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EFFICIENCY OF ICT DEVELOPMENT INDICATORS IN OECD COUNTRIES

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ABSTRACT

Purpose- Information and communication technologies have a strong influence on sustainable economic growth and global competition. The countries that adapt to the speed of these technologies and have skills, infrastructure and accessibility to use these technologies will benefit from the strong influence of ICT. Various analyses, measurements, and comparisons are made to measure this effect.
Methodology- Information and Communication Technologies (ICT) Development Index prepared annually by the International Telecommunication Union (ITU) is a composite index calculated from eleven indicators to monitor developments in the field of ICT and make the comparison between countries.
Findings- In this study, the efficiency of the indicators in the ICT Development Index (IDI) in OECD countries was examined by data envelopment analysis.
Conclusion- By evaluating the relative effectiveness of the countries, the efficiency scores and reference values were determined for 2015.

Keywords: Data envelopment analysis, ICT development index (IDI), innovation, OECD countries, technology.
JEL Codes: O31, O33, 034

1. INTRODUCTION

Countries investing in human capital, producing information and converting the information they produce into technology provide significant advantages in becoming a global leader and achieving sustainable competition. Therefore, innovations towards information and technology, which have become an important power and competitive element, constitute driving force of economic growth and development. The efficient use of these technologies gives the countries advantages such as productivity increase, qualified employment and sustainable economic growth. It is necessary for countries to achieve positive growth performance in order to gain competitive power in the international arena and take a high part in the world rankings and to make this performance sustainable.

The countries that adapt to the speed of these technologies and have skills, infrastructure and accessibility to use these technologies will benefit from the strong influence of Information and Communication Technologies (ICT). Various analyses, measurements, comparisons, and indices created are being made to measure this effect.

ICT Diffusion Index reported by United Nations Conference on Trade and Development (UNCTAD), the Network Readiness Index developed by the World Economic Forum (WEF), and ICT Development Index (IDI) developed by the International Telecommunication Union (ITU) are included in the indices that measure the different aspect of the ICT.

Information and Communication Technologies (ICT) Development Index (IDI) provides a holistic picture of ICT development in countries. IDI is a composite index calculated from 11 indicators to monitor developments in the field of ICT and compares the level of ICT advancement in countries across the world. The index is grouped by the three sub-indices as ICT access, ICT use, and ICT skills. While ICT use index and skills index consist of three indicators, ICT access index includes five indicators.

The main purpose of the IDI is to measure the level and evolution over time of ICT developments within countries and their experience relative to other countries as well as evaluate advance in ICT development in developed and developing countries. It also indicates the potential of the ICT development and which countries can use them to increase growth and development in the context of existing abilities and skills. (Measuring the Information Society Report, 2016) The index is generated by using the Principal Component Analysis and each sub-indices in the IDI is weighted based on the Principal Component Analysis (PCA) results. (Measuring the Information Society Report, 2016)

In the study, the effectiveness of the ICT Development Index (IDI) indicators in OECD countries was examined by CCR output-oriented data envelopment analysis. With the help of the CCR output model, the total relative effectiveness of the countries was calculated to determine the relative effective and ineffective countries, and the relative effective countries that formed the country's efficiency scores and reference values for the year of 2015 were identified.

2. LITERATURE REVIEW

Factors such as innovation development capacity, knowledge production, technology development have become essential conditions for countries' growth activities, economic development and sustainable competition in the global arena. Thus, it has become important to create a suitable ICT infrastructure for the production, dissemination, and use and increase the efficiency of ICT that has become a strategic force for the countries.

Many methods have been used to measure countries' ICT developments, efficiency, and productivity. Data envelopment analysis is one of the analyses used to measure the relative effectiveness of ICT.

Bollou (2006) investigated the impact of ICT investments in the ICT sectors in six West African countries by using the DEA and some new analysis during the period of 1995 and 2002. Bollou examined the efficiency of ICT investments in ICT technical efficiency with regard to the expansion of ICT infrastructure and also investigated the efficiency of investments on GDP growth, and revenue growth. Furthermore, he indicated that how the countries could manage their ICT investments more efficient. As a result, his study shows that while some countries efficiently utilize their investments in ICT to achieve the significant return in infrastructure expansion, some do not.

