An Assessment of Schools' Efficiency of Different Educational Systems

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Abstract

The allocation of public resources is an important concern of developed economies in modern societies and there are many studies that aim at measuring their efficiency. This work presents an efficiency assessment of public elementary schools in Andorra, a little country where there are three public educational systems (Andorran, Spanish – congregational and non congregational-, and French). Therefore, the aim of this study is to compare the efficiency of public elementary schools among the three different educational systems existing in Andorra. The methodology used to measure the efficiency of the educational process in this study is the DEA (Data Envelopment Analysis), a nonparametric frontier method, introduced by Charnes, Cooper and Rhodes in 1978. In this study the DEA technique is applied with bootstrap (Simar and Wilson, 2000), that correct the bias by generating successive evaluations with changed data in order to obtain a new distribution of efficiency levels representative of the original (correct but unknown) distribution. Then two nonparametric tests are used (median test and Kruskal-Wallis test) to establish the comparison of efficiency results between different educational systems and identify which system is the most efficient.Results show a decreasing of efficiency along the years and suggest that there are significant differences between different centres depending on their educational system. These results seem to confirm the benefits of decentralization in efficiency of schools.

Keywords: *DEA, efficiency, bootstrap, production function, education, academic performance, public resources.*

1. Introduction

Adam Smith starts the discussion on the role of state in the economy with his work *Wealth of Nations*, in 1776. The development of the welfare economy and the current context, with an increasing national debt in the developed economies, has generated new lines of discussion about the efficiency of public services.

The measurement of the profitability of the public sector as a supplier of public services is difficult; particularly, in the field of education several attempts have been observed in the literature to do it. The estimation of efficient frontiers opens the possibility of detecting inefficient situations. This means that we can improve the performance of the public sector without increasing the resources assigned (output orientation) or that we can maintain performance of the public sector even if we reduce public resources (input orientation). Furthermore, the question of efficiency gives a new dimension to the current debate on the size of the state (Afonso and Aubyn, 2005).

Farrell opened the studies of organization's efficiency in 1957 using the concept of "Pareto efficiency". From this perspective, the most efficient organization is one that carries out like the best and even better. Given that the concept of efficiency is closely related to productivity, which establishes the relationship between inputs and outputs, the organization with the highest productivity in all inputs will be the most efficient one. With this information, it is possible to calculate the percentage of inefficiency of the other organizations compared to one the most efficient one.

When there are multiple inputs and multiple outputs, there appears the concept of "overall productivity". Early indicators appeared in a paper by Charnes, Cooper and Rhodes published in 1978. They propose to do a weighted sum of all inputs and all outputs and the ratio of the two sums. The weightings are the prices and the result is the ratio of income and expenses (Profitability). If the ratio is > 1 means there are benefits; if the ratio is = 1 means the benefit is zero; and if the result is <1, there are losses. When there are not prices for inputs, or for outputs, the solution proposed is to calculate the weights that maximize the ratio above with two constraints:

1. The weightings cannot tend to infinity.
2. It is necessary to apply the same weights to all units so that the sum is ≤ 1.

If these two constraints are introduced to maximize the function, the best unit has a value = 1 and all the rest must be <1.

This is how the DEA method (Data Envelopment Analysis) has been developed. This method draws the frontier of efficient DMUs (Decision Making Units) that act better than the rest, and measures the distance to the rest of the frontier. This method allows us to measure efficiency in organizations where there are multiple inputs and outputs, whose prices are unknown. Mainly, it is for this reason that it is an appropriate method to measure the efficiency of educational process.

The main objective of this study is to analyze the efficiency of elementary schools in Andorra, identifying the variables involved in this process. Some previous studies that followed this general objective in elementary level schools are: Bessent and Bessent (1980), in a Californian urban district; Kim et al. (2006), in New York City; Conroy and Arguea (2008), in Florida; Addonizio (2009), in Minnessota; and Barbosa and Wilhelm (2009), in Paraná; and Thieme et al. (2011) in Chile. The particular environment in Andorra, with three public educational systems (Andorran, Spanish and French), provide a new context to apply efficiency studies of educational process and results of this study can give new contributions to existent literature in this field.

