MEASURING EFFICIENCY IN EDUCATION: AN ANALYSIS OF DIFFERENT APPROACHES FOR INCORPORATING NON-DISCRETIONARY INPUTS

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“Measuring efficiency in education: an analysis of different approaches for incorporating non-discretionary inputs”

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Summary

Measuring efficiency in the education sector is a highly complex task. One of the reasons is that the main resource of schools (the type of students they have) lie outside of their control, which means that it must be treated differently to other factors in analysis. This study examines the different options available in the literature for incorporating non-controllable inputs in a DEA analysis in order to determine the most appropriate model for evaluating schools. Our empirical study presents the results obtained using the model proposed by Fried et. al (1999), though we use bootstrap techniques to avoid problems of bias in the estimations.

Key words: **DEA, Efficiency, Exogenous Factors, Bootstrap**

1. INTRODUCTION

The special attention that both public authorities and the scientific community have always paid to the educational sector makes good sense if we remember that there is a strong correlation between the quality of education, measured through the results obtained in international tests, and countries' economic growth (Hanushek and Kimko, 2000, or, Barro, 2001).

A good part of research activity in recent years has been directed towards analysing the behaviour of schools by trying to measure their efficiency levels, making it necessary to relate results with resources. The analysis of efficiency in the educational field is more complex than in other production sectors for various reasons. These include the difficulty of measuring output, medium term effects or the fact that the production function is unknown. Since the publication of the Coleman Report (1966), it has also been recognized that the effects of certain exogenous factors on output, such as the pupils' socio-economic characteristics or their abilities, may be greater than others typical of the educational process (teachers, cost per student, class sizes, etc.) If we take into account that these factors are outside the control of schools the complicated task of evaluating the efficiency of their performance becomes more difficult.

A review of the literature in this area enables us to verify that, in addition to the accepted significance of these exogenous factors, there are many different options for including them in evaluations. While the first studies considered controllable and non-controllable inputs in the same way (Bessent et. al, 1982), more recent studies include both inputs together in a single stage, though treating them differently (Ruggiero, 1998). The evaluation process in other studies comprises several stages with the objective of treating the special nature of these factors in an appropriate way (Ray, 1991; McCarty and Yaisawarng, 1993; and, Muñiz, 2002). Within the multi-stage options, there are theoretical propositions that have not yet been applied in the educational field (Fried et. al, 1999; Fried et. al 2002 or Simar and Wilson, 2003).

In this context it seems appropriate to question the suitability of the different models. There are some interesting earlier studies into this issue which compare the results obtained from applying some of the proposed models to a specific sample (Worthington and Dollery, 2002). In this study, in addition to considering new options, we analyse their advantages and disadvantages from both a methodological and practical perspective.

To this end, our article is organised as follows. Section 2 is a brief synopsis of some important issues concerning the measurement of efficiency in education and Data Envelopment Analysis (DEA). Section 3 presents and analyses the different options for incorporating non-discretionary inputs into the measurement of efficiency. In section 4, we analyze the performance of a group of Spanish high schools using an extension of the model proposed by Fried et. al (1999) in order to discount the effect of non-controllable inputs. This model has not been applied before to the measurement of the efficiency of schools. Section 5 shows the main conclusions.

2. THE MEASUREMENT OF EFFICIENCY IN THE EDUCATIONAL SECTOR

Despite the great number of papers published in recent decades about the assessment of efficiency in education, the production function in the sector is still unknown (Engert, 1996). There are several explanations for this. Education is not an instantaneous thing but generates its effects in the medium term; the output, which is multi-dimensional and difficult to measure, is the consequence of a complex process influenced by many factors, some outside the control of the productive units. This makes it extraordinarily difficult to define a general educational production function that accurately includes all relevant aspects of the school production process and, consequently, making it possible to measure efficiency though a simple comparison between real results and those which could potentially be achieved (Hanushek, 1986).

The main interest of researchers in this area had been trying to define and measure the school output, identifying the factors that influence it most and linking the former with the latter while respecting the sector's special characteristics.

The measurement of educational output is usually restricted to those aspects that are relatively easy to measure and are directly related to the basic objectives of the relevant educational level. In the case of secondary education, it is usual to use the results achieved by students in an homogeneous test for all schools at the end of the school year.

With respect to inputs, despite the difficulties presented by the specification of an educational production function, there is empirical evidence to identify the factors that have a greater influence on school output. The Coleman Report (1966), which analysed the behaviour of a broad sample of non-university educational schools and is one of the most influential studies in the literature, concluded that the characteristics of pupils – a variable on which the centres in principle do not exercise any control – affected performance more than the typical resources of schools such as the number of teachers, class sizes or the school costs.