Emrouznejad et al. (2010) developed an alternative approach to measure information and communication technology (ICT) of 183 economies by using Data Envelopment Analysis (DEA). The data used in the study were obtained from the International Telecommunications Union (ITU). They created a DEA Opportunity Index (DEA-OI) and compared it with the ICT Opportunity Index (ICT-OI) developed by the ITU. A high correlation was found between the two indices as a result of the comparison. Furthermore, 183 economies were grouped into four categories as low, medium, upper, and high for comparison with ICT-OI. As a result, both indices showed comparable and consistent measurement results.

Bankole et al. (2011) analyzed the efficiency of ICT utilization of four regions (SADC, ECOWAS, North Africa and East Africa) including 28 countries in Africa by using the Data Envelopment Analysis (DEA). The purpose of their study was to determine which regions are effective in the ICT utilization and the factors that affect the ICT utilization. As a result, their study shows that the ICT utilization in Africa was changed across the regions and the ICT utilization was determined by the level of infrastructure accessibility and the cost of ICT services. DEA result also indicates that the best managed of the group is North Africa region. This is followed by the ECOWAS, SADC, and East Africa regions.

Fatulescu (2013) compared two statistical methods, Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA), to measure the impact of ICT utilization. Two hypotheses put forward in his study. The hypotheses of the study are that there is a real linkage between the scores obtained by DEA and SFA methods. It is assumed that the level of ICT use is higher for more developed countries and is driven by several key factors selected as input variables in this study. The results demonstrate that both hypotheses are valid because of the obtained efficacy scores are statistically correlated with different methods and the input variables are significant in the SFA model.

3. DATA AND METHODOLOGY

Data Envelopment Analysis (DEA) was first used in 1978 by Charnes, Cooper and Rhodes to measure the activities of state schools in the USA. Later on, the development of computer package programs has facilitated the solution of the models and has become widely used in the evaluation of the activities of hospitals, banks, the manufacturing sector, and comparison of resource utilization activities of countries and regions. (Ozden, 2008)

DEA is generally admitted as one of the best methods use for evaluating the efficiency of a set of decision-making units (DMU)s. The DEA model that input or output oriented is a nonparametric linear programming, based on empirically observed data. Thus, it allows multiple inputs and outputs to be examined together. Output-oriented DEA model is channeled towards maximizing the outputs acquired by the DMUs while keeping the inputs constant, the input-oriented models focus on minimizing the inputs used for processing the given amount of outputs. (Charnes, A. et al., 1978)

DEA is a method that enables to obtain a single activity value by analyzing multiple inputs and outputs together. DEA creates an empirical efficient boundary by using observed data. By using a large amount of output with a large number of inputs a boundary value accounts for the best unit. The relative effectiveness of each DMU is measured based on the distance to the boundary value of the best unit such as a country. The DEA calculates an efficiency score for each DMU in the range [0, 1]. In summary, the DMU farthest from the limit value is the unit with the lowest efficiency score. However, the DEA efficacy threshold can be used as a guide for ineffective units to improve their input and output in order to achieve the best unit efficiency value. (Cooper et. al. 2011).

The efficiency score is formulated as follows if the DEA which is a multi-factor productivity measurement model for measuring the relative effectiveness of similar decision-making units, is more than one input and output. (Cooper, W.,etal., 2000)

$$\text{Efficiency} = \frac{u_1y_1 + u_2y_2 + \ldots + u_ny_n}{v_1x_1 + v_2x_2 + \ldots + v_mx_m}$$

U_n = n. weight of output
Y_n = n. amount of output
V_m = m. weight of input
X_m = m. amount of input

There are two commonly used DAE models in the literature. These models are the CCR model based on the fixed return-to-scale assumption developed by Charnes, Cooper and Rhodes (1978); BCC model based on the variable return-to-scale assumption developed by Banker, Charnes and Cooper(1984). (Charnes et al, 1994)

The CCR model measures the total effectiveness composed of the combination of technical efficiency and scale effectiveness. In determining the relative activities of DMUs using the CCR model, it is necessary to have both technical efficiency and scale efficiency so that the analyzed DMUs can be effectively accepted. The CCR model is addressed as "Input-Oriented CCR" and "Output-Oriented CCR". (Cooper et. al. 2011).