2. Educational Context in Andorra

Andorra is a small country of 468 km^2 with 78,115 inhabitants[1] where there are three different educational systems: Andorran, French and Spanish. Regarding at Spanish educational system, must distinguish between the Spanish public schools, private schools and public congregational schools. This study was carried out in all Andorran public schools, excluding one school belonging to the private Spanish educational system, but including congregational schools, which are financed, like schools of the Andorran educational system, by the Andorran Government. It is for this reason that four educational systems are considered: a) Andorran, b) Spanish public, c) Spanish congregational and d) French.

Considering elementary levels (from 3 to 12 years old, for Andorran and Spanish systems, and from 3 to 11 years old for French system), there were 25 schools (8 from the Andorran educational system, 5 from the public Spanish educational system, 3 from the congregational Spanish educational system and 9 from the French system) during five academic years (from 2005-6 until 2009-10). In June 2011, according to data provided by the head of the school, there were 6.663 children at elementary level (2832 in the Andorran educational system, 527 in the Spanish educational system, 1,342 in the Spanish congregational educational system and 1,962 in the French educational system).

One of the main features that distinguish the four systems is the vehicular language or languages used, in addition, of course, of the specificities of the official curriculum for each system. In the Andorran system, the vehicular languages are Catalan and French. There are two permanent teachers in the classroom (one Catalan-speaking and one French-speaking). In the Spanish non-congregational system, the vehicular language is Spanish; French is taught as a foreign language, just like English. In the Spanish congregational system, the vehicular language is Catalan; Spanish is taught more intensively than the other languages; French and English are taught as foreign languages. In the French system, the vehicular language is French; Spanish and English are taught as foreign languages. Moreover, the educational agreement between Andorra and neighbouring states establishes that it is necessary to include two subjects in the curricula of all systems: Catalan and Andorran history.

Another important difference between the four systems is the level of autonomy in school management, especially in the recruitment process of teachers. In Andorran and french systems, the process is centralized by the national government of each country, and teachers hired achieve the working place in Andorra for a long time. In Spanish non-congregational system hiring process is also centralized by the Spanish government, but it is a temporal hiring: places are offered to existing Spanish teachers, that have yet a place in a Spanish school and want to change the place for a limited period (maximum 6 years). After this period, teachers have to leave Andorra and return to the originally Spanish school. Is for this reason that teachers rotation is bigger in schools of the Spanish non-congregational educational system. The most different recruitment process of teachers in Andorra is in schools of Spanish congregational system, where is decentralized and is the principal of each school the responsible of the process. The school calendar is set by the Andorran Government and it is the same for all schools regardless of the educational system to which they belong. There is also the same number of teaching hours in the schedule of all schools. While it is true that the evaluation system has some specificities for each system, like qualification system, all the systems apply the same criteria to determine if a student can move up to the next course, as has been confirmed in interviews with the heads of the three educational

[1] Source: web of national andorran statistics institute (www.estadistica.ad)

systems.

In Andorra there is no common test for all educational systems and it is a country out of the Pisa project, at this moment. No data are available that provide homogeneous academic results in order to compare the different educational systems. It is for this reason that when we need an indicator of academic results we will use the number of students that move up to the next course.

With regard to funding, the Andorran educational system and the Spanish congregational system are fully financed by the Andorran Government. The Andorran Government also finances infrastructure, facilities, teaching assistants and training in Andorran subjects (Catalan and Andorran history) of all schools in the country. The Spanish non-congregational and the French educational systems are financed by the governments of their respective countries (Spain and France).

The Andorran educational system emerged in 1980. Before then, public education in Andorra was offered by educational systems of neighbouring countries and the Andorran Government contributed with the two subjects mentioned above (Catalan and Andorran history). Public data in the web of national Andorran statistics institute (www.estadistica.ad) show a decrease of elementary students in Andorra in the last years (2004-2011). There has been a decrease of population in Andorra during this period. This decrease of students (-2,6%) has been more important in Spanish non-congregational educational system (-37,57%). French educational system has also had a decrease of students, with a -11,15% of variation, but Andorran and Spanish congregational educational systems have increased their students with a 12,05% and a 3,86% respectively. The Spanish non-congregational educational system in recent years has closed two elementary schools.

