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Economic efficiency of public secondary education expenditure: how different are developed and developing countries?

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Abstract

This study measures the efficiency of public secondary education expenditure in 35 developing and developed countries using a two-step semi-parametric DEA (data envelopment analysis) methodology. First, we implement two cross-country frontier models for the 2009-2012 period: one using a physical input (i.e., teacher-pupil ratio) and one using a monetary input (i.e., government expenditure per secondary student). These results are corrected by the effects of GDP per capita and adult educational attainment as non-discretionary inputs. We obtain four important results: (i) developed and developing countries have the same education production processes when they are compared using physical inputs but not when compared using monetary inputs; (ii) developing countries could increase their enrollment rates and PISA scores by approximately 9% and 5%, respectively, by maintaining the same teacher-pupil ratios and public spending levels as developed countries; (iii) Ireland, Japan and Korea are efficient countries in the two frontier models (Colombia is also included in this category when the teacher-pupil ratio is used as input); and (iv) robust empirical evidence indicates that both income and

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parental educational attainment positively affect the efficiency of public education in both models.

Keywords: Secondary education, government expenditure, efficiency, DEA.

JEL: H52, I22

I. Introduction

The difference between developed and developing countries in terms of student performance on international tests, such as PISA, is significant. Specifically, the mean score for high-income countries in 2009-2012 was 497, whereas the mean score for lower- and middle-income countries in the same period was 422. Similar results are obtained if we compare other indicators of the quality of the education system, such as enrollment rates (Table 1). These data have fostered intense political debates in developing countries (Colombia and Mexico provide examples of such discussions in recent years), which have been trying to improve their poor results to promote economic growth and social well-being (Gennaioli and Shleifer, 2013; Ben Mimoun, 2013).

Most discussions have focused on the importance of increasing public expenditure on education; but less attention has been paid to the issue of efficiency in the use of public expenditure. In fact, developed countries spend more than developing countries on secondary education as a percentage of GDP (5.59 *vs* 4.65, Table 1), however developing countries spend a higher percentage of their public budgets on education compared to developed countries (16.11 *vs* 12.56, Table 1). These data suggest that the significant expenditure of developing countries on education has not yielded improvements in student quality. Analysis of the efficiency of public spending is even more important if we consider the scarcity of public resources and the mounting pressure on governments to improve their allocation (Aristovnik, 2013 and Afonso, Schuknecht and Tanzi, 2010).

How different are developed and developing countries in terms of the efficiency of their public expenditure on education? Could differences in coverage and quality indicators be explained exclusively by the efficiency of public expenditure? The aim of our paper is to answer these questions. To this end, we implement two frontier models using DEA (data envelopment analysis) to assess the efficiency of education expenditure in 35 developed and developing countries during 2009-2012. To control for differences in the cost of inputs between the two groups of countries, we use a monetary input (government expenditure per secondary student) in the first model and a physical input (teacher-pupil ratio) in the second model. PISA results and enrollment rates are considered outputs of the production process in both models.

Table 1

Descriptive statistics by income group countries

Variable	Obs	Mean	Std. Dev.	Min	Max
High income					
Enrollment (%)	25	92.5	4.54	83.25	99.16
PISA	25	497.36	32.55	382.66	542.66
Teachers per 100 students	25	9.19	1.70	5.81	11.68
Government expenditure per secondary student (US$)	25	975745.4	382752.8	467250.1	1941545
Expenditure on education (% of total government expend.)	23	12.56	2.71	7.36	18.48
Public expenditure on education (% of GDP)	25	5.59	1.17	2.45	7.59
Lower and upper-middle income					
Enrollment (%)	10	77.35	9.02	65.96	91.49

PISA	10	422	33	375	486
Teachers per 100 students	10	7.04	2.07	3.78	10.37
Expenditure (US$)	10	240059.7	141404.4	72965.88	542095.6
Expenditure on education (% of total government expend.)	10	16.11	4.49	9.72	23.38
Public expenditure on education (% of GDP)	10	4.65	1.02	2.89	6.28

Source: Own calculations based on WDI and UNESCO databases.

The first novel contribution of this paper is that it compares the efficiency of developing and developed countries simultaneously, whereas most papers consider only one of these groups to control for possible heterogeneity between countries (for example, Afonso and Aubyn, 2006). The results indicate that is possible to compare both group of countries, especially when a physical input is considered.

Additionally, we correct our efficiency estimations for each country using income level and adult educational attainment, which are considered by the literature to be non-discretionary factors that can affect output. Specifically, we implement a second-stage approach using a truncated regression to isolate the effect of these variables on the outputs.

We obtain four important results: (i) developed and developing countries differ in terms of the education production process, especially when they are compared using monetary inputs; (ii) developing countries could increase their enrollment rates and PISA scores by approximately 9% and 5%, respectively, by maintaining the same teacher-pupil ratios and public spending levels ; (iii) Ireland, Japan and Korea are efficient countries in the two frontier models; and (iv) robust empirical evidence indicates that both income and parental educational attainment positively affect efficiency in both models.

The article is organized as follows. In Section II, we present a brief review of the literature. In Section III, we introduce the theoretical model and explain the second-stage semi-parametric methodology (DEA). In Section IV, we describe the data and certain stylized facts. In Section V, we discus the main empirical results, and we conclude in Section VI.

II. Literature review

Two approaches have been used to evaluate the efficiency of government expenditure on education. The first approach assesses the determinants of schooling quality across countries using cross-country regressions (for example, Fuchs and Woessmann, 2004 and Barro and Lee, 2001). The determinants of educational performance used in these studies include resources allocated to education (teachers per pupil or public expenditure) and other factors, such as parental income or education levels. The results imply that family inputs and school resources are key factors for improving educational performance.

The second approach studies the efficiency of public spending on education by comparing the resources spent with performance obtained through DEA and FHD analysis. Previous studies have analyzed the efficiency of the public sector in general (Afonso, Romero and Monsalve, 2013; Afonso, Schuknecht and Tanzi, 2006; Afonso, Schuknecht and Tanzi, 2005) or focused on specific sectors, such as health and education. Studies have also attempted to measure efficiency within each educational level to better focus public policies.

