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An Examination of Educational Inputs with the Data Envelopment Analysis: The Example of ICILS 2013*

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Abstract

The aim of this study was to determine how efficiently different countries, comparatively, use educational inputs, which are considered to affect information and communication technology literacy. The study was designed using the survey model. The study was conducted with data belonging to 21 countries participating in the International Computer and Information Literacy Study (ICIL) 2013. The data of this study were grouped as educational inputs and educational outputs. The educational inputs were the ratio of school size and teachers, the ratio of school size and number of computers, the ratio of school size and number of computers available for students, the ratio of school size and number of computers with access to internet/World Wide Web, and the ratio of school size and number of smartboards. The educational outputs were determined by the average student grades obtained in ICILS 2013. The data were analysed with data envelopment analysis. The research results revealed that relatively, Australia, Canada (Newfoundland and Labrador, Ontario), Denmark, Korea, and Norway were the countries with total efficiencies. It was determined that with the exception of the Czech Republic, all the countries without total efficiencies had the characteristic of increasing returns to scale. According to the projections that were put forward for countries to become totally efficient, the most reduction recommendations were received for the inputs for ratio of school size and teachers by Argentina (Buenos Aires); for ratio of school size and number of computers, ratio of school size and number of computers available for students, and ratio of school size and number of computers with access to internet/World Wide Web by Turkey; and for ratio of school size and smartboards by Thailand. That is to say, these countries were the ones least able to use these inputs efficiently.

Keywords: Educational inputs, educational outputs, data envelopment analysis, computer and information literacy

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Introduction

Education can be considered as a system that individuals can access throughout their lives to be able to make changes to human behaviour in the desired direction. Tyler (1950, p. 4) defined education as “the process of changing people’s behaviour”. Ertürk (1972), however, approached education as “the process by which individuals change their behaviour in the desired direction through their own experiences and in a purposeful way.” In this context, education can be discussed as a change and integration in the desired direction within the process. Especially with the development in information technologies, new facilities and opportunities have become one of the most important issues for developed countries.

The correct use of these technologies can contribute to (Kıncal, 2006):

a. Individuals’ lifelong self-development, thereby increasing their qualities,
b. Developing automation systems by transferring trade and production onto information systems,
c. Developing individuals’ creativity in a universal rather than a local sense, thereby creating opportunities for their knowledge to benefit not only their immediate environment but also different areas in a broad perspective.

Scientific and technological improvements lead to the development of education by allowing it to keep pace with the times and also with the many changes that accompany it. With the information age, education has ceased to be local and has become global and more easily accessible. This also requires a universal point of view. This universal view, however, requires a healthy education system, and social solidarity and cooperation (Ministry of National Education’s 2023 vision, 2018). One of these universal qualities is undoubtedly students’ level of knowledge and skill in information and communication technologies.

Just as they affect all areas, developments in Information and Communication Technologies (ICT)undoubtedly have an effect on the areas of education and training and provide opportunities to develop up-to-date technological teaching materials and for learners to carry out learning independently of time and place (Roblyer, 2006; Usluel, 2007). Especially during the last 15 years, technological and economic developments have made it essential for countries to follow these innovations and changes closely (Eryılmaz, 2018,). It can be accepted that the strong relationships between countries’ information and communication technology development indices and their social and economic development (EMO, 2017) also indicate that there is a tight connection between technology and development. In an index study made of ICT skills in Information and Communication Technologies, a report was prepared by discussing variables such as individuals’ average years in education, their rates of registration in secondary education, and rates of registration in higher education. According to this report, for the assessment made in the area of ICT skills, it was determined that while the USA obtained the highest score of 9.18, the African countries received the lowest score of 1.01. The first ten countries in this ranking were the United States, Australia, South Korea, Greece, Belarus, Denmark, Slovenia, New Zealand, Norway and Finland, respectively. Turkey, however, was placed 39th in this list with a score of 7.72 (EMO, 2017). Considering that according to this assessment, the average score was 5.74, it can be said that Turkey performed above average.

When discussing performance in a broad sense as all learning outputs, it is not necessary to include all the variables and factors related to a learning product in order to measure performance. The basic principle in measuring performance is to show the real states (Turgut and Baykul, 2010). Therefore, for an effective performance measurement, it is necessary to select each of the criteria to be used with the same care. In other words, the selected criteria or the inputs to be used in measuring performance should have the necessary quality to reveal the true state of performance.

Examining what kind of effect educational inputs have on obtaining a product or what kind of impact the inputs have on the outputs is an important factor in deciding whether the inputs used are correct or incorrect. In this context, the data envelopment method occupies an important place, since this method creates a mechanism for presenting information about the returns from converting a large number of inputs into an output or outputs.

Data envelopment analysis (DEA) is a non-parametric statistical technique developed by Charnes et al., based on Farrell’s (1957) study (Charnes, Cooper and Rhodes, 1978). Enabling the comparison of a large number of inputs and outputs obtained from different scales, DEA is a linear program-based analysis aimed at measuring the comparative performances of decision-making units. By determining the weights of the inputs and outputs in production relationships that include multiple inputs and multiple outputs, the DEA method makes it possible for performance to be compared (Mirzapour, 2014). DEA is used effectively in many areas such as management, tourism, aviation, meteorology and the effectiveness of public expenditure (Banker, Charnes and Cooper, 1984: 1078; Doğan, 2015: 187; Golany and Roll, 1989: 237; Gökgöz, 2009; Karahan and Özgür, 2009; Kıran, 2008; Kutlar and Babacan, 2008; Önsoy, 2013; Ray, 2004; Seyrek and Ata, 2010; Taheri and Ansari, 2013; Ulucan, 2002; Yu and Wen, 2010; Zhu, 2009). However, the number of studies that reveal the interaction between the inputs and outputs and how the inputs are converted into outputs is limited. Large-scale examinations such as TIMSS, PISA, PIRLS and ICILS, which allow for comparison of educational quality on an international level, are carried out, but only a limited number of studies have examined educational inputs with regard to Turkey. In one of these studies, Yalçın (2011) examined the changes in the answers given to the questionnaire and cognitive skills test by students participating in the PISA implementation, and their relative efficiencies with regard to school type, during the years 2003, 2006 and 2009. The results of this study revealed that the difference in quality among high schools continued from 2003 to 2009, that the low socio-economic and cultural indices of students attending primary schools did not change over the years, and that students attending vocational schools did not set aside enough time for studying outside school. According to study that was conducted by Depren (2008), the relationships between students' mathematics, science and reading skills and their ability to solve problems that they might encounter in their daily lives were investigated. In this study, the changes and relative efficiency levels in schools, countries and regions between 2003 and 2006 were examined.

