 |

[1] TE: Technical efficiency; [2] TEvrs: Technical efficiency from the variable return to scale Data Envelopment Analysis (VRS DEA); [3] SE: Scale efficiency = TE/TEvrs.

**Table 3.** The efficiency of healthcare in the counties of OECD from 2000 to 2015 (input-oriented Banker, Charnes and Cooper (BCC) model)

The Malmquist index model was applied to analyses on the changes in productivity over the 2000–2015 period, and the year 2007 was taken as the technical reference. Table 4 presents the Malmquist index summary of annual geometric means. On average, TFP increased by 4.93%, among which, TECHCH increased by 4.73% and EFFCH increased slightly by 0.28%. During the period 2000–2015, 27 (77.14%) countries had TFP score greater than 1, indicating growth in TFP; 6 (17.14%) countries had TFP score less than 1, indicating a deterioration in TFP. The TFP (input oriented) and TFP (output oriented) of each country is shown in Table 5, Table 6, respectively, Appendix A. It should be noted that, in some cases the dataset containing missing values in DEA will happen. Kuosmanen [51] presented a first systematic attempt to address the issue of missing data in DEA. They showed that DEA can automatically exclude the missing data from the analysis if blank data entries are coded by appropriate numerical values. Thus, the calculations of some countries such as Australia, United Kingdom, Czech Republic for some years seem incomplete in the appendix tables. however, missing data is not a problem for Malmquist productivity analysis.

| **Period** | **PECH** | **SECH** | **EFFCH** | **TECHCH** | **TFP** |
|---|---|---|---|---|---|
| 2000 - 2001 | 1,0202 | 0,9257 | 1,0385 | 1,0884 | 1,1274 |
| 2001 - 2002 | 1,0172 | 0,9776 | 0,9869 | 1,0776 | 1,0632 |
| 2002 - 2003 | 1,0032 | 0,9968 | 1,0253 | 0,9974 | 1,0216 |
| 2003 - 2004 | 1,0026 | 0,9739 | 0,9981 | 1,0534 | 1,0513 |
| 2004 - 2005 | 1,0261 | 0,9562 | 1,0140 | 1,0850 | 1,0956 |
| 2005 - 2006 | 1,0140 | 0,9784 | 0,9932 | 1,0462 | 1,0378 |
| 2006 - 2007 | 1,0228 | 1,0006 | 0,9973 | 1,0323 | 1,0292 |
| 2007 - 2008 | 1,0400 | 0,9515 | 1,0100 | 1,1025 | 1,1119 |
| 2008 - 2009 | 0,9790 | 0,9723 | 1,0004 | 1,0151 | 1,0157 |
| 2009 - 2010 | 1,0140 | 0,9686 | 1,0005 | 1,0568 | 1,0568 |
| 2010 - 2011 | 1,0524 | 0,9978 | 0,9915 | 1,0767 | 1,0659 |
| 2011 - 2012 | 1,0029 | 1,0042 | 0,9770 | 1,0234 | 0,9989 |
| 2012 - 2013 | 0,9871 | 0,9319 | 1,0157 | 1,0647 | 1,0802 |
| 2013 - 2014 | 1,0100 | 0,9835 | 1,0046 | 1,0245 | 1,0278 |
| 2014 - 2015 | 0,9969 | 1,0553 | 0,9895 | 0,9664 | 0,9564 |
| **Mean** | **1,0125** | **0,9782** | **1,0028** | **1,0473** | **1,0493** |

[1] EFFCH: Technical efficiency change; [2] TECHCH: Technical change; [3] PECH: Pure technical efficiency change; [4] SECH: Scale efficiency change; [5] TFP: Total factor productivity change

**Table 4.** Results of the Malmquist index model (input-oriented)

## 5. Conclusions and Remarks

We evaluated the performances of health services across the OECD member states, including Turkey between the years 2000 – 2015. The data in this study was collected from various statistical reports and OECD database. Five input variables, and two output variables were used in order to determine the efficiency values of countries. Due to lack of data for each country every year, the number of countries evaluated each year fluctuates. Data for 26 countries were readily available for every year, while there was a shortage of data for 9 countries every year, so they were only evaluated in years when there was available data. First, we calculated the efficiency values for healthcare services with the model in question through the utilization of DEA. Then, we assessed the fluctuations in healthcare services of countries on a yearly basis through Malmquist Productivity Index, as we aimed to assess the fluctuations in efficiency relative to years.

