

ASSESSING EDUCATION AND HEALTH EFFICIENCY IN OECD COUNTRIES USING ALTERNATIVE INPUT MEASURES

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1. Introduction and motivation

Economics is often defined as the science that studies the allocation of resources to alternative uses, so that some concept of satisfaction is maximised. Moreover, economists make a useful distinction between resources that are the “ingredients”, or inputs, that allow the production of some other goods or services, sometimes final, the outputs. The relationship between inputs and outputs is usually rationalised in terms of a production function, and, in many theoretical and empirical work, it is assumed that this relationship or function holds for all production units involved.

In this paper, we do not assume that all units produce the maximum quantities allowed by input resources available to them. On the contrary, we are especially interested in allowing for, and providing estimates of, possible inefficiencies in production. These inefficiencies are, in fact, distances to a production frontier. They are a measure of what is lost when inputs are not put into the best of possible uses, so that output is lower than the one that could be attained.

Following Afonso and St. Aubyn (2005a), we assess efficiency in providing education and health services across OECD countries. These are two sectors where public expenditure is of great importance, and also determinant for economic growth and welfare.¹ Therefore, if there are important inefficiencies in one country, this may well mean that either education or health provision could be improved significantly without more pressure on the public purse, or else that resources could be freed to alternative uses, be they public or private.

Results presented in Afonso and St. Aubyn (2005a) are based in physically measured inputs. For example, education inputs are the number of teachers per 100 students and hours per year students spend at school. Here, we compare results using physically measured inputs to results attained when inputs are measured in financial

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¹ According to Afonso and St. Aubyn (2005a), Table 1, public expenditure on education and health averaged 88.4 and 72.2 per cent of total expenditure in those activities, respectively, in 2000, in OECD countries. Also, average total expenditure on education and on health was equal to 5.4 and 8.0 of GDP.

terms, *i.e.*, expenditure on education or health in monetary units. As it will be shown later, estimated inefficiencies are not the same when these two different approaches are followed. In the conclusion to this paper, we develop some possible explanations to this, and defend that physically measured inefficiencies are probably more meaningful.

Not many other authors have previously studied public expenditure inefficiency in an international and aggregate framework. Fakin and Crombrugghe (1997) and Afonso, Schuknecht and Tanzi (2003) have done so for public expenditure in the OECD, Clements (2002) for education spending in Europe, Gupta and Verhoeven (2001) for education and health in Africa and St. Aubyn (2002, 2003) for health and education expenditure in the OECD. Although these studies use methods similar to ours (Free Disposable Hull or Data Envelopment Analysis, to be described later), inputs are always measured in monetary terms only.

Note that our purpose is to measure inefficiency across countries, and not to explain it. For an attempt to do the latter, we refer the interested reader to Afonso and St. Aubyn (2005b).

The rest of the paper is organised as follows. Section 2 presents our methodology. Section 3 explains how we measure the education and health inputs and outputs. Section 4 presents the empirical results and section 5 contains our concluding remarks.

2. Methodology

We apply two different non-parametric methods – Free Disposable Hull (FDH) analysis and Data Envelopment Analysis (DEA). These methods have been developed and applied to Decision Making Units (DMUs) that convert inputs into outputs.² These units may include public organisations, such as hospitals, schools, universities, local authorities or regional governments.³

2.1. Free Disposable Hull (FDH) analysis

We apply a so-called FDH analysis, which is a non-parametric technique first proposed by Deprins, Simar, and Tulkens (1984). Suppose that under efficient conditions, the education or health status of a population i , measured by an

² See Coelli, Rao and Battese (1998), Sengupta (2000) and Simar and Wilson (2003) for an introduction to this literature.

³ De Borger and Kerstens (1996) provide an analysis of Belgian local governments, Coelli (1996) assess the efficiency of Australian universities, Afonso and Fernandes (2005) study the efficiency of local municipalities in the Lisbon region, Afonso and Scaglioni (2005) analyse the efficiency of Italian regions, while Afonso and Santos (2005) investigate the performance of public tertiary education in Portugal.

indicator y_i , the output, depends solely on education or health expenditure per habitant, x_i , the input:

$$y_i = F(x_i) \tag{1}$$

If $y_i < F(x_i)$, it is said that country i exhibits inefficiency. For the observed expense level, the actual output is smaller than the best attainable one. FDH is one of the different methods of estimating function F , the efficiency frontier.

In a simple example, four different countries display the following values for indicator y and expense level x :

Table 1

Fictitious Values for Countries A, B, C and D

	Indicator	Expenditure
Country A	65	800
Country B	66	950
Country C	75	1,000
Country D	70	1,300

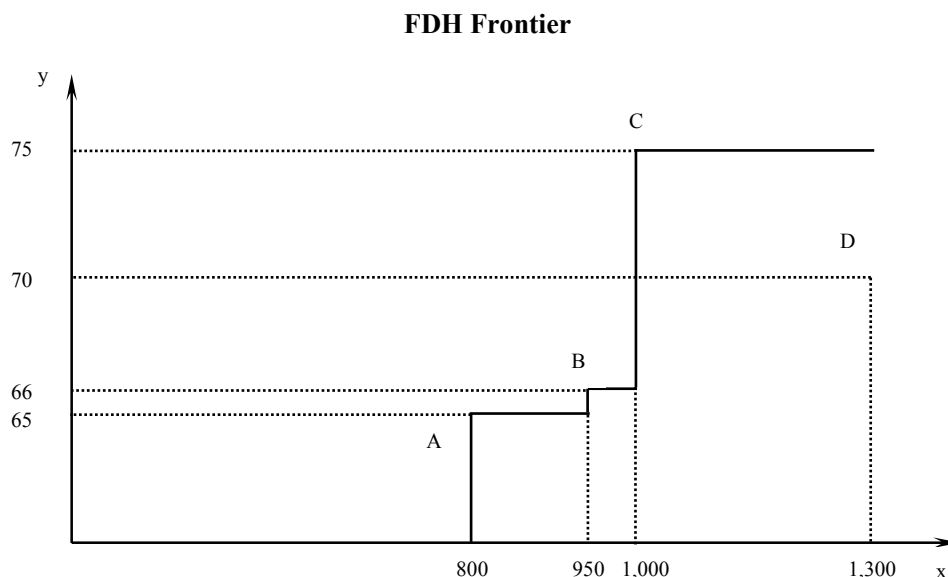
Expenditure is lower in country A (800), and the output level is also the lowest (65). Country D exhibits the highest expenditure (1300), but it is country C that attains the best level of output (75).

Country D may be considered inefficient, in the sense that it performs worse than country C. The latter achieves a better status with less expense. On the other hand, countries A, B or C do not show as inefficient using the same criterion.

In FDH analysis, countries A, B and C are supposed to be located on the efficiency frontier.⁴ This frontier takes the following form in this example:

⁴ Of course, it could still be the case that there are inefficiencies in those countries, in the sense that they could improve outcomes without increasing resources used. The point here is that there are no other countries in the sample that provided evidence this is so. As in a court, a country is presumed efficient till inefficiency evidence is provided.

Figure 1



$$y = F(x) = \begin{cases} 65, & 800 \leq x < 950 \\ 66, & 950 \leq x < 1000 \\ 75, & 1000 \leq x \leq 1300 \end{cases} \quad (2)$$

This function is represented in Figure 1.

