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Health System Efficiency of OECD Countries with Data Envelopment Analysis

Yusuf Ersoy

Malazgirt Vocational School, Muş Alparslan University, Muş, Turkey
https://orcid.org/0000-0002-0106-1695

Adem Aktaş

Malazgirt Vocational School, Muş Alparslan University, Muş, Turkey
https://orcid.org/0000-0003-1451-913X

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Abstract

Purpose: This study is aimed at measuring the efficiency of 37 OECD countries for 2020 using the Data Envelopment Analysis (DEA) method. Besides, it is aimed at ranking the efficient decision making units by using the super-efficiency DEA model.

Design/methodology/approach: In the study, analyses were carried out with input-oriented Charnes, Cooper and Rhodes (CCR), input-oriented Banker, Charnes and Cooper (BCC) models and super-efficiency models of these models by using 4 inputs and 3 outputs.

Findings: As a result of the analysis, 14 countries in the CCR model and 20 countries in the BCC model were efficient. According to the results of the super-efficiency models, the efficient countries were ranked.

Research limitations/implications: The limitations of the study are the analyses are based on input-oriented DEA models and the research was conducted in OECD countries.

Originality/value: Performance evaluation of health systems has gained importance in recent years. Many countries are making efforts to improve their health systems. Due to epidemics such as COVID-19, OECD countries, like many countries around the world, have increased the share of health expenditures in GDP. Because of this situation, the evaluation of the performance of OECD countries in the field of health has emerged as a very important research topic.

Keywords: data envelopment analysis, GDP, health system efficiency, OECD countries, performance measurement.

JEL: C44, I15, P40

Correspondence address: Malazgirt Vocational School, Muş Alparslan University, Üniversiteler, 1600. Cad. No:10, 06800 Çankaya/Ankara, Muş, Turkey; e-mails: y.ersoy@alparslan.edu.tr, a.aktas@alparslan.edu.tr.

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Efektywność systemów opieki zdrowotnej w krajach OECD – badanie za pomocą metody granicznej analizy danych

Streszczenie

Cel: opracowanie ma na celu pomiar efektywności w 37 krajach OECD w roku 2020 za pomocą metody granicznej analizy danych (Data Envelopment Analysis – DEA), a ponadto uszeregowanie efektywnych jednostek decyzyjnych przy użyciu modelu DEA z nadefektywnością.

Metodologia: w ramach badania przeprowadzono analizy z wykorzystaniem zorientowanych na nakłady modeli Charnesa, Coopera i Rhodesa (CCR), zorientowanych na nakłady modeli Bankera, Charnesa i Coopera (BCC) oraz tych modeli z nadefektywnością przy użyciu czterech nakładów i trzech wyników.

Wyniki: przeprowadzona analiza wykazała, że efektywnością cechuje się czternaście krajów w modelu CCR i dwadzieścia krajów w modelu BCC. Kraje efektywne uszeregowano zgodnie z wynikami modeli z nadefektywnością.

Ograniczenia/implikacje badawcze: ograniczeniami badania są analizy oparte na modelach DEA zorientowanych na nakłady oraz to, że zostało ono przeprowadzone w krajach OECD.

Oryginalność/wartość: ocena efektywności systemów opieki zdrowotnej zyskała w ostatnich latach na znaczeniu. Wiele krajów podejmuje starania na rzecz poprawy swoich systemów opieki zdrowotnej. Z powodu epidemii, takich jak COVID-19, kraje OECD, podobnie jak wiele krajów na całym świecie, zwiększyły udział wydatków na opiekę zdrowotną w PKB. W związku z tą sytuacją ocena efektywności krajów OECD w dziedzinie zdrowia stała się bardzo istotnym tematem badawczym.

Słowa kluczowe: metoda granicznej analizy danych, PKB, efektywność systemu opieki zdrowotnej, kraje OECD, pomiar efektywności.

1. Introduction

Health services are the services provided for the protection and treatment of individuals' health. The ability of individuals to lead a healthy life depends on many factors such as economic, cultural, social, environmental and genetic. Along with these factors, the well-organized and efficient functioning of health systems is also very important in terms of sustainability (Kar & Demireli, 2021, p 123).