Almost all studies have focused their efficiency analyses on specific country groups owing to their homogeneity in terms of economic development[1]. For instance, Afonso & Aubyn (2006), Afonso, Schuknecht & Tanzi (2005) and Afonso & Aubyn (2004) analyze the efficiency of public expenditure exclusively for OECD countries. Afonso & Aubyn (2004) focus their discussion on the differences in efficiency score estimates based on whether inputs are measured in monetary or physical terms. In this manner, certain countries could appear very inefficient in monetary terms because they have higher costs than other countries but not in performance terms. Afonso *et al*. (2005) use an FDH methodology and conclude that countries with small governments have higher efficiency scores in terms of both inputs and outputs. Similarly, Sutherland *et al.* (2007) analyze efficiency in primary and secondary education using both second-stage DEA and stochastic frontier analysis. They expand on previous research by conducting an efficiency analysis at macro and micro levels within schools. Among their main results is evidence that at the national level, holding resources constant, PISA scores could increase by an average of 5% for OECD countries and by approximately 10% for the least efficient countries.

In addition to these studies, the works of Herrera and Pang (2005), Afonso and Aubyn (2006) and Afonso *et al.* (2013) use two-stage DEA methodology to estimate the effect of exogenous variables on national efficiency scores. Herrera and Pang (2005) undertake an efficiency comparison in education and health among 140 developing countries using DEA and FDH and find that the most inefficient countries could produce the same output levels with 50% less input. They also verify the statistical association between efficiency scores and certain exogenous variables, such as the share of wages in the total budget, the

1 According to Afonso & Aubyn (2004), the selection of OECD countries is based on the low heterogeneity within the sample given the countries' wealth and development levels.

share of total services that is publicly financed, urbanization level, income distribution, and the degree of external aid financing.

Afonso and Aubyn (2006) focus on 25 countries, almost all of which are OECD countries, and find that OECD countries could increase PISA scores by 11.6% with the same resources. In addition, they demonstrate that GDP per capita and parental education are significant variables that explain efficiency. Finally, Afonso *et al.* (2013) calculate the efficiency of the public sector in Latin America and the Caribbean. Using a Tobit analysis, they find that important determinants of relative efficiency in these countries include transparency, property rights, regulation and quality control. In general, these countries could increase their performance by 19% through efficient public spending.

Among recent studies, Salazar (2014) measures the efficiency of public spending on primary and secondary education in Latin American countries using both DEA and FDH. He finds that countries could increase enrollment rates and PISA scores by 10% and 6% (using DEA and FDH, respectively) through efficient public spending. Moreover, countries could obtain even greater benefits by using teacher-student ratios efficiently (11% and 9%, using DEA and FDA, respectively). Similarly, Aristovnik (2013) studies the efficiency of primary, secondary and tertiary education in Eastern European countries and new EU member countries and finds that the average country could increase secondary education outputs by nearly 7% through efficiency.

Finally, among studies that conduct regional and income group comparisons, Gupta & Verhoeven (2001) analyze the efficiency of public expenditure on education and health in 37 African countries, comparing them with each other and with Asian and Western Hemisphere countries. The authors also conduct an efficiency analysis between country groups to isolate the effect of economic development on government expenditure. Afonso, Schuknecht & Tanzi (2006) assess public sector efficiency, comparing new EU members with emerging markets. They find that Singapore, Thailand, Cyprus, Korea and Ireland define the efficiency frontier. The average output scores suggest that countries are delivering approximately 2/3 of the output that they could deliver if they were on the efficiency frontier. Using Tobit analysis, they find that security of property rights, per capita GDP, the competence of civil servants, and education levels affect expenditure efficiency.

In summary, as seen in previous literature, only few studies have tried to correct the estimated inefficiency scores including the effect of exogenous variables that are not under government control, using a semi-parametric DEA methodology in two stages.

III. Methodology

In this paper, we combine two strands of literature by estimating a semi-parametric model of the secondary education production process using a two-stage approach. Theoretically, the measure of efficiency is based on the education production function specified by Barro and Lee (2001):

$$y = G(w, f) + \varepsilon \qquad (1)$$

where educational achievement (y) depends on the physical and monetary resources used by schools (w) and on the student´s family characteristics (f). These characteristics are crucial for measuring students' educational performance because they affect not only the probability of enrollment, attendance and graduation rates but also students' learning outcomes. Usually, key variables such as income, parental education levels and father's occupation are used as non-governmental explanatory factors related to educational performance[2].

It is possible to estimate an envelopment frontier based on the inputs and outputs of each country. This frontier can be used as reference to classify countries as efficient or inefficient based on their respective distances from the estimated efficiency frontier. The literature uses parametric and non-parametric methods to estimate this frontier. In the parametric approach, the researcher must specify the functional form of the efficiency frontier, that is, he must establish a previous relationship between inputs and outputs. In the non-parametric approach, the efficiency frontier is obtained using input and output data following an optimization program without any specification for the production function. It is then possible to compare the results for each decision-making unit (DMU) (in our case, each country) included in the analysis (Aristovnik, 2013).

Following the previous literature, we use the non-parametric approach – specifically, the DEA methodology – to assess the efficiency of government expenditure[3] (for example, Salazar, 2014; Aristovnik, 2013; Afonso *et al.*, 2013; Afonso *et al.*, 2010; Afonso and Aubyn, 2006; Sutherland, Price, Joumard and Nicq, 2007). The objective of this technique is to classify DMUs as efficient or inefficient by calculating their efficiency scores, which represent their respective distances from the production point of the DMU at the PPF (production possibility frontier). The efficiency scores are bounded between 0 and 1 for the input-oriented approach and between 1 and infinity for the output-oriented

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2 This specification could suffer from endogeneity problems due to interactions between school inputs and outcomes. However, this problem is less severe in cross-country data than in cross-region data, because the mobility of individuals, given the school quality, is easier within a country than across countries (Barro and Lee, 2001).

3 Another available non-parametric technique is the FDH (free disposal hull). However, the use of this technique in the literature is limited because it is cannot be used in a multi-input and multi-output framework. See, for example, Aubyn (2003), who measures the efficiency of education and health in the Portuguese economy.

approach. We can interpret these scoresas how muchinputs (outputs) could decrease (increase) while keeping outputs (inputs) constant to reach the efficient frontier.

The DEA model is specified as the following optimization problem (Charnes, Cooper and Rhones, 1978):

$Max_{x\lambda,\delta_i}\delta_i$

s.t $\delta_i \; y_i \leq Y\lambda$

$x_i \leq X\lambda$

$n1'\lambda = 1$

$\lambda \geq 0$ (2)

where X is the vector of inputs, Y is the vector of outputs, and λ is a vector of constants that correspond to the weights of the peer countries (that is, those that are more efficient than the inefficient DMUs to be analyzed) to be used to calculate a country's location and the best method for it to became efficient. Additionally, the $n1'\lambda = 1$ constraint imposes convexity on the frontier with variable returns to scale. This program is solved for the n DMUs included in the analysis to estimate the output efficiency scores (δ_i). When $\delta_i > 1$, the DMU is inside the frontier, meaning that it is inefficient. Conversely, when $\delta_i = 1$, the DMU is efficient.