It is possible to measure country D inefficiency, or its efficiency scores, in two different ways:

- i) inefficiency may be measured as the vertical distance between point D and the efficiency frontier. Here, one is evaluating the difference between the output level that could have been achieved if all expense was applied in an efficient way, and the actual level of output. In this example, the efficiency loss equals 5 – country D should, at least, achieve the same indicator level as country C, under efficient conditions.
- ii) if one computes the horizontal distance to the frontier, the efficiency loss is now 300, in units of expense. It can be said that efficiency losses in country D are about 24 per cent ($=300/1300$) of total expense. To attain an indicator level of 70, it is necessary to spend no more than 1000, as shown by country C.

FDH analysis is also applicable in the multiple input-output cases. We sketch here how this is done, supposing the case of k inputs, m outputs and n countries.⁵

⁵ The interested reader may refer to Gupta and Verhoeven (2001) and to Simar and Wilson (2003).

For country i , we select all countries that are more efficient – the ones that produce more of each output with less of each input. If no more efficient country is found, country i is considered as an efficient one, and we assign unit input and output efficiency scores to it. If country i is not efficient, its input efficiency score is equal to:

$$\text{MIN}_{n=n_1, \dots, n_l} \text{MAX}_{j=1, \dots, k} \frac{x_j(n)}{x_j(i)}$$

where n_1, \dots, n_l are the l countries that are more efficient than country i .

The output efficiency score is calculated in a similar way and is equal to:

$$\text{MIN}_{n=n_1, \dots, n_l} \text{MAX}_{j=1, \dots, m} \frac{y_j(i)}{y_j(n)}$$

Following the input and output scores calculation, countries can be ranked accordingly. Efficient countries are the same in both the input and output perspective, but the ranking and the efficiency scores of inefficient countries is not necessarily similar from both points of view.

2.2 Data Envelopment Analysis (DEA)

Data Envelopment Analysis, originating from Farrell (1957) seminal work and popularised by Charnes, Cooper and Rhodes (1978), assumes the existence of a convex production frontier, constructed using linear programming methods.⁶

Similarly to FDH, DEA allows the calculation of technical efficiency measures that can be either input or output oriented. The two measures provide the same results under constant returns to scale but give different values under variable returns to scale. Nevertheless, and since the computation uses linear programming, not subject to statistical problems such as simultaneous equation bias and specification errors, both output and input-oriented models will identify the same set of DMUs.

The analytical description of the linear programming problem to be solved, in the variable returns to scale hypothesis, is sketched below. Suppose there are k inputs and m outputs for n DMUs. For the i -th DMU, y_i is the column vector of the outputs and x_i is the column vector of the inputs. We can also define X as the $(k \times n)$ input matrix and Y as the $(m \times n)$ output matrix. The DEA model is then specified with the following mathematical programming problem, for a given i -th DMU:⁷

⁶ Coelli *et al.* (1998), and Thanassoulis (2001) introduce the reader to the DEA.

⁷ We simply present here the equivalent envelopment form, derived by Charnes *et al.* (1978), using the duality property of the multiplier form of the original programming model. See Coelli *et al.* (1998) for more details.

$$\begin{aligned}
& \text{MIN}_{\theta, \lambda} \theta \\
& \text{s. to } -y_i + Y\lambda \geq 0 \\
& \quad \theta x_i - X\lambda \geq 0 \\
& \quad n1' \lambda = 1 \\
& \quad \lambda \geq 0
\end{aligned} \tag{3}$$

In problem (3), θ is a scalar (that satisfies $\theta \leq 1$), more specifically it is the efficiency score that measures technical efficiency of unit (x_i, y_i) . It measures the distance between a decision unit and the efficiency frontier, defined as a linear combination of best practice observations. With $\theta < 1$, the decision unit is inside the frontier (*i.e.* it is inefficient), while $\theta = 1$ implies that the decision unit is on the frontier (*i.e.* it is efficient).

The vector λ is a $(n \times 1)$ vector of constants, which measures the weights used to compute the location of an inefficient DMU if it were to become efficient. The inefficient DMU would be projected on the production frontier as a linear combination, using those weights, of the peers of the inefficient DMU. The peers are other DMUs that are more efficient and therefore are used as references for the inefficient DMU.

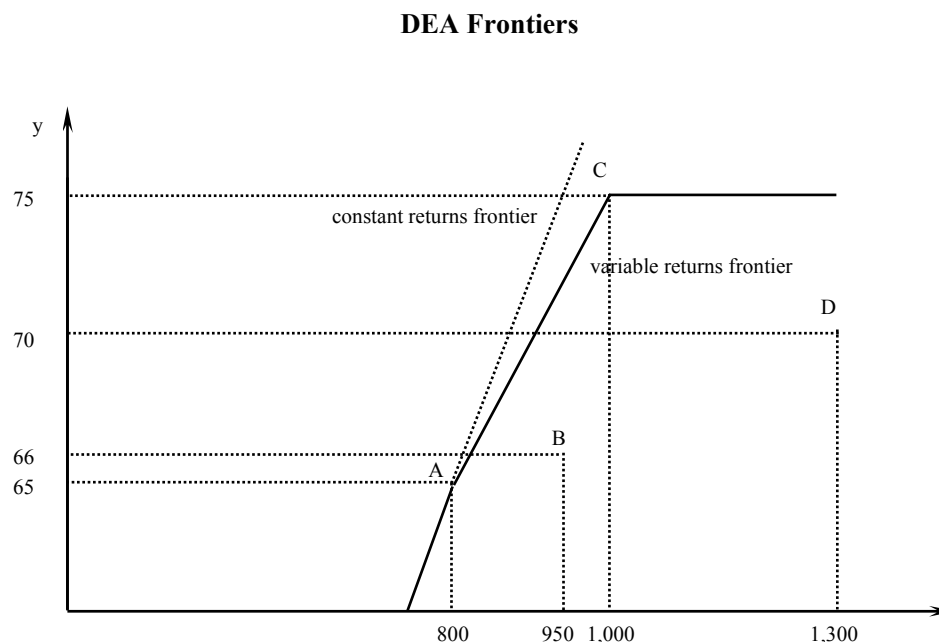
$n1$ is a n -dimensional vector of ones. The restriction $n1' \lambda = 1$ imposes convexity of the frontier, accounting for variable returns to scale. Dropping this restriction would amount to admit that returns to scale were constant.

Notice that problem (3) has to be solved for each of the n DMUs in order to obtain the n efficiency scores.

Figure 2 illustrates DEA frontiers with the very same invented data of Table 1. The variable returns to scale frontier unites the origin to point A, and then point A to point C. If one compares this frontier to the FDH frontier in Figure 1, one notices that country B is now deemed inefficient. This is the result of the convexity restriction imposed when applying DEA. In fact, DEA is more stringent than FDH – a country that is efficient under FDH is not always efficient under DEA, but a country efficient under DEA will be efficient under FDH. In more general terms, input or output efficiency scores will be smaller with DEA.

The constant returns to scale frontier is represented in Figure 2 as a dotted line. In this one input – one output framework, this frontier is a straight line that passes through the origin and country A, where the output/input ratio is higher. Under this hypothesis, only one country is considered as efficient. In the empirical analysis that follows, *a priori* conceptions about the shape of the frontier were kept to a minimum and the constant returns to scale hypothesis is never imposed.

Figure 2



3. Input and output measurement

3.1 Education indicators

As in Afonso and St. Aubyn (2005a), our main source of education data is OECD (2002a).⁸ Concerning education achievement we selected two frontier models: one model where the input is a financial variable and another version where we use only quantity explanatory variables as inputs. In both specifications, the output is measured by the performance of 15-year-olds on the PISA reading, mathematics and science literacy scales in 2000 (simple average of the three scores for each country).