Around the world, attempts have been made to develop health systems with a number of laws and efforts put into practice in recent years. The USA officially launched the 2010 Affordable Care Act in 2014. Germany passed a law on health reform in 2010 to address health expenditures and increase health insurance profitability. Besides, countries such as Russia, China, Brazil and India are making more efforts to achieve universal health coverage. Therefore, health reforms aimed at improving people's living standards have become an important issue for many countries (Lee & Kim, 2018, p. 1).

The health sector can be described as one of the priority areas that are effective in the development of countries. The healthcare sector is a service sector that is different from other sectors and has critical importance (Bostan & Tehci, 2020, p. 181). Nowadays, health systems constitute one of the largest sectors of the world economy. In terms of health expenditures, purchasing power in low- and middle-income countries increased from 26.1% to 39.7%

between 1995 and 2013 (Seddighi et al., 2020, p. 1). In the period from 1975 to 2008, the ratio of average health expenditures of OECD countries to GDP increased from 6.3% to 8.8% (Hadad et al., 2013, p. 253). According to OECD health statistics data, the ratio of average health expenditures of OECD countries to GDP increased from 9% to 9.9% in the period from 2019 to 2020 (OECD, 2021a; OECD, 2022). It can be said that an approximately 0.9% increase in health expenditures in a short period of one year is related to COVID-19. Therefore, the percentage of OECD countries' health expenditures in GDP is very important. Technological developments in the field of health and the desire of people to benefit more from health services have increased the average human lifespan. Depending on this situation, the health sector around the world is constantly developing and gaining more importance.

Epidemics, global and natural disasters experienced in recent years have caught the health systems of many countries unprepared or inadequate in combating these disasters. For this reason, many organizations operating in the field of health, especially WHO (the World Health Organization), act together for the improvement of health systems. Under global conditions, many countries are constantly making new investments or increasing capacity in the field of health in order to provide better health services to their citizens. The health sector is important in supporting economic growth, employment and fighting epidemics such as COVID-19. Therefore, many countries give more importance to the share of health expenditures in GDP and develop policies in the field of health. In recent days, the aging of the population in OECD countries, the increase in the number of epidemic diseases such as COVID-19 and global inflation have rapidly increased the cost of health services. These increasing costs reveal the importance of the concept of efficiency in health services.

Efficiency is a comprehensive concept discussed in various fields such as engineering, management, economics and health (Seddighi et al., 2020, p. 2). This study is aimed at evaluating the performance of 37 OECD countries in the field of health for 2020. The rest of the study is designed as follows. In the second part, the literature related to the studies in which efficiency measurement was carried out using the DEA method is given. In the third chapter, the method of the study and the data set are mentioned. In the fourth chapter, the efficiency analysis of OECD countries in the field of health was carried out. In the fifth chapter, a general evaluation of the study was made.

2. Literature Review

It is possible to find many studies in the literature in which the DEA method is applied in different areas (Liu et al., 2013, p. 896; Hafidz et al., 2018, p. 455; Emrouznejad & Yang, 2018, p. 7; Selamzade, 2020, p. 864; Ersoy, 2021, p. 1805; Sarıçam & Yilmaz, 2021, p. 1).

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Some researchers have systematically examined studies evaluating health system effectiveness (Hollingsworth, 2008, pp. 110–1728; Hafidz et al., 2018, pp. 465–480; Kohl et al., 2019, p. 245). It is understood from these studies that there are many studies carried out using the DEA method in the field of health.

In the field of health, some studies mostly evaluate the efficiency of OECD or EU countries. In addition to these studies, some studies evaluate the efficiency of organizations that produce services such as hospitals in different countries (Çetin & Bahçe, 2016, p. 3498). Some of the studies evaluating the efficiency of hospitals or other organizations and countries using DEA are given in the following paragraphs.

