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Original Article

Efficiency Analysis of Health Systems in World Bank Countries

Dünya Bankası Ülkelerinde Sağlık Sistemlerinin Etkinlik Analizi

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ABSTRACT

Objective: Performance analysis is vital in the health sector owing to health expenditures, increased quality demands, and competition. In this study, we aimed to evaluate the relative efficiencies of different countries that use similar health status indicators.

Material and Methods: A K-means clustering algorithm with five different variables was used to ensure homogeneity among the countries selected for comparison. The resulting clusters were analyzed using an input-oriented data envelopment analysis with four inputs and three output variables for evaluating the relative efficiencies of countries within each cluster. Accordingly, input variables, such as current health expenditure per capita (current US$), hospital beds (per 1000 people), physicians (per 1,000 individuals), and nurses and midwives (per 1,000 people); and output variables, such as life expectancy at birth, maternal survival rate (per 100,000 live births), and infant survival rate (per 1,000 live births) were determined, and efficiency analysis was performed.

Results: The countries were first clustered into three homogenous groups using a k-means clustering algorithm. For 177 countries whose data were accessible (out of 189 countries), the first, second, and third clusters comprised of 74, 55, and 48 countries, respectively. Then, scale efficiency, pure technical efficiency, and technical efficiency scores were obtained by data envelopment analysis. In the first cluster, 31 countries (41.89%) were categorized as pure technical efficient, whereas in the second and third clusters, 20 (37.03%) and 23 (47.92%) countries were categorized as pure technical efficient, respectively.

Conclusion: Cross-country studies are crucial for countries for the assessment of comparative positions and for improvement of their health status accordingly. Policymakers can compare the relative efficiency of their countries with other countries that possess similar health resources. Accordingly, they can set achievable targets by referring data of efficient countries.

Keywords: Clustering, data envelopment analysis, efficiency, health system, K-means algorithm

ÖZ

Amaç: Artan sağlık harcamaları, kalite talepleri ve rekabet sağlık sektöründe performans analizlerini artırmaktadır. Bu çalışmanın amacı, sağlık indikatörleri açısından benzer özelliklere sahip ülkelerin göreli etkinliklerini kıyaslamaktır.

Gereç ve Yöntem: Çalışmada ülkelerin homojenliğini sağlamak adına beş farklı değişken kullanılarak k-ortalamalar kümeleme algoritması, ülkelerin göreli etkinliklerinin değerlendirilmesinde ise dört girdi ve üç çıktı değişkeni kullanılarak girdi odaklı Veri Zarflama Analizi uygulanmıştır. Buna göre, kişi başı sağlık harcamaları (cari ABD doları), hastane yatağı sayısı (1000 kişi başına), hekim sayısı (1000 kişi başına), hemşire ve ebe sayısı (1000 kişi başına) girdi değişkenleri olarak; doğumda beklenen yaşam süresi, anne sağkalım oranı (100000 canlı doğum başına) ve bebek sağkalım oranı (1000 canlı doğum başına) değişkenleri ise çıktı değişkenleri olarak belirlenerek etkinlik analizi yapılmıştır.

Bulgular: Ülkeler kendi aralarında heterojen, kendi içlerinde homojen 3 kümeye ayrılmıştır. Çalışmada Dünya Bankasına üye 189 ülkeden verisi ulaşılabilir olan 177 ülkenin kümelenmesi sonrasında ilk kümede 74 ülke, ikinci kümede 55 ülke ve üçüncü kümede 48 ülke yer aldığı tespit edilmiştir. Kümeleme analizi sonrası yapılan VZA ile ülkelerin ölçek etkinlik, saf teknik etkinlik ve teknik etkinlik skorları elde edilmiştir. İlk kümede 31 ülkenin (%41,89) saf teknik etkin olduğu, ikinci ve üçüncü kümede ise sırasıyla 20 ülke (%37,03) ve 23 ülkenin (%47,92) saf teknik olduğu görülmüştür.