According to the input and output-oriented DEA model Chile, Denmark, Iceland, Israel, Japan, Korea, Mexico, Slovenia, Sweden, and Turkey were shown to be both technically efficient and scale efficient across all years. And Canada, Chile, Denmark, Iceland, Israel, Japan, Korea, Luxembourg, Mexico, Slovenia, Spain, Sweden, and Turkey were shown to be pure technically efficient. It would be incorrect to say that the health services of those decision-making units deemed to be efficient are perfect. However, through a comparative evaluation in accordance with available sources and outputs, countries were shown to produce good outputs through optimal use of available resources.

Furthermore, the shift in Malmquist productivity reflects the increase or decrease in efficiency between the given periods. The assessment of input-oriented Malmquist Productivity Index showed that the countries that showed the highest increase in efficiency when each countries' average efficiency is taken into consideration are as follows: Chile (62%), Luxemburg (61%), Iceland (47%), Sweden (33%), and Portugal (31%). The assessment of average efficiency values showed that New Zealand (27%), Netherlands (22%), Japan (21%), South Korea (19%), and Slovakia (16%) are five countries that lost the highest efficiency. The assessment of output-oriented Malmquist Productivity Index showed that first five countries that showed the highest increase in efficiency are Chile (62%), Luxemburg (61%), Iceland (47%), Sweden (33%), and Ireland (31%). The assessment of average efficiency values showed that New Zealand (27%), Netherlands (22%), Japan (10%), South Korea (9%), and Slovakia (6%) are five countries that lost the highest efficiency.

The assessment of Malmquist Productivity Index of scale efficient values showed that Iceland (81%), Luxemburg (32%), Japan (25%), United Kingdom (5%), and Lithuania (3%) are five countries that showed the highest average increase in efficiency. The assessment of average efficiency values showed that Sweden (21%), Chile (13%), Switzerland (10%), Spain (7%), and Australia (6%) are five countries that lost the highest efficiency.

Considering that the only indicators that countries can influence are the input values, that is, investment on healthcare services, we can make the following deductions with the help of interpretations of the input-oriented model, the assumption of scale oriented constant returns in healthcare industry, CCR input-oriented model, as well as increase of Malmquist productivity index. The relevant interpretations shed light upon the activity in the sector.

Canada was not able to reach efficiency in healthcare services until 2006; however, with an increase of 9% in its efficiency over the previous three years, it was able to reach efficiency in 2006. The analysis shows that the increase in input values and decrease in efficiency values in the following years, the country is no longer efficient. On the other hand, Czech Republic was deemed efficient without significant increase in its input values, thanks to its high baby survival rates, and high life expectancy rates at birth. It was also observed that prior to years where it was efficient, Czech Republic showed an increase in its efficiency values. Estonia maintained a 3% increase to its efficiency values on average until 2006, after which it was deemed efficient. This efficiency is mainly due to an increase in the output of baby survival rate despite the constant input. Ireland cut the number of hospital and healthcare employees by 10% during the 2008 economic crisis, which forced the country to maintain the same output with fewer resources. The constant increase in efficiency until the year 2012 granted Ireland to be deemed efficient until 2014. Australia, with its high input in healthcare services maintained its average efficiency without significant increase or decrease between 2000 and 2015, but it was never deemed efficient. The reason for this is that, as is often said, Australia keeps input handy in order to reach even output values for comparative evaluation. That is, it keeps a stock of resources on standby. Likewise, despite not showing a significant shift in efficiency, Israel, deemed as efficient during the observation period, maintained an increase of 1% in efficiency.

In Turkey, the input value “number of doctors per 1000 population” increased from 1.34 to 1.8 between 2000 – 2015. However, the share of healthcare expenditure relative to GNI decreased from 4.62% to 4.14%, while the number of hospitals per one million population increased from 17.9 to 19.6. Considering these input values, the life expectancy gradually increased from 71.1 to 78, and baby survival rate increased from 34% to 92%. Turkey maintained an average of 2% increase in efficiency, and it was deemed efficient according to comparative assessments relative to the OECD countries across 2000 – 2015.