In the first specification, inputs are measured by the annual expenditure on educational institutions per student in equivalent US dollars converted using Purchasing Power Parities, in secondary education, based on full-time equivalents, 1999.

In the second specification, we use two quantitative input measures:

⁸ The data and the sources used in this paper are presented in the Appendix. Note that total expenditure (public and private) was considered.

- the total intended instruction time in public institutions in hours per year for the 12 to 14-year-olds, 2000,
- the number of teachers per student in public and private institutions for secondary education, calculations based on full-time equivalents, 2000.

Since with these non-parametric approaches, higher performance is directly linked with higher input levels, we constructed the variable “Teachers Per Student,” *TPS*:

$$TPS = \left(\frac{Students}{Teachers} \right)^{-1} \times 100 \quad (4)$$

using the original information for the students-to-teachers ratio (see Appendix). Naturally, one would expect education performance to increase with the number of teachers per student.

3.2 Health indicators

Following Afonso and St. Aubyn (2005a), we took two usual measures of health attainment, infant mortality and life expectancy, from OECD (2000b) and have calculated an “Infant Survival Rate”, *ISR*:

$$ISR = \frac{1000 - IMR}{IMR} \quad (5)$$

which is interpretable as the ratio of children that survived the first year to the number of children that died; and increases with a better health status.

We have chosen to measure health spending in per capita terms and in purchasing power parities, therefore allowing for the fact that poorer countries spend less in real and per capita terms, even if their health spending is hypothetically comparable to richer nations when measured as a percentage of GDP.⁹

Therefore, our first frontier model for health has two outputs:

- the infant survival rate, and
- life expectancy,

the input being per capita health expenditure in purchasing power parities.

In a second formulation, and following the same reasoning that was made for education, we compared physically measured inputs to outcomes. In our second frontier model for health outputs are the same as before. Quantitative inputs are the number of doctors, of nurses and of in-patient beds per thousand habitants.

⁹ As with education, total expenditure (public and private) was considered. See the Appendix for data details.

4. Empirical results

4.1 Education – financial input results

Concerning the education performance for the secondary level in the OECD countries, we present in Table 2 the results of the FDH analysis using a single output, the PISA rankings for 2000, and a single input, annual expenditure per student in 1999.

From the results it is possible to conclude that five countries are located on the possibility production frontier: Hungary, Japan, Korea, Mexico, and Poland. Overall, average input efficiency is around 0.61 implying that on average countries in our sample might be able to achieve the same level of performance using only 61 per cent of the per capita expenditure they were using. In other words, there seems to be a “waste” of input resources of around 39 per cent on average.

The scope for input efficiency improvement is quite large since for some countries (Italy, Portugal) the input efficiency score is roughly half of the average score. For instance, countries such as Italy and Germany, where expenditure per student is above average, deliver a performance in secondary attainment below the average of the PISA index.

Some important differences have to be mentioned when looking at the set of efficient countries in terms of education performance. Japan and Korea are located in the efficient frontier because they do indeed perform quite well in the PISA survey, getting respectively the first and the second position in the overall education performance index ranking. However, in terms of annual spending per student, Japan ranks above the average (6039 *versus* 5595 US dollars) and Korea (3419 US dollars) is clearly below average.¹⁰

On the other hand, countries like Mexico, Poland and Hungary are deemed efficient in the FDH analysis because they are quite below average in terms of spending per student. Given the expenditure allocated to education by these countries, their performance in the PISA index is not comparable to any other country with similar or inferior outcome and with less expenditure per student. Moreover, one has to note that Mexico, Poland and Hungary all have PISA outcomes below the country sample average.¹¹

In Table 3 we present the DEA variable-returns-to-scale technical efficiency results using the same one-input and one-output framework. We report for each country its peers, *i.e.* the countries that give the efficient production for each decision unit.¹²

¹⁰ See Appendix for details on the data.

¹¹ Notice that, by construction, the country that spends less is always on the frontier, even if its results are poor. Afonso and St. Aubyn (2005a) report results which exclude these countries from the sample.

¹² Additionally, and as a measure of comparison, we also present the constant returns to scale results. All the DEA computations of this paper were performed with the computer software DEAP 2.1 provided by Coelli *et al.* (1998).

Table 2

FDH Education Efficiency Scores: 1 Input (*annual expenditure on secondary education per student in 1999*) **and 1 Output** (*PISA 2000 survey Indicator*)

Country	Input efficiency		Output efficiency		Dominating producer *
	Score	Rank	Score	Rank	
Australia	0.499	14	0.975	9	Korea/Japan
Austria	0.402	20	0.946	12	Korea/Japan
Belgium	0.531	13	0.935	14	Korea/Japan
Canada	0.572	11	0.983	7	Korea/Korea
Czech Republic	0.991	6	0.924	17	Korea/Korea
Denmark	0.448	17	0.916	20	Korea/Japan
Finland	0.583	9	0.998	6	Korea/Korea
France	0.478	16	0.934	15	Korea/Japan
Germany	0.359	21	0.897	22	Hungary/Japan
Greece	0.545	12	0.943	13	Poland/Hungary
Hungary	1.000	1	1.000	1	
Ireland	0.780	7	0.950	10	Korea/Korea
Italy	0.243	24	0.872	23	Poland/Japan
Japan	1.000	1	1.000	1	
Korea	1.000	1	1.000	1	
Mexico	1.000	1	1.000	1	
Norway	0.448	18	0.923	18	Korea/Japan
Poland	1.000	1	1.000	1	
Portugal	0.306	23	0.842	24	Poland/Korea
Spain	0.487	15	0.899	21	Hungary/Korea
Sweden	0.578	10	0.947	11	Korea/Korea
Switzerland	0.350	22	0.933	16	Korea/Japan
United Kingdom	0.610	8	0.976	8	Korea/Korea
United States	0.419	19	0.918	19	Korea/Japan
Average	0.610		0.966		

* In terms of input efficiency/in terms of output efficiency.

Table 3

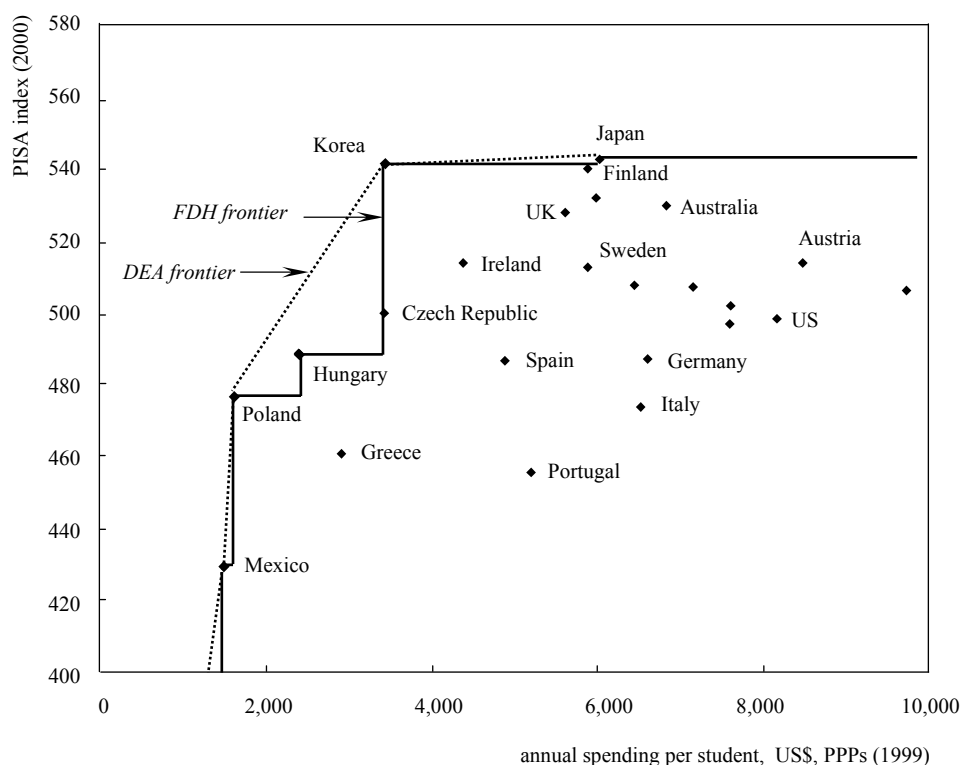
DEA Results for Education Efficiency in OECD Countries
1 Input (*annual expenditure on secondary education per student in 1999*)
and 1 Output (*PISA 2000 survey indicator*)