The DEA method has been used for the efficiency measurement of 53 hospitals in the USA (Nayar & Ozcan, 2008), 22 public hospitals in Greece between 2003 and 2005 (Dimas et al., 2012), hospitals in 40 different regions of India in 2010 (Jat & Sebastian, 2013), 12 hospitals in Iran between 2007 and 2010 (Torabipour et al., 2014), 128 hospitals in Ghana (Jehu-Appiah et al., 2014), 87 hospitals in Greece between 2005 and 2009 (Fragkiadakis et al., 2016), 16 health research centers in Iran (Amiri et al., 2016), health systems of 28 countries around the world between 2014 and 2015 (Lee, 2016), health systems of 19 different regions of Spain (Carillo & Jorge, 2017), 37 private hospitals in India (Gandhi & Sharma, 2018), the Lebanese healthcare system between 2000 and 2015 (Ibrahim & Daneshvar, 2018), health systems of 8 regions in Slovakia between 2008 and 2015 (Stefko et al., 2018), public hospitals in 81 provinces in Turkey (Karahan, 2019), 33 private hospitals in Egypt (Habib & Shahwan, 2020) health systems of 16 countries in the Eastern Mediterranean region (Seddighi et al., 2020), 17 maternal and child health hospitals in Turkey between 2014 and 2017 (İlgün et al., 2022), 19 medical centers in Taiwan between 2015 and 2018 (Chiu et al., 2022).

Some of the studies in which the efficiency evaluation of OECD or EU countries was carried out using the DEA method are given in Table 1.

Table 1
Other Studies on the Efficiency of OECD or EU Countries Using the DEA Method

Papers	Units	Inputs	Outputs
Varabyova and Schreyögg (2013)	30 OECD countries	Beds Employment Physicians Nurses	Discharges Mortality
Hadad et al. (2013)	31 OECD countries	Physicians' density Inpatient bed density Health expenditure per capita GDP per capita Consumption of fruit and vegetables per capita	Life expectancy at birth Infant mortality

Table 1 – continued

Papers	Units	Inputs	Outputs
Asandului et al. (2014)	30 EU member states	Number of doctors, Number of hospital beds Public health expenditures as percentage of GDP	Life expectancy(years) Infant mortality rate Health adjusted life expectancy (years)
Samut and Cafrı (2016)	29 OECD countries	Beds Physicians Nurses Number of Magnetic Resonance Imaging Number computerized tomography (CT) Scanners	Discharge rates from all hospitals Infant survival rate
Ozcan and Khushalani (2017)	34 OECD countries	Alcohol consumption Tobacco consumption Overweight or obese population Expenditure on public health and prevention services	Life expectancy at birth-female Life expectancy at birth-male
Lee and Kim (2018)	35 OECD countries	Expenditure on health per capita Practicing physicians per capita The number of beds per capita	Infant survival rate Life expectancy
Bekaroğlu and Heffley (2018)	34 OECD countries	Physicians Nurses Hospital beds	Life Expectancy at birth Life expectancy at 65 Infant mortality
Kocisova and Sopko (2020)	23 EU member states	Alcohol consumption Tobacco consumption Computed tomography scanners per million inhabitants Nurses and physicians per 1000 inhabitants	Life expectancy Number of inpatient discharges per 100,000 inhabitants Number of outpatient consultation per capita
Yüksel (2021)	29 OECD countries	The number of physicians The number of nurses The number of hospital beds Health spending	Life expectancy at birth Infant survival rate
Mitropoulos (2021)	26 EU member states	Physicians Hospital beds Expenditures	Quality of care Patient safety

Source: Own elaboration.

3. Methodology

In this study, the health performance of OECD countries for 2020 was evaluated using the DEA method. Efficiency analyzes were carried out in the EMS 1.3.0 computer program using 4 input and 3 output variables. The framework of the study can be seen in Figure 1.

