Research on the Relative Efficiency of Educational Intensity： Evidence from OECD Countries

Wei-KangWang
Department of Accounting,
Yuan Ze University,
135 Yuan-Tung Road, Chung-Li,
Tao-Yuan, Taiwan,
jameswang@saturn.yzu.edu.tw

Jing-I Lu
Department of International Business,
Yuan Ze University,
135 Yuan-Tung Road, Chung-Li,
Tao-Yuan,Taiwan,

Lee-Hsuan Lin
Department of Accounting,
Yuan Ze University,
135 Yuan-Tung Road, Chung-Li,
Tao-Yuan, Taiwan

Abstract

This paper uses DEA models to evaluate educational intensity of OECD countries. The input variables include total public expenditure on education (expenditure), pupil-teacher ratio (primary education, PT ratio 1), pupil-teacher ratio (secondary education, PT ratio 2), educational system, and university education, and the output variables include literacy, higher education achievement (higher education), and qualified engineer. The analysis models of DEA includeCCR, BCC, Slack-Based Measure （SBM）, and the FDH model. We analyze the overall efficiency, pure technique efficiency and scale efficiency of OECD countries. We also investigate the most productive scale size for OECD countries. Finally, we provide some management suggestions for OECD countries.

Keywords: Education production function; DEA, FDH, Performance Evaluation

1.Introduction

For most countries in the world, education has been one of the major concerns of the governments. Many reasons contribute to this. For instance, most governments have already recognized that accumulating human capital is one of the methods to enhance economic growth and to equalize income distributions, and education is the gateway to it. For this reason, governments utilize many policies, such as increasing expenditures on education, to improve or increase education quality and status of their countries.

Regard governments' education policies, there are two aspects one could investigate: the effects of these policies and the efficiency of them. The former has been the major focus of many studies in the field of education, for example, the on-going debates about the effects of government expenditures on education, class size, educator's incentives, etc. Some authors, like Hanushek, argue that spending on education of the U.S. government increases over time, but student performance does not improve in the same period; therefore, Hanushek [13] concludes that "added sources are not consistently translated into improved student performance. Improving the incentives in schools appears to be the most important task if resources are to be used more effectively in the future." However, after adjusting selection method employed in many Hanushek's works, Krueger [17] finds that "class size is systematically related to student performance", and "the results of my reanalysis should give pause to those who argue that radical changes in public school incentives are required because schooling inputs are unrelated to schooling outputs."

In the present paper, we put our attentions on the latter. That is, we try to evaluate the efficiency of government's efforts in improving education achievements of their countries. We would like to see which country utilizes the education resources most efficiently and which one did the worst. With this result, we then could give suggestions to the countries performing worse about what they could work on and what they should adjust.

To perform this task, we utilize the data envelopment analysis (DEA) to help us evaluate every country's efforts. DEA has been used to determine the relative efficiency of universities in several studies. Various researches have used DEA to measure the relative efficiency of MBA programs, including Colbert, Levary & Shaner [8]. Colbert et al. [8] determined the relative efficiency of the top 24 US MBA programs from Business Week's top 25 programs in the United States. Efficiency scores were determined using two output sets and three input variables for the MBA programs, an output set that measured student satisfaction and recruiter satisfaction, an input set that measured the faculty to student ratio, the average GMAT score of students in the program, and the number of electives offered. DEA was also used to determine the relative efficiency of three foreign MBA programs as compared to several top the ranking US MBA programs. The results of this study highlight the importance of the inputs and outputs used in determining relative efficiency.

In another study, Sinuany-Stern, Mehrez & Barboy [19] used DEA to determine the relative efficiency of 21 departments at Ben-Gurion University. Operational expenditures and faculty salaries were used as inputs. The output variables included grant money, the number of publications, the number of graduate students, and the number of credit hours offered. They also tested the effects of variations in inputs and outputs on efficiency scores. The results showed that fourteen of the departments were inefficient.

Research on the educational production function has been done by Banker, Janakiraman & Natarajan [3], Caballero, Galache, Gomez, Molina & Torrico [6], Bifulco & Bretschneider [4], Grosskopf & Moutray [12], Colbert et al. [8] etc. This involves the estimating the input-output production correspondence in order to evaluate the relative efficiency of educational institutions. The input measures used typically include expenditures, full time equivalents of teachers, and other physical measures such as equipment investment, the number of square feet of space etc. Output measures used include full time student equivalents, the degree of satisfaction of students, research outcomes etc.

