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Comparison of Efficiency of Healthcare Systems of Countries with Global Competitiveness Using Data Envelopment Analysis

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A B S T R A C T

The purpose of this study is to evaluate and compare the efficiency of healthcare systems among 28 countries around the world by applying the data envelopment analysis (DEA) method. Two output variables are used: life expectancy at birth and infant mortality rate. Four input variables are used: number of physicians, number of hospital beds, radiotherapy units per million of the population, and total health expenditure as a percentage of the country's GDP. Using the DEA method, we evaluate how healthcare systems could set service levels in accordance with their strategic purpose or operational characteristics. This study contributes to the practice of healthcare management and could theoretically improve operational efficiency in the healthcare industry based on the compared efficiency of various healthcare systems.

Keywords: Healthcare System; Efficiency; Data Envelopment Analysis; Global Competitiveness Country

I . Introduction

The healthcare industry not only has a significant impact on the world economy, it also affects the quality of individuals' healthcare to create value in their daily lives. However, healthcare providers are also under pressure to reduce health costs by improving operational efficiency, which is expected to become essential because of consumers' increasing expectations in terms of improved health benefits. At the same time, this would require healthcare providers to strive to reduce costs.

The efficiency of healthcare systems has become a relevant topic for both healthcare providers and for policy makers in the healthcare industry. In the past, increased

health expenditures were accompanied by improved healthcare outcomes. Various studies have been conducted to attempt to quantitatively measure the degree of improvement in healthcare outcomes, including determining the efficiency of health resources, and the effects of increasing the number of patients, reducing the mortality rate at birth, and/or increasing life expectancy (Joumard et al., 2010; European Commission, 2015; Lee et al., 2016).

Another study suggested the existence of a nonlinear relationship between health expenditures and outcomes, reflecting the impact of other factors, namely historical expenditure patterns on healthcare and other welfare policies, people's lifestyle choices, and environmental factors (Medeiros and Schwierz, 2015).

Thus, estimating the efficiency of a healthcare system needs to take into account a wide range of relevant variables to obtain unbiased and efficient estimates. There is also a need to examine the influence of improving the efficiency

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of healthcare systems. The efficient use of resources involved in healthcare systems is a relevant topic both for CEOs or managers and for policymakers of the healthcare industry. Therefore, we need to first examine the influence of efficiency of healthcare systems among countries. Based on a review of literature on efficiency in the healthcare sector, this study examines how to improve the efficiency of healthcare systems using DEA methods.

The rest of the paper is organized as follows: Section 2 reviews the most relevant literature; Section 3 develops a brief description of the method; Section 4 describes the research methodology and the data used as input and output variables; Section 5 reports results; and Section 6 presents the conclusion of the results and the limitations of the study.

II. Literature Review

Data envelopment analysis (DEA) was developed by Farrell (1957), after which Charnes et al. (1978) extended the method with a nonparametric technique to measure the efficiency and decision making units (DMUs) using a multiple-inputs and multiple-outputs setting. A DMU is an entity that produces output and input variables.

According to Farrell (1957), the technical efficiency in a hospital can be measured by assessing the service outputs achieved by implementing a given level of care with the least input resources. Charnes et al. (1978) developed the theory to measure the efficiency of DMUs in healthcare system through care service activities. In addition, the same authors defined DEA as ‘a non-parametric programming technique that develops an efficiency frontier by optimizing the weighted output/input ratio of each provider, subject to the condition that this ratio can equal, but never exceed, unity for any other provider in the data set.’

Efforts by a healthcare organization to improve the quality of care service for patients, while at the same time reducing the cost involves a trade-off between the quality and quantity of care provided within different diagnoses, which increases the cost (Ferrier & Trivitt, 2013). Healthcare organizations strive to have efficient care services with a continuous improvement in the patient’s healthcare status including healthcare expenditures.