Conducting studies that can reveal the relationships between educational inputs and success rates in large-scale examinations that measure students' skills in subjects such as science, mathematics, reading comprehension and ICT in certain years, and examining the relative efficiency levels of variables that can be named outputs, are of great importance. This is because it is very important to know or reveal the extent to which variables that can be educational inputs affect the outputs expected of students or to which they affect the product, in order to be able to make correct decisions for investments in education. In this context, the research problem consists of an examination of the efficient and effective use of educational inputs based on the data of 21 countries, including Turkey, on the basis of the inputs in the International Computer and Information Literacy Study's (ICILS) 2013 examination, with the aim of measuring students' ICT skills. With regard to this, in the study, answers were sought to the following questions:

1. What are the total relative efficiency levels among the countries that participated in ICILS 2013?
2. Which of the countries that participated in ICILS 2013 and were relatively inefficient are the countries that need take references?
3. What are the returns to scale situations of the countries that participated in ICILS 2013 and were relatively inefficient?
4. What projection, that is, what value/level of inputs do the countries that participated in ICILS 2013 and were relatively inefficient need to have?
5. What are the relative levels of technical efficiency among the countries that participated in ICILS 2013?
6. What are the relative levels of scale efficiency among the countries that participated in ICILS 2013?

The first four questions making up the research problem investigate total efficiencies and what countries need to do in order to achieve total efficiency. The last two sub-problems attempt to reveal two efficiencies (technical and scale) that make up total efficiency and that determine why a Decision-making Unit (DMU) is or is not efficient.

Method

Research Model

This research, which was designed as a quantitative study, was carried out with data obtained from the ICILS 2013 study. Therefore, the study uses the survey model. The general aim of studies conducted with the survey model is to reveal the existing situation as it is (Fraenkel and Wallen, 2006). Within the framework of this study, a data envelopment analysis was carried out to determine the extent to which countries participating in ICILS 2013 used educational inputs in order to be efficient in computer and information literacies.

Universe and Sample

The study universe was made up of 21 countries that participated in the ICILS 2013 study. In this study, answers given by students participating in the ICILS 2013 study were used. The numbers of participants from the countries that took part in the study are given in Table 1.

Table 1. Numbers of participants from countries included in the study.

	Frequency	Percent
Argentina*	302	,6
Australia	4420	9,2
Switzerland	1982	4,1
Chile	2962	6,2
NL**	1092	2,3
Ontario***	2072	4,3
Czech Republic	3046	6,3
Germany	1660	3,4
Denmark	1194	2,5
Hong Kong, SAR****	1589	3,3
Croatia	2752	5,7
Korea	2888	6,0
Lithuania	2417	5,0
Netherlands	704	1,5
Norway	1564	3,2
Poland	2640	5,5
Russian Federation	3383	7,0
Slovak Republic	2945	6,1
Slovenia	3381	7,0
Thailand	2739	5,7
Turkey	2404	5,0
Total	48136	100,0

*Buenos Aires, Argentina
**Newfoundland and Labrador, Canada
***Ontario, Canada
**** Hong Kong SAR

Data Collection Tool

The ICILS 2013 questionnaire was used as the data collection tool in the study. As inputs, “the ratio of school size and teachers”, “the ratio of school size and number of computers”, “the ratio of school size and number of computers available for students”, “the ratio of school size and number of computers with access to internet”, and “the ratio of school size and number of smartboards” included in this questionnaire were used, while the average grades obtained by students in ICILS 2013 were used as outputs. These inputs are explained in the ICILS 2013 study as follows (ICILS 2013 Technical Report):

Ratio of school size and teachers (P_RATTCH): These data were obtained by dividing the number of teachers by the number of students in the school. The number of teachers was determined by summing the number of full-time teachers (IP1G06A) with the number of part-time teachers weighted at 50 percent (0.5 x IP1G06B) in the school. This data source was obtained from the questionnaire applied to the school principals. The other variables used in the study were:

Ratio of school size and number of computers (C_RATCOM): These data were obtained by dividing the number of students in the school (P_NUMSTD) by the number of computers in the school altogether (IIG07A). This data source was obtained from the scales collected by the ICT coordinators.

Ratio of school size and number of computers available for students (C_RATSTD): These data were obtained by dividing the number of students in the school (P_NUMSTD) by the number of computers in the school available to students (IIG07B). This data source was obtained from the scales collected by the ICT coordinators.

Ratio of school size and number of computers with access to internet/World Wide Web (C_RATWWW): These data were obtained by dividing the number of students in the school (P_NUMSTD) by the number of computers in the school connected to the internet/World Wide Web (IIG07C). This data source was obtained from the scales collected by the ICT coordinators.

Ratio of school size and smartboards (C_RATSMB): These data were obtained by dividing the number of students in the school (P_NUMSTD) by the number of smartboards or interactive white boards available (IIG08). This data source was obtained from the scales collected by the ICT coordinators.