One of the main advantages of the DEA method is that it can be applied in multi-input and multi-output frameworks. However, this methodology cannot treat environmental (or exogenous) variables, which may influence the production process but are out of the manager's control. To overcome this problem, multi-stage methods have been developed to capture the effect of non-discretionary variables in the DEA analysis and to correct the efficiency scores calculated in the first stage.

Although several studies have tried to determine the best method to correct this problem, the results are inconclusive (for example, Cordero, Pedraja and Santin, 2009; Huguenin, 2015). We opted to use the second-stage model because it is the most widely used model in studies on education expenditure efficiency that use cross-country data. Specifically, we implement the approach proposed by Simar and Wilson (2007), which allows correcting for serial correlation among the estimated efficiency scores. This strategy entails correcting the error correlation problem using bootstrap methods to obtain consistent and unbiased estimates for the regression parameters.

To implement the second-stage approach, we estimate a semi-parametric model of the education production process that includes income and adult educational attainment as external factors affecting educational performance (z_i). The estimated regression is as follows:

$$\hat{\delta}_i = z_i\beta + \varepsilon_i \qquad (3)$$

Figure 1 shows the estimated efficiency scores with and without environmental variables. All efficiency scores within the PPF are greater than 1; those on the PPF are equal to one. Certain countries can be independently efficient if no other DMU uses less input and has a greater output. With one input and one output, we see that countries such as A, B and C are efficient. However, the inefficiency of country D could be attributable to a harsh environment. For example, if D's environment improves, D's efficiency score would improve to the point Dc. The correction given by the exogenous factors is calculated as the efficiency score in Dc minus the efficiency score in D.

After measuring the efficiency scores for all DMUs in the sample ($\hat{\delta}_i$) in the first stage, we regress the estimated scores against the selected non-discretionary or environmental variables. The regression of estimated efficiency scores ($\hat{\delta}_i$) on external variables with bootstrapping is as follows:

$$\hat{\delta}_i = \psi(z_i\beta) + \varepsilon_i \geq 1 \qquad (3)$$

where ψ is a smooth function, β is the vector of parameters, and ε_i is a truncated normal random variable with $N(0, \sigma_\varepsilon^2)$ distribution and left truncation at $(1 - z_i\beta)$.

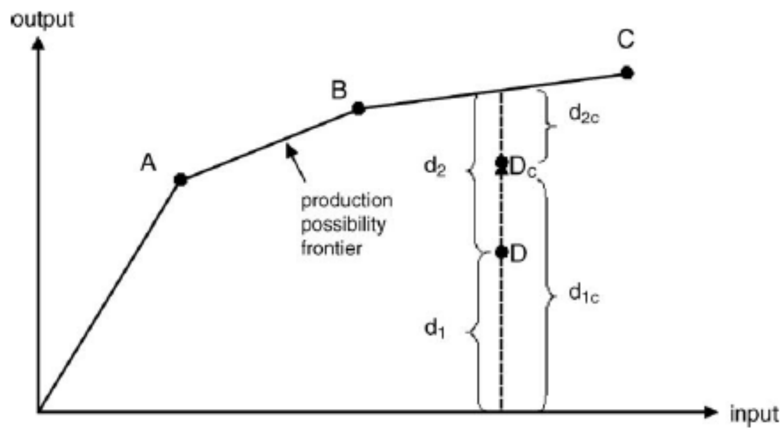
Most studies that employ second-stage approaches use censored (Tobit) and OLS regression models after estimating δ_i in the first stage, thereby omitting the bias of efficiency scores calculated in the first stage due to the serial correlation of ε_i and the correlation of X_i and Y_i with Z_i. Thus, the error ε_i is correlated with Z_i[4].

Simar and Wilson (2007) propose a single and double bootstrap procedure to avoid serial correlation among the estimated efficiencies. The first algorithm improves the inference but does not take into account the bias term. In contrast, the second algorithm improves both the inference and the bias. Therefore, we use the bootstrap method to estimate efficiency scores with environmental variables following subsequent steps (consult Simar and Wilson, 2007, pp. 42-43 for details).

Figure 1

Production frontier with non-discretionary inputs

4 The related papers are Afonso et al. (2013), Afonso et al. (2010) and Herrera et al. (2005).



Source: Afonso and Aubyn (2006, pp. 481).

IV. Descriptive statistics: data and stylized facts

The data compiled in this study cover 35 countries (Table 3). The composition and size of the sample were determined based on the availability of data needed to compute efficiency scores. The descriptive statistics for the variables included in this study are listed in Table A.3 in the appendix.

Efficiency scores are calculated using alternative measures for inputs and outputs. The teacher-pupil ratio and government expenditure per student (in 2011 international dollars converted using purchasing power parity, PPP) are used as input variables.[5] For outputs, we consider two different variables related to the performance of secondary education systems: enrollment rates and performance on the PISA reading, mathematics and science literacy scales in 2012.[6] We use PISA data because PISA assesses 15-year-old children,

5 There is scant availability of other data, such as teacher salaries and education levels, length of the school year, and availability of teaching materials. However, teacher salaries and instructional materials account for a major portion of educational expenditure per student. (Barro and Lee, 2001).

6 To simplify, we use the simple average of the three scores for each country.

who (based on their age) are approaching the end of the compulsory schooling period. For environmental variables, we use GDP per capita and parental education.

Table 3

Countries by income group

High income: OECD	*High income: nonOECD*
Australia	Cyprus
Estonia	Latvia
Finland	Lithuania
France	Qatar
Iceland	
Ireland	*Upper-middle income*
Israel	Bulgaria
Italy	Colombia
Japan	Costa Rica
Korea, Rep.	Hungary
Luxembourg	Malaysia
Netherlands	Mexico
New Zealand	Peru
Norway	Serbia
Poland	Thailand
Slovenia	
Spain	*Lower-middle income*
Sweden	Indonesia
Switzerland	
United Kingdom	
United States	

Source: WDI classification.

The net enrollment rate in secondary education ranges from 66% (Malaysia) to 99% (Ireland).[7] The PISA scores, teacher-pupil ratios and public spending per student are very heterogeneous, particularly when comparing countries across different income groups. In fact, the lowest score for a developing country is 375 (Peru), whereas the highest score is 543 (Korea). Teacher-pupil ratios range from 3.78 (Colombia) to 11.68 (Luxembourg), and public spending per student ranges from 72,966 US$ (Indonesia) to 1,941,545 US$ (Luxembourg).

