Journal of Applied Economics. Vol VIII, No. 2 (Nov 2005), 227-246

NON-PARAMETRIC APPROACHES TO EDUCATION AND HEALTH EFFICIENCY IN OECD COUNTRIES

António Afonso[*]
Technical University of Lisbon and European Central Bank

Miguel St. Aubyn
Technical University of Lisbon

Submitted February 2004; accepted September 2004

We address the efficiency in education and health sectors for a sample of OECD countries by applying two alternative non-parametric methodologies: FDH and DEA. Those are two areas where public expenditure is of great importance so that findings have strong implications in what concerns public sector efficiency. When estimating the efficiency frontier we focus on measures of quantity inputs. We believe this approach to be advantageous since a country may well be efficient from a technical point of view but appear as inefficient if the inputs it uses are expensive. Efficient outcomes across sectors and analytical methods seem to cluster around a small number of core countries, even if for different reasons: Japan, Korea and Sweden.

JEL classification codes: C14, H51, H52, I18, I21, I28
Key words: education, health, expenditure efficiency, production possibility frontier, FDH, DEA

---

[*] António Afonso (corrresponding author): ISEG/UTL - Technical University of Lisbon, CISEP – Research Centre on the Portuguese Economy, R. Miguel Lupi 20, 1249-078 Lisbon, Portugal, email: aafonso@iseg.utl.pt; European Central Bank, Kaiserstraße 29, D-60311 Frankfurt am Main, Germany, email: antonio.afonso@ecb.int. Miguel St. Aubyn: ISEG/UTL - Technical University of Lisbon, UECE – Research Unit on Complexity in Economics, R. Miguel Lupi 20, 1249-078 Lisbon, Portugal, email: mstaubyn@iseg.utl.pt. We are grateful to Manuela Arcanjo, Rigmar Osterkamp, Álvaro Pina, Ludger Schuknecht, Léopold Simar, Guido Wolswijk, an anonymous referee, the co-editor Germán Coloma, and participants at the 57th International Atlantic Economic Conference, Lisbon, 2004, at the 59th European Meeting of the Econometric Society, Madrid, 2004, and at the 4th International Symposium of DEA, Birmingham, 2004, for helpful comments. Any remaining errors are the responsibility of the authors. The opinions expressed herein are those of the authors and do not necessarily reflect those of the author's employers.

I. Introduction

The debate in economics on the proper size and role of the state is pervasive since Adam Smith. Nevertheless, the proper measurement of public sector performance when it concerns services provision is a delicate empirical issue and the literature on it, particularly when it comes to aggregate and international data, is still limited. This measurement issue is here considered in terms of efficiency measurement. In our framework, we compare resources used to provide certain services, the inputs, with outputs. Efficiency frontiers are estimated, and therefore inefficient situations can be detected. As the latter will imply the possibility of a better performance without increasing allocated resources, the efficiency issue gives a new dimension to the recurring discussion about the size of the state.

Although methods proposed and used here can be applied to several sectors where government is the main or an important service provider, we restrict ourselves to efficiency evaluation in education and health in the OECD countries. These are important expenditure items everywhere and the quantities of public and private provision have a direct impact on welfare and are important for the prospects of economic growth. OECD countries were chosen because data for these countries were collected following the same criteria and provided by the OECD itself, both for education and health. Also, this sample is not too heterogeneous in wealth and development terms, so that an efficiency comparison across countries is meaningful.

Our study presents two advances in what concerns the recent literature on the subject. First, when estimating the efficiency frontier, we use quantity inputs, and not simply a measure of expenditure. We consider this procedure to be advantageous, as a country may well be efficient from a technical point of view but appear as inefficient in previous analysis if the inputs it uses are expensive. Moreover, our method allows the detection of some sources of inefficiency (e. g. due to an inappropriate composition of inputs). Second, we do not restrain to one sole method, but compare results using two methods. To our knowledge, Data Envelopment Analysis has not yet been used in this context. This is a step forward in what concerns the evaluation of result robustness.

The paper is organized as follows. In section II we briefly review some of the literature on spending efficiency. Section III outlines the two non-parametric approaches used in the paper and in section IV we present and discuss the results of our non-parametric efficiency analysis. Section V provides conclusions.

II. Literature on spending efficiency and motivation

Even when public organizations are studied, this is seldom done in an international and more aggregate framework. International comparisons of expenditure performance implying the estimation of efficiency frontiers do not abound. To our knowledge, this has been done by Fakin and Crombrugghe (1997) and Afonso, Schuknecht and Tanzi (2004) for public expenditure in the OECD, by Clements (2002) for education spending in Europe, by Gupta and Verhoeven (2001) for education and health in Africa, and by St. Aubyn (2002, 2003) for health and education expenditure in the OECD. All these studies use Free Disposable Hull analysis and the inputs are measured in monetary terms. Using a more extended sample, Evans, Tandon, Murray and Lauer (2000) evaluate the efficiency of health expenditure in 191 countries using a parametric methodology.