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Sonuç: Ülkeler arası yapılan kıyaslama çalışmaları, ülkelerin kendi durumlarını görmeleri ve sağlık sistemlerinin ortak amacı olan sağlığın geliştirmeleri açısından oldukça önemlidir. Politikacılar benzer kaynaklara sahip diğer ülkelerle kendi ülkelerinin durumlarını kıyaslayarak, göreli olarak ne durumda olduklarını görebilirler. Böylece, etkin ülkeleri referans alarak ulaşılabilir hedefler belirleyebilirler.

Anahtar Kelimeler: Kümeleme, veri zarflama analizi, etkinlik, sağlık sistemi, K-ortalamalar algoritması

Introduction

Performance analysis has garnered considerable attention and increased importance in the health sector owing to health expenditures, increased quality demands, and competition. In many countries, expenditure on health is a policy issue because health resources are limited and resource shortages are prevalent in many countries.[1, 2] Most international healthcare delivery systems are focused on healthcare and health service performance analysis. Such studies help explain the impact of various policies and institutional arrangements; however, it is difficult to interpret health expenditures among countries as they are measured in different currencies with different purchasing power.[2] In performance evaluation, confusion arises between productivity and efficiency. Accordingly, when a product or service is the output of a system, productivity is defined as the ratio of outputs to inputs. However, efficiency is the state of production where maximum output can be produced with minimum input.[3]

To manage these resources in an efficient and equitable manner, various studies have been conducted. The Organization for Economic Co-operation and Development (OECD) and the World Health Organization (WHO) are pioneers in data collection and have published international comparisons in recent years.[4] Analysis of health status as the final output and related inputs of health services allows us to identify the most effective approach to allocate resources to improve health. It is important to derive experimental estimates of this relationship as increased spending on healthcare services is expected to improve health performance.[5]

To perform cross-country comparisons for health status, objective, standard, and quantitative indicators are necessary. These health status parameters are known as health indicators in literature.[6] Health indicators are important sources for assessing the level of development in most countries, and they are selected as economically and ethically as possible to improve the effectiveness, safety, and patient-centeredness of healthcare systems.[7] These parameters, developed to improve health outcomes, provide comparative information to be used for monitoring, management, and for formulating policies within and across health services.[8]

According to Donabedian[9], resources used in health services consist of five sub-dimensions. These sub-dimensions are human, financial, technological, material, and organizational. The inputs and outputs obtained from this classification have been used in numerous studies. According to these studies, the most common input and output variables used in the evaluation of health systems include the density of physicians (P) (total number per 1,000 population), nurses and midwives (NM) per 1,000 people, infant mortality rate (IMR) per 1,000 live births, maternal mortality ratio (MMR) per 100,000 live births, life expectancy at birth, health expenditure per capita, hospital beds (HB) per 1,000 people, number of MRI units, smoking prevalence, total alcohol consumption per capita, average number of inpatient days, and number of outpatient visits per 10,000 people per year.[2, 10-16]

Material and Methods

The objective of this study was to identify countries with similar characteristics in terms of health resources and to evaluate the relative efficiency of these countries in terms of health status indicators. With this study, we aimed to observe differences in terms of health resources, especially between undeveloped and developed countries, and to determine reference countries that will create more accessible and more realistic efficiency targets for ineffective countries among countries with similar resource composition.

To obtain homogeneous sub-groups, cluster analysis was performed using five different indicators, namely urban population (UP) (%), current health expenditure (CHE) per capita (current US$), HB (per 1,000 people), P (total number per 1,000 population), and NM (per 1,000 people) for 177 countries. A k-means clustering algorithm programmed in R was used for performing the cluster analysis.

In cluster analysis, the primary aim was to divide the whole group into sub-groups according to their similarities with each other by considering the basic characteristics of the individuals or objects.[17] Cluster analysis, which is an unsupervised machine learning algorithm, is used to define groups with common properties using the distances between units in multivariate data and by gathering similar or different units with each other. As a result, the clusters are internally homogeneous and heterogeneity exists among the clusters.[18]

Data clustering algorithms can be classified into two main categories, namely hierarchical and partitional.[19] Partitioning methods include square error, graph theoretic, mixture resolving, and mode seeking sub-dimensions.[20] K-means clustering, performed in the present study, is a type of square error method and is one of the most popular partitional clustering algorithms. It presents with easy applicability and efficiency in processing a substantial amount of data. However, hierarchical clustering results in a nested series of partition by merging or splitting clusters based on similarity criterion.[19]

The number of clusters is specified using the elbow method, which is a validation method used in cluster analysis. The purpose of the elbow method is to select the lowest k (number of clusters) with the lowest SSE (sum of squared errors). The elbow method is performed by subjecting the dataset to k-means clustering for a range of values for k and by calculating the SSE for each value of k. As a result of cluster analysis, the optimal number of clusters and the objects (countries) in each cluster (group of countries) are determined.