Country	Input oriented		Output oriented		Peers Input/output	CRS TE
	VRS TE	Rank	VRS TE	Rank		
Australia	0.453	12	0.976	7	Korea, Poland/Japan	0.257
Austria	0.311	17	0.947	11	Korea, Poland/Japan	0.201
Belgium	0.384	14	0.936	13	Korea, Poland/Japan	0.262
Canada	0.528	11	0.98	6	Korea, Poland/Japan, Korea	0.295
Czech Republic	0.650	6	0.924	16	Korea, Poland/Japan, Korea	0.481
Denmark	0.283	20	0.915	19	Korea, Poland/Japan	0.216
Finland	0.578	8	0.995	5	Korea, Poland/Japan, Korea	0.306
France	0.342	16	0.934	14	Korea, Poland/Japan	0.235
Germany	0.283	21	0.897	21	Korea, Poland/Japan	0.245
Greece	0.533	10	0.879	22	Mexico, Poland/Korea, Poland	0.526
Hungary	0.802	5	0.968	9	Korea, Poland/Korea, Poland	0.684
Ireland	0.603	7	0.949	10	Korea, Poland/Japan	0.389
Italy	0.242	24	0.871	23	Mexico, Poland/Japan	0.241
Japan	1.000	1	1.000	1	Japan/Japan	0.298
Korea	1.000	1	1.000	1	Korea/Korea	0.525
Mexico	1.000	1	1.000	1	Mexico/Mexico	0.962
Norway	0.298	18	0.923	17	Korea, Poland/Japan	0.218
Poland	1.000	1	1.000	1	Poland/Poland	1.000
Portugal	0.297	19	0.841	24	Mexico, Poland/Japan, Korea	0.292
Spain	0.384	15	0.898	20	Korea, Poland/Japan, Korea	0.332
Sweden	0.443	13	0.945	12	Korea, Poland/Japan, Korea	0.288
Switzerland	0.248	23	0.932	15	Korea, Poland/Japan	0.172
United Kingdom	0.543	9	0.973	8	Korea, Poland/Japan, Korea	0.312
United States	0.271	22	0.919	18	Korea, Poland/Japan	0.203
Average	0.520		0.942			0.373

Notes: CRS TE = constant returns to scale technical efficiency,
 VRS TE = variable returns to scale technical efficiency.

Figure 3

Production Possibility Frontier, 24 OECD Countries, 2000



It seems interesting to point out that in terms of variable returns to scale, the set of efficient countries that comes out from the DEA approach, Japan, Korea, Mexico and Poland, are basically the same countries that were on the production possibility frontier built previously with the FDH results. In the DEA analysis only Hungary is no longer efficient.

Using the results obtained from both DEA and FDH analysis, we constructed the production possibility frontiers for this set of OECD countries (see Figure 3), concerning spending per student and the PISA report outcomes. The graphical portrayal of the production possibility frontiers helps locating the countries in terms of distance from those frontiers. The dotted line represents the DEA frontier, while the full line stands for the FDH one. It is visually apparent how Hungary is dropped from the efficiency frontier when convexity is imposed. Notice that, while some countries are positioned rather away from the frontier, such as the already mentioned cases of Portugal, Germany and Italy, other countries are relatively close to it, such as the Czech Republic, Finland, Australia or the UK.

4.2 Education – results with quantitatively measured inputs

We broadened our education efficiency analysis by looking at quantity measures of inputs used to reach the recorded outcome of education secondary performance. This implied an alternative specification, still using the PISA index as the output but now with two input measures instead of one. These new input measures are the following quantity variables: number of hours per year spent in school and the number of teachers per student (see details in the Appendix).

The results of the FDH analysis for this 2 inputs and 1 output alternative are reported in Table 4. We can observe that three of the countries that are now labelled

Table 4

FDH Education Efficiency Scores: 2 Inputs (*hours per year in school, 2000, teachers per 100 students, 2000*) **and 1 Output** (*PISA 2000 survey indicator*)

Country	Input efficiency		Output efficiency		Dominating producers *
	Score	Rank	Score	Rank	
Australia	0.850	13	0.975	7	Korea/Japan
Belgium	0.689	18	0.935	9	Sweden/Japan
Czech Republic	0.931	7	0.926	11	Sweden/Finland
Denmark	0.912	10	0.916	12	Sweden/Japan
Finland	1.000	1	1.000	1	
France	0.832	14	0.934	10	Korea/Japan
Germany	0.961	6	0.897	15	Korea/Japan
Greece	0.758	16	0.848	17	Sweden/Japan
Hungary	0.801	15	0.899	14	Sweden/Japan
Italy	0.730	17	0.872	16	Sweden/Japan
Japan	1.000	1	1.000	1	
Korea	1.000	1	1.000	1	
Mexico	1.000	1	1.000	1	
New Zealand	0.914	9	0.982	6	Korea/Korea
Portugal	0.879	11	0.844	18	Sweden/Finland
Spain	0.876	12	0.901	13	Sweden/Finland
Sweden	1.000	1	1.000	1	
United Kingdom	0.922	8	0.973	8	Korea/Japan
Average	0.892		0.939		

* In terms of input efficiency/in terms of output efficiency.

as efficient, Japan, Korea, and Mexico, are precisely the same as before, when we used a financial measure as the sole input variable. However, now Hungary is no longer efficient, while Poland, another efficient country in the financial input setup was dropped from the sample due to the unavailability of data concerning the number of hours per year spent in school.

Mexico is still deemed efficient essentially due to the fact that it has the highest students-to-teachers ratio in the country sample. On the other hand Hungary has now worse efficiency rankings and is dominated by Sweden and by Japan, that have a lower number of hours per year spent in school and a higher students-to-teachers ratio. Furthermore, both Japan and Sweden had a better performance outcome than Hungary in the PISA education index. Additionally, Sweden and Finland now come up as efficient since they have a students per teacher ratio not very different from the average, they are below average in terms of hours per year spent in school, and are above average concerning the PISA index ranking.

Therefore, this supplementary set of results, using quantity measures as inputs instead of a financial measure, seems to better balance the relative importance of the inputs used by each country. Indeed, it seems natural that in more developed countries like Sweden and Finland the cost of resources is higher than in less developed countries like Hungary and Mexico. Both Sweden and Finland were being somehow penalised when only a financial input was being used but this bias can be corrected using quantity measures as inputs.