7 The limitation of this variable is that it can, in principle, exceed 100% due to the inclusion of over-aged and under-aged students (because of early or late entry) and grade repetition. Nevertheless, increases in this variable indicate improvements in the education sector.

We control for the effect of GDP per capita in 2012 PPP and for parental education by including them as environmental variables in the second-stage approach. The minimum value of GDP per capita is 8,855 US$ (Indonesia) and the maximum value is 127,819 US$ (Qatar). Parental educational attainment is measured as the share of the population aged 35-44 years who have attained at least secondary education. This variable ranges from 31.10% (Thailand) to 95.89% (Korea).

The low correlation between inputs and outputs gives a first idea about inefficiencies (Afonso, Schuknecht and Tanzi, 2005). In fact, Table 4 indicates low correlations between the inputs of teacher ratios and government expenditure per secondary student and the outputs of enrollment rates and PISA scores. Therefore, increases in inputs do not necessarily result in increases in outputs.

Table 4

Correlation between inputs and outputs

Variable	**Enrollment**	**PISA**	**Teacher ratio**	**Expenditure**
Enrollment	1			
PISA	0.7193	1		
Teacher ratio	**0.4843**	**0.3499**	1	
Expenditure	**0.4919**	**0.4969**	0.4227	1

Source: Own calculations based on WDI and UNESCO databases.

V. Efficiency results

We implement two alternative frontier models. In the first model, we use government expenditure per secondary student as a monetary input, whereas in the second model, we use the number of teachers per 100 students as a physical input. The purpose of these two models is to evaluate whether efficiency results are influenced by differences in input costs between developed and developing countries.[8]

i. The efficiency of monetary inputs: the case of public spending on education

Table 5 shows the naive[9] efficiency scores for a core group of 35 countries[10] using government expenditure per secondary student as the input. Seven countries appear as efficient DMUs: Indonesia, Ireland, Japan, Korea, Lithuania, Poland and Serbia. These results can be explained by the facts that among the countries in the sample, Korea, Japan and Poland are in the top five in terms of PISA scores and Ireland has the highest enrollment rate in secondary education. In the case of Indonesia (a developing country), the main explanation may be related to a low level of inputs rather than a high level of outputs. In fact, Indonesia has the lowest level of government expenditure on secondary education in the entire sample (72,966 US$). These results are consistent with those of Afonso and Aubyn (2005), although that study uses PISA 2003 as output.

One important aspect of these results relates to the peer countries associated with each country in the sample. In general, developing countries are compared with each other (with the exceptions of Bulgaria and Hungary); the same applies to developed countries. In terms of efficiency scores, developing countries have an inefficiency average of 8% relative to efficient countries, whereas this value is 4% for developed countries.

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8 Herrera and Pang (2005) explain the positive association between public expenditure and GDP per capita based on the Balassa-Samuelson effect, which suggests that prices are higher in wealthier countries than in poorer countries. Thus, the price of the same service (for example, education) will be higher in countries with higher GDPs.

9 These scores are called naïve efficiency scores because they are computed in the first stage without external factors.

10 We use an extended sample that includes Chile. However, Chile is independently efficient, that is, it does not have a peer in the sample for purposes of comparing performance because no other country uses less input and achieves more output.

One limitation of using public expenditure as an input relates to the cost of inputs. For example, although Finland, Luxembourg, Norway, Sweden and Switzerland have the highest government expenditures per secondary student, they have an inefficiency average greater than that of the developed countries (6.4%). However, their PISA results are above the mean. For this reason, we conduct the same exercise using physical inputs.

Table 5

Naïve scores- First frontier model

Input: Public spending per student. Outputs (enrollment rates and PISA 2012)

Sample: 35 countries

Country	Naive Score	Rank	Peers
Australia	1.0592	21	Korea
Bulgaria*	1.1025	28	Japan
Colombia*	1.1214	34	Indonesia, Serbia
Costa Rica*	1.0339	13	Indonesia, Serbia
Cyprus	1.0851	26	Ireland, Japan
Estonia	1.0199	11	Japan, Korea
Finland	1.0250	12	Japan, Korea
France	1.0353	14	Ireland, Japan
Hungary*	1.0638	23	Japan, Lithuania
Iceland	1.1128	32	Ireland, Japan
Indonesia*	**1**	1	Indonesia
Ireland	**1**	1	Ireland, Japan
Israel	1.0034	8	Japan, Lithuania
Italy	1.0662	25	Ireland, Japan
Japan	**1**	1	Japan
Korea, Rep.	**1**	1	Korea
Latvia	1.0529	20	Korea, Poland, Serbia
Lithuania	**1**	1	Japan, Lithuania, Serbia
Luxembourg	1.1082	31	Japan, Korea
Malaysia*	1.2147	35	Poland, Serbia
Mexico*	1.1180	33	Poland, Serbia
Netherlands	1.0463	18	Korea
New Zealand	1.0353	15	Japan, Lithuania
Norway	1.0360	16	Ireland
Peru*	1.0115	9	Indonesia, Serbia
Poland	**1**	1	Korea, Poland, Serbia
Qatar	1.1054	30	Ireland
Serbia*	**1**	1	Serbia
Slovenia	1.0656	24	Ireland, Japan
Spain	1.0435	17	Ireland, Japan
Sweden	1.0635	22	Ireland
Switzerland	1.0469	19	Korea
Thailand*	1.1027	29	Poland, Serbia
United Kingdom	1.0169	10	Ireland, Japan
United States	1.1019	27	Japan, Korea

Average	1.0542
Developed	1.0452
Developing	1.0768

Note: (*) identifies developing countries. Source: Own calculations.

ii. The efficiency of physical inputs: the case of the teacher-pupil ratio

Table 6 shows the naive efficiency scores using the number of teachers per 100 secondary students. In this case, five countries appear on the efficiency frontier, including a developing country: Colombia, Ireland, Japan, Korea and the United Kingdom. The inclusion of Colombia in the efficiency group suggest that the results are related not only to high levels of output (that is, Korea and Japan) but also to low levels of input relative to the output obtained. In fact, although Colombia has the lowest teacher-pupil ratio in the sample (3.78), it also has one of the lowest PISA scores (Table A.3).

Additionally, it is not possible in this case to separate developing and developed countries using the peer country criterion, which implies that developing countries share the same production function and thus the inefficiency of developing countries is evaluated relative to developed countries.