Despite many efforts to reduce cost while maintaining a high quality of life, health expenditure as a percentage of GDP has continued to rise in all countries over the past decades (Medeiros and Schwierz, 2015). In 2014, national health expenditure was estimated at \$3.0 trillion, which accounted for 17.5% of GDP in the U.S.A (CMS.gov, 2014) and 10.2% of GDP in the EU in 2011 (Medeiros and Schwierz, 2015). Total health spending accounted for 7.2% of GDP in Korea in 2013 (The World Bank, 2016). Health spending is expected to continue rising at a faster pace than income (Medeiros and Schwierz, 2015).

Previous studies, especially those of Cicea and Pirlogea (2009) and Rivera (2010) contributed in this regard by analyzing the efficiency of healthcare systems, whereas other studies have documented the large degree of inefficiency at the level of acute care in hospitals (Medeiros and Schwierz, 2015). These studies found that health care performance, which is influenced by efficiency in hospitals, can differ significantly across different hospitals or countries. Joumard et al. (2010) argued that organizational characteristics can have a significant impact on the measured efficiency for improving the overall healthcare efficiency. For example, inserting or moving input resources for the treatment of cardiovascular diseases by focusing on prevention will increase health expenditures, whereas relying on treatment alone will be below an optimal level (AcademyHealth, 2012). Therefore, ensuring the efficiency of the healthcare system has become an essential strategy for overcoming the pressure of expenditure (Heller and Hauner, 2006).

When diagnostic related groupings (DRGs) were introduced during the 1980s, hospitals moved to evaluate the efficiency of the healthcare delivery process based on fixed medical costs. In the healthcare industry, the DEA was used by Nunamaker and Lewin (1983) in a study designed to measure nursing service efficiency. Sherman (1984) was the first to use DEA to evaluate overall hospital efficiency and the study addressed the fact that DEA is a means to ‘measure hospital inefficiency as a basis for directing management efforts toward increasing efficiency and reducing healthcare costs.’ The study of Asandului et al. (2014) found a significant difference between the efficiency of public healthcare systems in developed and developing European countries. Medeiros and Schwierz (2015) also reported that there is considerable waste cost, which increases health

expenditure although the relative efficiency of healthcare systems across participating EU countries is different.

There are many studies that utilize DEA using decision making units to assess different aspects of efficiency in the healthcare industry, such as hospital efficiency (Asandului *et al.*, 2014; Nedelea *et al.*, 2010; Sherman, 1984; Tambour *et al.*, 1997), health facilities efficiency (Ferrier *et al.*, 2006; Hollingsworth, 2008; Ozcan, 2008), and quality and productivity efficiency (Arocena and Garcia-Prado, 2007; Ferrier and Trivitt, 2013; Yang and Zeng, 2014).

Thus, in the study non-parametric frontier methods based on DEA to evaluate the technical efficiency of the healthcare system among countries mainly use. Additionally, similar to previous analyses, this study uses the DEA method to derive scores of the relative technical efficiency of transforming the input variables into output variables in healthcare systems of countries.

III. Method

Various DEA models have been applied to provide efficiency scores with different variables using linear programming techniques. This study evaluates technical efficiency in the healthcare system by focusing on non-parametric frontier methods based on DEA method. The DEA models also allow technical efficiency, both pure technical efficiency, and scale efficiency (SE), to be determined. The DEA model commonly uses both the BCC model proposed by Banker, Charnes, and Cooper (1984) and the CCR model of Charnes, Cooper, and Rhodes (1978).

The CCR model is based on the assumption of constant returns to scale (CRS), whereas the BCC model is based on the assumption of variable returns to scale (VRS). The scale efficiency (SE) score means that ‘the ability of management to choose the optimum size of resources (Kumar and Gulati, 2008)’; thus, it can be estimated by the ratio of technical efficiency to pure technical efficiency.

As the efficiency of DMUs can be measured by assessing how effectively resource inputs have been converted into outputs, the DEA model uses input and output resource. The measurement of efficiency through

data processing using DEA generally evaluates the technical efficiency by using input and output variables (Sánchez, 2009). Technical efficiency can be split into pure technical efficiency and scale efficiency. Thus, the objective of this study is to estimate the technical and scale efficiency of healthcare systems among countries using two output and four input variables. Input-oriented DEA model is used to test if a DMU under evaluation can reduce its inputs while keeping the outputs at given amount of current levels. In this paper, the term of efficiency refers to technical efficiency, implying the maximization of output variables for a given level of input variables or the minimization of input variables for a given level of output variables in a healthcare system.