3. Methodology

The particularities of the educational process are different from those characterizing other productive processes. The educational process is a multi-input and multi-output very complex production process whose prices are unknown. Another particularity of the educational processes is that there is not a clear productive function to describe it.

There are different methods used in the literature to measure the efficiency of educational process. Some of these methods are parametric, like regression analysis (Gray *et al.,* 1986; Jesson et al., 1987) or Cobb Douglas function production (Henderson and Quandt, 1971) or the Stochastic Frontier Analysis (SFA) method (Aigner *et al.,* 1977; Meeusen and van den Broeck, 1977; Franta and Konecny, 2009). Other methods used in the literature revised are non-parametric, like the Free Disposable Hull (FDH) method (Thieme *et al.,* 2011; Lavado and Cabanda, 2009; Agasisti, 2009; Afonso and Aubyn, 2006; and Oliveira and Santos, 2006), and Data Envelopment Analysis (DEA).

DEA is a non-parametric frontier method that designs the best weight for each input and output in order to obtain the best efficiency measure for each unit (for each Decision-Making Unit: DMU). It can work, then, without prices for inputs and outputs. This method is also useful if there are multiple inputs and outputs, and it allows identifying the inefficiency causes through peer comparison. DEA compares each DMU with the nearest one in the frontier and measures the distance to the frontier. This distance shows the reduction of inputs (input orientation) or the increase of outputs (output orientation) that each non-efficient DMU can achieve to become efficient (to be at the frontier). DEA was introduced by Charnes, Cooper and Rhodes in 1978. Focused on educational process, previous studies that have used this methodology are: Chen and Chen, 2011; Afonso et al., 2010; Naper, 2010; Chang *et al*., 2009; Tyagi *et al*., 2009; Barbosa and Wilhelm, 2009; Lavado and Cabanda, 2009; Agasisti, 2009; Cordero et al., 2009; Kao and Hung, 2008; Johnes and Yu, 2008; Murias *et al*., 2008; Manzebón and Muñiz, 2008; Ray and Jeon, 2008; Spircu *et al*., 2007; Giménez *et al.* 2007; Afonso and Aubyn, 2006; Portela and Thanassoulis, 2001; Thanassoulis, 1996.

DEA method constructs the production frontier that envelops the set of observation using linear programming methods. Afonso et al. (2010) describe the linear programming for an input-orientation with variable-returns to scale by this form:

$\text{Min}_{\delta,\lambda} \delta_i$

s. t. $-y_i + Y\lambda \geq 0$

$\delta x_i - X\lambda \geq 0$

$n1'\lambda = 1$

$\lambda \geq 0$

Where there are *k* inputs, *m* outputs and *n* DMUs, and:

i is the DMU under assessment

x_i is the column vector of the inputs

y_i is the column vector of the outputs

X is the ($k \times n$) input matrix

Y is the ($m \times n$) output matrix

δ is a scalar that satisfies $\delta \leq 1$. More specifically, it is the efficiency score that measures the distance between a DMU and the efficiency frontier, defined as a linear combination of the best practice observations.

With $\delta < 1$, the DMU is inside the frontier (i.e. it is inefficient),

While $\delta = 1$ implies that the DMU is on the frontier (i.e. it is efficient)

λ is a ($n \times 1$) activity vector that measures the weights used to mix the efficient units taken as a benchmark of the unit under assessment.

1 is an n-dimensional vector of ones.

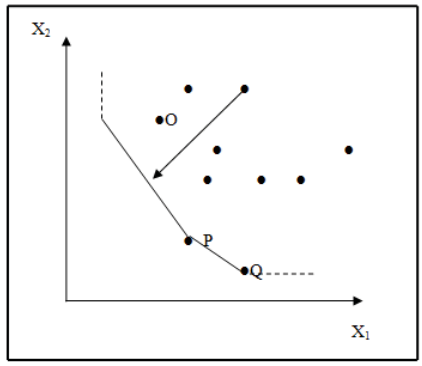
The inefficient DMU is projected on the production frontier. The frontier is composed of efficient units and their lineal combination.

The restriction $n1'\lambda = 1$ imposes a technology exhibiting variable returns to scale (VRS). Dropping this restriction implies that constant returns to scale are prevalent.