Within each cluster, a relative efficiency assessment is conducted by comparing the level of resources used (inputs) with health outcomes (outputs). Data envelopment analysis (programmed in R) has been used to perform the relative efficiency analyses. Data envelopment analysis (DEA), a nonparametric method used in operations research and economics, is conducted to determine production efficiency of decision-making units (DMUs). DEA was first published in 1978 by Charnes et al.[21] In this study, they developed the CCR model which provided the technical efficiency score under the assumption of constant returns to scale (CRS). Following this, based on the definition of the concept of scale efficiency, Banker et al.[22] developed a BCC model that provided the pure technical efficiency score under the assumption of variable returns to scale (VRS). The mathematical formula including the input orientation of the above-mentioned two models, known as the basic models of DEA, used in the present study is provided in Table 1.[23] The BCC model is used to obtain a distinction between technical and scale inefficiencies by estimating pure technical efficiency at the given scale of operation. Accordingly, scale efficiency scores of DMUs are obtained as a result of the ratio of CCR efficiency score to BCC efficiency score.[4]

Under the assumptions of constant and variable returns to scale of DEA, an efficiency score is calculated for each DMU. Accordingly, if the efficiency score is 1, it is interpreted that the inputs are above the borderline that cannot be decreased proportionally and, therefore, the DMU is efficient. If the efficiency score is less than 1, then DMU is out of the efficiency border, and the efficiency goal is created according to the orientation type determined for this DMU.

DEA is a relative efficiency measurement technique. The most important feature of DEA is that it can be used to accommodate multiple inputs and outputs.[15] Most DEA studies conducted for the healthcare sector help in the examination of the relative performances of different countries or different regions (or hospitals) within a single country.[15]

The input variables selected for the DEA include CHE per capita (current US$), HB (per 1,000 people), P (total number per 1,000

Table 1. Basic Models of Data Envelopment Analysis

Frontier type	Input-oriented (dual form)	Input-oriented (multiplier form)
CRS	$\min\theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$	$\max\sum_{r=1}^{s} u_r y_{ro} + u$
	subject to;	subject to;
	$\sum_{j=1}^{n}\lambda_j x_{ij} + s_i^- = \theta x_{io}$ i = 1,2,..., m;	$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0,$
	$\sum_{j=1}^{n}\lambda_j y_{rj} - s_r^+ = y_{ro}$ r = 1,2,..., s;	$\sum_{i=1}^{m} v_i x_{io} = 1$
	$\lambda_j \geq 0$ j = 1,2,..., n.	$u_r, v_i \geq \varepsilon > 0$
VRS	Add $\sum_{j=1}^{n}\lambda_j = 1$	"u = free"

Abbreviations: CRS, constant returns to scale; VRS, variable returns to scale

population), and NM (per 1,000 people), whereas the output variables include life expectancy at birth, maternal survival rate (MSR) (per 100,000 live births) (instead of MMR), and infant survival rate (ISR) (per 1,000 live births) (instead of IMR). It is necessary for DEA that an increase in an output variable should be an indication of an increase in efficiency. As opposed to IMR and MMR, ISR and MSR satisfy this requirement as their values increase with better health status.

ISR and MSR are obtained by using the following formulas[24]:

$$ISR = \frac{1{,}000 - IMR}{IMR}$$

$$MSR = \frac{100{,}000 - MMR}{MMR}$$

Input-oriented CCR (CRS-I) and input-oriented BCC (VRS-I) models have been used in the DEA. As a result, technical efficiency, pure technical efficiency, and scale efficiency scores for 177 countries have been calculated. Data for 2017 or for the nearest year have been obtained from the World Bank (WB).[25]

The study was conducted using the public data of World Bank. As people or animals were not included for the conduction of this study, ethical approval was not necessary.