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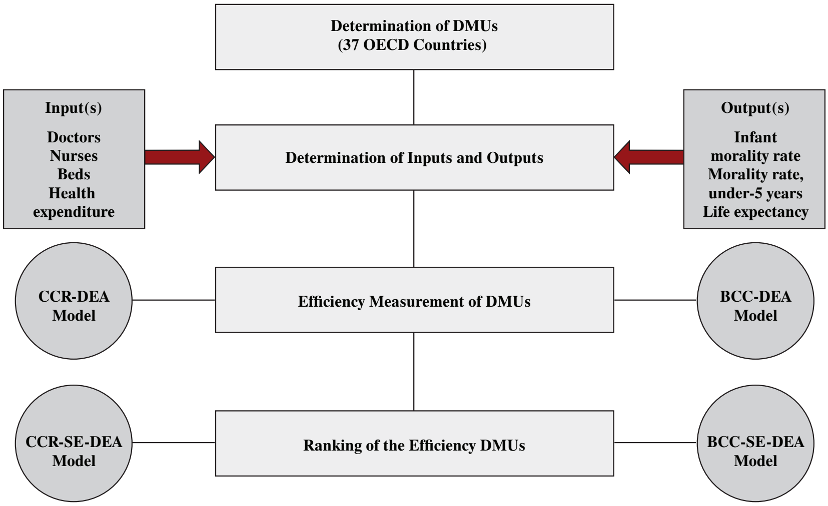
Figure 1
The Framework of the Study



Source: Own elaboration.

3.1. DEA Method

Data envelopment analysis (DEA) is a non-parametric method (Yeşilyurt et al., 2021, p. 1). There are different versions of DEA depending on the scale structure: constant return scale (CRS) and variable return scale (VRS). The CRS version was created by Charnes, Cooper and Rhodes (1978) and is called the CCR model, the VRS version was created by Banker, Charnes and Cooper (1984) and is called the BCC model (Dalfard et al., 2012, p. 186).

DEA is an approach used to measure the relative efficiency of Decision Making Units (DMUs) characterized by multiple inputs and outputs (Popovic et al., 2020, p. 2). In the DEA method, the efficiency scores of DMUs are calculated using linear programming (Yeşilyurt et al., 2021, p. 1).

The DEA method proposed by Charnes et al. (1978) is an effective method for productivity evaluation. The DEA method has been widely used in the efficiency measurement of various organizations in the last 40 years (Zhong et al., 2021, p. 2). The DEA method is used for efficiency measurements in many fields such as banking, production, services, transportation, health services and education (Yang et al., 2021, p. 3). The main reason for the widespread use of DEA is that it allows an analysis in multiple input and multiple output environments (Charles & Kumar, 2012, p. 2; Ersoy, 2021).

In order for the DEA method to be applied successfully, the number of decision making units to be evaluated must be greater than the number of inputs and outputs. Some researchers suggest that the number of DMUs should be at least twice the sum of the number of inputs and outputs (Boussofiane et al., 1991, pp. 1–15; Martic et al., 2009, p. 40; Yoshimoto et al., 2018, p. 32; Ersoy, 2021).

The input-oriented CCR model and the input-oriented BCC model were used in the study. In classical CCR and BCC models, the efficiency score of efficient DMUs is 100%, that is, "1". For this reason, super efficiency (SE) models were used in the analysis to rank the efficient DMUs.

Input-oriented classical CCR model number (1) (Cooper et al., 2011, p. 9; Xu & Ouenniche, 2012, p. 579; Ersoy, 2021), input-oriented CCR super-efficiency model (2) (Seiford & Zhu, 1999, p. 175; Xu & Ouenniche, 2012, p. 580; Ersoy, 2021) and input- oriented classical BCC model (3) (Cheng et al., 2011, p. 3; Dalfard et al., 2012, p. 187), input-oriented BCC super-efficiency model number (4) (Cheng et al., 2011, p. 3) are shown in Table 2.