The output-oriented CCR model aims to maximize the output value without requiring more of the input values possessed. The DP model and the Envelope Model with regard to the output-oriented CCR model are given below. (Cooper et. al. 2011).

DP MODEL

$$E_0 = \min \sum_{i=1}^{m} v_i x_{io}$$

LIMITATION

$$\sum_{r=1}^{s} u_r y_{ro} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} \leq \sum_{i=1}^{m} v_i x_{ij}$$

$$j = 1,2,\ldots\ldots n$$

$$v_i \cdot u_r \geq \varepsilon \qquad r = 1,2,\ldots\ldots s$$

$$i = 1,2,\ldots\ldots m$$

ENVELOP MODEL

$$maks\varphi + \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$$

LIMITATION

$$\sum_{j=1}^{n} x_{ij}\beta_j - x_{io} + s_i^- = 0$$

$$i = 1,2,\ldots\ldots m$$

$$\sum_{j=1}^{n} y_{rj}\beta_j - \varphi y_{ro} - s_r^+ = 0$$

$$r = 1,2,\ldots\ldots s$$

$$\beta_j, s_i^-, s_r^+ \geq 0 \qquad r = 1,2,\ldots\ldots s$$

$$i = 1,2,\ldots\ldots m \qquad j = 1,2,\ldots\ldots n$$

ø; The expansion coefficient, βj, determines how much the radial output of the DMU can be increased; For output-oriented models j. It shows the density value of DMU. The expansion coefficient, βj, determines how much the radial output of the DMU can be increased; For output-oriented models j. It shows the density value of DMU. (o. the value of the reference set of the DMU)

4. FINDINGS AND DISCUSSIONS

The data used in the study consist of data of 35 OECD countries belonging to the year of 2015. The data are derived from International Telecommunication Union (ITU) and the World Bank.

In the study, the effectiveness of the ICT Development Index (IDI) indicators in OECD countries was examined by CCR output-oriented data envelopment analysis. With the help of the CCR output model, the total relative effectiveness of the countries was calculated to determine the relative effective and ineffective countries, and the relative effective countries that formed the country's efficiency scores and reference values for the year 2015 were identified.

Data Envelopment Analysis (DEA), which is designed with CCR output model in the study, consists of nine inputs and three output variables, and the variables used as input and output are listed in Table 1 below.

Tablo 1: List of Variables Used in DEA Analysis

Input Variables	Output Variables
Mobile-Cellular Telephone Subscriptions Per 100 Inhabitants (x1)	GDP Per Capita Growth (annual %)
International Internet Bandwidth per Internet User (x2)	High Technology Export (% of manufactured export)
Percentage of Households with a Computer (x3)	Patents granted to residents 2015 (number)
Percentage of Individuals Using the Internet (x4)	
Fixed-Broadband Internet Subscriptions per 100 Inhabitants (x5)	
Active Mobile-Broadband Subscriptions per 100 Inhabitants (x6)	
Mean Years of Schooling (x7)	
Secondary Gross Enrolment Ratio (x8)	
Territary Gross Enrolment Ratio (x9)	

The results obtained from CCR output oriented Data Envelopment Analysis generated from the data for the year of 2015 are given in Table 2.