We formed the models in this study according to the available data. For case in a point, due to the difficulty in getting Denmark and Norway’s data, we were unable to evaluate them with Malmquist Productivity Index values. Even though we have already assessed healthcare service performances of OECD member states with the readily available data, it is still possible to replicate this study with new variables and updated data, as the results obtained through DEA may change depending on the variables and data that are included or excluded in the model. Therefore, it would be beneficial for Norway and Denmark to assess their healthcare service performances, and for other countries as well.

In order to provide people with high quality healthcare services, and to evaluate the countries both in terms of their funding and performances, carrying out similar studies to this one poses as a crucial step.

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# Appendix

## Appendix 1.

TFP scores of each country (input-oriented BCC model)

| **Countries** | **2000-2001** | **2001-2002** | **2002-2003** | **2003-2004** | **2004-2005** | **2005-2006** | **2006-2007** | **2007-2008** | **2008-2009** | **2009-2010** | **2010-2011** | **2011-2012** | **2012-2013** | **2013-2014** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| USA | 1,00 | 1,01 | 1,00 | 1,02 | 1,01 | 1,01 | 1,02 | 0,99 | 1,02 | 1,01 | 1,00 | 1,00 | 1,00 | 1,02 |
| Germany | 1,03 | 1,01 | 1,00 | 1,08 | 1,04 | 1,06 | 1,03 | 1,01 | 0,96 | 1,02 | 0,98 | 1,00 | 0,98 | 1,04 |
| Australia | 1,07 | 1,10 | 1,12 | 1,21 | 1,11 | 1,09 | | | 1,01 | | | 1,01 | 0,99 | 1,00 |
| Austria | 1,05 | 1,07 | 0,93 | 1,04 | 1,05 | 1,11 | 1,01 | 1,00 | 0,95 | 1,01 | 1,04 | 0,99 | 1,01 | 1,02 |
| Belgium | 1,13 | 1,02 | 1,04 | 1,00 | 1,06 | 1,00 | 1,04 | 0,99 | 1,03 | 1,03 | 1,03 | 0,98 | 1,01 | 1,05 |
| United Kingdom | | | | | | | | | | | | | 1,00 | 1,01 |
| Czech Republic | | | | | | 1,04 | 1,05 | 0,97 | 0,89 | 1,07 | 1,01 | 1,01 | 0,96 | 1,03 |
| Denmark | | | | | | | | | | | | | | |
| Estonia | 1,08 | 1,03 | 0,97 | 0,96 | 1,03 | 1,04 | 0,97 | 0,89 | 0,98 | 1,06 | 1,27 | 0,91 | 1,21 | 0,85 |
| Finland | 1,51 | 1,01 | 0,98 | 0,92 | 1,23 | 1,06 | 1,04 | 1,02 | 0,95 | 1,08 | 0,99 | 0,98 | 1,08 | 0,94 |
| France | 1,01 | 1,05 | 0,97 | 1,31 | 1,11 | 1,15 | 0,97 | 1,12 | 1,03 | 1,08 | 1,10 | 0,96 | 1,05 | 1,09 |
| Holland | 0,97 | 0,98 | 1,01 | 1,05 | 0,98 | 1,00 | 1,01 | 1,07 | 0,83 | 1,00 | 1,08 | 0,91 | 1,00 | |
| Ireland | 1,02 | 1,05 | 1,02 | 1,03 | 1,10 | 1,03 | 1,05 | 0,93 | 1,31 | 1,02 | 1,05 | 1,09 | 0,95 | 1,00 |
| Spain | 1,18 | 0,99 | 0,97 | 1,57 | 1,04 | 1,01 | 1,04 | 1,13 | 1,39 | 1,00 | 1,51 | 0,90 | 2,15 | 0,96 |
| Israel | 1,02 | 1,03 | 1,04 | 1,23 | 1,06 | 1,28 | 1,00 | 1,14 | 1,21 | 1,12 | 1,04 | 1,03 | 1,10 | 1,02 |