Table 2

Input-Oriented CCR Models and BCC Models

Classic CCR Model		CCR-SE Model	
$\begin{aligned}&\min \theta_t\\ &s.t.\\ &\sum_{j=1}^{n} \lambda_i x_{ij} \le \theta_t x_{it}, i = 1,\dots,m\\ &\sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rt}, r = 1,\dots,s\\ &\lambda_j \ge 0, j = 1,\dots,n\end{aligned}$	(1)	$\begin{aligned}&\min \theta_t\\ &s.t.\\ &\sum_{\substack{j=1\\ j\ne t}}^{n} \lambda_i x_{ij} \le \theta_t x_{it}, i = 1,\dots,m\\ &\sum_{\substack{j=1\\ j\ne t}}^{n} \lambda_j y_{rj} \ge y_{rt}, r = 1,\dots,s\\ &\lambda_j \ge 0, j = 1,\dots,n\end{aligned}$	(2)
Classic BCC Model		**BCC-SE Model**	
$\begin{aligned}&\min \theta_t\\ &s.t.\\ &\sum_{j=1}^{n} \lambda_i x_{ij} \le \theta_t x_{it}, i = 1,\dots,m\\ &\sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{rt}, r = 1,\dots,s\\ &\sum_{j=1}^{n} \lambda_j = 1\\ &\lambda_j \ge 0, j = 1,\dots,n\end{aligned}$	(3)	$\begin{aligned}&\min \theta_t\\ &s.t.\\ &\sum_{\substack{j=1\\ j\ne t}}^{n} \lambda_i x_{ij} \le \theta_t x_{it}, i = 1,\dots,m\\ &\sum_{\substack{j=1\\ j\ne t}}^{n} \lambda_j y_{rj} \ge y_{rt}, r = 1,\dots,s\\ &\sum_{j=1}^{n} \lambda_j = 1\\ &\lambda_j \ge 0, j = 1,\dots,n\end{aligned}$	(4)

Source: Own elaboration.

In four different models $j = 1, \ldots, n$ and, θ_t refers DMU_t whose efficiency is measured. In model (1) and model (3), if the optimal value of θ_t equals 1, then DMU_t under evaluation is efficient; otherwise, $\theta_t < 1$ indicates that DMU_t is inefficient and the current level of inputs (outputs, respectively) should be decreased (increased, respectively). In model (2) and model (4), $\theta_t < 1$ indicates that DMU_t is inefficient; otherwise, efficient *DMUs* have a $\theta_t \geq 1$ (Xu & Quenniche 2012, pp. 579–580).

3.2. Data Collection and Variables

The data set of the research has been obtained from the latest statistics of OECD and the World Bank (OECD, 2021a; OECD, 2021b; OECD, 2021c; OECD, 2022; The World Bank, 2021a; The World Bank, 2021b; The World Bank, 2022). The input and output variables used in the research were determined based on the literature review. The explanations regarding the input and output variables of the research are given in Table 3.

Table 3
The Descriptions of Input and Output Variables

Variable	Explanation
Input(s)	
Doctors	Doctor (per 1,000 inhabitants)
Nurses	Nurse (per 1,000 inhabitants)
Beds	Hospital beds (per 1,000 inhabitants)
Health expenditure	Current health expenditure (% of GDP)
Output(s)	
Infant mortality rate	Transformed into infant survival rate (deaths/1,000 live births)
Mortality rate under 5 years	Transformed into under-5 years survival rate (deaths/1,000 kids)
Life expectancy	Life expectancy at birth

Source: Own elaboration.

In the study, the infant mortality rate and mortality rate under 5 years, which are among the output variables, are positive variables. However, not all variables included in the study area have the same direction (positive or negative). For this reason, instead of the infant mortality rate "IMR", the infant survival rate "ISR" and mortality rate under 5 years "MRU5" instead of the survival rate under 5 years "SRU5" were calculated. The formulas developed for the calculation method are as follows (Alfonso & Aubyn, 2006, p. 10; Hadad, 2013, p. 256; Yüksel, 2021, p. 253):

$$ISR = \frac{(1000 - IMR)}{IMR} \tag{5}$$

$$SRU5 = \frac{(1000 - MRU5)}{MRU5} \tag{6}$$

In this study, 37 OECD countries have been selected as DMUs. The number of DMUs used in the study is more than twice the total input and output. Descriptive statistics for input and output variables can be seen in Table 4.