Results

The objective of this study was to obtain data on homogenous sub-groups of countries and to evaluate the relative efficiencies of the countries within the same sub-group. Presently, WB considers the gross national product (GNP) per capita using the Atlas Method for country classification.[26] In this study, the variables used for the purpose of country classification are UP (%), CHE per capita (current US $), HB (per 1,000 people), P (total number per 1,000 population), and NM (per 1,000 people). Although four of these variables are used as indicators of healthcare resources, UP ratio has been used as a variable that determines the distribution and accessibility of these resources in a given country. One hundred and seventy seven countries whose data were accessible (out of 189 countries) have been included in the study.

Using the k-means clustering algorithm, we obtained three subgroups (clusters) which were internally homogeneous and were heterogeneous among each other. The first, second, and third sub-groups comprised of 74, 55, and 48 countries, respectively.

After examining the results of the cluster analysis, we found that the first sub-group included countries with low health resources, whereas the second and third sub-groups comprised countries with medium and high health resources, respectively. Table 2 shows the mean values of variables used in cluster analysis for WB classification (high income, upper middle income, lower and middle income, and low income), OECD, EU, World, and the resulting clusters obtained by using the k-means algorithm. The superiority of k-means clustering over WB classification is based on the fact that the clustering algorithm relies on the inclusion of five variables, four of which are health status indicators as opposed to the WB classification which considers GNP per capita for analysis.

Comparing the results of the cluster analysis with those based on WB classification, low-income countries were categorized into cluster 1, and upper middle-income and lower- and middle-income countries were categorized into cluster 2. High-income countries were categorized into cluster 3. However, as mentioned above, the cluster analysis is based on the inclusion of more variables that are directly related to health status, and this leads to the obtainment of different classification results for certain countries. For instance, although Pakistan, Indonesia, and Vietnam are lower- and middle-income countries, and Grenada and Jamaica are upper middle-income countries, they were categorized into cluster 1. However, Uzbekistan and Ukraine have been categorized into cluster 3 although they are lower- and middle-income countries. Hence, health status shows a positive correlation with the income level; however, the correlation is not accurate. The exceptions demonstrate the importance of adopting k-means clustering as a classification tool where classification according to health status rather than the income level is to be performed.

After the countries were clustered under homogeneous subgroups, an input-oriented DEA was performed for each subgroup. Inefficient countries have been identified using the input-oriented DEA, and target values that may be used to provide potential improvement in the input values of these countries have been determined first. To ensure that inefficient countries reach these target values, the reference group consisting of the efficient countries in the cluster and lambda values have been obtained. This indicates that inefficient countries can reach their current output levels with a reduced combination of inputs. DEA is important in determining the reference country groups that will guide the countries that are not efficient.

Table 2. Mean Values for Variables Used in Cluster Analysis

	UP	CHE	HB	P	NM
Cluster 1	37.37	238.41	1.33	0.30	1.23
Cluster 2	69.64	1090.95	2.77	1.71	3.24
Cluster 3	76.13	3274.32	5.23	3.46	9.16
High income	81.53	5279.91	4.15	3.01	8.68
Upper middle income	65.45	903.49	3.83	1.92	3.35
Lower & middle income	49.52	510.83	2.41	1.18	2.33
Low income	32.44	97.92	1.21	0.31	0.82
OECD members	80.39	4880.16	3.81	2.86	7.90
European Union	75.45	3752.99	5.60	3.56	8.77
World	54.83	1300.11	2.70	1.49	3.14

Abbreviations: CHE, Current health expenditure per capita (current US$); HB, Hospital beds (per 1.000 people); NM, Nurses and midwives (per 1.000 people); OECD, Organization for economic co-operation and development; P, Density of physicians (total number per 1.000 population); UP, Urban population (%).