Data Analysis

The aim of this study was to determine whether or not the inputs considered to have an impact on computer and information literacy were managed in an efficient manner by the countries that participated in ICILS 2013. In this direction, data envelopment analysis was carried out. Data envelopment analysis is able to evaluate multiple input-output factors at the same time (Lorcu, 2008). In this analysis approach, the relative performances according to decision-making unit (DMU) of multiple inputs and outputs obtained with different scales are examined on a linear programming database. Decision-making units are defined as "homogeneous structures operating in a similar environment, having the same inputs and outputs, in the same production process, and directed at the same aim, even if their amounts and ratios are different" (Lorcu, 2008, p. 10). The DMUs included in this study are the countries that participated in ICILS 2013.

Data envelopment analysis (DEA) is one of the statistical techniques frequently used in operations and management science. DEA brings together similar decision-making units and provides information about the efficiency levels of inputs in the decision-making process (Deveci Kocakoç, 2003). The most important difference between DEA and other performance evaluation methods is that many inputs and outputs are formed and that the inputs and outputs can be compared following analysis.

The following formula is used in evaluating efficiency/performance with DEA (Charnes, Cooper, Rhodes, 1978):

$$efficiency\ of\ unit\ j = \frac{u_1 y_{1j} + u_2 y_{2j} + \cdots + u_s y_{sj}}{v_1 x_{1j} + v_2 x_{2j} + \cdots + v_m x_{mj}} \quad (1)$$

u_s : weight given to output s

v_m : weight given to input m

y_{sj} : amount of output s from unit j

x_{mj} : amount of output m from unit j

The u and v weight coefficients included in Formula 1 are weighted by the analysis with the linear programming method during the calculation depending on the data set, and intervention by the person conducting the analysis is out of the question. Therefore, the weights of the inputs and outputs cannot be known before the analysis, or can be different for each data set (Deveci Kocakoç, 2003).

With DEA, the weights of the inputs and outputs are determined during the analysis, and what kind of output is from which input can be learnt following the analysis. Moreover, to maximise decomposition ability with DEA, it is necessary for a large number of inputs and outputs to be used in the decision-making unit. What is important here is that the chosen input and output should be able to be used for the decision-making unit. To express this mathematically, for a “k” number of decision-making units, an “x” number of inputs and a number of outputs that is “y” can be calculated with at least k≥x+y+1. Accordingly, let it be assumed that for a k number of decision-making units, a y number of outputs is produced by using an x number of input elements. In this context, the relative efficiency of any decision-making unit is found from the values obtained as a result of weighting the inputs and outputs by proportioning the outputs to the inputs. If this operation is carried out for a k number of decision-making units that perform a similar task, the efficiency of every unit can be calculated. In DEA, two basic orientations can be mentioned. These are the input-oriented approach and the output-oriented approach. In the output-oriented approach, the aim is to obtain the maximum output from the inputs available. In the input-oriented approach, however, the aim is for analysis to be carried out with a minimum number of inputs. In other words, it concentrates on what the minimum number of inputs should be (Mirzapour, 2014). The number of x inputs and y outputs that will maximise the decision-making units and the output/input ratio in which a k number of units will be maximised in DEA analysis can be expressed as follows (Charnes et al., 1978):

$$Maxh_k = \frac{\sum_{s=1}^{y} u_{sk} y_{sk}}{\sum_{i=1}^{x} v_{ik} X_{ik}} \quad (2)$$

According to Formula 2 given above, X_{ik}>0 expresses the ith amount of inputs used by the kth decision-making unit, while y_{rk}>0 expresses the rth amount of outputs used by the kth decision-making unit. In this decision formula, u_{sk} and v_{ik} show the weights that decision unit k will give for the sth output and ith input, respectively.

Different models (the CCR, BCC and Additive models) have been developed within the scope of DEA. Of these models, the CCR model was developed by Charnes, Cooper and Rhodes (1978) and is one of the basic DEA models. This model was developed to measure the relative efficiency values of decision-making units and is a linear programming-based method (Mirzapour, 2014). Accordingly, the relative efficiency of any unit can be measured with the formula below (Cooper et al.,2000):

$$FP_0 \max \quad \frac{u_1 y_{1o} + u_2 y_{2o} + \cdots + u_s y_{so}}{v_1 x_{1o} + v_1 x_{1o} + \cdots + v_m x_{mo}} \quad (3)$$

$$Constraints \quad \frac{u_1 y_{1j} + u_2 y_{2j} + \cdots + u_s y_{sj}}{v_1 x_{1j} + v_1 x_{1j} + \cdots + v_m x_{mj}} \leq 1 \; (j = 1,\ldots,n) \quad (4)$$

$$v_1, v_2, \ldots, v_m \geq 0$$

$$u_1, u_2, \ldots, u_s \geq 0$$

With the FP_0max function, the basic aim is to be able to determine the input and output weights that will make the decision-making unit 0. Accordingly, as the input/output ratio is at least 1, the efficiency ratio is expected to range between [0,1] (Deveci Kocakoç, 2003).

In the BCC model developed by Banker, Charnes and Cooper, the technical inefficiencies and scale inefficiencies are separated. The BCC is one of the DEA models, and was obtained by making changes to the hypotheses in the CCR model (Yıldız, 2014). The BCC frontier is generally below the CCR frontier. The reason for this is that a type of yield can be created that can vary from scale to scale (Kale, 2009). The results obtained in this model make it possible for analyses to be performed in future studies for increasing, decreasing and constant returns to scale situations (Tokpunar, 2015).