So far, few studies on OECD (Organization for Economic Co-operation and Development) countries have been done.[1] In this paper we discuss the relative efficiency of inputs and outputs for the OECD countries. The analysis models of DEA include CCR (named after Charnes, Cooper & Rhodes, 1978), BCC (named after Banker, Charnes & Cooper, [2]), Bilateral, Slack-Based Measure (SBM), and the free disposal hull (FDH) model. We use the idea of education production function that has been discussed a lot in the debates mentioned above to choose variables that could represent each country's efforts. With the assists of this production function, the rationale supporting our choice of variables should be more solid, not just basing on common senses. In addition to the relative efficiency analysis, we investigate the most productive scale size for OECD countries. Finally, we provide some management suggestions for OECD countries.

This paper is tailored as follows. Section 2 explains the logic of choice of variables we employ in the empirical study. Section 3 introduces the econometric models. Data source and empirical results are presented in Section 4. Section 5 is the conclusion.

2. Education production function and the choice of variables

In this section, we introduce the rationale we choose the input and output variable for the DEA models.

Like the idea of a general production function, the education production function relates inputs of education to education output, the achievements of education. In the literature on this field, the most discussed inputs of this function include government education expenditures, class size (or pupil-teacher ratio), teacher's education, and teacher's experience. In the present paper, due to data availability, we choose two variables from the list, the government expenditure and pupil-teacher ratio. Moreover, we add two variables that we believe could represent general public's perception about the orientation of education of their countries: the variable that evaluates whether the education system meets the need of the economy and the variable that evaluates whether the university education meets the need of the economy.

As to the output variables, we choose three variables to evaluate education achievements of a country: literacy rate of the adult over 15 years old (*Literacy*), the percentage of population that has attained at least tertiary education for persons aged 25 to 34 (*Higher Education*), and a variable that evaluates whether qualified engineers are available in the labor market of a country (*Qualified Engineers*).

The reason of choosing the three output variables is quite straight forward. So in the following paragraphs, we only introduce the arguments and findings in the literature regard the four input variables.

As we mentioned in the above section, the effect of government spending on education achievement is ambiguous. In Hanushek & Somers [16], the authors say that "(I)n the context of government interventions, it is natural to concentrate on government spending as the measure of quality. Nonetheless, past work has suggested that governmental spending is not very closely related to quality (Hanushek [14], [15])". However, the other party of this debate finds evidences that governments increase expenditures on education to reduce class size and pupil-teacher ratio, which in turn, has a positive effect in improving student performance (Krueger [17], [18]). Since the facts of the debates come from only US data, to be more conservative about the effect of this variable, we take it (*Expenditure*) as one of the input variables of our education production function.

The second input variable is pupil-teacher ratio. Actually, reduced pupil-teacher ratio is the result of governments' education policy, which makes the effect of this ratio part of the debate above. For the same reason, we still put pupil-teacher ratio in our input variable pool.[2]

To achieve the objects that human capital could be enhanced and income distribution could be equalized, the government has to not only invest more money in education system, but to navigate the system to the correct direction to achieve the goals. Therefore, except the two variables about spending, namely government expenditure and pupil-teacher ratio, we employ two other variables that could evaluate whether the education system and university education meets the needs of the economy: *Education System*, *University Education*. Data of these two variables come from surveys that will be discussed in the following section.

Table 1 is the summary of the input and output variables in our education production function. Due to data availability, we have two evaluations for pupil-teacher ratio, one for primary education (*PT ratio* 1), and another for secondary education (*PT ratio* 2).

The purpose of this model is to evaluate the educational performance and intensity of OECD countries in order to provide an additional measure of how efficiently OECD countries are operated. There are five inputs and three outputs for this model. In this research, OECD countries employ the five inputs: *Expenditure*, *PT ratio 1*, *PT ratio 2*, *Educational system*, and *University education*, which produce the outputs: *Literacy*, *Higher Education*, and *Qualified Engineers*. Table 1 shows the definition of the input and output statistics that were used to construct the DEA models. Constructing the models allowed us to investigate the relative efficiency scores for OECD countries. The above three inputs have generally been used throughout the literature. Identifying the output of productive activities in general and OECD countries in particular, presents difficulties for cost measurement and also production performance.

Table 1
Input-Output Variables

Input variables:	Output variables:
1. Total public expenditure on education (*Expenditure*): Percentage of GDP	6. *Literacy*: Adult (over 15 years) illiteracy rate as a percentage of population
2. Pupil-teacher ratio (primary education, *PT ratio* 1): Ratio of students to teaching staff	7. Higher education achievement (*Higher Education*): Percentage of population that has attained at least tertiary education for persons 25-34
3. Pupil-teacher ratio (secondary education, *PT ratio* 2): Ratio of students to teaching staff	8. *Qualified engineers*: Qualified engineers are (not) available in your labor market
4. *Educational system*: Whether the education meets the needs of a competitive economy?	
5. *University education*: Whether the university education meets the needs of a competitive economy?	