Table 2: Output Oriented CCR Model

CCR MODEL				
Output Oriented				
No	DMU	Efficiency Score	Rank	Reference set
1	Australia	0,536297503	26	15/19/22
2	Austria	0,609682051	21	10/15/19/22
3	Belgium	0,550814288	24	10/13/15
4	Canada	0,683587553	18	10
5	Chile	0,347218094	32	15/16/22
6	Czech Republic	0,676869457	19	10/15/16/22
7	Denmark	0,541360496	25	10/15/
8	Estonia	0,594799243	22	15/19/22/28
9	Finland	0,370073074	30	10/15/
10	France	1	1	
11	Germany	1	1	
12	Greece	0,671394901	20	10/13/
13	Hungary	1	1	
14	Iceland	0,804479887	13	10/15/
15	Ireland	1	1	
16	Israel	1	1	
17	Italy	0,407298684	28	10/15/22/35
18	Japan	1	1	
19	Korea	1	1	
20	Latvia	0,709224241	17	10/15/16/22
21	Luxembourg	0,783618094	15	15/22/32
22	Mexico	1	1	
23	Netherlands	0,794210516	14	10/13/15
24	New Zealand	0,361748857	31	15/19/22
25	Norway	0,742514604	16	10/15/19/32
26	Poland	0,558226496	23	10/15/16/22
27	Portugal	0,273136969	34	10/13/15
28	Slowak Republic	1	1	
29	Slovenia	0,372677187	29	10/13/15
30	Spain	0,32274801	33	10/15/19
31	Sweden	0,527092384	27	
32	Switzerland	1	1	
33	Turkey	0,269123575	35	15/18/28
34	United Kingdom	0,83046303	12	10/15/22

35	United States	1	1	

In the analysis of the CCR model which is calculated of the countries efficiency values and reference groups, concluded that 11 countries from the 35 OECD countries were relatively effective and 24 countries were not. As shown in Table 2, while the country which has the lowest efficiency score among the ineffective countries is Turkey with a 0,269 value, the country which has the highest efficiency score is the United Kingdom with a 0.830 value.

While France, Ireland, and Mexico comprise the reference group of United Kingdom which ranked 12th in relative total effectiveness ranking; The reference group of Turkey which is the last in the ranking of relative effectiveness is Ireland, Japan, and the Slovak Republic.

Ireland has been shown as a reference for 21 times when the reference clusters of ineffective countries were examined. Following the Ireland, France 17, Mexico 11, Korea 6, Hungary 5, Israel 4, Slovakia 2, Switzerland 2, United States 1, Japan 1 time has been shown as a reference by ineffective decision-making units.

As the explanations for the potential improvement rates of the 35 OECD countries covered in the CCR-O analysis will be quite lengthy, the potential improvement values of the variables that cause only Turkey's and the United Kingdom output-oriented (CCR-O) total relative ineffectiveness are explained in this study. When we examine the potential improvement rates in the input values for Turkey in this context, Turkey needs to achieve a potential improvement in the following variables to become a relative effective country like the Ireland, Japan, and Slovakia that are in the reference set of Turkey: mobile-cellular telephone subscription per 100 inhabitants 49.85% , percentage of households with a computer 33.58%, percentage of individuals using the internet 32.48% active mobile-broadband subscriptions per 100 inhabitants 14,36%, mean years of schooling 31,99%, secondary gross enrollment ratio 53,22%, territory gross enrollment ratio 60,39%.

When we investigate the potential improvement rates in the input values for the United Kingdom, the United Kingdom needs to achieve a potential improvement in the following variables to become a relative effective country like the France, Ireland, and Mexico that are included in the reference set of the United Kingdom: mobile-cellular telephone subscription per 100 inhabitants 15,75%, international internet bandwidth per internet user 71,34%, percentage of households with a computer 15,20%, percentage of individuals using the internet 10,67%, fixed-broadband internet subscriptions per 100 inhabitants 9,41%, active mobile-broadband subscriptions per 100 inhabitants 16,71%, secondary gross enrolment ratio 10,21%.

The other countries potential improvement values are shown in Table 3.