Barro and Lee (2001) and Hanuschek and Luque (2002) have econometrically estimated education production functions in an international framework. The education outcome, or "school quality", was measured by cross-country comparative studies assessing learning achievement and inputs included resources allocated to education, parents' income and their instruction level. The inefficiency concept is not embodied in the empirical method used by these authors as deviations from the function were supposed to derive from unmeasured factors only and to have zero mean. Simply, when there is no evidence of correlation between one or more inputs and the output, the authors draw some inefficiency conclusions. An interesting development following this econometric methodology would be to allow both for zero mean measurement errors and one sided inefficient variations in this international framework.[1]

In our approach, we do not assume that all decision units operate on the production function. Moreover, our production function envelops our data and has no a priori functional form. Differently from the regression analysis, output may be measured by more than one variable. We intend to measure inefficiency, and not so much to explain it. We compare resources allocated to the health or education production processes to outcomes, and do not enter into account with some other factors that vary across countries and that may well be important for the achieved results, like the family factors mentioned above. Of course, these factors would become important candidate variables when it comes to explain measured inefficiencies, a logical research step to follow.

[1] Jondrow et al. (1982), Ferrier and Lovell (1990) and De Borger and Kerstens (1996) address this econometric problem.

Education and health expenditure are two important public spending items. For instance, for some EU countries, spending in these two categories, plus R&D, accounted for between 10 and 15 per cent of GDP in 2000. Public expenditure in these items increased during the last 20 years with particular emphasis in countries where the levels of intervention were rather low, such as Portugal and Greece.[2]

Table 1 summarizes some data on education and health spending in OECD countries. In 2000, education spending varied between 4 and 7.1 percent of GDP within OECD countries. This expenditure is predominantly public, and particularly in European countries (92.4 percent of total educational expenditure is public in the EU). Total expenditure on health is usually higher than expenditure on education, and it averaged 8 percent of GDP in the OECD. Public expenditure in health is usually more than half of total expenditure, and it averaged 72.2 percent of total in the OECD. The United States is a notable exception – being the country where health spending is relatively higher (13.1 of GDP) and were private spending is more important (55.8 per cent of total).

Table 1. Public and total expenditure on education and on health, 2000

	Public expenditure on education (% of total expenditure)	Total expenditure on education (% of GDP)	Public expenditure on health (% of total expenditure)	Total expenditure on health (% of GDP)
Australia	75.9	6.0	68.9	8.9
Austria	94.2	5.7	69.4	7.7
Belgium	93.3	5.5	72.1	8.6
Canada	80.6	6.4	70.9	9.2
Czech Republic	90.0	4.6	91.4	7.1
Denmark	96.0	6.7	82.5	8.3
Finland	98.4	5.6	75.1	6.7
France	93.8	6.1	75.8	9.3
Germany	81.1	5.3	75.0	10.6
Greece	93.8	4.0	56.1	9.4
Hungary	88.3	5.0	75.5	6.7
Iceland	91.1	6.3	83.7	9.3
Ireland	90.6	4.6	73.3	6.4

[2] See EC (2002).

Table 1. (Continued) Public and total expenditure on education and on health, 2000

	Public expenditure on education (% of total expenditure)	Total expenditure on education (% of GDP)	Public expenditure on health (% of total expenditure)	Total expenditure on health (% of GDP)
Italy	92.2	4.9	73.4	8.2
Japan	75.2	4.6	78.3	7.6
Korea	61.0	7.1	44.4	5.9
Luxembourg	na	na	87.8	5.6
Mexico	85.9	5.5	47.9	5.6
Netherlands	91.6	4.7	63.4	8.6
New Zealand	na	na	78.0	8.0
Norway	98.7	5.9	85.2	7.6
Poland	na	na	70.0	6.0
Portugal	98.6	5.7	68.5	9.0
Slovak Republic	96.4	4.2	89.4	5.7
Spain	88.1	4.9	71.7	7.5
Sweden	97.0	6.5	85.0	8.4
Switzerland	92.8	5.7	55.6	10.7
Turkey	na	na	na	na
United Kingdom	86.1	5.3	80.9	7.3
United States	68.2	7.0	44.2	13.1
OECD countries	88.4	5.5	72.2	8.0
EU countries	92.4	5.4	74.7	8.0
Minimum	61.0 (Korea)	4.0 (Greece)	44.2 (US)	5.6 (Mexico, Luxembourg)
Maximum	98.7 (Norway)	7.1 (Korea)	91.4 (Czech Rep.)	13.1 (US)

Notes: na is non available. Public expenditure on education includes public subsidies to households attributable for educational institutions and direct expenditure on educational institutions from international sources. Private expenditure on education is net of public subsidies attributable for educational institutions. Source for health expenditure is OECD Health Data 2003 - Frequently asked data http://www.oecd.org/document/16/0, 2340, en_2825_495642_2085200_1_1_1_1,00.html. Source for education expenditure is Education at a Glance 2003 – Tables, OECD http://www.oecd.org/document/34/0,2340, en_2649_34515_14152482_1_1_1_1,00.html.