Table 6

Naïve scores- Second frontier model

Input: Teacher-pupil ratio. Outputs (enrollment rates and PISA 2012)

Sample: 35 countries

Country	Naive Score	Rank	Peers
Australia	1.0592	17	Korea
Bulgaria*	1.1730	30	Ireland, Japan
Colombia*	1	1	Colombia
Costa Rica*	1.2749	33	Korea
Cyprus	1.0856	22	Ireland
Estonia	1.0299	9	Korea, Japan
Finland	1.0250	8	Korea, Japan
France	1.0358	11	Ireland, Japan
Hungary*	1.0822	21	Ireland, Japan
Iceland	1.1128	29	Ireland, Japan

Indonesia*	1.4028	35	Ireland, Japan, Korea
Ireland	1	1	Ireland, Japan
Israel	1.0109	7	Ireland
Italy	1.0669	20	Ireland, Japan
Japan	1	1	Japan
Korea, Rep.	1	1	Korea
Latvia	1.0985	23	Korea
Lithuania	1.0102	6	Ireland
Luxembourg	1.1082	28	Japan
Malaysia*	1.3140	34	Korea
Mexico*	1.2695	32	Colombia, Korea
Netherlands	1.0463	14	Korea
New Zealand	1.0300	10	Ireland, Japan, Korea
Norway	1.0360	12	Ireland
Peru*	1.2453	31	Ireland, Korea
Poland	1.0423	13	Korea
Qatar	1.1054	26	Ireland
Serbia*	1.0988	24	Ireland
Slovenia	1.0661	19	Ireland, Japan
Spain	1.0468	15	Ireland
Sweden	1.0635	18	Ireland
Switzerland	1.0469	16	Korea
Thailand*	1.1078	27	Colombia, Korea
United Kingdom	1	1	Ireland, Korea
United States	1.1019	25	Japan, Korea
Average	1.0913		
Developed countries	1.0491		
Developing countries	1.1968		

Note: (*) identifies developing countries. Source: Own calculations.

A comparison of the results of both estimations (Tables 5 and 6) indicates that developing countries are less efficient with physical inputs than with monetary inputs, on average (1.1968 *vs* 1.0768), which support the hypothesis that the monetary model frontier penalizes developed countries because they use more expensive inputs. It is also important to note that Ireland, Japan and Korea remain relatively efficient countries (even with more expensive inputs) regardless of how input is measured.

The effect of non-discretionary inputs - Case I

To assess the effect of non-discretionary variables on efficiency scores, we implement the second-stage approach using a truncated regression with and without bootstrap correction. We initially consider the effect of adult educational attainment (as a proxy for parental education) on the efficiency scores previously computed.. GDP per capita (as a proxy for parental income) is another potential control variable but was not included in this case because it is highly correlated with government expenditure. The equation to be estimated is the following:

$$\widehat{\delta_i} = \beta_0 + \beta_1 * E_i + \varepsilon_i \quad (4)$$

Using a truncated normal regression with and without bootstrap correction (Table 11), we find evidence that parental education can improve countries' performance, bringing them closer to the efficiency frontier. This negative relationship is plotted in figure 2.

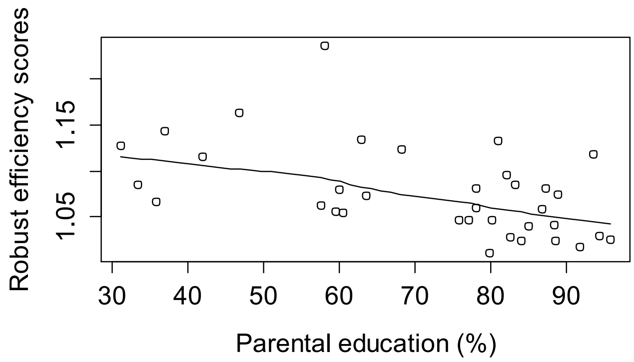
Table 7

Truncated Regression with Bootstrap		
Intercept	1.1844	***
E	-0.0017	***
Sigma	0.0490	***
Truncated Regression without		
Intercept	1.1434	***
E	-0.0014	***
Sigma	0.0542	***

Source: Own calculations.

Figure 2

Parental education *vs* robust efficiency scores



Source: Own calculations.

Table 8 presents the robust efficiency scores. In the third column, the initial scores are recalculated using algorithm 2 (see methodology). As with the previous results, the average efficiency score for developing countries is greater than that for developed countries. In column four, we include the correction for parental education, which is measured as the robust score considering that parental education for each country is equal to the mean sample minus the robust score previously calculated in the second column. This correction is useful to isolate the influence of acts of God or a poor economic environment on efficiency. The results indicate that in nearly all developing countries (except Bulgaria and Hungary), there is a negative correction with education, that is, if developing countries had higher parental educational attainment, they would achieve better educational performance by limiting inefficiency in the use of public resources.

Finally, the fifth column presents the fully corrected scores after adding columns 3 and 4. Because we control for external factors, it is expected that countries with harsh environmental conditions will obtain better rankings in this stage. We find that Bulgaria, Hungary, Indonesia, Serbia, Peru and Costa Rica, all of which were previously ranked higher (based on naive scores), are now further away from the efficiency frontier. Even more notable are the cases of Indonesia and Serbia, which were considered efficient countries in stage 1 but fell numerous positions (23 and 11, respectively) in the ranking after correction. The rankings of Colombia and Malaysia do not change after considering external factors. Thus, when we control for external factors, it is clear that developing countries are highly inefficient in secondary education expenditure.