The previous mathematical program has to be solved n times, one for each DMU in the analysis.

In order to design the frontier with the DMUs that have shown the best practice DEA with input orientation is used, considering variable returns to scale (VRS) with 2 inputs (X_1 and X_2) and 2 outputs. Figure 1 provides a graphical intuition of the analysis performed.

Figure 1. Efficiency frontier input oriented



A contemporary DEA for 5 academic years (from 2005-6 to 2009-10) is applied considering 25 DMUs per year (the 25 public elementary schools) so the analysis considers the data year by year, not pooling them. In order to increase the number of units, an intertemporal DEA is also applied pooling the data from all the years (considering 125 DMUs and interpreting the same school in different years as different DMUs).

In the second step, the intertemporal DEA estimation is bootstrapped (Simar and Wilson, 2000) in order to correct the potential bias in the original estimations. Bootstrap technique with DEA is introduced by Simar and Wilson (2000) and has been used by others, like Blank and Van Hulst, 2011; Murillo et al., 2010; Oliveira and Santos, 2005; and Fuentes, 2011.

Finally, two nonparametric tests (Median test and Kruskal-Wallis test) are used to establish the comparison of efficiency results between different educational systems. These methods allow us to test differences between groups (educational systems in this study) by comparing the medians and the mean ranks respectively. Both methods are useful when the normality distribution assumption is not guaranteed.

4. Data

As it is exposed above, most of educational data are not available in Andorra. There is just a data used in this study that is public: the total number of students per year. This data is published by the National Statistic Service of the Government of Andorra (www.estadistica.ad).

The rest of data were provided by the Ministry of Education of the Government of Andorra. To get the authorisation

to obtain these data it is has been necessary to sign a confidentiality commitment in which we agree to identify anonymously the different schools in the results of the study. Therefore, we identify the four educational systems (with the terms: A, B, C and D, and the different schools by numbers (from 1 to 125).

4.1 Inputs

Two general inputs are identified in the literature on schools efficiency: financial and human resources. The most usual indicators for each of these inputs are: operating expenses and academic staff, respectively.

Operating expenses (we will tell this variable *Opex*) has been used as an input in educational process efficiency studies by Casu and Thanassoulis, 2006; Kim *et al.,* 2006; Kao and Hung, 2008; Yuhong and Yongmei, 2008; Addonizio, 2009; and Tyagi *et al.,* 2009, among others.

Moreover, academic staff (we will tell this variable *Teachers*) has been used as an input in educational process efficiency studies by Kantabutra and Tang, 2006; Kim *et al.,* 2006; Martín, 2006; Giménez *et al.,* 2007; Spircu *et al.,* 2007; Conroy and Arguea, 2008; Yuhong and Yongmei, 2008; Cordero *et al.,* 2008; Addonizio, 2009; Agasisti, 2009; Cheo, 2009; Franta and Konecny, 2009; Tyagi *et al.,* 2009; Naper, 2010; Ouellette and Vierstraete, 2010; Chen and Chen, 2011; and Thieme *et al.,* 2011, among others.

4.2 Outputs

The difficulty in measuring the outputs of the educational process, such as the positive effects of education on economic and social development of a society focused most efficiency studies of education in more easily measurable outputs. It is for this reason that attempts to measure the efficiency of the schools is limited to internal efficiency, which considers only the relationship between inputs and measurable outputs schools.

It is difficult to define the social value of education. Additionally educational outputs don't have market prices and it is difficult to identify their value. As shown in Shields and Shields(2009), education has a. direct impact on the overall country's equity, as there are positive externalities of education, which are long-term and difficult to measure. Afonso et al. (2010) studied the impact of the quality of education in the efficiency of public resources for equality in several OECD countries and found that the efficiency of social spending is more enhanced by the success of education than to the education spending.

The most frequent outputs in the literature .are the academic results in a global test (maths and reading or language), as Hanushek (1997) has shown in a literature review. This test is passed to all the students at the end of some school level.