In an environment of low growth and increased attention devoted by both the authorities and the public to government spending, the efficient allocation of resources in such growth promoting items as education and health seems therefore of paramount importance. Furthermore, and in what concerns the health sector, there is a genuine concern that for most OECD countries public spending in healthcare is bound to increase significantly in the next decades due to aging related issues. Again, and since most of expenditure on healthcare comes from the public budget, how well these resources are used assumes increased relevance.

III. Analytical methodology

We apply two different non-parametric methods that allow the estimation of efficiency frontiers and efficiency losses – Free Disposable Hull (FDH) analysis and Data Envelopment Analysis (DEA). These methods are applied to decision-making units, be they firms, non-profit or public organizations that convert inputs into outputs. Coelli, Rao and Battese (1998), Sengupta (2000) and Simar and Wilson (2003) introduce the reader to this literature and describe several applications. Here, we only provide an intuitive approach to both methods.

A. FDH framework

In a simple example, four different countries display values for output level *y* and input level *x* reported in Figure 1.

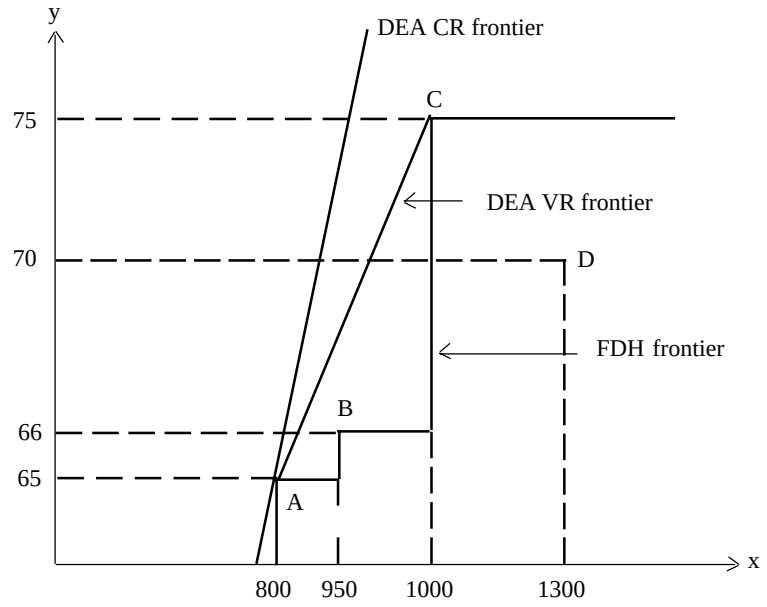
In FDH analysis, country D is inefficient, as country C provides more output using less input - country C is said to dominate country D. In contrast to D, countries A, B and C are supposed to be located on the efficiency frontier, as there are no other countries in the sample that provide evidence that they could improve outcomes without increasing resources used. Countries A and B are said to be efficient by default, as they do not dominate any other country.

It is possible to measure country D inefficiency, or its efficiency score, as the vertical, or, alternatively, horizontal distance between point D and the efficiency frontier. With the first, one is evaluating the difference between the output level that could have been achieved if all input was applied in an efficient way, and the actual level of output. With the latter, efficiency loss is measured in input terms.

Following the same logic, FDH analysis is also applicable in a multiple input-output situation, as it is the case in section IV.[3]

[3] The reader interested in the details of FDH in a multidimensional setting may refer to Gupta and Verhoeven (2001) and to Simar and Wilson (2003).

Figure 1. FDH and DEA frontiers



B. DEA framework

Data Envelopment Analysis, originating from Farrell's (1957) seminal work and popularized by Charnes, Cooper and Rhodes (1978), assumes the existence of a convex production frontier, a hypothesis that is not required in the FDH approach. The production frontier in the DEA approach is constructed using linear programming methods. The terminology "envelopment" stems out from the fact that the production frontier envelops the set of observations.[4]

Similarly to FDH, DEA allows the calculation of technical efficiency measures that can be either input or output oriented. The purpose of an input-oriented study is to evaluate by how much input quantity can be proportionally reduced without changing the output quantities. Alternatively, and by computing output-oriented measures, one could also try to assess how much output quantities can be proportionally increased without changing the input quantities used. The two

[4] Coelli et al. (1998) and Thanassoulis (2001) offer good introductions to the DEA methodology. For a more advanced text see Simar and Wilson (2003).

measures provide the same results under constant returns to scale but give different values under variable returns to scale. Nevertheless, both output and input-oriented models will identify the same set of efficient/inefficient decision-making units.[5]

In Figure 1 the variable returns to scale DEA frontier unites the origin to point A, and then point A to point C. If we compare this frontier to the FDH one, we notice that country B is now deemed inefficient. This results from 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 DEA frontier is also represented in the figure. It is a straight line that passes through the origin and point A.[6] In the empirical analysis presented in this paper, the constant returns to scale hypothesis is never imposed. As a matter of fact, a priori conceptions about the shape of the frontier were kept to a minimum. Convexity is the only one considered here on top of the sensible efficiency concept embedded in FDH analysis.