| Sweden | 1,46 | 0,98 | 1,67 | | | | | | | | | | | |
| Switzerland | 1,42 | 1,05 | 1,00 | 1,11 | 1,20 | 1,06 | 1,35 | 1,28 | 1,15 | 1,07 | 1,52 | 0,99 | 1,00 | 1,11 |
| Italy | 1,27 | 1,00 | 0,69 | 1,03 | 1,15 | 1,00 | 1,16 | 1,08 | 1,06 | 1,73 | 0,98 | 0,99 | 1,42 | 1,03 |
| Iceland | | | | | | | | 1,10 | 1,02 | 1,00 | 1,05 | 1,00 | 0,98 | 1,00 |
| Japan | | | | | | | 1,00 | 0,91 | | | | | | |
| Canada | 1,10 | 1,07 | 1,00 | 1,14 | 1,03 | 1,16 | 0,98 | 1,11 | 0,98 | 1,14 | 0,94 | 1,02 | 1,02 | 1,03 |
| Korea | 0,95 | 1,06 | 0,96 | 1,06 | 1,00 | 1,05 | 1,09 | 0,99 | 1,01 | 1,01 | 1,05 | 1,04 | 1,00 | 1,04 |
| Lithuania | 0,94 | 1,00 | 1,05 | 0,88 | 1,06 | 1,02 | 0,99 | 1,03 | 0,90 | 1,05 | 1,08 | 1,03 | 1,07 | 1,02 |
| Luxemburg | | | | | | 1,00 | 1,04 | | | 0,95 | 1,08 | 1,01 | 0,99 | 1,12 |
| Hungary | 0,99 | 0,98 | 0,94 | 1,01 | 1,02 | 1,00 | 1,05 | 1,01 | 1,00 | 0,99 | 0,99 | 0,97 | 1,00 | 1,00 |
| Mexico | 0,99 | 1,00 | 0,99 | 0,99 | 1,00 | 1,02 | 0,99 | 1,01 | 0,99 | 1,01 | 1,00 | 1,01 | 0,98 | 1,01 |
| Norway | | | | | | | | | | | | | | |
| Poland | | | 1,03 | 0,99 | 1,02 | 1,02 | 0,98 | 0,95 | 0,97 | 1,04 | 1,03 | | | 1,01 |
| Portugal | 1,04 | 1,01 | 1,09 | 1,11 | 1,09 | 1,09 | 0,97 | 1,02 | 0,95 | 1,31 | 0,89 | 0,95 | 1,09 | 1,01 |
| Chili | 1,88 | 2,10 | 0,96 | 0,63 | 2,12 | 0,51 | 0,75 | 2,81 | 1,28 | 1,12 | | | | |
| Slovakia | 1,03 | 0,96 | 1,00 | 0,90 | 0,98 | 0,97 | 0,97 | 1,04 | 0,90 | 1,02 | 1,06 | 0,97 | 1,02 | 1,05 |
| Slovenia | 1,05 | 1,12 | 0,95 | 1,03 | 0,91 | 1,18 | 1,27 | 1,14 | 0,96 | 0,91 | 0,98 | 1,11 | 1,00 | 1,32 |
| Turkey | 1,04 | 1,02 | 1,01 | 1,01 | 1,01 | 1,04 | 0,90 | 1,04 | 0,97 | 1,03 | 1,01 | 0,99 | 1,30 | 0,98 |
| New Zeland | | | | | | | | | | 0,93 | 1,00 | 1,00 | 1,03 | 1,01 |
| Greece | 1,09 | 0,95 | 1,20 | 1,03 | 1,08 | 1,07 | 1,08 | 1,35 | 0,75 | 0,85 | 1,08 | 1,12 | 0,98 | 1,03 |
| Efficient country | 21 | 19 | 14 | 18 | 22 | 25 | 18 | 19 | 12 | 22 | 20 | 12 | 15 | 22 |
| Inefficient country | 5 | 7 | 13 | 8 | 4 | 3 | 10 | 9 | 16 | 6 | 8 | 15 | 14 | 6 |
| **Mean** | **1,13** | **1,06** | **1,02** | **1,05** | **1,10** | **1,04** | **1,03** | **1,11** | **1,02** | **1,06** | **1,07** | **1,00** | **1,08** | **1,03** |
| **Std.Dev.** | **0,21** | **0,21** | **0,15** | **0,16** | **0,22** | **0,12** | **0,10** | **0,34** | **0,14** | **0,15** | **0,14** | **0,05** | **0,23** | **0,08** |
| **Min.** | **0,94** | **0,95** | **0,69** | **0,63** | **0,91** | **0,51** | **0,75** | **0,89** | **0,75** | **0,85** | **0,89** | **0,90** | **0,95** | **0,85** |
| **Max.** | **1,88** | **2,10** | **1,67** | **1,57** | **2,12** | **1,28** | **1,35** | **2,81** | **1,39** | **1,73** | **1,52** | **1,12** | **2,15** | **1,32** |