Additionally, this set of results also reveals a higher average input efficiency score than before, placing the average “wasted” resources at a lower threshold of around 11 per cent. Concerning the average output efficiency score the results are nevertheless similar either using a financial input measure or two quantity input measures.

In Table 5 we report similar DEA variable-returns-to-scale technical efficiency results for 2 inputs and 1 output case.

With these quantity inputs one notices that three countries are still labelled efficient as before (DEA with 1 input and 1 output) assuming variable returns to scale: Japan, Korea, and Mexico. However, now two new countries appear as well as efficient, Sweden and Finland, in line with the results we obtained with the FDH analysis. Again Poland was dropped from the sample due to data unavailability and Hungary is once more no longer located on the frontier.

4.3 Health – financial input results

Results using input measured in monetary terms are a tentative answer to the following questions: do countries that spend more on health attain a better health status for their population? Or else are there a number of countries that spend comparatively more on health without an improved result?

Table 5

DEA Results for Education Efficiency in OECD Countries, 2 Inputs (*hours per year in school and teachers per 100 students*) **and 1 Output** (*PISA survey indicator*)

Country	Input oriented		Output oriented		Peers Input/output	CRS TE
	VRS TE	Rank	VRS TE	Rank		
Australia	0.788	14	0.976	7	Sweden, Finland, Korea/Japan	0.783
Belgium	0.689	18	0.936	9	Sweden, Korea/Japan	0.683
Czech Republic	0.880	6	0.921	11	Sweden, Korea/Japan, Finland	0.849
Denmark	0.857	12	0.915	12	Sweden, Korea/Japan	0.823
Finland	1.000	1	1.000	1	Finland/Finland	0.981
France	0.762	15	0.934	10	Sweden, Korea/Japan	0.736
Germany	0.891	6	0.897	15	Sweden, Korea/Japan	0.823
Greece	0.715	17	0.847	17	Sweden, Korea/Japan	0.636
Hungary	0.801	13	0.899	13	Sweden/Japan	0.762
Italy	0.728	16	0.871	16	Sweden, Korea/Japan	0.671
Japan	1.000	1	1.000	1	Japan/Japan	0.942
Korea	1.000	1	1.000	1	Korea/Korea	1.000
Mexico	1.000	1	1.000	1	Mexico/Mexico	1.000
New Zealand	0.878	9	0.979	6	Sweden, Korea/Japan, Finland	0.874
Portugal	0.880	8	0.842	18	Sweden/Japan, Finland	0.782
Spain	0.877	10	0.899	14	Sweden/Japan, Finland	0.832
Sweden	1.000	1	1.000	1	Sweden/Sweden	1.000
United Kingdom	0.859	11	0.972	8	Sweden, Finland, Korea/Japan	0.859
Average	0.867		0.938			0.835

Notes: CRS TE = constant returns to scale technical efficiency.
VRS TE = variable returns to scale technical efficiency.

Table 6 displays FDH results when a financial input, total per capita expenditure, is considered. In 30 considered countries, 11 were estimated to be on the efficiency frontier – the Czech Republic, Finland, Greece, Iceland, Japan, Korea, Mexico, Poland, Portugal, Spain and Turkey.

Note again that, by construction, the country that spends less is always on the frontier, even if its results are poor. This is why Mexico and Turkey are considered here as efficient, as both spend clearly below average and have results also clearly below average.

Another group of countries located in the frontier is the “less than average spenders” that attains “average to good results.” Here, we can include the Czech Republic, Greece, Korea, Portugal and Spain. Finally, Finland, Iceland and Japan belong to a third group – those that have very good results without spending that much.

If we analyse the inefficient group of countries, the ones not in the FDH frontier, a number of countries display strong spending inefficiency. The United States have an input efficiency score of 0.313 with Greece as a reference, meaning that Greece spends less than a third of what the US spends, having better results. From this point of view, the US wastes more than two thirds of its spending. Similarly, Spain, an efficient country, spends slightly more than half (56.5 per cent) of German expenditure, being better off. Germany therefore is estimated to waste 43.5 per cent of its spending.

Results for this 1 input – 2 output model using DEA are summarised in Table 7.

In general terms, DEA results are not very different from FDH ones, the efficient group of countries being a subset of those previously efficient under FDH analysis. Specifically, Finland, Greece, Portugal and Spain are now inefficient, and the Czech Republic, Iceland, Japan, Korea, Mexico, Poland and Turkey define the frontier. The most striking difference is for Portugal – under DEA, this country is now near the end of the ranking, either in terms of input or output scores. Indeed, Portugal is dominated by the Czech Republic, Korea, and Japan, the first two countries having lower per capita spending in health and similar life expectancy.

4.4 Health – results with quantitatively measured inputs

When using quantitatively measured inputs, we are simply comparing resources available to the health sector (doctors, nurses, beds) with outcomes, without controlling for the cost of those resources. It is therefore possible that a country is efficient under this framework, but not in a model where spending is the input.

Half among the 26 countries analysed with this second formulation for health was estimated as efficient under FDH analysis (see Table 8). These are Canada, Denmark, France, Japan, Korea, Mexico, Norway, Portugal, Spain, Sweden, Turkey,

Table 6

FDH Health Efficiency Scores: 1 Input (per capita total health expenditure)
and 2 Outputs (infant survival rate and life expectancy)

Country	Input efficiency		Output efficiency		Dominating producers *
	Score	Rank	Score	Rank	
Australia	0.843	18	0.981	16	Japan
Austria	0.882	15	0.969	22	Japan
Belgium	0.689	24	0.964	27	Spain/Japan
Canada	0.759	22	0.981	17	Japan
Czech Republic	1.000	1	1.000	1	
Denmark	0.682	25	0.952	29	Finland/Japan
Finland	1.000	1	1.000	1	
France	0.823	20	0.979	18	Japan
Germany	0.565	29	0.965	26	Spain/Japan
Greece	1.000	1	1.000	1	
Hungary	0.839	19	0.936	30	Korea
Iceland	1.000	1	1.000	1	
Ireland	0.878	17	0.972	21	Spain
Italy	0.780	21	0.975	19	Spain/Japan
Japan	1.000	1	1.000	1	
Korea	1.000	1	1.000	1	
Luxembourg	0.586	28	0.969	23	Spain/Japan
Mexico	1.000	1	1.000	1	
Netherlands	0.678	26	0.968	24	Spain/Japan
New Zealand	0.954	14	0.995	13	Spain
Norway	0.717	23	0.974	20	Japan
Poland	1.000	1	1.000	1	
Portugal	1.000	1	1.000	1	
Slovak Republic	0.983	13	0.967	25	Korea
Spain	1.000	1	1.000	1	
Sweden	0.993	12	1.000	12	Japan
Switzerland	0.588	27	0.990	14	Japan
Turkey	1.000	1	1.000	1	
United Kingdom	0.881	16	0.983	15	Spain
United States	0.313	30	0.953	28	Greece/Japan
Average	0.848		0.982		

* In terms input efficiency/in terms of output efficiency.