Tablo 3: Potential Improvement Values

	x1	x2	x3	x4	x5	x6	x7	x8	x9
Australia	-13,01%	0,00%	-5,44%	0,00%	0,00%	-17,30%	-6,55%	-14,59%	-17,90%
Austria	-40,76%	0,00%	-18,85%	-14,32%	0,00%	0,00%	-6,90%	0,00%	-33,87%
Belgium	-14,19%	-52,96%	-7,08%	-7,82%	0,00%	0,00%	-4,96%	-35,62%	-19,24%
Canada	-6,80%	-27,70%	-27,82%	-27,85%	-14,22%	0,00%	-33,91%	-19,17%	-29,72%
Chile	-26,02%	-68,11%	-14,80%	-0,43%	0,00%	0,00%	-2,62%	-4,39%	-54,46%
Czech Republic	-19,47%	-19,43%	-11,60%	-9,76%	0,00%	0,00%	-13,65%	0,00%	-17,44%
Denmark	-11,95%	-54,78%	-2,50%	-4,40%	0,00%	-25,98%	0,00%	-3,52%	-13,02%
Estonia	-15,03%	0,00%	-10,11%	-3,02%	-10,85%	-26,66%	0,00%	0,00%	-12,46%
Finland	-33,10%	-40,98%	-18,97%	-21,30%	0,00%	-49,58%	0,00%	-28,16%	-35,87%
France	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Germany	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Greece	-42,08%	-21,93%	-25,48%	-20,85%	-17,59%	0,00%	-31,44%	-35,46%	-64,66%
Hungary	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Iceland	-16,93%	-83,09%	-23,50%	-21,03%	-1,09%	-23,79%	0,00%	-7,13%	-28,12%
Ireland	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Israel	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Italy	-35,39%	0,00%	-10,99%	-1,87%	0,00%	-11,81%	0,00%	-13,60%	-12,39%
Japan	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%

Korea	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Latvia	-11,52%	-25,49%	-4,77%	-4,14%	0,00%	0,00%	0,00%	-2,12%	-17,23%
Luxembourg	-70,59%	-99,40%	-71,38%	-69,10%	-73,87%	-63,22%	-61,31%	-57,62%	0,00%
Mexico	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Netherlands	-10,87%	-50,70%	-13,42%	-8,36%	-4,98%	0,00%	0,00%	-12,07%	-17,68%
New Zealand	-8,60%	0,00%	-2,22%	-4,36%	0,00%	-13,04%	-2,51%	0,00%	-0,50%
Norway	0,00%	-47,89%	-13,92%	-9,19%	0,00%	-1,18%	-5,67%	0,00%	0,00%
Poland	-40,65%	-9,02%	-25,91%	-19,19%	0,00%	0,00%	-26,52%	-27,95%	-33,44%
Portugal	-25,17%	-63,64%	-14,79%	-12,59%	-17,73%	0,00%	0,00%	-27,18%	-26,91%
Slowak Republic	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Slovenia	-11,34%	-47,11%	-10,21%	-5,74%	0,00%	0,00%	-13,83%	-9,58%	-35,83%
Spain	-19,12%	0,00%	-11,14%	-12,43%	0,00%	-8,97%	0,00%	-27,00%	-30,55%
Sweden	-14,15%	-70,91%	-6,41%	-3,37%	0,00%	-32,95%	-0,45%	-5,09%	0,00%
Switzerland	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Turkey	-49,85%	0,00%	-33,58%	-32,48%	0,00%	-14,36%	-31,99%	-53,22%	-60,39%
United Kingdom	-15,75%	-71,34%	-15,20%	-10,67%	-9,41%	-16,71%	0,00%	-10,21%	0,00%
United States	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%

5. CONCLUSION

In this study, the effectiveness of the indicators in the ICT Development Index (IDI) of 35 OECD countries using the data of 2015 was examined by the CCR output-oriented DEA model. In the study, the total relative efficiencies of countries were calculated using nine inputs and three output variables, and effective and ineffective countries were identified. As a result of the calculations made with the CCR model, 11 countries were found to be relatively effective and 24 countries were found to be relatively ineffective. Relative effective countries consisting of 11 countries are France, Germany, Hungary, Ireland, Israel, Japan, Korea, Mexico, Slowak Republic, Switzerland, and United States.

This study predicts that which variables should be improved, which inputs should be reduced and which countries should be taken as a reference by 24 ineffective countries in order to be able to become a relatively effective country.

In this context, Turkey needs to achieve a potential improvement in the following variables to become a relative effective country: Mobile-Cellular Telephone Subscription per 100 inhabitants 49,85%; in Percentage of Households with a computer 33,58%; in Percentage of individuals using the internet 32,48%; in Active mobile-broadband subscriptions per 100 inhabitants 14,36%; in Mean years of schooling 31,99%; in Secondary gross enrollment ratio 53,22%; in Territory gross enrollment ratio 60,39%. Furthermore, according to analyses results of Turkey it is not necessary to make potential improvements in International Internet Bandwidth per Internet User and Fixed-Broadband Internet Subscriptions per 100 Inhabitants variables.

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