3. Econometric Model (DEA)

This section introduces DEA. Farrell[11] introduced a framework for efficiency evaluation and measurement, which was subsequently studied by Charnes et al [7], Banker et al. [2] etc. The development of linear programming approach is known as data envelopment analysis. The DEA model assumes that the random error is zero so that all unexplained variations can be treated as reflecting inefficiencies. The linear programming approach is flexible. It can measure input or output efficiency under the assumption of various types of constant returns to scale (CRS) and variable returns to scale (VRS).

Figure 1 shows the relationship between the CCR model and BCC model using a single input-single output scenario. The constant returns to scale envelopment surface (the CCR model) must pass through the origin and is, therefore, less restrictive than the envelopment surface of the BCC model. The BCC model reduces the size of the feasible production region by enveloping the data more tightly, and as expected, the number of efficient Decision Marking Units (DMUs) declared efficient increases as do the overall efficiency scores. It should be noted that constant returns to scale may exist in a data set if the frontier formed using the BCC model follows the same frontier formed by the CCR model. DEA is a non-parametric linear programming technique used to compare input and output data of production units, DMUs, with input and output data of other similar DMUs. It is a technique used to measure and evaluate the relative performance of production units. DEA is commonly used to evaluate the efficiency of a number of producers. A typical statistical approach is characterized as a central tendency approach and it evaluates producers relative to an average producer. In contrast, DEA is an extreme point method and compares each producer with only the "best" producers.

The development of DEA methodology stems from the usual measure of productivity, a ratio of outputs to inputs. The formulation of a relative efficiency measure, or the ratio of weighted outputs to weighted inputs, was introduced to account for the existence of multiple inputs and multiple outputs.

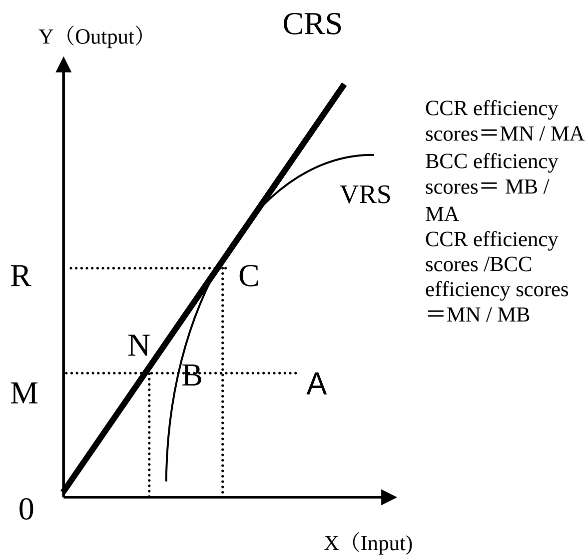

Fig. 1 Envelopment surfaces

In the following sub-sections, we briefly introduce the models that we will use in section 4, the CCR, BCC, SBM, and FDH models.

3.1 CCR model

For any special DMUs , the CCR model with constant return to scale can be formulated as follows to obtain a score of technical efficiency:

Maximize

$$w_0 = \sum_r u_r y_{rj_0} , \qquad (1)$$

Subject to

$$\sum_i v_i x_{ij_0} = 1;$$
$$\sum_r u_r y_{rj} - \sum_i v_i x_{ij} \le 0,\ j = 1, \cdots, n;$$
$$u_r \ge \varepsilon,\ r = 1, \cdots, s;$$
$$v_i \ge \varepsilon,\ i = 1, \cdots, m,$$

where m is the number of inputs, and s is the number of outputs.

Using the duality in linear programming, we can derive an equivalent envelopment form for this problem. The envelopment form involves fewer constraints than the CCR formulation and is, thus, preferred for programming.

The dual can be formulated for any linear programming problem and can prove to be particularly useful to solve it. The dual of the multiplier problem is the envelopment problem. The envelopment problem is often solved rather than the multiplier problem since it does not have nearly as many constraints as the multiplier form. The number of constraints in the multiplier form is equal to the number of DMUs plus one, (n + 1), the additional constraints that the sum of the inputs equal to a constant or one.