Although Namibia, Eswatini, and Grenada are among the countries categorized with the highest health resources under cluster 1, they exhibit the lowest technical efficiency scores. This is because of both mismanagement of resources and scale inefficiency. As a result, out of 74 countries in cluster 1, 22 (29.73%) are scale efficient, 31 (41.89%) are pure technical efficient, and 20 (27.03%) are technical efficient (see Appendix 1). Among these countries, the most common reference DMUs for inefficient units are Ethiopia (for 31 countries), Tajikistan (for 17 countries), Madagascar (for 14 countries), Vanuatu (for 13 countries), and Senegal (for 9 countries). Of these reference units, particularly, the input values for Ethiopia, Madagascar, and Vanuatu are markedly below average. This can also be explained by considering factors other than health status indicators that may exert an impact on efficiency scores. For instance, Vanuatu and Senegal showed considerably better performance than their peers in the same cluster in terms of undernourishment, safely managed drinking water services, air pollution, and immunization. These factors might have contributed to the discrepancy observed between the efficiency scores of countries in cluster 1.

Of the countries categorized in cluster 2, Saudi Arabia, Trinidad and Tobago, Brunei Darussalam, Bahamas, Oman, and Serbia present with below average technical efficiency scores despite reporting the highest health expenditures. Of the 55 countries in this cluster, 17 (30.91%) are scale efficient, 20 (36.36%) are pure technical efficient, and 16 (29.09%) are technical efficient (see Appendix 2). Among these countries, the most common reference DMUs for inefficient units are Cabo Verde (for 26 countries), Costa Rica (for 23 countries), Bolivia (for 17 countries), Venezuela (for 15 countries), and Montenegro (for 14 countries). In cluster 2, Turkey's pure technical efficiency score is 0.828, which indicates managerial efficiency. After determining the efficiency targets, it has been demonstrated that the same output level can be achieved with lower input values.

Although Uzbekistan, Ukraine, Belarus, Romania, Argentina, and Latvia present with the lowest health expenditures in cluster 3, they are among the technical efficient countries. However, countries reporting the highest health expenditure per capita, namely the USA, Switzerland, Luxembourg, Norway, Germany, Ireland, and Netherlands are not technical efficient. This is mainly owing to managerial inefficiencies rather than scale inefficiency as demonstrated by the fact that scale efficiency scores are close to 1. Of the 48 countries in cluster 3, 21 (43.75%) are scale efficient, 23 (47.92%) are pure technical

Table 3. Efficiency Scores and Efficient DMUs within Clusters

	Technical Efficiency (CRS)	Number of Efficient DMUs	Pure Technical Efficiency (VRS)	Number of Efficient DMUs	Scale Efficiency (CRS/VRS)	Number of Efficient DMUs
Cluster 1	0.676	20	0.750	31	0.906	22
Cluster 2	0.761	16	0.820	20	0.926	17
Cluster 3	0.889	21	0.907	23	0.979	21

Abbreviations: CRS, Constant returns to scale; DMUs, Decision making units; VRS, Variable returns to scale.

efficient, and 21 (43.75%) are technical efficient (see Appendix 3). Among these countries, the most common reference DMUs for inefficient units are Poland (for 16 countries), Singapore (for 16 countries), and Kuwait (for 7 countries).

Table 3 summarizes the efficiency scores and efficient DMUs within each cluster. The results indicate that allocation of more health resources translates into higher efficiency scores or, in other words, indicates better health status. Countries in cluster 3 are generally more efficient than countries in cluster 2, and countries in cluster 2 are generally more efficient than countries in cluster 1 in terms of scale efficiency, pure technical efficiency, and technical efficiency.

Discussion

DEA is a well-known technique that is extensively used by policy makers in the healthcare sector. However, if the group of countries under consideration is not homogeneous in terms of inputs, the results of DEA analyses may be misleading. For instance, countries such as Mexico and Turkey are generally reported as technical efficient in studies for OECD countries where homogeneity of inputs is disregarded.[15, 27] However, our results indicate that these countries are not technical efficient when they are appropriately evaluated in a homogeneous subgroup (cluster 2).

The countries that have the highest health expenditure per capita, namely the USA, Switzerland, Luxembourg, Norway, and Germany are not technical efficient. This is mainly owing to managerial inefficiency.