In Andorra does not exist a homogeneous test for all the students of the different educational systems, so it is not possible to choose this indicator as an output to our study. We take the number of students that moved up to the next course successfully as an indicator of academic results. We will name this variable *Passstudents*. The same indicator is used by Oliveira and Santos, 2005; Spircu *et al.,* 2007; Mancebón and Muñiz, 2008; Cordero *et al.,* 2008; Cheo, 2009; and Barbosa and Wilhelm, 2009, among other.

The second output used in this study is a measure of the number of students (*Students*). This output has been used by Martín, 2006; Kao and Hung, 2008; Tyagi *et al.,* 2009; Ouellette and Vierstraete, 2010, among others.

5. Results

Results of contemporary study (25 DMUs per year, 5 frontiers –one for each year-) show a slight decrease in efficiency measures over the years and the same 5 schools appear at the frontier over the years. This result serves to confirm the consistency of the frontier along the years. These 5 schools belong to two different educational systems (C and D) and those used as peers for more inefficient DMUs are from educational system C. Another result is the presence of the same school with the lowest efficiency score every year, belonging to the educational system B. Again another signal of consistency.

Results of the intertemporal study (125 DMUs considering all 5 years together) show a decrease in efficiency scores during the 2008-2009 period. This period was also the first with a decrease in the Andorran population and in the number of students in the elementary grade. Efficiency scores of these 125 DMUs also show one school belonging to the educational system C that appears every year at the frontier (DMU14, DMU39, DMU64 DMU89 and DMU114). In table 1 we can observe that this school, during the first academic year analysed is the most used as a benchmark for other

DMUs and every year is used less as a benchmark, as the other schools at the frontier. There are 4 more schools, 2 belonging to the educational system C and 2 belonging to the educational system D, which appeared different times at the frontier. The school with the lowest score is the same in different years and belongs to the educational system B. Overall the intertemporal results depicts a similar assessment than the one produced with the contemporary estimation. Table 1 resume these results.

Table 1. Efficiency results with an intertemporal DEA methodology (125 DMUs: the 25 elementary schools in Andorra from 2005 to 2010)

		Min.	Max.	Mean	St.Dev.
Efficiency scores	Global	0,59	1	0,83	0,110
	Ed. System A	0,76	1	0,85	0,063
	Ed. System B	0,59	1	0,72	0,097
	Ed. System C	0,87	1	0,98	0,041
	Ed. System D	0,61	1	0,82	0,110
		DMUs	**Educational System**	**Academic Year**	**Benchmarks**
Efficiency frontier		DMU14	C	2004- 2005	84
		DMU15	C	2004- 2005	34
		DMU16	C	2004- 2005	29
		DMU19	D	2004- 2005	9
		DMU23	D	2004- 2005	45
		DMU33	A	2005- 2006	2
		DMU39	C	2005- 2006	8
		DMU48	D	2005- 2006	32
		DMU58	A	2006- 2007	1
		DMU64	C	2006- 2007	2
		DMU89	C	2007- 2008	4
		DMU90	C	2007- 2008	4
		DMU110	B	2008- 2009	2
		DMU114	C	2008- 2009	14
		DMU115	C	2008- 2009	6
		DMU123	D	2008- 2009	15

Just for controlling the potential bias in the deterministic frontier and for solving dimensionality problems, a second analysis was performed through the bootstrapping estimation method. To do this, FEAR software is used to apply the intertemporal DEA technique with bootstrap (Simar and Wilson, 2000). Generating successive evaluations with changed data in order to obtain a new distribution of efficiency levels representative of the original (correct but unknown) distribution it is possible to correct the potential bias.

We organise efficiency scores and we find the most efficient DMUs: DMU16, DMU41, DMU19, DMU64, DMU39, DMU14, DMU89, DMU44, DMU114. All of them are from educational system C, except two (DMU19 and DMU44), that are the same school of educational system D, in different years. This confirms that the C systems appears to be the most efficient independently of the estimation method employed. Table 2 resumes these results.

Table 2. Bootstrapped efficiency results with an intertemporal DEA methodology (125 DMUs: the 25 elementary schools in Andorra from 2005 to 2010).