IV. Non-parametric efficiency analysis

A. Education indicators

In what concerns education our main source of data is OECD (2002a). Input variables to be used are available there or can be constructed from raw data. Examples of possible output variables are graduation rates, and student mathematical, reading and scientific literacy indicators. Input variables may include not only expenditure per student, but also physical indicators such as the average class size, the ratio of students to teaching staff, number of instruction hours and the use and availability of computers.

Concerning education achievement, 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).[7] We use two quantitative

[5] In fact, and as mentioned namely by Coelli et al. (1998), the choice between input and output orientations is not crucial since only the two measures associated with the inefficient units may be different between the two methodologies.

[6] The origin is not actually represented in the figure because the axes were truncated.

[7] The three results in the PISA report are quite correlated, with the following correlation

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

We have considered the alternative use of expenditures with education as an input measure. However, results would depend on the exchange rate used to convert expenditures to the same units. Moreover, they would reflect a mix of inefficiency and cost provision differences. Considering that adjusting for cost differences would be a difficult task with uncertain results, we have decided to present results based on physical inputs and outputs, which are immediately and internationally comparable.[8]

B. Education efficiency results

In these non-parametric approaches higher performance is directly linked with higher input levels. Therefore we constructed the variable "Teachers Per Student", *TPS*,

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

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

The results from the FDH analysis for this 2 inputs and 1 output model are reported in Table 2.

We can observe that four countries are labeled as efficient – Finland, Japan, Korea, and Sweden. For each of them, there is no other country where students achieve a better result with fewer resources. Students in the four efficient dominating producers achieve a higher than average PISA result. A subtle distinction can be made between Korea and Japan, on the one hand, and Finland and Sweden, on the other hand. The two Asian countries achieve the two best

coefficients: (reading, mathematics) = 0.90, (reading, science) = 0.82, (mathematics, science) = 0.79. An alternative output measure for education attainment, the graduation rate, is unfortunately not very complete on the OECD source, and we decided not to use it.

[8] Results using spending per student and per capita spending in health in purchasing power parities as inputs are available from the authors on request.

Table 2. FDH education efficiency scores

Country	Input efficiency		Output efficiency		Dominating producers*
	Score	Rank	Score	Rank	
Australia	0.850	12	0.975	6	Korea/Japan
Belgium	0.689	17	0.935	8	Sweden/Japan
Czech Republic	0.931	6	0.926	10	Sweden/Finland
Denmark	0.912	9	0.916	11	Sweden/Japan
Finland	**1.000**	**1**	**1.000**	**1**	
France	0.832	13	0.934	9	Korea/Japan
Germany	0.961	5	0.897	14	Korea/Japan
Greece	0.758	15	0.848	16	Sweden/Japan
Hungary	0.801	14	0.899	13	Sweden/Japan
Italy	0.730	16	0.872	15	Sweden/Japan
Japan	**1.000**	**1**	**1.000**	**1**	
Korea	**1.000**	**1**	**1.000**	**1**	
New Zealand	0.914	8	0.982	5	Korea/Korea
Portugal	0.879	10	0.844	17	Sweden/Finland
Spain	0.876	11	0.901	12	Sweden/Finland
Sweden	**1.000**	**1**	**1.000**	**1**	
United Kingdom	0.922	7	0.973	7	Korea/Japan
Average	0.886		0.935		

Notes: 2 inputs – hours per year in school (2000) and teachers per 100 students (2000) –, and 1 output – PISA 2000 survey indicator –. Countries in **bold** are located on the efficiency frontier. * In terms of input efficiency/in terms of output efficiency.

outcomes. Students spend time at school close to the average, and classes have a relative big size, especially in Korea. In the two Scandinavian countries, hours spent at school are at the minimum, students per teacher being below but close to the average.[9]

Table 2 also includes input and output efficiency scores and rankings. The average input efficiency score is 0.886. This means that the average country could

[9] Mexico was dropped from the sample. This country is an outlier, as it is where students spend more time per year at school (1167 hours) and also where there are more students per teacher (31.7, more than double the average). With this asymmetric combination of resources, Mexico students achieved the worse PISA average performance in the sample (429, the average being 500). Including Mexico in the analysis would not affect results for other countries, as it would be an efficient by default observation.

have achieved the same output using about 11 percent less resources. In a different perspective, the average output efficient score equals 0.935 – with the same inputs, the average country is producing about 6 percent less that it should if it were efficient. The rank columns indicate the placement of a country in the efficiency league. Belgium is the least efficient country from an input perspective, our results indicating it is wasting 31.1 percent of its resources. The output rank suggests that Portugal is the least efficient country. Resources employed by the Portuguese in the education sector yield a PISA result 15.6 percent lower than the one under efficient conditions.