Another model used in DEA is the Additive model, in which the CCR and BCC models are evaluated together. In this model, the main aim is to deal with an excess of inputs and a shortfall of outputs at the same time in arriving at a point that is most distant on the efficiency frontier from an inefficient decision-making unit. In cases where the input and output variables are inefficient, this means that the slack variables are different from zero (Charnes et al.,1994). In other words, the state of whether the decision-making units are efficient or not is determined according to the slack variables. If both slack variables are zero, this can express that the decision-making unit is efficient (Mirzapour, 2014: 46).

Another approach included in this study is scale efficiency. Scale efficiency is expressed as “the success of productivity on an optimum scale” (Aslan, 2017; Günay, 2015). In other words, it is the capacity for high productivity with low input. Moreover, since this study is concerned with the field of education, and since direct intervention in outputs in the field of education cannot be made and it is necessary to change the inputs in order to change the outputs, the input-based approach has been adopted in the analyses.

To determine which of the countries participating in ICIL 2013 were relatively efficient or not, the CCR technique was used. Therefore, by calculating total efficiency, it will be possible to determine the countries which had characteristics of technical and scale efficiency. Moreover, with the information obtained with the input-based CCR model, it will also be possible to examine the input states under constant returns by totalling the reference coefficients (lambda) of the referenced countries.

Besides total efficiencies, the countries’ technical and scale efficiency states were examined. A decision-making unit that is technically efficient means using its inputs in such a way as to generate maximum output. To determine this, the BCC technique was used.

Another type of efficiency used in the study is scale efficiency. This efficiency expresses the capacity of a decision-making unit to generate maximum output with low inputs. For this study, the scale efficient countries are those having higher computer and information literacy scores with low inputs. The scale efficiency of a decision-making unit can be calculated with the ratio of total efficiency (i.e. CCR) to technical efficiency (i.e. BCC).

The analyses in this study were carried out in the following stages:

1. In the first stage of DEA, it is first of all necessary to determine which decision-making units are suitable and need to be included in the study. Moreover, decision-making units' performing of similar tasks can affect the reliability of the analysis (Gökgöz, 2009). In this study, based on the ICIL 2013 data, the decision-making units used consist of Australia, Newfoundland and Labrador (Canada), Ontario (Canada), Denmark, Korea, Norway, the Czech Republic, Germany, Hong Kong SAR, Chile, the Netherlands, Russian, Turkey, Slovakia, Thailand, Switzerland, Croatia, Lithuania, Slovenia, Poland, and Buenos Aires (Argentina) that participated in the study.
2. Next, an attempt was made to determine whether the number of decision-making units was sufficient or not when considering the inputs and outputs. Dyson, Allen, Camanho, Podinovski, Sarrico, and Shale (2001) stated that the number of decision-making units (DMU) should be twice the number of inputs and outputs. Since the study was conducted with 5 inputs and 1 output, 21 countries were, therefore, enough as DMUs.
Cooper, Li, Seiford, Tone, Thrall, and Zhu (2001) however, state that for m inputs and s outputs, there should be an N number of DMUs, where $N \geq \{m \text{ x } s; 3 \text{ X } (m + s)\}$. According to this view, since $21 \geq \{5 \text{ X } 1; 3 \text{ X } (5 + 1)\} = 21 \geq \{6; 18\}$, the number of DMUs was sufficient.
3. Selection of inputs and outputs. In order for reliability not to be low, the inputs and outputs used in the DMU should be fit for the purpose. The input and output units dealt with in the scope of this study were chosen to suit the purpose. The inputs of the study were "ratio of school size and teachers", "ratio of school size and number of computers", "ratio of school size and number of computers available for students", "ratio of school size and number of computers with access to internet/World Wide Web", and "ratio of school size and smartboards". The outputs of the study were determined as the average grades obtained by students in ICILS 2013.
4. In the process of determining the model for data envelopment analysis, total efficiencies were calculated with CCR. The CCR model is the most suitable model to be used for obtaining the most outputs in the most efficient way under the assumption of constant returns.

5. Based on the reference coefficients obtained in the total efficiency model, the returns to scale situations were determined.
6. The technical efficiencies were calculated with the BCC model.
7. Based on the CCR/BCC ratios, the scale efficiencies were calculated.

Findings

Total efficiencies were calculated with the CCR model and are presented in Table 2.

Table 2. Total efficiencies according to CCR model

DMU	Score	Rank	1. Reference Country		2. Reference Country		3. Reference Country		Total λ	Returns to Scale
			Name	λ	Name	λ	Name	λ		
Australia	1	1	Australia	1					1	
NL**	1	1	NL**	1					1	
Ontario***	1	1	Ontario	1					1	
Denmark	1	1	Denmark	1					1	
Korea	1	1	Korea	1					1	
Norway	1	1	Norway	1					1	
Czech	0,9923	7	Ontario***	1,005	Korea	0,036			1,041	Decreasing
Germany	0,9494	8	Ontario***	0,72	Korea	0,269			0,989	Increasing
Hong Kong****	0,9438	9	Australia	0,377	Ontario***	0,303	Korea	0,276	0,956	Increasing
Chile	0,9421	10	Ontario***	0,266	Korea	0,659			0,925	Increasing
Netherlands	0,9125	11	Australia	0,372	Ontario***	0,165	Denmark	0,429	0,966	Increasing
Russian	0,8607	12	Ontario***	0,884	Korea	0,08			0,964	Increasing
Turkey	0,8285	13	Korea	0,678					0,678	Increasing
Slovak	0,7704	14	Ontario***	0,94	Korea	0,023			0,963	Increasing
Thailand	0,7508	15	Ontario***	0,282	Korea	0,44			0,722	Increasing
Switzerland	0,7236	16	Ontario***	0,949	Korea	0,003			0,952	Increasing
Croatia	0,719	17	Ontario***	0,516	Korea	0,445			0,961	Increasing
Lithuania	0,626	18	Australia	0,077	Ontario***	0,741	Korea	0,102	0,92	Increasing
Slovenia	0,5751	19	Australia	0,102	Ontario***	0,174	Denmark	0,667	0,943	Increasing
Poland	0,5714	20	Australia	0,121	Ontario***	0,422	Denmark	0,442	0,985	Increasing
Argentina*	0,5125	21	Ontario***	0,323	Korea	0,572			0,895	Increasing

*Buenos Aires, Argentina

**Newfoundland and Labrador, Canada

***Ontario, Canada

**** Hong Kong, SAR

Examining Table 2, it is seen that respectively, Australia, Newfoundland and Labrador (Canada), Ontario (Canada), Denmark, Korea, and Norway were the relatively efficient countries.