The dual model is constructed by assigning a dual variable to each constraint in the primal problem. The following model is the envelopment form of the CCR model (input-orientation):

Minimize

$$z_0 = \theta - \varepsilon \sum_i s_i^- - \varepsilon \sum_r s_r^+ , \qquad (2)$$

Subject to

$$\theta_{ij_0} - s_i^- - \sum_j x_{ij}\lambda_j = 0, i = 1,...,m,$$

$$-s_r^+ + \sum_j y_{rj}\lambda_j = y_{rj_0}, r = 1,...,s,$$

$$s_i^-, s_r^+, \lambda_j \geq 0,$$

where z_0 unconstrained, m is the number of inputs, and s is the number of outputs.

The number of constraints in the envelopment form is reduced to the sum of the inputs and outputs. A unit is efficient only if w^*_0 and z^*_0 are equal to 1. In other words, if the optimal values θ^* for a unit is equal to 1, and the slack variables s^-_i and s^+_r are both equal to 0, then a unit is considered to be efficient. The dual variables are identical to the shadow prices in the multiplier form; therefore, the λ_j's are the shadow prices related to the constraints that limit the efficiency of each unit to be no greater than 1. In the multiplier, or primal, problem, if a constraint is binding, the shadow price will be positive, and when the constraint is non-binding, the shadow price will be 0. A positive shadow price in the primal or a positive value for the λ_j's in the dual identify the inefficiency unit's peer group or the reference set.

The CCR model described above is limited to the following three restrictions: (1) constant returns to scales, (2) strong disposability of inputs and outputs, and (3) convexity of the set of feasible input-output combinations. Each restriction can be relaxed although the constant returns to scale restriction is most often relaxed. By relaxing the constant returns to scale constraint, we can achieve discrimination between departures due to pure technical inefficiency or to scale inefficiency can be made.

3.2 BCC model

The BCC model was developed by relaxing the CCR model or the constant returns to scale assumption on the envelopment surface. The constraint $\Sigma_j\lambda_j = 1$ is added to the above mathematical formulation of the CCR model. Because the constant returns to scale constraint is relaxed, the facets forming the envelopment surface are no longer forced to pass through the origin. As a result, projected points for inefficiency units are determined as convex combinations of efficient units rather than as linear combinations, as is the case with constant returns to scale envelopment surface. The following model is the envelopment form of the BCC model (input orientation):

Minimize

$$z_0 = \theta_B - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right),$$

Subject to

$$\theta_B X_{io} = \sum_{j=1}^{n} X_{ij}\lambda_j + s_i^-,\ i = 1, \ldots, m;$$

$$Y_{ro} = \sum_{j=1}^{n} Y_{rj}\lambda_j - s_r^+,\ r = 1, \ldots, s;$$

$$\sum_{j=1}^{n}\lambda_j = 1,\ s_i^-,\ s_r^+,\ \lambda_j \geq 0,$$

where z_0 is unconstrained, m is the number of inputs, and s is the number of outputs.

3.3 SBM model

Tone [21] has proposed a slacks-based measure, which is non-radial and deals with input/output slacks directly. The SBM returns an efficiency measure between 0 and 1, and gives unity if and only if the DMU concerned is on the frontiers of the production possibility set with no input/output slacks.

In order to estimate the efficiency of a DMU (x_0, y_0),we formulate the following fractional program in λ, s^- and s^+:

Minimize

$$\rho = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{i0}}{1 + \frac{1}{s}\sum_{r=1}^{s} s_r^+ / y_{r0}} \qquad (4)$$

Subject to

$$x_0 = X\lambda + s^-$$

$$y_0 = Y\lambda + s^-$$

$$\lambda \geq 0, s^- \geq 0, s^+ \geq 0.$$

In this model, we assume that $X \geq 0$. If $x_{i0} = 0$, then we delete the term s^-_i / s_{i0} in the objective function. If $y_{i0} \leq 0$, then we replace it with a very small positive number so that the term s^+_r / y_{r0} plays the role of a penalty.

3.4 FDH model

The purpose of FDH is to measure and evaluate the performance of a producer. FDH is a mathematical programming technique, developed by Deprins, Simar & Tulkens [10]. FDH generalizes the more commonly used data envelopment analysis technique by relaxing the convexity assumption of the latter. The following model is the equation form of the FDH. Let $Y_0 = \{(x^k, u^k) \mid x^k \in R^I_+, u^k \in R^J_-, k = 1, 2, \dots, n\} \cup \{(O^I, O^J)\}$ denote a set of n actually observed production plans, to which the origin of the input-output space is added by convention (O^I and O^J are the I- and J-dimensional null vectors); for the sake of brevity, we call Y_0 the observations set or the data set. Also let $Y(Y_0)$ denote a reference production set constructed from Y_0. Then, a FDH reference production set (Y_{FDH}) constructed from Y_0 can be written as follows:

$$Y_{FDH}(Y_0) = \left\{ \begin{bmatrix} u \\ x \end{bmatrix} \in R_+^{I+J} \begin{bmatrix} u^h \\ x^h \end{bmatrix} + \sum_{i=1}^{I} u_i \begin{bmatrix} o^J \\ e_i^J \end{bmatrix} - \sum_{i=1}^{J} v_j \begin{bmatrix} e_j^J \\ o^I \end{bmatrix}, (x^h, u^h) \in Y_0; u_i \geq 0; \right.$$
$$\left. v_j \geq 0,\ i = 1, 2, \dots, I;\ j = 1, 2, \dots, J \right\}, \quad (5)$$

where e^I_i denotes an I-dimensional zero vector with the ith component equal to 1, and similarly, e^J_j denotes a J-dimensional zero vector with the jth component equal to 1.

4. Data source and empirical results

In this section, we first explain the sources of our data, and then in sub-sections 4.2 to 4.6, we explain the results of our empirical findings.

4.1 Data sources

Our sample contains thirty OECD countries in 2003. This is the latest data set we could obtain when writing this paper. Data for all the eight input and output variables come from the *World Competitiveness Yearbook* [20] (WCY). Among the eight variables, data for three (*Education System*, *University Education*, and *Qualified Engineers*) of them are from survey. The questions asked, respectively, are: whether the education system meets the needs of a competitive economy? Whether the university education meets the needs of a competitive economy? And are qualified engineers (not) available in your labor market? The surveys are conducted by the International Institute for Management Development. The respondents of the survey are executives in top-and-middle management in all the countries covered by the WCY. The score of each country is the average value (transformation from 1-6 scale to a 1-10 scale) of respondents' rating for their respective countries. Data of the rest five variables (*PT ratio* 1, *PT ratio* 2, *Expenditure*, *Literacy*, and *Higher Education*) are real data.

4.2 Correlation analysis

Table 2 shows the Pearson correlation coefficients for several of these variables. The main findings can be summarized as follows. These are highly positive correlation coefficients, and they indicate that there is a strong relationship between input and output. The correlation analysis results show the positive relationship between the input and output variables examined in this study.

Table 2
Pearson correlation analysis

	1	2	3	4	5	6	7	8
1	1	0.111	0.023	0.566	0.623	0.245	0.355	0.269
2		1	0.158	0.136	0.062	0.167	0.728	0.380
3			1	0.261	0.139	0.211	0.109	0.260
4				1	0.936	0.629	0.438	0.302
5					1	0.618	0.334	0.261
6						1	0.097	0.136
7							1	0.392
8								1

Table 3 shows the Pearson correlation coefficients for several of these DEA models, including CCR, BCC, SBM and FDH. The correlation analysis results show a positive relationship among the DEA models investigated in this study.

Table 3
Correlation analysis of DEA models

	CCR	BCC	SBM	FDH
CCR	1			
BCC	0.81**	1		
SBM	0.94**	0.70**	1	
FDH	0.54**	0.64**	0.48**	1

Note: * indicates significant at the 0.01 level.
** indicates significant at the 0.05 level.
*** indicates significant at the 0.1 level.

4.3 Efficiency analysis

DEA results in each unit being allocated an efficiency score. This score is between zero and 1. A unit with a score of 1 is relatively efficient. Any unit with a score of less than 1 is relatively inefficient. The efficiency score obtained by a unit will vary depending on the other units and factors included in the analysis. Scores are relative, not absolute - they are relative to the other units in the data set. In this research, the analysis models of DEA included CCR, BCC, SBM, and FDH. DEA provides a comprehensive evaluation of overall performance. The results for each DEA model are shown in Table 4.