In Table 3 we report similar DEA variable-returns-to-scale technical efficiency results for this 2 inputs and 1 output model.

DEA results are very similar to FDH ones. Efficient countries are the same and

Table 3. DEA results for education efficiency in OECD countries

Country	Input oriented		Output oriented		Peers	CRS TE
	VRS TE	Rank	VRS TE	Rank	Input/output	
Australia	0.788	13	0.975	6	Sweden, Finland, Korea/Japan	0.784
Belgium	0.689	17	0.935	8	Sweden, Korea/Japan	0.682
Czech Republic	0.879	6	0.922	10	Sweden, Korea/Japan, Finland	0.849
Denmark	0.857	11	0.916	11	Sweden, Korea/Japan	0.823
Finland	**1.000**	**1**	**1.000**	**1**	Finland/Finland	0.981
France	0.761	14	0.934	9	Sweden, Korea/Japan	0.736
Germany	0.893	5	0.897	14	Sweden, Korea/Japan	0.824
Greece	0.716	16	0.848	16	Sweden, Korea/Japan	0.637
Hungary	0.801	12	0.899	12	Sweden/Japan	0.762
Italy	0.727	15	0.872	15	Sweden, Korea/Japan	0.671
Japan	**1.000**	**1**	**1.000**	**1**	Japan/Japan	0.943
Korea	**1.000**	**1**	**1.000**	**1**	Korea/Korea	1.000
New Zealand	0.877	8	0.979	5	Sweden, Korea/Japan, Finland	0.874
Portugal	0.879	7	0.841	17	Sweden/Japan, Finland	0.781
Spain	0.876	9	0.898	13	Sweden/Japan, Finland	0.831
Sweden	**1.000**	**1**	**1.000**	**1**	Sweden/Sweden	1.000
United Kingdom	0.860	10	0.973	7	Sweden, Finland, Korea/Japan	0.860
Average	0.859		0.935			0.826

Notes: 2 inputs – hours per year in school and teachers per 100 students – and 1 output – PISA survey indicator –. Countries in **bold** are located on the efficiency frontier. CRS TE is constant returns to scale technical efficiency. VRS TE is variable returns to scale technical efficiency.

rankings are not substantially different. Note that scores are a bit smaller, as convexity of the frontier is now imposed.[10]

C. Health indicators

OECD (2000b) is our chosen health database for OECD countries. Typical input variables include in-patient beds, medical technology indicators and health employment. Output is to be measured by indicators such as life expectancy and infant and maternal mortality, in order to assess potential years of added life.

It is of course difficult to measure something as complex as the health status of a population. We have not innovated here, and took two usual measures of health attainment, infant mortality and life expectancy.[11] Efficiency measurement techniques used in this paper imply that outputs are measured in such a way that "more is better". This is clearly not the case with infant mortality. Recall that the Infant Mortality Rate (IMR) is equal to: (Number of children who died before 12 months)/(Number of born children) $\times$ 1000.

We have calculated an "Infant Survival Rate", *ISR*,

$$ISR = \frac{1000 - IMR}{IMR} \tag{2}$$

which has two nice properties: it is directly interpretable as the ratio of children that survived the first year to the number of children that died; and, of course, it increases with a better health status. Therefore, our frontier model for health has two outputs: the infant survival rate, and life expectancy,

Following the same reasoning that was made for education, we compared physically measured inputs to outcomes. Quantitative inputs are the number of doctors, of nurses and of in-patient beds per thousand habitants.

D. Health efficiency results

Table 4 summarizes efficiency results for health using FDH analysis.

---

[10] Again Mexico was dropped from the sample, for the same reasons pointed out for the FDH analysis. In the DEA calculations where Mexico was considered, it was not a peer of any other country.

[11] These health measures, or similar ones, have been used in other studies on health and public expenditure efficiency – see Afonso, Schuknecht and Tanzi (2004), Evans, Tandon, Murray and Lauer (2000), Gupta and Verhoeven (2001) and St. Aubyn (2002).