			Min.	Max.	Mean	St.Dev.
Bootstrapped Efficiency scores		Global	0,57	0,98	0,79	0,10
		Ed. System A	0,70	0,92	0,82	0,05
		Ed. System B	0,57	0,90	0,70	0,08
		Ed. System C	0,85	0,98	0,92	0,04
		Ed. System D	0,59	0,96	0,78	0,10
			Min.	**Max.**	**Mean**	**St.Dev.**
Confidence Interval	Lower bound	Global	0,58	1	0,82	0,11
		Ed. System A	0,76	0,99	0,85	0,06
		Ed. System B	0,58	0,99	0,72	0,10
		Ed. System C	0,87	1	0,97	0,04

		Ed. System D	0,60	0,99	0,81	0,11
	Upper bound		**Min.**	**Max.**	**Mean**	**St.Dev.**
		Global	0,55	0,95	0,75	0,09
		Ed. System A	0,65	0,89	0,79	0,06
		Ed. System B	0,55	0,82	0,67	0,06
		Ed. System C	0,77	0,95	0,86	0,05
		Ed. System D	0,57	0,92	0,74	0,09

To establish the comparison between different Educational Systems we used two non-parametric methods. The results of these methods are illustrated in table 3.

Median test confirms that there are significant differences in median scores of efficiency between Educational Systems. Schools of Educational System C have a higher median value than schools of other Educational Systems, and schools of Educational System B have a lower median value.

Kruskal-Wallis test confirms that there are significant differences in efficiency between Educational Systems by comparing ranks of the original values.

Table 3. Non-parametric tests to establish the comparison of efficiency between different Educational Systems

Median test	**Median**	0,800025608
	Chi-Square	37,077
	Degree of freedom	3
	Asymptotic Significance	0,000
	% of schools with efficiency scores > median	Educ. System A: 58% Educ. System B: 4% Educ. System C: 100% Educ. System D: 51%
Kruskal-Wallis test	**Chi-Square**	54,664
	Degree of freedom	3
	Asymptotic Significance	0,000
	Mean Rank	Educ. System A: 73,28 Educ. System B: 27,84 Educ. System C: 111,40 Educ. System D: 57,27

6. Summary and Conclusions

In a society focused in the problem of public debt, the study of efficiency in public resources allocation is an important concern.

Literature about efficiency of educational process is extensive and show the DEA methodology as a non-parametric frontier method very appropriate to analyse the efficiency of this process, due to their particularities (there are multiple inputs and outputs and their prices are unknown).

This study analyses the efficiency of 25 elementary schools in Andorra, during 5 years, with a contemporary and an intertemporal study, using DEA and applying a bootstrap technique to correct the potential bias.

Considering the 4 different public educational systems that exist in Andorra (Andorran, French, Spanish non-congregational and Spanish congregational), this study makes also a comparison between different educational systems, using nonparametric methods to compare the median values or the mean ranks.

Conclusions that can be drawn from the results of this study are:

1. A decreasing in the efficiency of schools along the years possibly due to the decreasing of Andorran population and of elementary students.
2. A significant difference between educational systems exists. It is shown that the educational system C has the higher median efficiency value and the higher mean efficiency rank value, and the educational system B has the lower values. Causes of these differences may be analysed but these results suggest us to identify the autonomy in school management, which is a feature of educational system C that differs from the others, as a positive contribution in efficiency, and stability of staff during the time, that is not a feature of educational system B, as another positive contribution in efficiency.

These results confirm extensive literature that suggests a positive contribution of decentralization in educational outcomes. Some examples are Wößmann (2003), Eskeland and Filmer (2007) and Clark (2005). In the field of efficiency

of schools, Naper (2010) studies the impact of decentralization in school's efficiency and he concludes that efficiency of schools is higher in districts where hiring is decentralized.Agasisti (2009) suggest the same contribution of decentralization.

This confirms the intuition that, in the same physical environment, the system has a significant impact on the performance of the students. Therefore, it is not the same to enrol a student in one school of C system than in a school of B system because the school will have a significant impact on the students' result: an important message for the family and for the policy makers in Andorra.

Finally, and anticipating future research work, it is worth to point out that these results need to be contrasted by introducing other factors, for example environmental ones, that could have an effect in efficiency of educational process and that are not considered in this study. As Coleman report (Coleman et al., 1966) shows, the environmental variables role in educational process is truly important. That is the reason why several studies are considering these variables in efficiency measures. Future research will introduce the effect of environmental variables.

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