An estimation of the technical efficiency of healthcare systems among countries using DEA requires a decision as to whether to use input- or output-oriented efficiency measures. An input-oriented measure holds the current level of output constant and minimizes inputs, whereas an output-oriented one maximizes output while keeping the amount of input constant. Both of these efficiency measures are equivalent measures of technical efficiency only under CRS (Sánchez, 2009).’ Thus, for the study, we select an input-oriented BCC-DEA model to estimate technical efficiency.

The linear programming method, as described by Charnes *et al.* (1978), is presented below. There are 4 inputs ($k = 4$) and 2 outputs ($m = 2$) for 28 DMUs ($n = 28$). We can also define X as the ($k \times n$) input matrix and Y as the ($m \times n$) output matrix. The specifications of the mathematical programming problem, for a given i -th DMUs, are described below, and require one problem to be solved for each DMU:

$$\begin{aligned} \min_{\theta, \lambda} \quad & \theta \\ -y_i + Y\lambda & \geq 0 \\ \theta x_i - X\lambda & \geq 0 \\ N_1 \lambda & \leq 1 \\ \lambda & \geq 0 \end{aligned}$$

In the above formula, θ is a scalar and its ranges are between 1 and ∞ . The inverse of θ ranges between 0 and 1 and is the technical efficiency score. If it is equal to 1, it implies that the DMU is efficient; if it is less than 1, then the DMU is inefficient. Vector λ

is a $(n \times 1)$ vector of constants that measures the weights used to compute the location of an inefficient DMU if it were to become efficient.

The model specification under the hypothesis of variable returns to scale implies the condition of convexity of the frontier. This presumes that the restriction $N_1 \lambda \leq 1$ is introduced in the model, N_1 being an n dimensional vector of ones. The absence of this restriction would imply that the returns to scale were constant.

In this paper, both the CSR and VRS DEA models are used to compute the efficiency of the healthcare systems for the DMUs among 28 countries around the world. Thus, this compares the ratio between the efficiency scores in the CRS and VRS and explains the increase or decrease of the SE, which is obtained by dividing the pure technical efficiency by the technical efficiency.

IV. Data and variables

According to the World Economic Forum (2014), the Global Competitiveness Index has been used as “an important tool by policymakers of many countries over the years”. The selected 30 countries were ranked by the World Economic Forum as the global competitiveness index in the year 2014-2015 rankings. However, Hong Kong and Taiwan were excluded from this study because the World Bank did not provide the necessary data for the study. In this study, we developed assessment criteria for efficiency in the healthcare industry and analyzed the efficiency of healthcare systems among 28 countries around the world- Switzerland, Singapore, United States, Finland, Germany, Japan, Netherlands, United Kingdom, Sweden, Norway, United Arab Emirates, Denmark, Canada, Qatar, New Zealand, Belgium, Luxembourg, Malaysia, Austria, Australia, France, Saudi Arabia, Ireland, South Korea, Israel, China, Estonia, and Iceland- using the DEA method to identify differences among these countries.

A. Input and Output Variables for Computing Efficiency Scores

The large variety of data that was available for the

study enabled us to focus on selecting data on the basis of consistency. Thus, we used data that was produced by a certain institution as WHO (World Health Organization). In addition, we also considered the accuracy and comparability of data, which are important features of DEA models for the study.

Since DEA results are influenced by the size of the sample, Cooper et al. (2007) provides rules that can be expressed as: $n \geq \max \{(k \times m) \text{ or } 3(k + m)\}$, where n = number of DMUs, k = number of inputs and m = number of outputs. The number of DMUs exceeds 18 $\{=3(4+2) \text{ or } 8= (4 \times 2)\}$; hence, the number of DMUs in the study is 28. Thus, we applied the DEA method in combination with an input-oriented specification for assessing the efficiency of healthcare systems among 28 countries around the world.