As the sub-groups are homogeneous in terms of health resources, the countries in each sub-group are similar in terms of their development level. Hence, the output levels within the same cluster are also similar. Developed countries present with higher efficiency scores as they possess better management systems for their health resources. Other factors that also contribute to higher efficiency scores include better urban infrastructure, supply of clean drinking water, waste disposal, nutrition, economic status, life style, and education. Therefore, allocation of resources for such factors rather than for health services alone is another approach for attaining higher output levels. Numerous studies have shown that the impact of environmental and socioeconomic factors on health outputs is significant.[24, 28-30]

It is known that it is included in technological and organizational resources except for the variables determined as health resources in this study. In this context, it can be stated as the limitation of the study, as the study was carried out on the accessible data of the determined countries. In addition, it is known that many different indicators are used in the measurement of health status. Due to the limited data of the countries identified in the study, the health status was expressed with the variables determined. In this study, health resources were considered as an input variable in evaluating the relative efficiencies of health status. Apart from health resources, other factors (environmental factors, socio-economic factors, etc.) that have an impact on health status are outside the scope of this study.

Conclusion

The primary objective of health systems is to attain efficiency. In pursuing this objective, measurement and monitoring of relative efficiencies with respect to other countries and gaining insights from their experiences are crucial for the development of health system of a country.

Particularly, in cases with multiple inputs and outputs, the homogeneity assumption may be violated for DEA. Performance of cluster analysis before DEA facilitates the conduction of studies with more homogeneous groups.

Using cluster analysis, countries were clustered into three sub-groups that showed internal homogeneity. DEA was then performed within each sub-group to obtain relative efficiency scores for similar countries. As a result, in the first, second, and third sub-groups, 31 (41.89%), 20 (36.36%), and 23 (47.92%) countries were pure technical efficient, respectively. This study differed from previous studies in a few important aspects. First, it used a considerably large data set with four inputs and three outputs for 177 countries. Second, the countries were clustered into three homogeneous sub-groups with respect to five variables, four of which were health status indicators. As stated above, this resulted in the obtainment of similar but different grouping results compared to the WB classification. Environmental and socioeconomic factors that may exert an impact on efficiency scores other than health resources can also be considered for the conduction of future studies. Such factors include safely managed drinking water services, air pollution, waste disposal, undernourishment, immunization, and economic status.

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Appendix 1. Efficiency Scores of Cluster-1

Country Name	Rank (CRS)	CRS Efficiency Scores	VRS Efficiency Scores	Scale Efficiency Scores
Afghanistan	49	0.514	0.515	0.999
Angola	70	0.327	0.347	0.940
Bangladesh	1	1.000	1.000	1.000
Belize	1	1.000	1.000	1.000
Benin	35	0.685	0.718	0.954
Bhutan	65	0.377	0.521	0.723
Burkina Faso	37	0.671	0.712	0.942
Burundi	1	1.000	1.000	1.000
Cambodia	41	0.592	0.791	0.749
Cameroon	69	0.354	0.360	0.981
Central African Republic	1	1.000	1.000	1.000
Chad	43	0.589	0.706	0.835
Comoros	58	0.447	0.485	0.922
Congo, Dem. Rep.	1	1.000	1.000	1.000
Congo, Rep.	67	0.366	0.435	0.842
Cote d'Ivoire	57	0.460	0.525	0.876
Egypt, Arab Rep.	22	0.937	0.938	0.999
Eritrea	1	1.000	1.000	1.000
Eswatini	73	0.153	0.167	0.916
Ethiopia	1	1.000	1.000	1.000
Gambia, The	54	0.471	0.486	0.969
Ghana	68	0.364	0.393	0.925
Grenada	38	0.630	0.632	0.997
Guatemala	26	0.817	1.000	0.817
Guinea	1	1.000	1.000	1.000
Guinea-Bissau	46	0.539	0.588	0.918
Guyana	48	0.519	0.766	0.677
Haiti	1	1.000	1.000	1.000
Honduras	30	0.722	1.000	0.722
India	56	0.465	0.546	0.851
Indonesia	52	0.480	0.618	0.776
Jamaica	53	0.476	1.000	0.476
Kenya	62	0.396	0.457	0.867
Kiribati	31	0.722	0.727	0.994
Lao PDR	55	0.470	0.474	0.992
Lesotho	66	0.375	0.420	0.895
Liberia	24	0.844	0.856	0.986
Madagascar	1	1.000	1.000	1.000
Malawi	1	1.000	1.000	1.000
Mali	1	1.000	1.000	1.000
Mauritania	40	0.601	0.601	1.000
Micronesia, Fed. Sts.	60	0.442	0.479	0.922
Morocco	47	0.524	1.000	0.524
Mozambique	29	0.780	0.806	0.969
Myanmar	63	0.390	0.393	0.993
Namibia	74	0.133	0.147	0.903
Nepal	25	0.829	1.000	0.829
Nicaragua	50	0.507	1.000	0.507
Niger	1	1.000	1.000	1.000
Nigeria	71	0.310	0.378	0.821
Pakistan	33	0.720	0.722	0.998
Papua New Guinea	27	0.816	0.818	0.997
Philippines	1	1.000	1.000	1.000