Table 4. FDH health efficiency scores

Country	Input efficiency		Output efficiency		Dominating
	Score	Rank	Score	Rank	producers*
Australia	0.926	17	1.000	12	Canada
Austria	0.967	14	0.981	17	Sweden
Canada	**1.000**	**1**	**1.000**	**1**	
Czech Republic	1.000	13	0.949	22	France
Denmark	**1.000**	**1**	**1.000**	**1**	
Finland	0.935	16	0.974	20	Sweden
France	**1.000**	**1**	**1.000**	**1**	
Germany	0.884	22	0.977	19	Sweden
Greece	0.923	18	0.992	14	Spain
Hungary	0.663	24	0.949	23	Korea/Spain
Ireland	0.913	20	0.968	21	Canada
Italy	0.837	23	0.997	13	Spain
Japan	**1.000**	**1**	**1.000**	**1**	
Korea	**1.000**	**1**	**1.000**	**1**	
Luxembourg	1.000	12	0.991	16	Spain
Netherlands	0.935	15	0.980	18	Sweden
New Zealand	0.913	19	0.991	15	Canada
Norway	**1.000**	**1**	**1.000**	**1**	
Poland	0.902	21	0.946	24	United Kingdom
Portugal	**1.000**	**1**	**1.000**	**1**	
Spain	**1.000**	**1**	**1.000**	**1**	
Sweden	**1.000**	**1**	**1.000**	**1**	
United Kingdom	**1.000**	**1**	**1.000**	**1**	
United States	**1.000**	**1**	**1.000**	**1**	
Average	0.946		0.987		

Notes: 3 inputs –doctors, nurses and beds – and 2 outputs– infant survival and life expectancy–. Countries in **bold** are located on the efficiency frontier. * In terms of input efficiency/in terms of output efficiency.

Eleven among the 24 countries analyzed with this formulation for health were estimated as efficient.[12] These countries are Canada, Denmark, France, Japan,

[12] Mexico and Turkey were excluded from the analysis. These two countries are outliers, as they have the worst results by large, especially in what concerns infant mortality (respectively

Korea, Norway, Portugal, Spain, Sweden, the United Kingdom and the United States. Note that increasing the number of inputs and outputs in a relatively small sample leads to a higher number of efficient by default observations.[13] Here, Denmark, Japan, Norway, Portugal and the United States are efficient by default, as they do not dominate any other country. Canada, France, Korea, Spain, Sweden and the United Kingdom are efficient and dominating producers. Next, we analyze the group of efficient by default countries in more detail.

Japan and Norway are among the best performers; Japan is even the country where people are expected to live longer (80.5 years). The fact that their outcomes are high precludes them to be dominated by any other country. However, both of them attain these high levels with considerable use of resources, at least in some items – Norway is the third country in the sample with more nurses (after Finland and the Netherlands), and Japan and Norway are the two countries with more hospital beds.

Denmark, Portugal and the United States are countries with not particularly striking outcomes, but where the combination of resources is somehow atypical. The three countries have a low ratio of hospital beds. In the Portuguese case, the number of nurses is also clearly below the average.

Considering the dominating countries, one can distinguish different reasons for being considered efficient. Korea has few resources allocated to health with not so bad results. A second group attains better than average results with lower than average resources (Canada, Spain, and the United Kingdom). Finally, France is essentially a good performer.

Under DEA the efficient group is smaller than under FDH.[14] DEA results are summarized in Table 5, and there are 8 countries in the frontier: Canada, Japan, Korea, Portugal, Spain, Sweden the United Kingdom and the United States. All these countries were already considered efficient under FDH, but three of the "FDH-efficient" nations are not efficient now (Denmark, France and Norway). It is interesting to note that two out of these three countries were efficient by default when FDH analysis was performed.

25.9 and 40.3 per 1000, the country average being 7.1). These results would preclude any of them to dominate any other country in the sample.

[13] Bowlin (1998) refers the rule of thumb according to which the number of observations should exceed the number of inputs and outputs multiplied by three to avoid the risk of getting too many efficient decision making units. Here, we have 24 observations, more than the critical level of 15 (5 inputs and outputs times 3).

[14] As before with FDH, DEA results do not include Mexico and Turkey.

Table 5. DEA results for health efficiency in OECD countries

Country	Input oriented VRS TE	Rank	Output oriented VRS TE	Rank	Peers Input/output	CRS TE
Australia	0.832	13	0.990	12	Canada, Japan, Spain, United Kingdom/Canada, Japan, Spain, Sweden	0.691
Austria	0.703	20	0.976	15	Japan, Korea, Sweden/ Japan, Sweden	0.703
Canada	1.000	1	1.000	1	Canada	1.000
Czech Republic	0.681	21	0.936	22	Japan, Korea, Sweden/ Japan, Sweden	0.675
Denmark	0.857	10	0.965	20	Portugal, Spain, Sweden, United Kingdom/Japan, Spain, Sweden	0.835
Finland	0.806	16	0.970	19	Japan, Korea, Sweden/ Japan, Sweden	0.802
France	0.835	11	0.991	10	Japan, Korea, Spain, Sweden, United Kingdom/Japan, Spain, Sweden	0.768
Germany	0.604	22	0.972	18	Japan, Korea, Sweden/ Japan, Sweden	0.604
Greece	0.866	9	0.991	11	Korea, Spain/Japan, Spain, Sweden	0.863
Hungary	0.574	24	0.892	24	Korea, Spain, United Kingdom/Japan, Spain	0.529
Ireland	0.716	18	0.958	21	Japan, Korea, Sweden/ Canada, Japan, Sweden	0.715
Italy	0.833	12	0.995	9	Portugal, Spain, United States/ Japan, Spain, Sweden	0.832
Japan	1.000	1	1.000	1	Japan	1.000
Korea	1.000	1	1.000	1	Korea	1.000
Luxembourg	0.707	19	0.979	14	Japan, Korea, Spain, Sweden, United Kingdom/ Japan, Spain, Sweden	0.683
Netherlands	0.579	23	0.973	17	Canada, Japan, Korea, United Kingdom/Japan, Sweden	0.577