To compute the efficiency scores, the output variables for this study were life expectancy at birth and infant mortality rate of the year 2013, and the four input variables were number of physicians per 1,000 of the population, number of hospital beds per 1,000 of the population, radiotherapy units per million of the population, and total health expenditure as a percentage of the GDP of 2013.

The value of life expectancy at birth was chosen as output variable because it reflects the overall mortality level of a population and because it is one of the indicators that can be used to evaluate the efficiency of a healthcare system (WHO, 2012). Life expectancy at birth was chosen as output variable because one of indicators to evaluate the efficiency of the healthcare systems and reflecting overall mortality level of a population (Asandului et al., 2014; Tudorel et al., 2009).

The infant mortality rate has been reported annually to WHO wherever possible from death registration (WHO, 2012). The WHO definition of infant mortality rate is as follows: ‘the probability of a child born in a specific year or period dying before reaching the age of one, if subject to age-specific mortality rates of that period.’ The value is expressed per 1,000 live births in a given year.

In terms of input variables, we considered easy access and distribution and support by government important components of the healthcare delivery service. Thus, the number of physicians, number of hospital beds, radiotherapy units per million of the population, and total health expenditure as percentage of GDP are selected for the study. Physicians and nurses are considered

resources and hospital beds are considered infrastructure, and this information is essential to enable healthcare providers and governments to determine how best to meet the health-related needs of their populations (WHO, 2012).

The number of physicians is a human resource and is considered the most valuable resource in a healthcare system. According to WHO, the definition of the number of physicians including generalists and specialists is the number of persons who have a degree in medicine at university level with an adequate diploma, and who are licensed to practice through interns and resident physicians in a healthcare facility, employed and self-employed physicians for the provision of healthcare services, and foreign physicians licensed to practice and actively practicing in the country. The number of physicians is calculated by number of physicians per 1,000 of the population.

According to the WHO, hospital beds are defined as the number of hospital beds per 1,000 of the population and include inpatient and maternity beds, whereas beds in emergency rooms, psychiatric care beds, and delivery beds are excluded. This means that hospital beds are accounted as beds that are available for the care of admitted patients.

The United Nations Commission on Life Saving Commodities (2012) addressed the density of medical technologies and devices as an essential indicator on the component of level of health services. WHO is provided country's data of density of medical technologies and devices, such as magnetic resonance imaging units, radiotherapy units, computed tomography units, positron emission tomography units, and gamma camera or nuclear medicine units, etc. In our study, radiotherapy units were

selected as an example of a medical technology because some countries have a missing information for the study. The value of radiotherapy units is calculated as a value per million of the population.

As health financing is a critical component of healthcare systems, the WHO defines the total expenditure on health as 'the sum of general government health expenditure and private health expenditure in a given year, calculated in national currency units in current prices.' As GDP is the value of all goods and services provided in a country, the total health expenditure as percentage of GDP refers to the scale health expenditure per GDP. Health expenditure is 'the most comprehensive and consistent data on health financing, which is generated from national health accounts (NHAs) that are collected from expenditure information within an internationally recognized framework (WHO, 2012).'

V. Results

Table 1 presents results of the descriptive statistics of the input and output variables. The number of physicians per 1,000 of the population ranges from 1.2 in Malaysia to 7.7 in Qatar. The standard deviation (SD) of the number of physicians is 1.24 physicians per 1,000 of the population, and the coefficient of variation (CV) is 38.87%. The number of hospital beds per 1,000 of the population ranges from 1.1 in United Arab Emirates to 13.7 in Japan. The average is 4.4 beds per 1,000 of the population with an SD of 2.8 and a CV of 63.96%. The number of

Table 1. Descriptive statistics for input and output variables

Statistics	Input Variables			Output Variables		
	Number of physicians per 1,000 of the population	Number of hospital beds per 1,000 of the population	Radiotherapy units per million of the population.	Total health expenditure as a percentage of the GDP	Life expectancy in years	Infant mortality rate (number of deaths per 1,000 live births)
Maximum	7.70	13.7	12.37	17.10%	83.0	13.0
Minimum	1.20	1.10	0	2.20%	74.0	2.0
Average	3.19	4.44	4.89	8.70%	80.18	4.11
Standard Deviation	1.24	2.84	3.26	3.37%	2.55	2.66
Coefficient of Variation	38.87%	63.96%	66.66%	38.74%	3.18%	64.72%