Accordingly, 6 countries were totally efficient, while 15 countries were not totally efficient. In DEA, total efficiency is an expression used for situations where inputs are used efficiently and outputs also operate on a suitable scale (Lorcu, 2008). Accordingly, it can be said that these 15 countries both used their resources efficiently and operated on a suitable scale. Moreover, according to Table 2, while Ontario was a reference for 15 countries, Australia for 6, Korea for 13 and Denmark for 4, neither Norway nor NL** was able to be a reference for any countries. It can be said that while the Czech Republic was closest to total efficiency, Argentina* was the furthest from it.

With total efficiency analysis, returns to scale situations can also be determined. The value obtained when the reference coefficients **(λ)** of the countries suggested to be totally efficient are added up (∑**λ**), gives a value for us to interpret the returns to scale situation. If this value is greater than 1, this shows decreasing returns to scale, if it is equal, it shows constant returns, while if it is less than 1, it shows increasing returns to scale (Lorcu, 2008). For example, for the Czech Republic, which was the country closest to total efficiency (0.9923), ∑**λ**=1.005Ontario + 0.036 Korea =1.005+0.036=1.041 and had decreasing returns to scale. For Germany, which was the second closest country to total efficiency and took Ontario and Korea as references, ∑**λ**=0.72Ontario + 0.239 Korea =0.72+0.239=0.989 and had increasing returns to scale. In this study, it was determined that all countries that were not totally efficient had increasing returns to scale except for the Czech Republic. When an increase occurs in the inputs of a decision-making unit that has increasing returns to scale, this will also cause an increase in its outputs.

The levels of inputs necessary (projections) for countries that were not totally efficient to be able to become efficient were determined and these are presented in Tables 3, 4, 5, 6 and 7.

Table 3. Data for ratio of school size and teachers

DMU	Score	Rank	Ratio of school size and teachers			
			Raw Value	Slack Variable	Hypothetic Value	Difference (%)
Czech	0,9923	7	0,071	0,000	0,070	-0,774
Germany	0,9494	8	0,067	0,000	0,064	-5,062
Hong Kong****	0,9438	9	0,069	0,000	0,065	-5,617
Chile	0,9421	10	0,057	0,000	0,054	-5,791
Netherlands	0,9125	11	0,080	0,000	0,073	-8,745
Russian	0,8607	12	0,075	0,000	0,064	-13,930
Turkey	0,8285	13	0,045	0,000	0,037	-17,155
Slovak	0,7704	14	0,085	0,000	0,065	-22,963
Thailand	0,7508	15	0,058	0,000	0,043	-24,917
Switzerland	0,7236	16	0,089	0,000	0,065	-27,635
Croatia	0,719	17	0,083	0,000	0,059	-28,101
Lithuania	0,626	18	0,099	0,000	0,062	-37,395
Slovenia	0,5751	19	0,124	0,000	0,071	-42,488
Poland	0,5714	20	0,126	0,000	0,072	-42,859
Argentina*	**0,5125**	**21**	**0,104**	**0,000**	**0,053**	**-48,751**

*Buenos Aires, Argentina

**** Hong Kong SAR

The most important input for carrying out teaching programmes and for the education system is the teacher. This input expresses the ratio of a lot of students with few teachers. This ratio was lowest in Turkey, but it can be said that this ratio also needed to be reduced for Turkey, in other words, that this input was not used efficiently. It was recommended that the Czech Republic should reduce this input by the least amount. The Czech Republic was, at the same time, the country closest to total efficiency. On the other hand, the country least able to use this input efficiently, that is, the country recommended to decrease it by the greatest amount, was Argentina. At the same time, Argentina was the country with the third highest amount of this input. It was recommended that Argentina reduce this input by almost 50%. Although Argentina was recommended to reduce this input by a high amount, it can be said that Poland and Slovenia were close to this country, with rates of almost 43%.

Table 4. Data for ratio of school size and number of computers

DMU	Score	Rank	Ratio of school size and number of computers			
			Raw Value	Slack Variable	Hypothetic Value	Difference (%)
Czech	0,9923	7	5,606	0,788	4,775	-14,826
Germany	0,9494	8	8,562	3,209	4,920	-42,538
Hong Kong****	0,9438	9	4,117	0,183	3,702	-10,071
Chile	0,9421	10	10,720	4,838	5,261	-50,923
Netherlands	0,9125	11	3,054	0,058	2,729	-10,643
Russian	0,8607	12	8,954	3,207	4,500	-49,748
Turkey	0,8285	13	48,783	36,242	4,172	-91,448
Slovak	0,7704	14	6,339	0,478	4,406	-30,500
Thailand	0,7508	15	10,598	3,972	3,986	-62,392
Switzerland	0,7236	16	6,101	0,091	4,323	-29,134
Croatia	0,719	17	13,297	4,483	5,077	-61,819
Lithuania	0,626	18	6,572	0,000	4,114	-37,395
Slovenia	0,5751	19	5,335	0,000	3,068	-42,488
Poland	0,5714	20	6,145	0,000	3,512	-42,859
Argentina*	0,5125	21	12,699	1,527	4,981	-60,778

*Buenos Aires, Argentina

**** Hong Kong SAR

Computers or devices that can process data are the basic tools of information and communication literacy. The quantity of these tools in schools can have an effect on computer and information literacies. Examining the efficiencies in using these tools for computer and information literacies, it is seen that Hong Kong was given the lowest recommendation for reduction, with 10.07%. This country had the second lowest raw value regarding input. At the same time, it was the third closest country to total efficiency. The Netherlands came in second place with a reduction recommendation of 10.643%. At the same time, the Netherlands had the lowest raw value.