Table 7

DEA Results for Health Efficiency in OECD Countries, 1 Input (per capita total expenditure in health) and 2 Outputs (infant survival rate and life expectancy)

Country	Input oriented		Output oriented		Peers Input/output	CRS TE
	VRS TE	Rank	VRS TE	Rank		
Australia	0.670	17	0.981	13	Japan, Mexico/Japan	0.385
Austria	0.634	19	0.969	20	Czech Republic, Japan, Korea/Japan	0.502
Belgium	0.556	25	0.964	25	Czech Republic, Japan, Korea/Japan	0.447
Canada	0.604	21	0.981	14	Japan, Mexico/Japan	0.369
Czech Republic	1.000	1	1.000	1	Czech Republic/Czech Republic	1.000
Denmark	0.526	26	0.952	29	Czech Republic, Japan, Korea/Japan	0.462
Finland	0.906	10	0.981	15	Czech Republic, Iceland, Japan/ Czech Republic, Iceland, Japan	0.768
France	0.641	18	0.979	16	Korea, Japan, Mexico/Japan	0.479
Germany	0.490	29	0.965	24	Czech Republic, Japan, Korea/Japan	0.395
Greece	0.892	12	0.992	9	Japan, Mexico/Japan, Mexico	0.564
Hungary	0.757	14	0.928	30	Czech Republic, Poland/ Japan, Korea, Mexico	0.751
Iceland	1.000	1	1.000	1	Iceland/Iceland	0.823
Ireland	0.591	22	0.958	27	Czech Republic, Japan, Korea/ Japan, Mexico	0.515
Italy	0.711	15	0.975	17	Japan, Mexico/Japan	0.490
Japan	1.000	1	1.000	1	Japan/Japan	0.737
Korea	1.000	1	1.000	1	Korea/Korea	0.973
Luxembourg	0.511	28	0.969	21	Czech Republic, Japan, Korea/Japan	0.402
Mexico	1.000	1	1.000	1	Mexico/Mexico	0.839
Netherlands	0.559	24	0.968	22	Japan, Korea, Mexico/Japan	0.419
New Zealand	0.837	13	0.987	12	Japan, Mexico/Japan, Mexico	0.571
Norway	0.580	23	0.974	18	Czech Republic, Japan, Korea/Japan	0.460
Poland	1.000	1	1.000	1	Poland/Poland	1.000
Portugal	0.628	20	0.959	26	Czech Republic, Japan, Korea/ Japan, Mexico	0.593
Slovak Republic	0.895	11	0.966	23	Czech Republic, Poland/ Japan, Korea, Mexico	0.895
Spain	0.955	8	0.996	8	Japan, Korea, Mexico/Japan, Mexico	0.700
Sweden	0.948	9	0.988	11	Czech Republic, Iceland, Japan/ Czech Republic, Iceland, Japan	0.732
Switzerland	0.523	27	0.990	10	Japan, Mexico/Japan	0.323
Turkey	1.000	1	1.000	1	Turkey/Turkey	1.000
United Kingdom	0.672	16	0.972	19	Japan, Korea, Mexico/Japan, Mexico	0.509
United States	0.206	30	0.953	28	Japan, Korea, Mexico/Japan	0.157
Average	0.743		0.978			0.609

Notes: CRS TE = constant returns to scale technical efficiency.

VRS TE = variable returns to scale technical efficiency.

Table 8

**FDH Health Efficiency Scores: 3 Inputs (doctors, nurses and beds)
and 2 Outputs (infant mortality and life expectancy)**

Country	Input efficiency		Output efficiency		Dominating producers *
	Score	Rank	Score	Rank	
Australia	0.926	18	1.000	14	Canada
Austria	0.967	16	0.981	19	Sweden
Canada	1.000	1	1.000	1	
Czech Republic	1.000	15	0.949	21	France
Denmark	1.000	1	1.000	1	
Finland	0.935	17	0.974	20	Sweden
France	1.000	1	1.000	1	
Germany	0.935	24	0.949	24	Sweden
Greece	0.923	19	0.992	16	Spain
Hungary	0.663	26	0.913	26	Korea/Spain
Ireland	0.902	25	0.946	25	Canada
Italy	0.837	22	0.997	15	Spain
Japan	1.000	1	1.000	1	
Korea	1.000	1	1.000	1	
Luxembourg	1.000	14	0.991	18	Spain
Mexico	1.000	1	1.000	1	
Netherlands	0.935	23	0.974	22	Sweden
New Zealand	0.913	20	0.991	17	Canada
Norway	1.000	1	1.000	1	
Poland	0.902	21	0.946	23	United Kingdom
Portugal	1.000	1	1.000	1	
Spain	1.000	1	1.000	1	
Sweden	1.000	1	1.000	1	
Turkey	1.000	1	1.000	1	
United Kingdom	1.000	1	1.000	1	
United States	1.000	1	1.000	1	
Average	0.959		0.987		

* In terms input efficiency/in terms of output efficiency.

the United Kingdom and the United States. Again one can distinguish different reasons for being considered efficient. Some countries have few resources allocated to health with corresponding low results (Mexico, Turkey); a second group attains better than average results with lower than average resources (e.g. the United Kingdom); finally, there is a third group of countries which are very good performers (e.g. Japan and Sweden).

Again, under DEA, the efficient group is smaller than under FDH. DEA results are summarised in Table 9, and there are 8 countries in the frontier: Canada, Japan, Korea, Mexico, Spain, Sweden, Turkey and the United Kingdom. All these countries were already considered efficient under FDH, but half of the “FDH-efficient” nations are not efficient now (Denmark, France, Norway, Portugal, Spain, Sweden, Turkey, and the United States). It is interesting to note that a group of ex-communist countries and European Union 2004 newcomers (the Czech Republic, Hungary, and Poland) are among the less efficient in providing health, when resources are physically measured.

5. Conclusion

Table 10 summarises our results, in terms of the countries that we found out as being efficient.

In general terms, similarly to Afonso and St. Aubyn (2005a), results suggest that efficiency in spending in education and health, two sectors where public provision is predominant, is an important issue. In the education sector, the average input inefficiency varies between 0.520 (1 input, 1 output, DEA) and 0.892 (2 inputs, 1 output, FDH), depending on the model and method, and on health, it varies between 0.743 (1 input, 2 outputs, DEA) and 0.959 (3 inputs, 2 outputs, FDH). Less efficient countries can therefore attain better results using the very same resources.

However, measuring efficiency when one considers the financial resources allocated to a sector is different from assessing efficiency from the measurement of resources in physical terms. The case of Sweden clearly illustrates this point. This is a country that only arises as efficient, in both education and health sectors, when inputs are physically measured. In our interpretation, this may well result from the fact that resources are comparatively expensive in Sweden. An opposite example is provided by the twin cases of the Czech Republic and Poland in what concerns health and by Hungary and Poland in the education sector. They are not efficient in physical terms. Probably because resources considered (doctors, nurses, hospital beds, teachers) are comparatively cheaper, they become efficient in financial terms.