Table 2. Result of correlation matrix

	Life expectancy	Infant mortality rate
Life expectancy	1	
Infant mortality rate	-.789**	1

radiotherapy units per million of the population ranges from 0 in Switzerland to 12.37 in United States. The average of radiotherapy units per million of the population is 4.89 with a SD of 3.37 and a CV of 66.66%. The percentage of total health expenditures as a percentage of the GDP is a minimum of 2.20% in Qatar and a maximum of 17.10% in United States. The average is 8.70% with a SD of 3.37% and a CV of 38.74%. Life expectancy is a minimum of 72.8 years in Saudi Arabia and a maximum of 81.6 years in Switzerland and Iceland. Life expectancy has an average of 80.18 years with an SD of 2.55 years and a CV of 3.18%. The infant mortality rate ranges from 2.0 deaths per 1,000 live births in 7 countries (Singapore, Finland, Japan, Sweden, Norway, Luxembourg, and Iceland) to 13.0 deaths per 1,000 live births in Saudi Arabia. On average, the countries from the sample have 4.11 deaths per 1,000 live births with an SD of 2.66 deaths and a CV of 64.72%.

As the CV represents the ratio of the SD to the mean, the life expectancy variable, which has a smaller CV (3.18%), is less dispersed than the radiotherapy unit variable, which has the largest CV (66.66%) among the six variables.

Banker et al. (1996) suggested that the number of variables might impact the increase of efficiency in units by introducing more degrees of freedom. Therefore, a correlation test was conducted between the output indicators, numerically greater than those of the inputs, obtaining the correlation matrix given in Table 2. As shown in this table, there is a strong negative correlation between life expectancy and infant mortality rate (value of correlation coefficient = -0.789), and therefore these two output variables are separated for the DEA model analyses in this study. In the first DEA model, the output variable is life expectancy, while infant mortality rate is the output variable in the second model. Both models use the four input variables.

Table 3 describes the findings from the CRS, VRS, and SE analysis of the data from the healthcare systems of the 28 countries. The technical efficiency can be examined by decomposing it into pure technical efficiency

and scale efficiency. As shown Table 3 and Figures 1 and 2, the results of DEA scores between two the model is very surprising.

In Model 1, which uses the output variable of life expectancy, the average index of technical efficiency is 65.0%, of pure technical efficiency is 77.0%, and of scale efficiency is 84.0%. Decomposition indicates that 22 of the countries (78.6%) show technical inefficiency and 19 of the countries (67.9%) show pure technical inefficiency. However, the means in Model 1 show that most of the technical inefficiency is in the form of scale inefficiency.

In Model 2, which uses the output variable of infant mortality rate, the average index of technical efficiency is 36.0%, of pure technical efficiency is 63.0%, and of scale efficiency is 50.0%. Analysis of Model 2 shows that the average efficiency scores are much lower for CRS and VRS in comparison to those same categories in Model 1. 25 countries (89.3%) show technical inefficiency and 22 countries (78.6%) show pure technical inefficiency. The group of efficient countries is almost completely changed in Model 2. Only three countries (Switzerland, Saudi Arabia, and China) have efficiency scores of 1, while 20 of the countries in the sampled countries have efficiency scores less than 0.4. Norway is the country with the least efficiency with a technical efficiency score of 0.1 in Model 2.

As shown efficiency scores of China and Saudi Arabia are 1 in Table 3, input variables of these two countries are below, while output variables of these countries are higher than average among other countries (see Table 1). Saudi Arabia: input variables are number of physicians per 1,000 of the population (2.5), number of hospital beds per 1,000 of the population (2.1), radiotherapy units per one million of the population (0.1), and total health expenditure as a percentage of the GDP (3.2), and output variables are life expectancy in years (74) and infant mortality (13). China: number of physicians per 1,000 of the population (1.9), number of hospital beds per 1,000 of the population (3.8), radiotherapy units per one million of the population (1.1), and total health expenditure as

a percentage of the GDP (5.6), and output variables are life expectancy in years (75) and infant mortality (11). It implies that that if the economic development or situation and population density is higher, there will be more demands for health services, and the overall technical efficiency is to be a higher level.