Table 5. (Continued) DEA results for health efficiency in OECD countries

Country	Input oriented VRS TE	Rank	Output oriented VRS TE	Rank	Peers Input/output	CRS TE
New Zealand	0.830	14	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	0.827	15	0.934	23	Korea, Spain, United Kingdom/Japan, Sweden	0.782
Portugal	1.000	1	1.000	1	Portugal	0.979
Spain	1.000	1	1.000	1	Spain	1.000
Sweden	1.000	1	1.000	1	Sweden	1.000
United Kingdom	1.000	1	1.000	1	United Kingdom	1.000
United States	1.000	1	1.000	1	United States	0.993
Average	0.832		0.979			0.815

Notes: 3 inputs – doctors, nurses and beds – and 2 outputs – infant survival and life expectancy –. Countries in **bold** are located on the efficiency frontier. CRS TE is constant returns to scale technical efficiency. VRS TE is variable returns to scale technical efficiency.

V. Conclusion

We summarize results for both sectors and methods in Table 6 in terms of countries that we found out as being efficient. Dominating countries in FDH analysis are highlighted.

The results from our empirical work in evaluating efficiency in health and education expenditure allow: i) computing efficiency measures for each country in producing health and education, with corresponding estimates of efficiency losses, therefore identifying the most efficient cases; ii) a comparison across methods (DEA and FDH), evaluating result robustness; iii) a comparison across the two sectors, education and health, to see whether efficiency and inefficiency are country specific.

Our results strongly suggest that efficiency in spending in these two economic sectors where public provision is usually very important is not an issue to be neglected. In the education sector, the average input efficiency varies between

Table 6. OECD countries efficient in education and in health sectors: Two non-parametric approaches

Sector	Inputs, Outputs	Non-parametric method	Countries
Education	- Hours per year in school (in) - Teachers per 100 students (in)	FDH	**Japan**, **Korea**, **Sweden**, **Finland**
	- PISA (out)	DEA	Japan, Korea, Sweden, Finland
Health	- Doctors (in) - Nurses (in) - Hospital beds (in) - Life expectancy (out) - Infant survival rate (out)	FDH	**Canada**, Denmark, **France**, Japan, **Korea**, Norway, Portugal, **Spain**, **Sweden**, **UK**, US
		DEA	Canada, Japan, Korea, Portugal, Spain, Sweden, UK, US

Note: Countries in **bold** are efficient and dominating countries in FDH analysis.

0.859 and 0.886, depending on method used; in health, it varies between 0.832 and 0.946. Consequently, in less efficient countries there is scope for attaining better results using the very same resources.

Results using DEA were broadly comparable to results using FDH. DEA is more stringent, in the sense that a country that is efficient under DEA is also efficient under FDH, the reverse not being true. In the education case, one output and two inputs were considered for a sample size of 17. Efficient countries under FDH and DEA were exactly the same. Differences in results arose only in the scores of inefficient countries and their ordering.

In the health case, we have considered two inputs and three outputs for a sample size of 24. Compared to education analysis, there is a decrease in the ratio of observations to the number of inputs and outputs from 5.7 to 4.8. As it is well known, increasing the number of dimensions in small samples leads to a higher number of efficient observations, especially by default. There is therefore a trade off between a realistic number of dimensions to characterize health production and meaningful results. We considered our choice to be a good compromise, but results have to be interpreted with care. Namely, when considering an individual efficient

country, it is important to take into account if that country is an outlier, or if it efficient by default in FDH analysis. Interestingly enough, the use of DEA eliminated an important number of FDH efficient by default observations.

Three countries appear as efficient no matter what method or sector is considered –Korea, Japan and Sweden. Japan is the best performer in education and one of the best in health as far as outputs are concerned, and does not spend too many resources. Korea is a very good education performer, and it spends very little on health with surprisingly good results in comparative terms. Sweden is never the best performer in terms of the output indicators, although outcomes are always clearly above the average. Efficient use of resources led this Nordic country to outperform or dominate a good number of other countries in the sample, either in education or health.

A comparison of Japan and Sweden leads to some interesting insights that show there are different ways of being efficient. In education, Japanese students spend more time at school in classes that are a bit larger. In health, if Japan does not have so many doctors per habitant, it exceeds in hospital beds.