Some countries always appear as efficient, either in health or in education – Mexico, Japan and Korea. Mexico is the country that spends fewer resources in these sectors and also gets the worse results. It appears as efficient for this sole reason. Japan is the best performer in health and education as far as outputs are concerned, and does not spend too many resources. Korea is a very good education

Table 9
DEA Results for Health Efficiency in OECD Countries, 3 Inputs (doctors, nurses and beds) and 2 Outputs (infant mortality and life expectancy)

Country	Input oriented		Output oriented		Peers Input/output	CRS TE
	VRS TE	Rank	VRS TE	Rank		
Australia	0.832	11	0.990	12	Canada, Japan, Spain, United Kingdom/ Canada, Japan, Spain, Sweden	0.691
Austria	0.703	21	0.976	15	Japan, Korea, Sweden/Japan, Sweden	0.703
Canada	1.000	1	1.000	1	Canada	0.978
Czech Republic	0.681	22	0.936	24	Japan, Korea, Sweden/Japan, Sweden	0.675
Denmark	0.808	14	0.965	21	Korea, Mexico, Spain, Sweden/ Japan, Spain, Sweden	0.802
Finland	0.806	15	0.970	19	Japan, Korea, Sweden/Japan, Sweden	0.802
France	0.835	10	0.991	10	Japan, Korea, Spain, Sweden, United Kingdom/ Japan, Spain, Sweden	0.768
Germany	0.604	24	0.972	18	Japan, Korea, Sweden/Japan, Sweden	0.604
Greece	0.820	13	0.991	11	Korea, Mexico, Spain/Japan, Spain, Sweden	0.695
Hungary	0.480	26	0.892	26	Korea, Mexico, Turkey, United Kingdom/ Japan, Spain	0.460
Ireland	0.716	19	0.958	23	Japan, Korea, Sweden/Canada, Japan, Sweden	0.715
Italy	0.798	16	0.995	9	Mexico, Spain, Sweden/Japan, Spain, Sweden	0.743
Japan	1.000	1	1.000	1	Japan	1.000
Korea	1.000	1	1.000	1	Korea	1.000
Luxembourg	0.707	20	0.979	14	Japan, Korea, Spain, Sweden, United Kingdom/ Japan, Spain, Sweden	0.683
Mexico	1.000	1	1.000	1	Mexico	1.000
Netherlands	0.579	25	0.973	17	Canada, Japan, Korea, United Kingdom/ Japan, Sweden	0.577
New Zealand	0.830	12	0.986	13	Canada, Japan, Korea, United Kingdom/ Canada, Japan, Sweden	0.802
Norway	0.726	17	0.976	16	Japan, Korea, Sweden/Japan, Sweden	0.725
Poland	0.679	23	0.934	25	Mexico, Turkey, United Kingdom/ Canada, Japan, Spain, United Kingdom	0.675
Portugal	0.844	9	0.961	22	Korea, Mexico, Spain, Sweden/ Mexico, Spain, Sweden	0.836
Spain	1.000	1	1.000	1	Spain	1.000
Sweden	1.000	1	1.000	1	Sweden	1.000
Turkey	1.000	1	1.000	1	Turkey	1.000
United Kingdom	1.000	1	1.000	1	United Kingdom	1.000
United States	0.725	18	0.968	20	Mexico, Sweden, United Kingdom/ Canada, Mexico, Sweden	0.724
Average	0.814		0.977			0.795

Notes: CRS TE = constant returns to scale technical efficiency.
VRS TE = variable returns to scale technical efficiency.

Table 10

**OECD Efficient Countries in Education and in Health Sectors:
Two Non-parametric Approaches and Different Input and Output Measures**

Sector	Inputs, Outputs	N-p M	Countries
Education	<ul style="list-style-type: none"> • Spending per student (in) • PISA (out) 	FDH	Japan, Korea, Mexico, Poland, Hungary
		DEA	Japan, Korea, Mexico, Poland
	<ul style="list-style-type: none"> • Hours per year in school (in) • Teachers per 100 students (in) • PISA (out) 	FDH	Japan, Korea, Mexico, Sweden, Finland
		DEA	Japan, Korea, Mexico, Sweden, Finland
Health	<ul style="list-style-type: none"> • Per capita health spending (in) • Life expectancy (out) • Infant mortality (out) 	FDH	Czech Republic, Finland, Greece, Iceland, Japan, Korea, Mexico, Poland, Portugal, Spain, Turkey
		DEA	Czech Republic, Iceland, Japan, Korea, Mexico, Poland, Turkey
	<ul style="list-style-type: none"> • Doctors (in) • Nurses (in) • Hospital beds (in) • Life expectancy (out) • Infant mortality (out) 	FDH	Canada, Denmark, France, Japan, Korea, Mexico, Norway, Portugal, Spain, Sweden, Turkey, UK, US
		DEA	Canada, Japan, Korea, Mexico, Spain, Sweden, Turkey, UK

N-p M = Non-parametric Method.

performer, and it spends very little on health with surprisingly good results in comparative terms.

Assessing efficiency across countries opens the way to a related line of research – one would like not only to measure inefficiency, but also to explain international differences. In Afonso and St. Aubyn (2005b), we find a statistically significant influence of GDP per head and of educational attainment by the adult population in explaining cross-country variation of output scores.¹³ Measuring and explaining inefficiency, and quantifying the systemic and the environment contributions to it, is something that, we believe, is of great relevance in economic policy terms.

¹³ The importance of these variables in explaining student achievement was already reported by Barro and Lee (2001), with different methods, countries, data and time period.

**APPENDIX
DATA AND SOURCES**

Table 11

Education Indicators

Country	PISA (2000) (1)	Spending per student (2)	Hours per year in school (3)	Students per teacher (4)
Australia	530	6850	1019	12.6
Austria	514	8504	1148	
Belgium	508	6444	1075	9.7
Canada	532	5981		18.8
Czech Republic	500	3449	867	13.1
Denmark	497	7626	890	12.8
Finland	540	5863	808	13.8
France	507	7152	1042	12.5
Germany	487	6603	903	15.2
Greece	460	2904	1064	10.7
Hungary	488	2368	925	11.2
Iceland	506		809	
Ireland	514	4383	891	
Italy	473	6518	1020	10.3
Japan	543	6039	875	15.2
Korea	541	3419	867	21.2
Luxembourg	436			9.2
Mexico	429	1480	1167	31.7
Netherlands			1067	17.1

Table 11 (continued)

Education Indicators

Country	PISA (2000) (1)	Spending per student (2)	Hours per year in school (3)	Students per teacher (4)
New Zealand	531		948	16.3
Norway	501	7628	827	
Poland	477	1583		15.5
Portugal	456	5181	842	9.0
Slovak Republic				13.2
Spain	487	4864	845	11.9
Sweden	513	5911	741	14.1
Switzerland	506	9756		
Turkey			796	14.0
United Kingdom	528	5608	940	14.8
United States	499	8157		15.2
Mean	500	5595	932	14.4
Median	506	5946	897	13.8
Minimum	429	1480	741	9.0
Maximum	543	9756	1167	31.7
Standard deviation	30	2186	117	4.6
Observations	27	24	24	25

(1) Average of performance of 15-year-olds on the PISA reading, mathematics and science literacy scales, 2000. Source: OECD (2001).

(2) Annual expenditure on educational institutions per student in equivalent US dollars converted using PPPs, secondary education, based on full-time equivalents, 1999. Source: OECD (2002a).

(3) Total intended instruction time in public institutions in hours per year for 12 to 14-year-olds, 2000. Source: OECD (2002a).

(4) Ratio of students to teaching staff in public and private institutions, secondary education, calculations based on full-time equivalents, 2000. Source: OECD (2002a).