Table 8

Robust scores- First frontier model

Input: Public spending per student. Outputs (enrollment rates and PISA 2012)

Sample: 35 countries

Code	Country	Robust	Correction Education	Fully Score	Rank Robust
AUS	Australia	1.0803	0.0001	1.0804	22
BGR	Bulgaria	1.1326	0.0002	1.1328	31
COL	Colombia	1.1632	-0.0004	1.1628	34
CRI	Costa Rica	1.0661	-0.0006	1.0655	18
CYP	Cyprus	1.0956	0.0002	1.0957	26
EST	Estonia	1.0413	0.0003	1.0416	9
FIN	Finland	1.0397	0.0002	1.0400	8
FRA	France	1.0468	0.0001	1.0469	11
HUN	Hungary	1.0851	0.0002	1.0853	25
ISL	Iceland	1.1344	-0.0001	1.1342	32
IDN	Indonesia	1.0844	-0.0006	1.0837	24
IRL	Ireland	1.0110	0.0001	1.0111	1
ISR	Israel	1.0234	0.0002	1.0237	3
ITA	Italy	1.0790	-0.0002	1.0788	21
JPN	Japan	1.0238	0.0003	1.0240	4
KOR	Korea, Rep.	1.0252	0.0004	1.0256	5
LVA	Latvia	1.0723	-0.0001	1.0722	19
LTU	Lithuania	1.0287	0.0004	1.0290	7
LUX	Luxembourg	1.1235	-0.0001	1.1235	29
MYS	Malaysia	1.2359	-0.0002	1.2357	35
MEX	Mexico	1.1428	-0.0006	1.1422	33
NLD	Netherlands	1.0593	0.0001	1.0594	16
NZL	New Zealand	1.0538	-0.0002	1.0537	13
NOR	Norway	1.0465	0.0001	1.0466	10
PER	Peru	1.0619	-0.0002	1.0617	17
POL	Poland	1.0179	0.0003	1.0182	2
QAT	Qatar	1.1156	-0.0005	1.1151	27
SRB	Serbia	1.0470	0.0001	1.0471	12
SVN	Slovenia	1.0813	0.0003	1.0815	23
ESP	Spain	1.0564	-0.0002	1.0562	14
SWE	Sweden	1.0744	0.0003	1.0747	20
CHE	Switzerland	1.0584	0.0003	1.0587	15
THA	Thailand	1.1271	-0.0007	1.1264	30
GBR	United Kingdom	1.0274	0.0002	1.0276	6
USA	United States	1.1181	0.0004	1.1185	28
	Average	1.0766	0.0000	1.0766	
	Developed	1.0614	0.0001	1.0615	
	Developing	1.1146	-0.0003	1.1143	

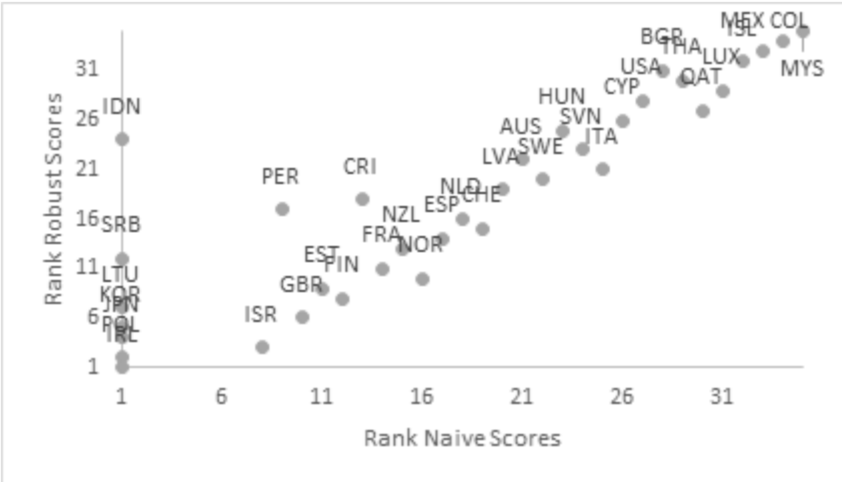
Source: Own calculations.

In contrast, the performance of most developed countries improves after the correction. Ireland, Poland, Korea and Japan remain efficient countries, and performance improves for Norway, Israel, Finland, Italy, Switzerland and the United Kingdom (Figure 3).

The results generated by controlling for the effects of socioeconomic background are consistent with those of Sutherland *et al.* (2007), who found that PISA scores could increase by an average of 5% for OECD countries and by approximately 10% for emerging countries.

Figure 3

Relative change in rankings (with financial input)



Source: Own calculations.

a) The effect of non-discretionary inputs - Case II

As before, we use a second-stage analysis to measure the effect of non-discretionary variables on the efficiency scores computed previously (see Table 5). In this case, GDP per capita and adult educational attainment are used as proxies for the income and education of parents, respectively. The equation to be estimated is

$$\widehat{\delta_i} = \beta_0 + \beta_1 * Y_i + \beta_2 * E_i + \varepsilon_i \quad (4)$$

Using a truncated normal regression with and without bootstrap adjustment (Table 9), we find evidence that higher GDP per capita and parental educational inputs improve efficiency scores. This negative relationship[11] is plotted in Figures 4 and 5.

Table 9

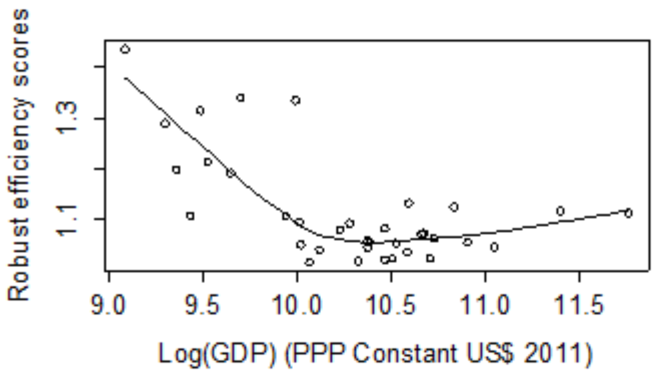
Truncated Regression with Bootstrap adjustment		
Intercept	2.3087	***
Log(GDP)	-0.0884	***
E	-0.0044	***
Sigma	0.0730	***
Truncated Regression without bootstrap		
Intercept	2.3277	***
Log(GDP)	-0.0958	***
E	-0.0042	***
Sigma	0.0844	***

Source: Own calculations based on UNESCO database.

Figure 4

GDP per capita *vs* robust efficiency scores

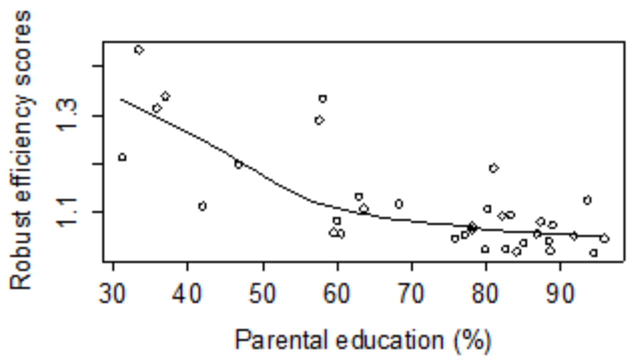
11 Please note that an increased efficiency score means that the DMU has moved farther away from the efficiency frontier, that is, the DMU is more inefficient.



Source: Own calculations.