Appendix 1. Efficiency Scores of Cluster-1 (Continued)

Country Name	Rank (CRS)	CRS Efficiency Scores	VRS Efficiency Scores	Scale Efficiency Scores
Rwanda	39	0.602	0.958	0.629
Samoa	23	0.898	1.000	0.898
Senegal	1	1.000	1.000	1.000
Sierra Leone	36	0.683	0.792	0.862
Solomon Islands	28	0.816	1.000	0.816
Sri Lanka	1	1.000	1.000	1.000
St. Lucia	1	1.000	1.000	1.000
St. Vincent and the Grenadines	45	0.559	0.576	0.972
Sudan	72	0.310	0.310	1.000
Tajikistan	1	1.000	1.000	1.000
Tanzania	21	0.999	1.000	0.999
Thailand	1	1.000	1.000	1.000
Timor-Leste	44	0.577	1.000	0.577
Togo	32	0.722	0.739	0.977
Tonga	51	0.505	0.705	0.716
Uganda	42	0.592	0.599	0.988
Vanuatu	1	1.000	1.000	1.000
Vietnam	34	0.696	1.000	0.696
Yemen, Rep.	59	0.444	0.445	0.998
Zambia	61	0.412	0.415	0.994
Zimbabwe	64	0.379	0.419	0.904

Abbreviations: CRS, constant returns to scale; VRS, variable returns to scale

Appendix 2. Efficiency Scores of Cluster-2

Country Name	Rank (CRS)	CRS Efficiency Scores	VRS Efficiency Scores	Scale Efficiency Scores
Albania	31	0.747	1.000	0.747
Algeria	39	0.611	0.801	0.763
Armenia	50	0.466	0.574	0.812
Bahamas, The	41	0.604	0.610	0.991
Bahrain	1	1.000	1.000	1.000
Barbados	53	0.390	0.578	0.675
Bolivia	1	1.000	1.000	1.000
Bosnia and Herzegovina	24	0.806	0.880	0.915
Botswana	23	0.820	1.000	0.820
Brazil	44	0.547	0.585	0.934
Brunei Darussalam	46	0.537	0.584	0.919
Cabo Verde	1	1.000	1.000	1.000
Chile	1	1.000	1.000	1.000
China	33	0.740	0.958	0.772
Colombia	26	0.797	0.797	0.999
Costa Rica	1	1.000	1.000	1.000
Cyprus	1	1.000	1.000	1.000
Djibouti	1	1.000	1.000	1.000
Dominican Republic	35	0.695	0.755	0.921
Ecuador	27	0.777	0.826	0.942
El Salvador	1	1.000	1.000	1.000
Equatorial Guinea	1	1.000	1.000	1.000
Fiji	18	0.909	1.000	0.909
Gabon	36	0.690	0.891	0.775
Georgia	40	0.606	0.656	0.923
Iran, Islamic Rep.	28	0.777	0.805	0.964
Iraq	17	0.937	0.964	0.971
Jordan	22	0.847	0.953	0.888
Kyrgyz Republic	43	0.602	0.709	0.849
Lebanon	25	0.800	1.000	0.800
Libya	1	1.000	1.000	1.000
Macedonia, FYR	1	1.000	1.000	1.000
Malaysia	20	0.864	0.873	0.989
Mauritius	51	0.463	0.515	0.900
Mexico	29	0.773	0.868	0.890
Moldova	38	0.645	0.650	0.993
Mongolia	49	0.487	0.491	0.992
Montenegro	1	1.000	1.000	1.000
Oman	32	0.747	0.755	0.990
Panama	47	0.520	0.665	0.781
Paraguay	21	0.848	0.874	0.970
Peru	19	0.898	0.983	0.913
Qatar	1	1.000	1.000	1.000
Sao Tome and Principe	37	0.690	0.828	0.832
Saudi Arabia	48	0.517	0.529	0.979
Serbia	42	0.603	0.603	1.000
South Africa	52	0.444	0.463	0.959
Suriname	45	0.538	0.733	0.734
Syrian Arab Republic	1	1.000	1.000	1.000
Trinidad and Tobago	54	0.364	0.365	0.998
Tunisia	34	0.697	0.845	0.825
Turkey	30	0.771	0.828	0.930
Turkmenistan	55	0.263	0.277	0.949
United Arab Emirates	1	1.000	1.000	1.000
Venezuela, RB	1	1.000	1.000	1.000