Table 4
Descriptive Statistics for Input and Output Variables

	Input(s)	
Doctors	Maximum	5.50
	Minimum	1.88
	Total	129.53
	Mean	3.50
	Standard deviation	0.90
Nurses	Maximum	17.97
	Minimum	1.33
	Total	325.97
	Mean	8.81
	Standard deviation	4.18
Beds	Maximum	12.98
	Minimum	0.98
	Total	167.30
	Mean	4.52
	Standard deviation	2.63
Health expenditure	Maximum	16.89
	Minimum	4.12
	Total	324.31
	Mean	8.77
	Standard deviation	2.36

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Table 4 – continued

	Output(s)	
Infant survival rate	Maximum	624.00
	Minimum	58.52
	Total	11689.78
	Mean	315.94
	Standard deviation	133.93
Survival rate, under-5 years	Maximum	499.00
	Minimum	70.43
	Total	10258.24
	Mean	277.25
	Standard deviation	114.16
Life expectancy	Maximum	81.90
	Minimum	70.10
	Total	2888.90
	Mean	78.08
	Standard deviation	3.24

Source: Own elaboration.

4. Results and Discussion

In the study, efficiency analyses were carried out with 4 different input-oriented DEA models. The efficiency results for 2020 are shown in Table 5. The efficiency scores (100%) obtained as a result of DEA models are shown as 1. The expression "**big**" in Table 5 indicates a very extreme efficiency score. In Table 5, DMUs are expressed as F1, F2…., F37, respectively. In the third column of Table 5, the efficiency scores obtained as a result of model (1) are included. As a result of the classical CCR model, 14 countries were efficient. The remaining 23 countries are inefficient. According to the results of model (1), the average efficiency score of 37 countries is 0.88. The efficiency score of 14 efficient countries is 1. To rank these efficient countries, it is necessary to look at the super-efficiency scores. According to the results of model (2), the most efficient country is F6 (Colombia) with an efficiency score of 1.73. According to the results of model (1) and model number (2), it is seen that the efficiency scores of the inefficient countries are the same. According to the results of the classical BCC model, 20 OECD countries were efficient. The remaining 17 countries were not efficient according to model (3). According to the results of model (4) (BCC-SE) in Table 5, the three countries with the highest efficiency among the efficient countries are F9, F15 and F34. According to models (1) and (3), the country with the lowest efficiency score is F12 (Germany).

Table 5
Efficiency Results of OECD Countries

OECD Countries	DMUs	CCR	CCR-SE	BCC	BCC-SE
Australia	F1	0.76	0.76	0.84	0.84
Austria	F2	0.63	0.63	0.71	0.71
Belgium	F3	0.85	0.85	0.90	0.90
Canada	F4	0.93	0.93	1.00	1.06
Chile	F5	1.00	1.04	1.00	1.22
Colombia	F6	1.00	1.73	1.00	1.76
Czech Republic	F7	0.74	0.74	0.76	0.76
Denmark	F8	0.74	0.74	0.85	0.85
Estonia	F9	1.00	1.57	1.00	big
Finland	F10	1.00	1.07	1.00	1.07
France	F11	0.69	0.69	0.80	0.80
Germany	F12	0.56	0.56	0.60	0.60
Greece	F13	1.00	1.02	1.00	1.32
Hungary	F14	0.75	0.75	0.77	0.77
Iceland	F15	1.00	1.29	1.00	big
Ireland	F16	0.97	0.97	1.00	1.05
Israel	F17	0.96	0.96	1.00	1.24
Italy	F18	0.94	0.94	1.00	1.58
Japan	F19	1.00	1.21	1.00	1.48
Korea	F20	1.00	1.10	1.00	1.17
Latvia	F21	0.86	0.86	0.89	0.89
Lithuania	F22	0.75	0.75	0.78	0.78

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Table 5 – continued

OECD Countries	DMUs	CCR	CCR-SE	BCC	BCC-SE
Luxembourg	F23	1.00	1.12	1.00	1.29
Mexico	F24	1.00	1.71	1.00	1.76
Netherlands	F25	0.84	0.84	0.91	0.91
New Zealand	F26	0.84	0.84	0.97	0.97
Norway	F27	0.83	0.83	0.84	0.84
Poland	F28	0.95	0.95	0.97	0.97
Portugal	F29	0.70	0.70	0.76	0.76
Slovak Republic	F30	0.68	0.68	0.69	0.69
Slovenia	F31	1.00	1.08	1.00	1.18
Spain	F32	1.00	1.03	1.00	1.10
Sweden	F33	1.00	1.20	1.00	1.28
Switzerland	F34	0.63	0.63	1.00	big
Turkey	F35	1.00	1.37	1.00	1.51
The United Kingdom	F36	0.95	0.95	1.00	1.00
The United States	F37	0.87	0.87	0.87	0.87
Mean		**0.88**	**0.97**	**0.92**	**1.06**

Source: Own elaboration.