Figure 5

Parental education *vs* robust efficiency scores



Source: Own calculations.

Table 10 presents the robust efficiency scores corrected by bootstrapping. In the fourth and fifth columns, we correct for GDP and parental education using the same procedure as in the first case. The sixth column includes the fully corrected scores after adding columns 2 to 4. For almost all countries, the correction for parental education is smaller than the correction for GDP. Thus, countries with relatively low GDP per capita will perform poorly in terms of efficiency in secondary education.

Table 10

Robust scores - second frontier model

Input: Teacher ratio. Outputs (enrollment rates and PISA 2012)

Sample: 35 countries

Code	Country	Robust	Correction	Correction	Fully Score	Robust
AUS	Australia	1.0713	0.0342	0.0003	1.1058	20
BGR	Bulgaria	1.1910	-0.0554	0.0004	1.1360	25
COL	Colombia	1.1978	-0.0805	-0.0011	1.1162	24
CRI	Costa Rica	1.3148	-0.0696	-0.0016	1.2437	31
CYP	Cyprus	1.0936	0.0006	0.0005	1.0947	17
EST	Estonia	1.0426	-0.0136	0.0008	1.0297	3
FIN	Finland	1.0359	0.0276	0.0006	1.0642	10
FRA	France	1.0537	0.0226	0.0003	1.0765	14
HUN	Hungary	1.0958	-0.0229	0.0005	1.0734	13
ISL	Iceland	1.1336	0.0284	-0.0004	1.1616	27
IDN	Indonesia	1.4351	-0.1046	-0.0017	1.3288	35
IRL	Ireland	1.0233	0.0386	0.0004	1.0622	9
ISR	Israel	1.0184	0.0049	0.0006	1.0238	2
ITA	Italy	1.0827	0.0170	-0.0005	1.0992	18
JPN	Japan	1.0222	0.0170	0.0008	1.0399	6
KOR	Korea, Rep.	1.0460	0.0088	0.0011	1.0559	8
LVA	Latvia	1.1089	-0.0293	-0.0003	1.0793	16
LTU	Lithuania	1.0174	-0.0184	0.0010	1.0000	1
LUX	Luxembourg	1.1190	0.0997	-0.0001	1.2185	30
MYS	Malaysia	1.3347	-0.0244	-0.0006	1.3097	34
MEX	Mexico	1.3392	-0.0505	-0.0015	1.2871	33
NLD	Netherlands	1.0628	0.0402	0.0003	1.1033	19
NZL	New Zealand	1.0555	0.0103	-0.0005	1.0653	11
NOR	Norway	1.0453	0.0687	0.0002	1.1142	22
PER	Peru	1.2902	-0.0861	-0.0006	1.2035	29
POL	Poland	1.0524	-0.0223	0.0009	1.0310	4
QAT	Qatar	1.1138	0.1316	-0.0013	1.2440	32
SRB	Serbia	1.1072	-0.0741	0.0004	1.0335	5
SVN	Slovenia	1.0810	-0.0038	0.0007	1.0779	15
ESP	Spain	1.0582	0.0090	-0.0005	1.0667	12
SWE	Sweden	1.0727	0.0357	0.0008	1.1092	21
CHE	Switzerland	1.0572	0.0563	0.0007	1.1142	23
THA	Thailand	1.2130	-0.0658	-0.0018	1.1455	26
GBR	United Kingdom	1.0238	0.0208	0.0005	1.0451	7
USA	United States	1.1254	0.0496	0.0010	1.1760	28
	Average	1.1182	0.0000	0.0000	1.1182	
	Developed countries	1.0647	0.0254	0.0003	1.0903	
	Developing countries	1.2519	-0.0634	-0.0008		

Source: Own calculations.

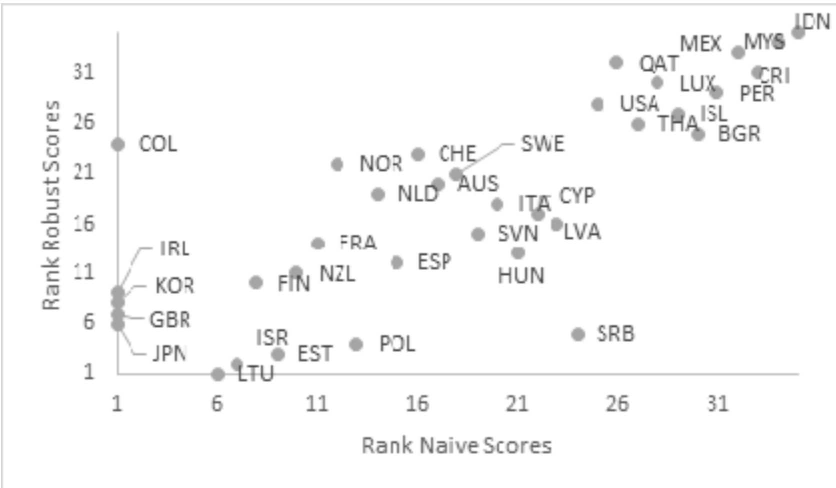
As expected, there are important differences between the rankings based on naive scores and those based on fully robust scores. First, Serbia, Poland, Hungary, Latvia and Estonia, which previously were poorly ranked (Rank Naive Scores), are now closer to the efficiency frontier. In contrast, the second stage negatively affects the performances of Colombia, Norway, Ireland, Switzerland and Korea (Figure 6).

Second, the developing countries in the sample with the lowest percentages of persons aged 35-44 years who have attained at least secondary education and the lowest GDPs per capita exhibit poor performance, especially Colombia, Costa Rica, Indonesia, Mexico, Peru and Thailand. Thus, we conclude that countries with harmful economic environments have much lower performance in terms of efficiency in education expenditure.

Finally, comparing the robust efficiency scores of the two estimated frontier models, we find that developing countries are less efficient than developed countries and that the gap increases when efficiency is measured in terms of the teacher-student ratio.

Figure 6

Relative change in rankings (with physical input)



Source: Own calculations.

Concluding remarks

We measure the efficiency of secondary education expenditure in 35 developing and developed countries using a two-step semi-parametric DEA methodology for the 2009-

2012 period. Our results highlight the importance of comparisons between income groups (that is, developing *vs* developed countries). However, after taking into account a division of the sample based on development level, the efficiency results remain constant. For this reason, we can affirm that our estimations are robust regardless of the heterogeneity within the selected core group.