Table 4
Efficiency scores of DEA models for OECD countries

OECD Countries	CCR Efficiency	BCC Efficiency	Scale Efficiency	SBM Efficiency	FDH Efficiency
Australia	0.5292	0.7282	0.726723	0.5183	1
Austria	0.5464	0.6463	0.845428	0.5256	1
Belgium	0.5645	0.5799	0.973444	0.4999	0.8903
Canada	0.5160	1	0.516	0.4832	1
Czech Republic	0.5971	0.6659	0.896681	0.5875	0.9094
Denmark	1	1	1	1	1
Finland	0.5614	1	0.5614	0.5497	1
France	0.6123	1	0.6123	0.6030	1
Germany	1	1	1	1	1
Greece	0.8643	0.8656	0.998498	0.8508	1
Hungary	0.5942	0.6511	0.912609	0.5839	0.9725
Iceland	0.5463	0.7876	0.693626	0.5350	1
Ireland	0.6446	1	0.6446	0.5163	1
Italy	0.6979	0.7740	0.90168	0.6770	0.8300
Japan	1	1	1	1	1
Korea	0.8416	0.8796	0.956799	0.7724	0.9889
Luxembourg	0.5366	0.6931	0.774203	0.5079	0.8984
Mexico	0.7404	0.7953	0.930969	0.6950	0.9325
Netherlands	0.4406	0.6162	0.715028	0.4138	1
New Zealand	0.4453	1	0.4453	0.4300	1
Norway	0.5493	1	0.5493	0.5377	1
Poland	0.7253	0.7734	0.937807	0.6604	1
Portugal	0.6773	0.8145	0.831553	0.6218	0.9021
Slovak Republic	0.7399	0.8263	0.895437	0.7259	1
Spain	0.7146	0.7409	0.964503	0.6993	1
Sweden	1	1	1	1	1
Switzerland	0.5159	1	0.5159	0.5066	0.9143
Turkey	0.8643	0.9189	0.940581	0.8294	1
U.K	1	1	1	1	1
USA	1	1	1	1	1

Table 4 presents the CCR efficiency scores under constant returns-to-scale, BCC technical efficiency scores, scale efficiency scores, slacks-based measure efficiency scores, and FDH efficiency scores. The main findings can be summarized as follows. The CCR efficiency score analysis results show that 6 countries (i.e., USA, U.K, Sweden, Japan, Germany, and Denmark) are relatively efficient, based on the same scale efficiency scores and SBM efficiency scores. Their efficiency scores are all equal to 1. This shows that resource utilization for these countries is excellent. On the other hand, 24 countries were found to be inefficient because their efficiency scores were less than 1.

Of the 30 OECD countries, 13 countries (Canada, Denmark, Finland, France, Germany, Ireland, Japan, New Zealand, Norway, Sweden, Switzerland, U.K, and USA) have BCC efficiency scores equal to 1. This can be interpreted as indicating that the CCR inefficiency scores can be mainly attributed to disadvantageous conditions.

Another model which has received a considerable amount of research attention is FDH.

The FDH results show that of the 30 countries, 21 countries are efficient. These results cannot distinguish efficient OECD countries from inefficient programs correctly, compared with the CCR, BCC and SBM models.

4.4 Reference Set Analysis

The reference set of an inefficient unit is the set of efficient units to which the inefficient unit has been most directly compared when calculating its efficiency rating. It contains the efficient units that have the most similar input/output orientation to the inefficient unit and should therefore provide examples of good operating practice for the inefficient unit to emulate. The reference set and their frequencies for the 30 OECD countries are given in Table 5. The most frequent reference country was found to be USA of CCR model. The results also show that U.K, Sweden, Japan, Germany, and Denmark are efficient and are in the reference set of all of the other OECD countries.

Table 5
Reference Set Analysis and Returns to Scale for OECD countries

OECD Countries	CCR Efficiency	Reference Set	Ranking	Frequency in Reference Set	Returns to Scale
Australia	0.5292	USA U.K	27	0	IRS
Austria	0.5464	USA U.K	24	0	IRS
Belgium	0.5645	USA U.K Japan	23	0	IRS
Canada	0.7160	USA U.K	14	0	DRS
Czech Republic	0.5971	USA U.K Germany	21	0	IRS
Denmark	1	Denmark	5	3	CRS
Finland	0.7614	USA U.K Germany	7	0	DRS
France	0.7123	USA U.K Germany	16	0	IRS
Germany	1	Germany	3	6	CRS
Greece	0.4643	USA U.K	29	0	IRS
Hungary	0.5942	USA U.K	22	0	IRS
Iceland	0.7463	USA U.K Germany	9	0	IRS
Ireland	0.7446	USA U.K Denmark	10	0	IRS
Italy	0.6979	USA U.K Germany	17	0	IRS
Japan	1	Japan	4	4	CRS
Korea	0.5416	USA U.K Japan	25	0	IRS
Luxembourg	0.5366	USA U.K	26	0	IRS
Mexico	0.4404	USA	30	0	IRS
Netherlands	0.7406	USA U.K	12	0	IRS
New Zealand	0.7453	U.K	11	0	IRS
Norway	0.7493	USA U.K Denmark	8	0	DRS
Poland	0.6253	USA U.K Germany	19	0	IRS
Portugal	0.6773	USA	18	0	IRS
Slovak Republic	0.7399	USA U.K	13	0	IRS
Spain	0.6146	USA U.K	20	0	IRS
Sweden	1	Sweden	6	1	CRS
Switzerland	0.7159	USA U.K	15	0	DRS
Turkey	0.4643	USA U.K Japan	28	0	IRS
U.K	1	U.K	2	23	CRS
USA	1	USA	1	24	CRS

4.5 Returns to scale and most productive scale size

We will discuss the returns to scale of the 30 OECD countries in this section. Let (x_0, y_0) be a point on the efficient frontier. If we employ a CCR model in envelopment form to obtain on optimal solution (λ^*_1, …, λ^*_n), then the returns to scale at this point can be determined based on the following conditions (Cooper et al.,2000).