## Appendix 2.

TFP scores of each country (output-oriented BCC model)

| Countries | 2000-2001 | 2001-2002 | 2002-2003 | 2003-2004 | 2004-2005 | 2005-2006 | 2006-2007 | 2007-2008 | 2008-2009 | 2009-2010 | 2010-2011 | 2011-2012 | 2012-2013 | 2013-2014 | 2014-2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| USA | 1,00 | 1,00 | 1,00 | 1,01 | 1,00 | 1,00 | 1,00 | 1,00 | 1,01 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 |
| Germany | 1,00 | 1,00 | 1,00 | 1,01 | 1,00 | 1,01 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,01 | 0,99 |
| Australia | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | | | 1,00 | | | 1,00 | 1,00 | 1,00 | 1,00 |
| Austria | 1,01 | 1,00 | 1,00 | 1,01 | 1,00 | 1,01 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 |
| Belgium | 1,01 | 1,00 | 1,00 | 1,01 | 1,01 | 1,00 | 1,01 | 1,00 | 1,01 | 1,00 | 1,01 | 1,00 | 1,00 | 1,01 | 1,00 |
| United Kingdom | | | | | | | | | | | | | 1,00 | 1,00 | 1,01 |
| Czech Republic | | | | | | 1,09 | 1,10 | 0,91 | 0,78 | 1,11 | 1,01 | 1,00 | 0,99 | 1,01 | 1,00 |
| Denmark | | | | | | | | | | | | | | | |
| Estonia | 1,01 | 1,04 | 0,96 | 1,01 | 1,04 | 1,00 | 0,99 | 0,95 | 0,82 | 1,13 | 1,40 | 0,91 | 1,22 | 0,84 | 1,00 |
| Finland | 1,07 | 1,04 | 0,95 | 0,96 | 1,05 | 1,01 | 1,00 | 1,00 | 1,00 | 1,01 | 1,00 | 1,00 | 1,01 | 0,99 | |
| France | 1,00 | 1,00 | 1,00 | 1,01 | 1,00 | 1,01 | 1,00 | 1,00 | 1,00 | 1,00 | 1,01 | 1,00 | 1,00 | 1,01 | 1,00 |
| Holland | 0,99 | 1,00 | 1,00 | 1,02 | 1,00 | 1,00 | 1,01 | 1,00 | 0,99 | 1,00 | 1,00 | 1,00 | 1,00 | | |
| Ireland | 1,00 | 1,00 | 1,00 | 1,00 | 1,01 | 1,00 | 1,01 | 1,00 | 1,13 | 1,03 | 1,08 | 1,00 | 1,00 | 1,03 | 1,00 |
| Spain | 1,05 | 0,98 | 0,98 | 0,99 | 1,06 | 1,07 | 1,03 | 1,03 | 1,02 | 1,02 | 1,05 | 1,00 | 1,09 | 0,98 | 1,01 |
| Israel | 1,05 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,02 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 |
| Sweden | 1,00 | 1,00 | 1,00 | | | | | | | | | | | | |
| Switzerland | 1,01 | 1,00 | 1,00 | 1,01 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 |
| Italy | 1,00 | 1,00 | 1,00 | 1,07 | 1,04 | 1,02 | 1,03 | 1,00 | 0,98 | 1,02 | 0,99 | 1,00 | 1,01 | 1,00 | 0,99 |
| Iceland | | | | | | | | 0,90 | 1,22 | 0,91 | 1,70 | 0,93 | 0,73 | 0,93 | 0,97 |
| Japan | | | | | | | 1,05 | 0,94 | | | | | | | 0,96 |
| Canada | 1,01 | 1,00 | 1,00 | 1,01 | 1,00 | 1,02 | 1,00 | 1,01 | 1,00 | 1,01 | 0,98 | 1,00 | 1,00 | 1,00 | 1,01 |