The country with the highest recommendation for reduction of this input was Turkey, and this rate was calculated as about 90%. This value indicates that the input was wasted or that it was used incorrectly. At the same time, Turkey had the highest raw value for this input. The country with the second highest rate was Thailand with 62.932%. It can be said that this value is a long way from Turkey's. When the inputs of Turkey (48.783) and Thailand (10.598) are compared, it is revealed that Turkey wasted a very high quantity of this input.

Table 5. Data for ratio of school size and number of computers available for students

DMU	Score	Rank	Ratio of school size and number of computers available for students			
			Raw Value	Slack Variable	Hypothetic Value	Difference (%)
Czech	0,9923	7	10,076	1,875	8,123	-19,381
Germany	0,9494	8	11,195	0,000	10,628	-5,062
Hong Kong****	0,9438	9	9,017	0,000	8,511	-5,617
Chile	0,9421	10	18,611	2,563	14,971	-19,562
Netherlands	0,9125	11	4,914	0,592	3,892	-20,787
Russian	0,8607	12	17,144	6,647	8,108	-52,704
Turkey	0,8285	13	78,923	52,002	13,382	-83,044
Slovak	0,7704	14	9,609	0,000	7,402	-22,963
Thailand	0,7508	15	14,337	0,000	10,765	-24,917
Switzerland	0,7236	16	9,774	0,000	7,073	-27,635
Croatia	0,719	17	25,104	5,455	12,594	-49,832
Lithuania	0,626	18	13,098	0,553	7,647	-41,618
Slovenia	0,5751	19	14,439	3,914	4,390	-69,594
Poland	0,5714	20	9,606	0,200	5,289	-44,943
Argentina*	0,5125	21	31,977	2,721	13,667	-57,261

*Buenos Aires, Argentina

**** Hong Kong, SAR

Another variable related to computers at school is that of availability of computers for use by students. The country given the lowest reduction recommendation for this variable was Germany, the country second closest to total efficiency. The country with the closest value to that country was the country third closest to total efficiency, Hong Kong. Hong Kong was, at the same time, the country that received the lowest reduction recommendation for the "ratio of school size and number of computers" input.

Just as with the "ratio of school size and number of computers" input, the country given the highest reduction recommendation was Turkey. At the same time, Turkey was again the country with the highest raw value. In other words, Turkey either used this input incorrectly or wasted it. After

Turkey, the country receiving the second highest recommendation rate was Slovenia. However, when the inputs for Turkey (78.923) and Slovenya (14.439) are compared, it is revealed that Turkey wasted a very high quantity of this input.

Table 6. Data for ratio of school size and number of computers with access to internet

DMU	Score	Rank	Ratio of school size and number of computers with access to internet			
			Raw Value	Slack Variable	Hypothetic Value	Difference (%)
Czech	0,9923	7	5,748	0,873	4,830	-15,967
Germany	0,9494	8	9,043	3,474	5,111	-43,483
Hong Kong****	0,9438	9	4,162	0,000	3,928	-5,617
Chile	0,9421	10	13,425	6,970	5,678	-57,706
Netherlands	0,9125	11	3,066	0,000	2,798	-8,745
Russian	0,8607	12	16,848	9,922	4,579	-72,822
Turkey	0,8285	13	66,361	50,385	4,592	-93,080
Slovak	0,7704	14	6,856	0,830	4,451	-35,071
Thailand	0,7508	15	12,440	5,073	4,268	-65,694
Switzerland	0,7236	16	6,291	0,195	4,357	-30,739
Croatia	0,719	17	15,928	6,083	5,370	-66,289
Lithuania	0,626	18	7,108	0,239	4,211	-40,754
Slovenia	0,5751	19	5,474	0,032	3,116	-43,071
Poland	0,5714	20	6,400	0,097	3,560	-44,369
Argentina*	0,5125	21	14,668	2,171	5,346	-63,554

*Buenos Aires, Argentina

**** Hong Kong, SAR

For the inputs for the ratio of school size and number of computers with access to internet, Hong Kong was given the lowest recommendation for reduction. Hong Kong was the country third closest to total efficiency. At the same time, Hong Kong was the country with the second lowest amount of inputs. Following Hong Kong, the country receiving the second lowest recommendation was the Netherlands. At the same time, the Netherlands had the lowest raw value with regard to this input.

Once again, the country given the highest reduction recommendation for this input was Turkey. At the same time, Turkey was again the country with the highest raw value. When the raw value and reduction rate are examined, it can again be stated that Turkey used this input incorrectly or wasted it. Croatia received the second highest recommendation for this input.