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, as in our models. Countries where resources are comparatively expensive could be wrongly considered as not efficient under an alternative specification. Also, countries where resources considered (doctors, nurses, hospital beds, and teachers) are comparatively cheaper would appear as efficient in financial terms.[15]

We evaluated efficiency across countries in two sectors, essentially comparing resources to outputs. This opens the way to a different but related line of research, which is to explain why some countries are more efficient than others when it comes to education or health provision. Different plausible linkages can be investigated. We point out some, to suggest some future research. As an important part of education or health expenditure and provision is public, it could be the case that inefficient provision is related to public sector inefficiency. Other differences across countries can play a role in explaining our results. For example, a different population density or composition may well imply different needs from an input perspective in order to attain the same measured outputs. Also, different levels of GDP per head or of educational attainment by the adult population could imply

[15] Results not presented here and available from the authors suggest this would be the case of Sweden, where costs are high, and of some Eastern European countries, where costs are low.

different outcomes in health or education, even under efficient public services.[16] Countries are also different in what concerns the mix of public and private funding of education and health (see Table 1). One possible source of inefficiency could derive from the interaction between these.

Clearly, and after measuring efficiency, identifying the (in)efficiency sources would be of great importance in economic policy terms.

References

Afonso, António, Ludger Schuknecht, and Vito Tanzi (2004), "Public sector efficiency: An international comparison", *Public Choice*, forthcoming.

Barro, Robert J., and Jong-Wha Lee (2001), "Schooling quality in a cross-section of countries", *Economica* **68**: 465-488.

Bowlin, William (1998), "Measuring performance: An introduction to data envelopment analysis (DEA)", *Journal of Cost Analysis* Fall 1998: 3-27.

Charnes, Abraham, William W. Cooper, and Eduardo Rhodes (1978), "Measuring the efficiency of decision making units", *European Journal of Operational Research* **2**: 429–444.

Clements, Benedict (2002), "How efficient is education spending in Europe?", *European Review of Economics and Finance* **1**: 3-26.

Coelli, Tim, D. S. Prasada Rao, and George E. Battese (1998), *An Introduction to Efficiency and Productivity Analysis*, Boston, Kluwer.

De Borger, Bruno, and Kristian Kerstens (1996), "Cost efficiency of Belgian local governments: A comparative analysis of FDH, DEA, and econometric approaches", *Regional Science and Urban Economics* **26**: 145-170.

Deprins, Dominique, Léopold Simar, and Henry 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.

EC (2002), "Public finances in EMU, 2002", *European Economy 3/2002*, European Commission.

Evans, David, Ajay Tandon, Christopher Murray, and Jeremy Lauer (2000), "The comparative efficiency of national health systems in producing health: An analysis of 191 countries", GPE Discussion Paper Series 29, Geneva, World Health Organisation.

[16] Barro and Lee (2001), with different countries, data and time period, found a statistically significant influence of these two variables on student achievement.

Fakin, Barbara, and Alain 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 1803, Washington, World Bank.

Farrell, Michael J. (1957), "The measurement of productive efficiency", *Journal of the Royal Statistical Society, Series A* **120**: 253-290.

Ferrier, Gary D., and C. A. Knox Lovell (1990), "Measuring cost efficiency in banking: Econometric and linear programming evidence", *Journal of Econometrics* **46**: 229-245.

Gupta, Sanjeev, and Marijn Verhoeven (2001), "The efficiency of government expenditure – experiences from Africa", *Journal of Policy Modelling* **23**: 433-467.

Hanushek, Eric A., and Javier A. Luque (2002), "Efficiency and equity in schools around the world", Working Paper 8949, Cambridge, MA, NBER.

Jondrow, James, C. A. Knox Lovell, Ivan Materov, and Peter Schmidt (1982), "On the estimation of technical inefficiency in the stochastic frontier production function model", *Journal of Econometrics* **19**: 233-238.

OECD (2001), *Knowledge and Skills for Life – First Results from Pisa 2000*, Paris, OECD.

OECD (2002a), *Education at a Glance – OECD Indicators 2002*, Paris, OECD.

OECD (2002b), *OECD Health Data 2002*, Paris, OECD.

Sengupta, Jati (2000), *Dynamic and Stochastic Efficiency Analysis – Economics of Data Envelopment Analysis*, Singapore, World Scientific.

Simar, Léopold and Paul Wilson (2003), *Efficiency Analysis: The Statistical Approach*, lecture notes.

St. Aubyn, Miguel (2002), "Evaluating efficiency in the Portuguese health and education sectors", unpublished manuscript, Lisbon, Banco de Portugal.

St. Aubyn, Miguel (2003), "Evaluating efficiency in the Portuguese education sector", *Economia* **26**: 25-51.

Thanassoulis, Emmanuel (2001), *Introduction to the Theory and Application of Data Envelopment Analysis*, Boston, Kluwer Academic Publishers.