Among our main results, we find a clear difference in the estimated efficiency scores depending on whether monetary or physical inputs are used. Moreover, we find that the monetary frontier model significantly favors developing countries, bringing them closer to the efficiency frontier. However, Ireland, Japan and Korea remain efficient regardless of whether efficiency is measured with monetary or physical inputs.

Given that the computed efficiency scores are computed in relative terms, the peer concept is quite relevant for our analysis. One important aspect of these results relates to the peer countries associated with each country based on whether we consider the monetary or physical model frontier. In the first model (monetary input), there are important differences between developing and developed countries, which means that countries within each group are compared with each other. In contrast, it is not possible to make this separation in the physical model because nearly all peer countries are developed countries. Consequently, although developing countries are more inefficient than developed countries, the efficiency gap is higher in the physical input frontier model.

An important contribution of this paper is that we take into account two non-discretionary (external) factors that affect educational performance: income and adult educational attainment. We provide robust evidence that both income and educational attainment positively affect efficiency in both models. Thus, countries with low GDP per capita or/and low parental education will perform relatively poorly in terms of efficiency in secondary education. Consequently, it is clear that developing countries are highly inefficient in secondary education expenditure, even after controlling for external factors.

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Appendix

Table A.1

Data and sources

Output	**Enrollment rate**	Net enrollment rates. Average for 2009-2011. Source: WDI.

	PISA score	Average performance of 15-year-old children on PISA reading, mathematics and science literacy scales, 2012. Source: OECD.
Input	Teacher-Pupil ratio	Teacher-pupil ratio in secondary education. Average for 2009-2011. Source: WDI.
	Government expenditure	Government expenditure per secondary student, PPP (constant 2011 international $). Average for 2009-2011. Source: UNESCO.
Exogenous	GDP PPP 2011	GDP per capita, PPP (constant 2011 international $), 2012. Source: WDI.
	Parental education	Share of population that has attained at least secondary education, aged 35-44, 2010. Source: Barro and Lee, 2013.

Source: Own calculations.

Table A.2

Expenditure on education (%) Average 2009-2011

Country	Expenditure on education (% of total	Public expenditure on education (% of GDP)
Australia	13.75	5.26
Bulgaria	11.64	4.17
Chile	17.40	4.16
Colombia	16.01	4.68
Costa Rica	23.38	6.28
Cyprus	16.24	7.48
Estonia	13.71	5.62
Finland	12.22	6.81
France	10.01	5.81
Hungary	9.72	4.91
Iceland	15.20	7.59
Indonesia	17.98	3.26
Ireland	12.06	6.33
Israel	13.22	5.59
Italy	8.25	4.50
Japan	9.58	3.78
Korea, Rep.	-	4.77
Latvia	8.69	5.20
Lithuania	13.07	5.39
Luxembourg	-	4.34*

Malaysia	19.28	5.68
Mexico	19.41	5.19
Netherlands	11.68	5.94
New Zealand	18.48	6.88
Norway	15.36	6.89
Peru	13.85	2.89
Poland	11.39	5.07
Qatar	7.36*	2.45*
Serbia	10.68	4.89
Slovenia	12.15	5.68
Spain	10.83	4.99
Sweden	13.27	7.02
Switzerland	16.01	5.29
Thailand	19.15	4.56
United Kingdom	13.12	5.93
United States	13.36	5.30
Total average	13.95	5.41

Source: Unesco database. Own calculations. (*): Values for 2008.

Table A.3

Descriptive data for sample countries

Country	Outputs		Inputs		Exogenous	
	Enrollment rates (%)	PISA	Teachers per 100 students	Government expenditure	GDP per capita (2011 US$ PPP)	Parental Education
Australia	85.25	512.33	8.33	713322.30	42521.63	78.01
Bulgaria	84.52	440.33	8.25	306361.90	15442.83	80.97
Colombia	74.35	392.67	3.78	158133.30	11636.55	46.69
Costa Rica	73.35	425.67	6.49	157648.10	13157.49	35.80
Cyprus	91.35	442.33	10.21	1083037.00	29087.37	82.12
Estonia	94.18	526.00	11.14	628180.60	24760.43	88.43
Finland	93.55	529.33	10.24	1239623.00	39476.03	84.97
France	95.71	499.67	7.92	1043585.00	37275.09	77.10
Hungary	91.49	486.33	9.82	542095.60	22305.84	83.26
Iceland	88.80	484.67	9.41	832945.10	39800.23	62.89
Indonesia	69.88	384.33	7.64	72965.88	8855.01	33.26
Ireland	99.17	515.33	7.24	1144647.00	44673.43	79.94
Israel	98.09	474.00	10.24	563231.30	30518.06	84.06
Italy	92.85	489.67	8.51	926692.40	34992.72	59.94
Japan	98.79	540.33	8.42	727928.10	34987.61	88.55
Korea, Rep.	95.79	542.67	5.81	670375.10	31901.07	95.89
Latvia	86.90	494.00	11.58	485049.70	20747.29	63.53
Lithuania	98.16	484.00	11.39	467250.10	23460.51	94.46
Luxembourg	86.48	489.67	11.68	1941545.00	89153.06	68.30
Malaysia	65.96	413.00	7.32	373683.20	21920.22	57.99
Mexico	67.29	417.33	5.64	228277.30	16316.33	36.93
Netherlands	88.16	518.67	7.37	1160727.00	45484.08	78.02
New Zealand	95.37	509.33	6.95	703509.00	32463.59	60.50
Norway	95.72	496.00	10.31	1684940.00	62771.39	75.80
Peru	77.47	375.00	6.10	104427.60	10912.56	57.62
Poland	90.80	520.67	10.07	488005.10	22448.08	91.75
Qatar	89.71	382.67	10.11	1310777.00	127818.90	41.83
Serbia	90.25	446.67	10.37	172582.50	12504.79	80.25
Slovenia	92.79	498.67	11.02	804519.60	27681.68	87.34
Spain	94.74	489.33	9.26	781796.80	31970.72	59.53
Sweden	93.25	482.00	10.40	1271555.00	43262.83	88.99

Switzerland	83.25	518.33	8.70	1501980.00	54573.20	86.81
Thailand	78.93	437.33	5.02	284421.70	13736.22	31.10
United	97.46	502.33	6.53	1065071.00	36535.38	82.69
United States	87.54	492.00	7.11	1153344.00	50585.66	93.65
Average	88.21	475.79	8.58	765549.52	34449.65	71.40
Min	65.96	375.00	3.78	72965.88	8855.01	31.10
Max	99.17	542.67	11.68	1941545.00	127818.90	95.89

Source: Own calculations based on WDI and UNESCO databases.