| Korea | 1,01 | 1,00 | 1,00 | 1,06 | 1,03 | 1,06 | 0,96 | 0,85 | 0,74 | 0,94 | 1,00 | 0,97 | 0,90 | 0,97 | 1,03 |
| Lithuania | 1,00 | 0,99 | 1,01 | 1,00 | 1,00 | 1,00 | 1,00 | 1,03 | 0,78 | 1,01 | 1,03 | 1,01 | 1,01 | 1,03 | 0,95 |
| Luxemburg | | | | | | 1,09 | 1,35 | | | 0,92 | 1,03 | 1,00 | 0,97 | 1,02 | 1,05 |
| Hungary | 1,00 | 0,99 | 1,00 | 1,01 | 1,01 | 1,00 | 1,01 | 1,00 | 1,00 | 1,01 | 1,00 | 1,00 | 1,01 | 1,00 | 1,00 |
| Mexico | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,01 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 |
| Norway | | | | | | | | | | | | | | | |
| Poland | | | 1,00 | 1,00 | 1,01 | 1,01 | 0,99 | 0,98 | 0,99 | 1,02 | 1,01 | | | 1,01 | 1,00 |
| Portugal | 1,00 | 1,00 | 1,01 | 1,04 | 1,06 | 1,05 | 0,99 | 1,00 | 1,00 | 1,13 | 0,98 | 1,00 | 1,00 | 1,01 | 1,00 |
| Chili | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | | | | | |
| Slovakia | 1,00 | 1,00 | 1,00 | 0,99 | 1,00 | 1,00 | 1,00 | 1,01 | 1,00 | 1,00 | 1,01 | 1,00 | 1,00 | 1,01 | 1,00 |
| Slovenia | 1,00 | 1,05 | 1,00 | 1,04 | 0,90 | 1,13 | 1,15 | 0,90 | 1,05 | 1,00 | 1,00 | 1,34 | 1,00 | 1,26 | 0,82 |
| Turkey | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,08 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 |
| New Zeland | | | | | | | | | | 0,99 | 1,00 | 1,00 | 1,00 | 1,00 | 1,00 |
| Greece | 1,00 | 1,00 | 1,06 | 1,00 | 1,03 | 1,03 | 1,03 | 1,14 | 0,92 | 0,95 | 1,01 | 1,12 | 0,90 | 1,02 | 0,95 |
| Efficient country | 20 | 15 | 12 | 18 | 20 | 23 | 21 | 13 | 12 | 20 | 18 | 11 | 16 | 21 | 11 |
| Inefficient country | 1 | 5 | 10 | 5 | 3 | 2 | 6 | 11 | 12 | 5 | 7 | 13 | 11 | 5 | 16 |
| **Mean** | **1,01** | **1,00** | **1,00** | **1,01** | **1,01** | **1,02** | **1,03** | **0,99** | **0,98** | **1,01** | **1,05** | **1,01** | **1,00** | **1,00** | **0,99** |
| **Std.Dev.** | **0,02** | **0,02** | **0,02** | **0,02** | **0,03** | **0,03** | **0,07** | **0,05** | **0,10** | **0,05** | **0,15** | **0,07** | **0,07** | **0,06** | **0,04** |
| **Min.** | **0,99** | **0,98** | **0,95** | **0,96** | **0,90** | **1,00** | **0,96** | **0,85** | **0,74** | **0,91** | **0,98** | **0,91** | **0,73** | **0,84** | **0,82** |
| **Max.** | **1,07** | **1,05** | **1,06** | **1,07** | **1,06** | **1,13** | **1,35** | **1,14** | **1,22** | **1,13** | **1,70** | **1,34** | **1,22** | **1,26** | **1,05** |