Among the countries that have lower than average efficiency scores, we find the same countries present as

in the model 1 (Finland, Germany, Japan, Netherlands, UK, Sweden, Norway, Denmark, Belgium, Luxembourg, Austria, Australia, France, Ireland, Israel, Estonia, and Iceland). Switzerland has the same efficiency scores compared to Model 1 and 2. Saudi Arabia and China have a better position compared to their Model 1 results with an efficiency score of 1 (see Table 3 and Figures 1 and 2). However, the efficiency scores of UAE, Qatar,

Table 3. CCR- and BCC-efficiency index for the healthcare systems of 28 countries

DMU Group number	Model 1: output is life expectancy					Model 2: output is infant mortality rate			
	DMU	CRS	VRS	SE	Reference DMU group	CRS	VRS	SE	Reference DMU group
1	Switzerland	1.00	1.00	1.00	1	1.00	1.00	1.00	1
2	Singapore	0.89	1.00	0.89	2	0.19	0.82	0.23	11,18
3	USA	0.62	0.67	0.93	2,11,18	0.45	0.59	0.75	11,18
4	Finland	0.46	0.65	0.70	2,18	0.12	0.42	0.28	18,22
5	Germany	0.37	0.49	0.77	2,18,24	0.13	0.35	0.39	18,22
6	Japan	0.58	1.00	0.58	6	0.15	0.52	0.29	18
7	Netherlands	0.45	0.65	0.69	2,18	0.18	0.41	0.45	18
8	UK	0.61	0.68	0.90	2,11,18	0.27	0.57	0.47	11,18
9	Sweden	0.56	0.74	0.75	2	0.12	0.52	0.23	11,18
10	Norway	0.47	0.55	0.86	2,11,14	0.10	0.44	0.22	11,18
11	UAE	1.00	1.00	1.00	11	0.88	1.00	0.88	11
12	Denmark	0.49	0.54	0.92	2,11,18	0.16	0.47	0.35	11,18
13	Canada	0.71	0.90	0.79	2,18	0.44	0.66	0.66	11,18
14	Qatar	1.00	1.00	1.00	14	0.94	1.00	0.94	14
15	New Zealand	0.71	0.79	0.90	2,11,14	0.36	0.67	0.53	11,18
16	Belgium	0.35	0.39	0.91	2,11,18	0.11	0.33	0.34	18,22
17	Luxembourg	0.58	0.77	0.75	1,2,24	0.12	0.53	0.23	18,22
18	Malaysia	1.00	1.00	1.00	18	0.90	1.00	0.90	18
19	Austria	0.36	0.44	0.82	1,2,11,14,24	0.11	0.34	0.33	18,22
20	Australia	0.48	0.70	0.69	1,2,11,24	0.17	0.44	0.38	11,18
21	France	0.41	0.63	0.66	2	0.22	0.38	0.58	18
22	Saudi Arabia	1.00	1.00	1.00	22	1.00	1.00	1.00	22
23	Ireland	0.62	0.75	0.82	2,11,18,24	0.21	0.58	0.36	11,18
24	South Korea	1.00	1.00	1.00	24	0.27	1.00	0.27	24
25	Israel	0.56	0.81	0.69	1,2,14,24	0.17	0.51	0.34	11,18,22
26	China	0.84	0.85	0.99	18,22,24	1.00	1.00	1.00	26
27	Estonia	0.62	0.62	1.00	11,18	0.17	0.62	0.28	18,22
28	Iceland	0.54	1.00	0.54	28	0.11	0.49	0.22	11,18
Average efficiency		0.65	0.77	0.84		0.36	0.63	0.50	
Efficiency units		6	9	7		3	6	3	
Inefficiency units		22	19	21		25	22	25	