Abbreviations: CRS, constant returns to scale; VRS, variable returns to scale

Appendix 3. Efficiency Scores of Cluster-3

Country Name	Rank (CRS)	CRS Efficiency Scores	VRS Efficiency Scores	Scale Efficiency Scores
Argentina	1	1.000	1.000	1.000
Australia	41	0.724	0.785	0.922
Austria	45	0.664	0.676	0.981
Azerbaijan	24	0.940	0.982	0.957
Belarus	1	1.000	1.000	1.000
Belgium	39	0.749	0.757	0.990
Bulgaria	28	0.896	0.911	0.983
Canada	25	0.939	0.971	0.967
Croatia	22	0.961	1.000	0.961
Czech Republic	32	0.848	0.852	0.995
Denmark	29	0.893	0.937	0.953
Estonia	1	1.000	1.000	1.000
Finland	1	1.000	1.000	1.000
France	43	0.709	0.729	0.973
Germany	48	0.543	0.544	0.998
Greece	1	1.000	1.000	1.000
Hungary	33	0.845	0.856	0.987
Iceland	1	1.000	1.000	1.000
Ireland	36	0.824	0.838	0.983
Israel	1	1.000	1.000	1.000
Italy	1	1.000	1.000	1.000
Japan	1	1.000	1.000	1.000
Kazakhstan	26	0.910	0.924	0.985
Korea, Rep.	1	1.000	1.000	1.000
Kuwait	1	1.000	1.000	1.000
Latvia	1	1.000	1.000	1.000
Lithuania	38	0.758	0.767	0.988
Luxembourg	37	0.801	0.802	0.999
Maldives	27	0.909	1.000	0.909
Malta	40	0.738	0.806	0.916
Netherlands	46	0.656	0.657	0.998
New Zealand	30	0.877	0.906	0.967
Norway	44	0.676	0.691	0.979
Poland	1	1.000	1.000	1.000
Portugal	23	0.941	0.956	0.984
Romania	1	1.000	1.000	1.000
Russian Federation	42	0.719	0.746	0.964
Singapore	1	1.000	1.000	1.000
Slovak Republic	31	0.863	0.879	0.982
Slovenia	1	1.000	1.000	1.000
Spain	1	1.000	1.000	1.000
Sweden	1	1.000	1.000	1.000
Switzerland	47	0.600	0.829	0.724
Ukraine	1	1.000	1.000	1.000
United Kingdom	35	0.839	0.840	0.998
United States	34	0.842	0.886	0.950
Uruguay	1	1.000	1.000	1.000
Uzbekistan	1	1.000	1.000	1.000

Abbreviations: CRS, constant returns to scale; VRS, variable returns to scale