(I) If $\sum_{j=1}^{n} \lambda_j^* = 1$ in any alternate optimum, then constant returns-to-scale prevails.

(II) If $\sum_{j=1}^{n} \lambda_j^* > 1$ in any alternate optimum, then decreasing returns-to-scale prevails.

(III) If $\sum_{j=1}^{n} \lambda_j^* < 1$ in any alternate optimum, then increasing returns-to-scale prevails.

Then, a DMU found to be efficient for a CCR model will also be found to be efficient for the corresponding BCC models, and constant returns-to-scale means that DMU_0 is the most productive scale size (Ahn, Charnes & Cooper; [1]).

Of the 30 OECD countries investigated in this study, 6 countries showed constant returns-to-scale, 20 countries showed increasing returns-to-scale, 4 countries showed decreasing returns-to-scale. When a country exhibits increasing returns-to-scale ($\sum_{j=1}^{n} \lambda_j^* < 1$), it is likely that the country can improve its performance by increasing its size. On the other hand, when a country exhibits decreasing return-to-scale ($\sum_{j=1}^{n} \lambda_j^* > 1$), it is likely that the country can improve its performance by decreasing its size. Table 5 shows that the USA, U.K, Sweden, Japan, Germany, and Denmark have the most productive scale sizes.

4.6 Slack variable analysis

Slack represents the under production of output or the over use of input. It represents the improvements needed to make an inefficient unit become efficient. These improvements are in the form of an increase/decrease in inputs or outputs. The next step of interest is estimating how much the outputs could be increased or inefficient countries could conserve the inputs. These mean additional decreases in inputs could enable a country to operate as well as efficient countries, and increases in output could be achieved through lower levels of inputs. Table 6 shows the results of slack analysis for 30 countries. More detailed insights can be found from slack analysis at the individual country level. In this study, it was found that all the inefficient countries could improve their performance by decreasing their inputs. For example, Australia should be able to become efficient if the *Literacy* is increased to 34.775, higher education achievement is increased to 15.86 of the existing level. The results show the existence of a great amount of slack for this country and the need for it to utilize its resources more efficiently.

Table 6
Slack variable analysis

OECD Countries	*Literacy*	*Higher education*	*Qualified Engineers*
Australia	34.775	15.86	0
Austria	11.877	32.28	0
Belgium	0	10.34	0.11
Canada	13.877	22.28	0.1
Czech Republic	31.26	40.48	0
Denmark	0	0	0
Finland	12.46	8.97	0
France	26.60	19.68	0
Germany	0	0	0
Greece	30.01	19.70	0.31
Hungary	16.30	20.75	0
Iceland	18.73	23.53	0
Ireland	14.775	15.84	0.13
Italy	20.867	12.28	0.11
Japan	0	0	0
Korea	16.30	20.35	0.14
Luxembourg	8.73	13.53	0.34
Mexico	34.775	35.84	0.13
Netherlands	10.867	12.28	0.11
New Zealand	8.30	20.75	0.32

Norway	8.73	3.53	0.21
Poland	20.775	12.84	0.13
Portugal	19.867	18.28	0.11
Slovak Republic	17.30	20.75	0.34
Spain	8.73	23.53	0.32
Sweden	0	0	0.21
Switzerland	16.30	10.75	0.23
Turkey	48.73	33.53	0.45
U.K	0	0	0
USA	0	0	0

5. Conclusion

In this study, we have used nonparametric DEA methods to analyze the educational efficiency of all OECD countries. As items for measuring efficiency we have used *Expenditure*, *PT ratio 1*, *PT ratio 2*, *Educational System*, and *University Education* as inputs, and *Literacy*, *Higher Education*, and *Qualified Engineers* as outputs. The main findings can be summarized as follows.