Technical efficiency (CRS scores); Pure technical efficiency (VRS scores-input oriented)

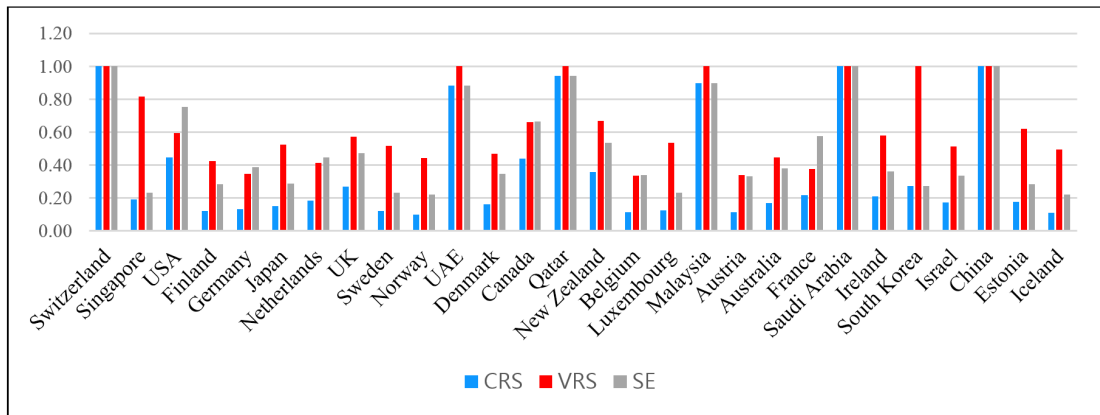


Figure 1. Efficiency score for DEA model 1 using output variable of life expectancy

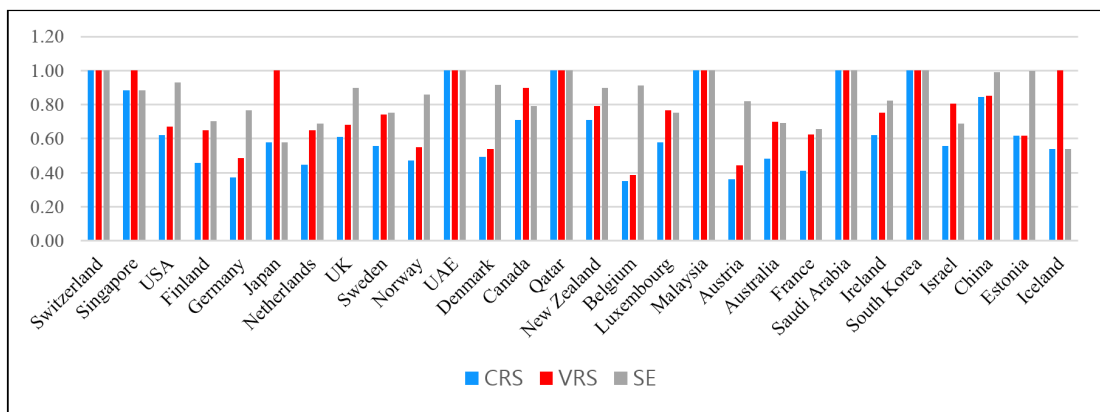


Figure 2. Efficiency score for DEA model 2 using output variable of infant mortality rate

Malaysia, and South Korea have dropped which compared to their Model 1 results with an efficiency score of 1 (see Table 3 and Figures 1 and 2).

The findings from both models reflect decreasing returns to scale for the majority of the DMUs, with a coefficient of returns to scale lower than 1. This implies that an increase in inputs will generate a smaller increase in outputs. In addition, there are no countries that are efficient in both models present for constant returns to scale. Although the SE score showed little difference between the two models, overall, the countries ranked at the top of global competitiveness by the World Economic Forum are marginally inefficient in their healthcare systems.

Inefficient countries can improve their efficiency by reducing inputs. CRS scores among the inefficient countries range from 0.35 for Belgium to 0.89 for

Singapore in Model 1. This finding implies that Belgium and Singapore can potentially reduce their current input levels by 65 percent and 11 percent, respectively, while leaving their output levels unchanged. This also implies that the CRS scores can be extended for the other inefficient countries in the sample.