Table 12

Health Indicators

Country	Life expectancy (1)	Infant mortality (2)	Per capita spending in health (3)	Doctors (4)	Nurses (5)	Hospital beds (6)
Australia	79.0	5.7	2058	2.5	8.1	7.9
Austria	78.0	4.4	1968	3.0	9.0	8.8
Belgium	77.6	4.9	2008	3.8		7.3
Canada	79.0	5.3	2285	2.1	7.5	3.9
Czech Republic	74.8	4.6	944	3.0	8.2	8.7
Denmark	76.6	4.2	2241	3.4	7.3	4.5
Finland	77.4	3.7	1529	3.1	14.4	7.6
France	78.8	4.3	2109	3	6	8.4
Germany	77.7	4.5	2451	3.5	9.5	9.2
Greece	78.1	6.2	1307	4.4	3.9	4.9
Hungary	70.7	8.4	751	3.2	5.0	8.3
Iceland	79.5	2.4	2204	3.4	14.2	
Ireland	76.5	5.5	1576	2.3	8.7	9.7
Italy	78.5	5.1	1774	5.9	4.5	4.9
Japan	80.5	3.4	1735	1.9	7.8	16.4
Korea	75.5	7.7	630	1.3	1.4	5.5
Luxembourg	78.0	4.6	2361	3.1	7.1	8
Mexico	75.0	25.9	431	1.7	1.2	1.1
Netherlands	77.9	5.2	2040	3.1	12.7	11.1
New Zealand	78.3	5.4	1450	2.3	9.6	6.2
Norway	78.4	3.9	2421	2.8	10.1	14.4

Table 12 (continued)

Health Indicators

Country	Life expectancy (1)	Infant mortality (2)	Per capita spending in health (3)	Doctors (4)	Nurses (5)	Hospital beds (6)
Poland	73.2	8.9	543	2.3	5.1	5.1
Portugal	75.6	5.6	1345	3.2	3.8	4
Slovak Republic	73.0	8.3	641		7.3	8.1
Spain	78.7	4.5	1384	3.1	3.6	4.1
Sweden	79.5	3.4	1748	2.9	8.4	3.7
Switzerland	79.7	4.6	2952	3.4		18.3
Turkey	68.4	40.3	303	1.2	1.1	2.6
United Kingdom	77.4	5.8	1527	1.8	4.6	4.1
United States	76.7	7.1	4178	2.8	8.3	3.6
Mean	76.9	7.1	1696.5	2.9	7.1	7.3
Median	77.8	5.2	1741.5	3.0	7.4	7.3
Minimum	68.4	2.4	303.0	1.2	1.1	1.1
Maximum	80.5	40.3	4178.0	5.9	14.4	18.3
Standard deviation	2.7	7.5	827.6	0.9	3.5	4.0
Observations	30	30	30	29	28	29

(1) Years of life expectancy. Total population at birth. 1999. Greece: 1998. Italy: 1997. Source: OECD (2002b).

(2) Deaths per 1000 live births. 1999. Korea: 1997. New Zealand: 1998. Source: OECD (2002b).

(3) Total expenditure on health per capita, purchasing power parities, US dollars. 1998. Source: OECD (2002b).

(4) Practising physicians, density per 1000 population. 1999. Australia, France and Japan: 1998. Source: OECD (2002b).

(5) Practising nurses, density per 1000 population. 1999. Australia, France: 1997. Japan: 1998. Slovakia: 2000. Source: OECD (2002b).

(6) Total in patient care beds per 1000 population. 1999. Denmark, Ireland, Luxembourg, New Zealand, Portugal: 1998. Belgium: 1997. Source: OECD (2002b).

REFERENCES

- Afonso, A., L. Schuknecht and V. Tanzi (2003), "Public Sector Efficiency: An International Comparison," ECB, Working Paper, No. 242, forthcoming in *Public Choice*.
- Afonso, A. and S. Fernandes (2005), "Local Government Spending Efficiency: DEA Evidence for the Lisbon Region," forthcoming in *Regional Studies*.
- Afonso, A. and M. Santos (2005), "Students and Teachers: A DEA Approach to the Relative Efficiency of Portuguese Public Universities," ISEG/UTL–Technical University of Lisbon, Department of Economics, Working Paper, No. 7/2005/DE/CISEP.
- Afonso, A. and C. Scaglioni (2005), "Public Services Efficiency Provision in Italian Regions: A Non-Parametric Analysis", Department of Economics, ISEG-UTL, Working Paper, No. 02/2005/DE/CISEP, forthcoming in F. Columbus (ed.), *State and Local Economics: Issues and Developments*, Nova Science Publishers, New York.
- Afonso, A. and M. St. Aubyn (2005a), "Non-parametric Approaches to Public Education and Health Expenditure Efficiency in OECD Countries", forthcoming in *Journal of Applied Economics*.
- (2005b), "Cross-country Efficiency of Secondary Education Provision: A Semi-parametric Analysis with Non-discretionary Inputs", European Central Bank, Working Paper, No. 494, June. ISEG/UTL–Technical University of Lisbon, Department of Economics, Working Paper, No. 5/2005/DE/CISEP/UECE.
- Barro, R. and J.W. Lee (2001), "Schooling Quality in a Cross-section of Countries", *Economica*, No. 68, pp. 465-88.
- Charnes, A., W. Cooper and E. Rhodes (1978), "Measuring the Efficiency of Decision-making Units," *European Journal of Operational Research*, Vol. 2, No. 6, pp. 429-44.
- Clements, B. (2002), "How Efficient is Education Spending in Europe?" *European Review of Economics and Finance*, Vol. 1, No. 1, pp. 3-26.
- Coelli, T. (1996), "Assessing the Performance of Australian Universities Using Data Envelopment Analysis," University of New England, mimeo.
- Coelli, T., P. Rao and G. Battese (1998), *An Introduction to Efficiency and Productivity Analysis*, Boston, Kluwer.
- De Borger, B. and K. Kerstens (1996), "Cost Efficiency of Belgian Local Governments: A Comparative Analysis of FDH, DEA, and Econometric Approaches," *Regional Science and Urban Economics*, Vol. 26, No. 2, pp. 145-70.

- Deprins, D., L. Simar and H. Tulkens (1984), "Measuring Labor-efficiency in Post Offices", in M. Marchand, P. Pestieau and H. Tulkens (eds.), *The Performance of Public Enterprises: Concepts and Measurement*, Amsterdam, North-Holland.
- Fakin, B. and A. de Crombrugghe (1997), "Fiscal Adjustment in Transition Economies: Social Transfers and the Efficiency of Public Spending: A Comparison with OECD Countries", Policy Research, Working Paper, No. 1803, Washington (D.C.), The World Bank.
- Farrell, M. (1957), "The Measurement of Productive Efficiency," *Journal of the Royal Statistical Society, Series A*, No. 120, Part 3, pp. 253-90.
- Gupta, S. and M. Verhoeven (2001), "The Efficiency of Government Expenditure – Experiences from Africa", *Journal of Policy Modelling*, No. 23, pp. 433-67.
- OECD (2001), *Knowledge and Skills for Life – First Results from Pisa 2000*, Paris, OECD.
- (2002a). *Education at a Glance – OECD Indicators 2002*, Paris, OECD.
- (2002b), *OECD Health Data 2002*, Paris, OECD.
- Sengupta, J. (2000), *Dynamic and Stochastic Efficiency Analysis – Economics of Data Envelopment Analysis*, Singapore, World Scientific.
- Simar, L. and P. Wilson (2003), *Efficiency Analysis: The Statistical Approach*, lecture notes, July.
- St. Aubyn, M. (2002), "Evaluating Efficiency in the Portuguese Health and Education Sectors," paper presented to the conference *Desenvolvimento Económico Português no Espaço Europeu: Determinantes e Políticas*, Banco de Portugal, May, Lisbon, Fundação Calouste Gulbenkian.
- (2003), "Evaluating Efficiency in the Portuguese Education Sector", *Economia*, No. 26, pp. 25-51.
- Thanassoulis, E. (2001), *Introduction to the Theory and Application of Data Envelopment Analysis*, Kluwer Academic Publishers.