Table 7. Data for ratio of school size and number of smartboards

DMU	Score	Rank	Ratio of school size and number of smartboards			
			Raw Value	Slack Variable	Hypothetic Value	Difference (%)
Czech	0,9923	7	105,684	0,000	104,866	-0,774
Germany	0,9494	8	260,565	57,518	189,859	-27,136
Hong Kong****	0,9438	9	528,600	296,861	202,049	-61,777
Chile	0,9421	10	354,171	0,000	333,660	-5,791
Netherlands	0,9125	11	84,739	0,000	77,329	-8,745
Russian	0,8607	12	133,884	0,000	115,234	-13,930
Turkey	0,8285	13	785,835	331,723	319,306	-59,367
Slovak	0,7704	14	147,861	20,520	93,388	-36,841
Thailand	0,7508	15	871,742	422,659	231,875	-73,401
Switzerland	0,7236	16	119,517	1,757	84,732	-29,105
Croatia	0,719	17	354,477	0,000	254,864	-28,101
Lithuania	0,626	18	195,018	0,000	122,091	-37,395
Slovenia	0,5751	19	96,198	0,000	55,326	-42,488
Poland	0,5714	20	122,380	0,000	69,930	-42,859
Argentina*	0,5125	21	580,562	0,000	297,533	-48,751

*Buenos Aires, Argentina

**** Hong Kong SAR

The Czech Republic was given the lowest recommendation for reducing input for the ratio of school size and the number of smartboards. The Czech Republic was, at the same time, the country closest to total efficiency. This country also occupied third lowest position for this input in terms of raw value. It was followed by Chile in second place. In terms of size of input amount, Chile occupied sixth place. This country was also the fourth closest country to total efficiency.

The country given the highest recommendation for reduction of this input was Thailand. This country also had the highest raw value for this input. Hong Kong followed Thailand in receiving the second highest reduction recommendation. What is striking here is that although Hong Kong was the third closest country to total efficiency, it was given the fourth highest reduction recommendation for this input; in other words, it was not able to use it efficiently.

To examine the countries' technical efficiencies, analysis was carried out with the BCC model, and the results are presented in Table 8.

Table 8. Technical efficiency results according to BCC model

DMU	Score	Rank	1. Reference Country		2. Reference Country		3. Reference Country	
			Name	**λ**	**Name**	**λ**	**Name**	**λ**
Australia	1	1	Australia	1				
Chile	1	1	Chile	1				
NL**	1	1	NL**	1				
Ontario***	1	1	Ontario***	1				
Czech	1	1	Czech	1				
Denmark	1	1	Denmark	1				
Korea	1	1	Korea	1				
Norway	1	1	Norway	1				
Thailand	1	1	Thailand	1				
Turkey	1	1	Turkey	1				
Hong Kong****	0,9874	11	Australia	0,395	Ontario***	0,317	Korea	0,288
Germany	0,9583	12	Ontario***	0,712	Korea	0,249	Thailand	0,039
Netherlands	0,9445	13	Australia	0,385	Ontario***	0,17	Denmark	0,444
Russian	0,8907	14	Chile	0,119	Ontario***	0,881		
Slovak	0,7982	15	Ontario***	0,96	Korea	0,002	Thailand	0,038
Switzerland	0,7594	16	Ontario***	0,995	Korea	0,002	Thailand	0,003
Croatia	0,7412	17	Chile	0,523	Ontario***	0,384	Korea	0,093
Lithuania	0,6805	18	Australia	0,084	Ontario***	0,806	Korea	0,11
Slovenia	0,6103	19	Australia	0,108	Ontario***	0,184	Denmark	0,707
Poland	0,5805	20	Australia	0,123	Ontario***	0,428	Denmark	0,449
Argentina*	0,5696	21	Chile	0,326	Ontario***	0,267	Korea	0,407

*Buenos Aires, Argentina

**Newfoundland and Labrador, Canada

***Ontario, Canada

**** Hong Kong, SAR

According to the BCC analysis, 10 countries were technically efficient, while 11 countries were not technically efficient. Among the countries that were not totally efficient, Chile, the Czech Republic, Thailand and Turkey appeared as technically efficient. Technical efficiency is "the process by which production inputs are converted into outputs" by a decision-making unit (Lorcu, 2008, p. 7). For example, let us assume that a software company, with the facilities it possesses, has the facility to produce 100 programmes, while it produces 90 programmes. In that case, this firm can be evaluated as being 90/100=0.90=90% technically efficient. Technical efficiency is, at the same time, an indicator that inputs have not been managed well or that the resources have been wasted. According to these results, Poland and Argentina, at rates of around 50%, were least able to manage their inputs or else they wasted their resources.

Finally, scale efficiency was examined. At the same time, this examination is in the form of a summary evaluation, and the results are presented in Table 9.

Table 9. Scale efficiency results

DMU	CCR	BBC	CCR/BBCC (Ölçek Etkinliği)
Australia	1	1	1
NL**	1	1	1
Ontario***	1	1	1
Denmark	1	1	1
Korea	1	1	1
Norway	1	1	1
Czech	0,9923	1	0,9923
Germany	0,9494	0,9583	0,9907
Poland	0,5714	0,5805	0,9843
Croatia	0,719	0,7412	0,9700
Russian	0,8607	0,8907	0,9663
Netherlands	0,9125	0,9445	0,9661
Slovak	0,7704	0,7982	0,9652
Hong Kong****	0,9438	0,9874	0,9558
Switzerland	0,7236	0,7594	0,9529
Slovenia	0,5751	0,6103	0,9423
Chile	0,9421	1	0,9421
Lithuania	0,626	0,6805	0,9199
Argentina*	0,5125	0,5696	0,8998
Turkey	0,8285	1	0,8285
Thailand	0,7508	1	0,7508

*Buenos Aires, Argentina
**Newfoundland and Labrador, Canada
***Ontario, Canada
**** Hong Kong SAR

Scale efficiency is succeeding in producing maximum outputs with a minimum of inputs. The Czech Republic (99.239%) and Germany (99.07%) were the closest countries to total scale efficiency. The Czech Republic was also technically efficient. That is, it can be said that for ICILS success, this country used its inputs completely, but that it could not achieve maximum ICILS success with minimum inputs. Thailand (77.08%) was the most distant country from this efficiency. Turkey was one place higher, with 82.85%. On the other hand, like the Czech Republic, Thailand and Turkey were technically efficient countries. When the tables regarding recommendations made for total efficiency are examined, it was determined that Turkey received input reduction recommendations in several areas, and that Thailand also received high reduction recommendations. According to these findings, it can be said that Thailand and Turkey were not able to use their inputs efficiently enough to affect their ICILS success.