VI. Conclusions

This paper evaluates the extent of technical, pure technical, and scale efficiencies in healthcare systems using data from the year 2013 for 28 countries. Analysis was done using the DEA method, in which the estimated scores of CRS (technical), VRS (pure technical), and

scale efficiencies for 28 countries were been obtained using the CCR and BCC DEA models.

The findings of the paper reflect that some countries are efficient in using their inputs in their healthcare system, while other countries proved to be inefficient in the use of their inputs (see Table 3 and Figures 1 and 2). Saudi Arabia had the highest infant mortality rate (13%) and lowest life expectancy (74 years old); Malaysia had one of the lowest numbers (1.2) of physicians per 1,000 of the population; United Arab Emirates had one of the lowest numbers (1.1) of hospital beds per 1,000 of the population; Switzerland had one of the lowest numbers (0.0) of radiotherapy units per million of the population; and Qatar had the lowest percentage of total health expenditures as a percentage of the GDP (2.2%).

Switzerland, UAE, Qatar, Malaysia, Saudi Arabia, and South Korea had an efficiency value of 1 in Model 1, while Switzerland, Saudi Arabia, and China had an efficiency score of 1 in Model 2. Although the results of these two DEA models show that the resources, even if they are limited, are efficiently used, some countries which generate a higher percentage of the GDP per capita for total health expenditures (United States, 17.1%; Netherlands, 12.9%; France, 11.7%) are not technically efficient (efficiency values in Model 1 is 0.62, 0.45, and 0.41, respectively). Also, while USA and Denmark had high density of medical technologies and devices as radiotherapy units per million of the population among 28 countries, efficiency values are not technically efficient (0.62 and 0.49 in Model 1, and 0.45 and 0.16 in Model 2, respectively).

According to the efficiency scores, there are major differences between the two models in the distribution of the 28 countries. In particular, Model 2, which has the output variable of infant mortality rate, only 9 countries (Switzerland, USA, UAE, Canada, Qatar, New Zealand, Malaysia, Saudi Arabia, and China) have more than an average efficiency level (0.33), while Norway has the lowest efficiency value as 0.10. These results show possible directions for improvement in the operations of inefficient healthcare systems among the 28 countries. For example, numbers of medical technologies and devices can lead to increase health expenditures in terms of inefficient healthcare systems. It means that addressing allocative inefficiency is more difficult task but central to controlling health expenditures. The results also suggest that countries with inefficient healthcare systems should

concentrate more on relevant healthcare resources.

Therefore, healthcare policy makers or administrators need to be innovative to find strategies that would lead to an improvement in the efficiency of the usage of resources, such as hospital beds, medical equipment, physicians, and nurses. Furthermore, policy makers and health administrators who manage the possible resources need to implement a strategy that would ensure more efficient utilization of resources in the healthcare system. In addition, policy makers may consider related input variables for healthcare to increase their efficiency. Health related organizations need to continuously improve the working environment using information technology with the aim of increasing the efficiency rate and reducing the possible variables. Especially reducing cost and improving operational efficiency in healthcare industry, investment of advanced systems and/or technologies will be considered in a complex system with many challenges.

In summary, this research is expected to increase the policy relevance for the healthcare system, which needs to establish more efficient ways for allotting their healthcare resources by using a new set of input and output variables. The productivity paradox concept could be considered to analyze whether improved efficiency can be achieved by other input factors such as investments in advanced information systems and IT.

This study has several limitations. First, data of 28 countries were collected from World Economic Forum as the global competitiveness index in the year 2014-2015 rankings. Second, we cannot figure out the health systems are fundamentally different or similar across each of the 28 countries. Thus, we used announced health data by OECD based on World Economic Forum because we assumed that the announced data have been measured using the same criteria. Although used data was public sources, and number of variables for DEA model was satisfactory in the study, the generalizability of study results may be limited because input and output variables are limited. Thus, future research should expand upon the research done in this study by using various variables with longitudinal data not considered in this study.

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