It should be noted that the efficiency measurement with the DEA method is relative. Therefore, if the DMUs change, the efficiency results will also change. According to Table 5, it is understood that the results of the CCR and BCC models are different. According to the CCR models, 14 countries are efficient, while according to the BCC models, 20 countries are efficient. All of the countries that were efficient in CCR models were also efficient in BCC models. Not all countries that were efficient in BCC models were efficient in CCR models.

Efficient and inefficient countries are given in Table 6. It is seen at what rate inefficient countries should take efficient countries as a reference to be efficient.

Table 6
Reference Sets by Countries According to CCR Model and BCC Model

DMUs	CCR Model Bencmarks	BCC Model Bencmarks
F1	5 (0.19) 15 (0.34) 31 (0.08) 35 (0.42)	4 (0.08) 10 (0.01) 17 (0.84) 19 (0.02) 23 (0.03) 35 (0.02)
F2	6 (0.12) 9 (0.46) 13 (0.15) 35 (0.33)	9 (0.17) 13 (0.18) 17 (0.64) 35 (0.01)
F3	10 (0.49) 20 (0.15) 35 (0.38)	5 (0.26) 10 (0.30) 17 (0.01) 19 (0.18) 23 (0.25)
F4	5 (0.87) 10 (0.07) 15 (0.04) 31 (0.04)	5
F5	9	4
F6	2	1
F7	9 (0.50) 23 (0.14) 35 (0.37)	9 (0.45) 17 (0.09) 23 (0.19) 35 (0.27)
F8	5 (0.07) 9 (0.05) 15 (0.34) 24 (0.57)	16 (0.12) 17 (0.23) 24 (0.20) 33 (0.45)
F9	12	8
F10	3	4
F11	19 (0.07) 31 (0.25) 35 (0.72)	4 (0.45) 17 (0.15) 19 (0.19) 23 (0.07) 35 (0.14)
F12	19 (0.10) 31 (0.33) 35 (0.59)	10 (0.03) 17 (0.27) 19 (0.16) 23 (0.04) 31 (0.12) 35 (0.37)
F13	2	1
F14	9 (0.38) 35 (0.59)	9 (0.38) 35 (0.62)
F15	11	4
F16	15 (0.44) 23 (0.26) 24 (0.21) 35 (0.11)	1
F17	5 (0.18) 9 (0.37) 24 (0.46) 31 (0.06) 35 (0.02)	11
F18	9 (0.18) 15 (0.08) 24 (0.22) 32 (0.56)	0
F19	2	5
F20	2	1

Table 6 – continued

DMUs	CCR Model Bencmarks	BCC Model Bencmarks
F21	6 (0.02) 9 (0.36) 13 (0.14) 35 (0.41)	6 (0.09) 9 (0.40) 35 (0.51)
F22	9 (0.36) 23 (0.05) 35 (0.53)	9 (0.35) 23 (0.05) 35 (0.61)
F23	3	7
F24	7	3
F25	5 (0.56) 15 (0.20) 31 (0.11) 35 (0.16)	4 (0.48) 10 (0.05) 15 (0.03) 17 (0.39) 19 (0.00) 23 (0.05)
F26	5 (0.41) 15 (0.24) 24 (0.26) 35 (0.13)	4 (0.01) 5 (0.30) 17 (0.43) 33 (0.26)
F27	9 (0.06) 15 (0.94) 35 (0.00)	15 (0.93) 31 (0.07)
F28	9 (0.14) 20 (0.33) 31 (0.06) 35 (0.43)	9 (0.11) 20 (0.34) 31 (0.07) 35 (0.49)
F29	9 (0.32) 15 (0.02) 24 (0.61) 32 (0.08) 33 (0.03)	9 (0.08) 15 (0.05) 17 (0.52) 24 (0.24) 32 (0.12)
F30	9 (0.17) 35 (0.81)	9 (0.17) 35 (0.83)
F31	9	4
F32	2	1
F33	1	3
F34	5 (0.35) 15 (0.20) 31 (0.13) 35 (0.38)	0
F35	18	11
F36	5 (0.48) 10 (0.25) 15 (0.08) 24 (0.22)	4 (0.26) 5 (0.41) 15 (0.23) 17 (0.10) 33 (0.00)
F37	5 (0.58) 31 (0.08) 35 (0.33)	5 (0.33) 24 (0.14) 31 (0.11) 35 (0.42)

Source: Own elaboration.