Discussion and Conclusion

In the age of information, access to information and communication technologies is becoming easier every day. In this context, products suitable for the information age (robotic coding, VR applications, software development, etc.) that are available due to nations' investments in ICT are undoubtedly also becoming more challenging for countries day by day. In other words, nowadays, ICT skills are becoming much easier due to the ease of access to technology at a basic level in almost all countries. When this is the case, the products that countries plan to obtain in their ICT-related investments need to be much more complex and of the highest order.

In this study, in which ICT skills were measured based on ICILS data, the aim was to reveal the relationship between inputs and outputs by using DEA. Accordingly, one of the findings obtained in the study was that according to total efficiency analysis, all countries within the scope of the study were at levels of increasing efficiency except for the Czech Republic. Consequently, it can be stated that in case of a new ICT-related input that can be added to these countries, it will be efficient as an output, that is, with regard to ICT skill, the product can be taken. According to the 2009 PISA results, it was reported that at least 50% of students in European countries had computers. In the report, it is recommended that the number of students with computers or the students' access to computers should be increased even further (Eurydice, 2011). At this point, the finding obtained in the study is in parallel with the increase in the number of computers. Accordingly, an important way to improve students' ICT skills is also to increase the number of computers so that all students have one. In this way, it can be expected that by increasing students' ICT skills, total efficiency levels will also attain ideal values.

Another significant finding of the study is related to the ratio of school size and teachers. According to this finding, the country with the lowest teacher input was Argentina, while that with the highest was Poland. According to the results for the ratio of school size and teachers input, it was concluded that in a number of countries, there was a difference between school size and the number of teachers, and that in almost all the countries participating in the ICILS 2013 study, there was a need for teacher numbers to be reduced. Especially when the ratios of school size and teachers are evaluated in the context of inputs and outputs, it should be stated that there was a need for reduction according to the DEA results. With the thought that it may be effective in improving the quality of education, it can be said that school size occupies an important place in determining education policies (Karakütük et al., 2012). Although it can be argued that large schools can be more efficient in an economic sense (Kenny, 1982), there are also researchers who defend the exact opposite of this idea (Walberg, 1993). In the study made by Kılıç (2015), it was determined that increasing the number of teachers was effective in reducing the number of punishments. In this context, it can be said that the number of teachers in schools being proportionate to school size is an important factor with regard to not only quality, curriculum diversity and but also reducing disciplinary punishments, etc. With regard to this, according to the relationship between school size and teacher numbers revealed in the study, it can be said that bringing the ratio of school size and teacher numbers to an ideal and efficient standard will be of benefit to schools in several respects listed above.

According to the results of the evaluation made on the relationship between inputs and outputs related to school size and technological tools (computer use, internet, smartboards), it was calculated that the country that least needed a reduction in the number of computers compared to school size was Hong Kong, while the country most in need of a reduction was Turkey. This finding reveals that computers were used more efficiently in Hong Kong than they were in Turkey. Various studies have been made related to the use and effect of computers in school environments (Noll, Older-Aguilar, Ross, and Rosston, 2001; Kirkpatrick and Cuban, 1998). Although a number of studies have been made on this subject, a clear conclusion has still not been drawn regarding the effect of computer use in schools. For example, according to a study conducted in schools in Israel, it was argued that computer use in school did not have a significant effect on mathematics grades (Angrist & Lavy, 1999), whereas the US Department of Education has conducted studies aimed at improving teachers' and school managers' skills related to technology use (SRI, 2002). In this context, considering the results obtained in the study, it is considered that since computers also bring an additional cost to schools, the efficient use of computers is important. For this reason, it can be said that countries like Turkey, Thailand and Hungary need to either reduce their computer numbers or use them more efficiently. According to the results of the BCC analysis, it was calculated that 11 of the countries that participated in ICILS 2013 were inefficient, while 10 of them were efficient. Accordingly, it can be said that the inputs in the decision-making units of almost half of the countries were able to generate a large number of outputs. However, it can be said that the other half of the countries had problems with regard to efficiency between their inputs and outputs. In other words, it can be stated that these countries were not efficient enough in their decision-making processes regarding the outputs from their inputs, and that they were not able to convert their inputs into outputs in an efficient way.

In the study, as well as technical efficiency, scale efficiency, which is part of total efficiency, and returns to scale situations were also examined. In most of the countries, it was determined that in the event of an increase in inputs, their success would increase, yet scale efficiency revealed that there was no maximum output with unit input. Furthermore, considering that half of the countries were technically efficient, it can be stated that the majority of ICT-related inputs were not used efficiently by countries. This also meant that the input expenditures did not achieve their targets. Therefore, rather than trainings and expenditures made with regard to communication and information literacy, other factors that cannot be controlled come into play. This situation is similar to the one stated by

Coleman et al. (1966) in their famous *Equality of Educational Opportunity* report. According to this report, rather than students' schools and the facilities that their schools have, their families and backgrounds are effective in their school success. This situation reveals that the facilities in schools are not used efficiently. In this case, it is considered that facilities for ICILS are not used efficiently, and that in ICILS success, rather than educational inputs, the socio-economic characteristics that students bring to school and their backgrounds may have an effect on ICILS scores. In this situation, the fact that countries' educational inputs related to ICILS fall short reveals that education is "left to chance".

ICILS depends heavily upon computer technology. Many of the countries that participated in ICILS 2013 generally import their computer technologies. Inefficient use of imported products results in the creation of unnecessary costs and therefore in the creation of current account deficits. Considering that ICILS is related to the economy (EMO, 2017), it is considered that in countries where inputs are used inefficiently, development will be weak, current account deficits will further increase and bad economic situations will arise.

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