The CCR efficiency score analysis results show that 6 countries are relatively efficient, and the results were scale efficiency and SBM efficiency. The results of FDH analysis cannot distinguish between efficient and inefficient countries correctly, compared with the CCR, BCC and SBM models. Of the 30 OECD countries investigated in this study, 6 countries exhibit constant returns-to-scale, 20 countries exhibit increasing returns-to-scale, and 4 countries exhibit decreasing returns-to-scale. These countries can improve their performance by increasing their size. Finally, of the 30 OECD countries, 6 are the most productive scale sizes. The results of this study highlight the importance of the inputs and outputs used to determine relative efficiency.

Throughout the study, special emphasis has been placed on quantifying and discussing the impact of model choice on the results. For this purpose, we have also introduced a framework for model comparison and used several simple techniques to analyze the results. The results of this research can help those involved in managing these programs understand their relative operating performance and, therefore, respond by appropriately regulating the levels of the input and output items.

Notes:

1. OECD now has 30 member countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and the United States.
2. Both reduced class size and pupil-teacher ratio are the results of education policy. In some studies, for example, Krueger [17], the authors do not differentiate between these two variables. Boozer and Rouse [5] examine the relation between these two variables. The authors find that the correlation is 0.13 in the New Jersey Survey data and 0.26 in the NELS (National Education Longitudinal Survey of 1988). In addition, the empirical results using these two variables separately are different.

References

[1] Ahn, T., Charnes, T., & Cooper, W. W. (1989). A note on the efficiency characterizations obtained in different DEA models. *Socio-Economic Planning Sciences* 22, 253-257.

[2]Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in Data Envelopment Analysis. *Management Science*, 30 (9), 1078-1092.

[3]Banker, R. D., Janakiraman, S., & Natarajan, R. (2004). Analysis of trends in technical and allocative efficiency: An application to Texas public school districts. *European Journal of Operational Research*, 154, 477-491.

[4]Bifulco, R. & Bretschneider, S. (2003). Response to comment on estimating school efficiency. *Economics of Education Review*, 22, 635-638.

[5]Boozer, M. & Rouse, C. (2001). Intraschool variation in class size: patterns and implications. *Journal of Urban Economics*, 50(1), 163-89.

[6]Caballero, R., Galache, T., Gomez, T., Molina, J. & Torrico, A. (2004). Budget allocations and efficiency in the human resources policy

of a university following multiple criteria. *Economics of Education Review*, 23, 67-74.
[7]Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2 (1), 95-112.
[8]Colbert, A., Levary, R. R., & Shaner, M. C. (2000). Determining the efficiency of MBA programs using DEA. *European Journal of Operational Research*, 125, 656-669.
[9]Cooper, W. W., Seiford, L. M. and Tone, K. （2000）. Data envelopment analysis: A comprehensive text with models, application, references and DEA-Solver software. Boston: Kluwer Academic Publishers.
[10]Deprins, D., Simar, I., & Tulkens, H. (1984). Measuring labor efficiency in post offices. In: M. Marchand, P. Pestienu, & H. Tulkens, *The Performance of Public Enterprises: Concepts and Measurement,* (pp. 243-267), Amsterdam: North-Holland.
[11]Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of The Royal Statistical Society*, 120 (3), 253-281.
[12]Grosskopf, S., & Moutray, C. (2001). Evaluating performance in Chicago public high schools in the wake of decentralization. *Economics of Education Review*, 20, 1-14.
[13]Hanushek, E.A. (2001). Spending on schools. In: T. Moe & W. Evers, *A Primer on American Education* (pp.69-88). Stanford: Hoover Institution Press.
[14]Hanushek, E.A. (1986). The Economics of schooling: production and efficiency in public schools. *Journal of Economic Literature*, 24(3), 1141-77.
[15]Hanushek, E.A. (1997). Assessing the effects of school resources on student performance: an update. *Educational Evaluation and Policy Analysis*, 19(2), 141-64.
[16]Hanushek, E.A., & Somers, J.A. (2001). Schooling, inequality, and the impact of government. In: F. Welch, *The Causes and Consequences of Increasing Inequality* (pp. 169-199). Chicago: University of Chicago Press.
[17]Krueger, A.B. (2003). Economic considerations and class size. *Economic Journal*, 113 (485), F34-63.
[18]Krueger, A.B. (1999). Experimental estimates of education production function. *Quarterly Journal of Economics*, 114(2), 497-532.
[19]Sinusny-Stern, Z., Mehrez, A., & Barboy, A. (1994). Academic departments' efficiency via DEA. *Computers and Operations Research*, 21, 543-556.
[20]*The World Competitiveness Yearbook 2003*, Switzerland: International Institute for Management Development.
[21]Tone, K. (2001). A Slack-based measure of efficiency in data envelopment analysis. *European Journal of Operational Research*, 130 (3), 498-509.