It is understood from Table 6 that 14 countries are efficient according to the results of the CCR model. For example, according to the CCR results, for F7 (Czech Republic) to be efficient, it should reference F9 (0.50). F23 (0.14) and F35 (0.37). Similarly, according to the BCC model results, F22 (Lithuania) should refer to F9 (0.35), F23 (0.05) and F35 (0.61).

In order for the inefficient countries to be effecient, inefficient countries should reduce their inputs and increase their outputs by taking efficient countries as a reference. After this decrease and increase process, the target input and output variables are determined. The potential improvement rates to be made in the input and output variables of inefficient countries can be calculated as follows.

$$\text{Potential improvement rate} = (\text{target rate} / \text{real rate}) - 1 \qquad (7)$$

According to the results of the CCR model, for the Czech Republic to be efficient, a potential improvement of 29.4% in the number of doctors, 30% in the number of nurses, 40.5% in the number of beds and 26.7% in the health expentidure is required. Since input-oriented DEA models are used in the study, in order for the Czech Republic to be efficient, its inputs should be reduced by as much as its potential improvement rates. Similarly, potential improvement rates can be calculated for other countries.

It is understood that inefficient countries do not use inputs efficiently and create excessive inputs. According to the results of the CCR-SE model, while the number of doctors and nurses is 1.33 per 1,000 inhabitants in Colombia, the number of doctors and nurses is 13.22 per 1,000 inhabitants in Germany. This situation can be explained by the fact that Germany does not use its inputs efficiently.

5. Conclusion

In an intensely competitive environment, OECD countries need to constantly measure their health performance due to globalization, epidemics and developments in the health sector. According to the literature, it is understood that the technique that is most commonly used in measuring the health efficiency of OECD countries is the DEA method.

As in many other sectors, it is very important to measure the efficiency of OECD countries in the health sector. For this purpose, the health efficiency of 37 OECD countries for 2020 was measured. As a result of the efficiency analysis carried out using 4 different DEA models, 14 countries according to models (1) and (2), 20 countries according to models (3) and (4) were efficient. 23 countries according to models (1) and (2), 17 countries according to models (3) and (4) were inefficient.

According to model (1) and (3) results, the country with the lowest efficiency score is Germany. According to the results of the CCR-SE model, the most efficient country is Colombia. According to the results of the BCC-SE model, the three countries with the highest efficiency scores are Estonia, Iceland and Switzerland.

Countries that were not efficient in the study should take as reference the efficient countries. By making some improvements in the inputs (doctors,

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nurses, beds, health expenditure) used in the study, inefficient countries can be efficient. For example, according to the results of the CCR model, the potential improvement rates for the Czech Republic to be efficient are 29.4%, 30%, 40.5% and 26.7%, respectively. Efficient and inefficient OECD country authorities should consider possible improvements. Especially in inefficient countries, health system administrators can come together with authorized public institutions and private sector representatives and act together so that the health system can be efficient.

As with any scientific study, this study has some limitations. It should be noted that the relative efficiency was measured with the DEA method used in the study. Therefore, efficient DMUs are relatively efficient. However, DEA is one of the most widely used methods in efficiency measurement and its advantages and/or superiorities are quite high when compared to alternative methods. One of the limitations of the study is the use of input-oriented DEA models and 4 input and 3 output variables. Another limitation of the study is that the analyses are limited to only 37 OECD countries. This study was carried out to determine the health efficiency of OECD countries. It can be used in different countries in future studies. More comprehensive efficiency measurement studies can be carried out by including new input and/or output variables.

Conflict of interest

The authors declare no conflict of interest.

Availability of data and material

The data of the study available upon request.

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