The publication of this report led to a wide-ranging debate between those who hold that these factors have no influence on educational results (Hanushek, 1986) and those who believe that spending more on education produces better results (Pritchett and Filmer, 1999). In any case, a study which aims to measure the productive efficiency of a group of schools must also consider these productive factors, since in the concept of technical efficiency is implicit the idea of how well resources are used.

The case of exogenous or environmental variables, which are common in other productive sectors, is different. Their influence on school output has been widely confirmed by empirical evidence and it is usually associated with a specific producer characteristic which may affect results (Pedraja and Salinas, 1996). Examples in the educational sector are the type of ownership of the schools (public or private) or their location (urban or rural). In these circumstances, the usual solution is to group units and compare them with those operating in a similar environment.

On the other hand, the representative variables of pupil characteristics, which are also sometimes considered as exogenous, are inputs which have a direct effect on the productive process and influence the results. These inputs, which the units cannot control (non-controllable inputs), should be considered in the efficiency evaluation so that those for which the educational centres are responsible can be calculated.

However, public data about these variables are not usually available, thus simple proxies for them are used in many studies[1]. One way to overcome these limitations, although costly and therefore infrequently used, is to conduct surveys of pupils in order to obtain information on the factors identified in the literature as the most influential: the socio-economic and family environment, the innate ability of the students and the characteristics of their class mates (peer group effect).

With respect to the technique used to estimate the relative efficiency of educational centres, most of studies choose non-parametric approximations and, specifically, Data Envelopment Analysis (DEA)[2]. The choice is based, amongst other reasons, on its great flexibility, which makes it particularly suitable in an area such as education where the production function is unknown, and on its ability to adapt to processes involving not only a range of inputs but also a series of intermediate

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[1] Some examples are the studies by Bessent et. al (1982) or Thanassoulis and Dunstan (1994), which approximate the economic situation of families by using the percentage of pupils entitled to discounted meals.

[2] The small number of studies using parametrical techniques in the sector (Bates, 1997 or Chakraborty et. al, 2001) all indicate a preference for the non-parametrical option.

outputs, rather than a single final input[3]. Moreover, in recent years different methods have been developed to incorporate in the technique the fact that there are non-controllable inputs when efficiency scores are calculated, which is of particular interest in the educational sector.

DEA, introduced by Charnes, Cooper and Rhodes (1978), is characterised by the fact that it does not impose a specific functional form on the production function, but rather establishes certain assumptions about the properties of technology which allow the definition of the set of feasible productive processes whose frontier envelops the observed data. The standard formulation of the programme can take several forms according to different criteria, so it can be oriented to reduce input values or increase output values. It can also be presented as a fractional programme (the original model), linear or dual. However, they all share the same approach: the efficiency of each unit depends on the ability of each producer to improve their results or reduce the consumption of resources while being subject to certain restrictions that reflect the activity of other producers.

From our perspective, if the aim is to evaluate the behaviour of a group of units, with a restricted budget, seeking to obtain the best possible results, it is advisable to use an output-orientated programme. In terms of its formulation, the dual programme is the most common option[4]:

$$\text{Max} \quad \phi + \varepsilon \sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$$

$$\text{s.a.} \quad \sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = x_{i0} \qquad i = 1,2,.....,m$$

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[3] Seiford and Thrall (1990) consider that using DEA is preferable to any other type of analysis when the objective is to measure the efficiency of a group of organisations producing various outputs.

[4] The model defined corresponds with the original version of DEA proposed by Charnes, Cooper and Rodhes (1978), which assumes a productive technology characterised by an assumption of constant scale returns. This highly restrictive assumption was later relaxed in the study by Banker, Charnes y Cooper (1984) with the introduction of a new restriction in the programme to allow variable scale returns: $\Sigma\lambda_j=1$.

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^{+} = \phi y_{r0} \qquad r = 1,2,.....,s$$

$$\lambda_j \geq 0\,;\; s_r^{+} \geq 0\,;\; s_i^{-} \geq 0 \qquad j = 1,2,....., n$$

where ϕ_0 is the efficiency score, ε is an infinitesimal non-Archimedean, λ_i are the weightings and s_i^{-} and s_r^{+} are the inputs slacks and outputs slacks respectively. If the score is equals one the producer is relatively efficient compared to other units. If the score is lower than one, the unit evaluated is inefficient as the sample contains other units which perform better.

This formulation of the programme is particularly attractive since, in addition to allocating an efficiency score to each unit, it allows possible additional reductions in inputs or potential increases in outputs to be detected in specific cases, using the slacks estimated for each variable. This interesting information is complementary to that offered by the efficiency score and may be extremely useful when it comes to identifying the source of possible producer inefficiencies.

3. DIFFERENT OPTIONS FOR INCORPORATING NON-CONTROLLABLE INPUTS: ADVANTAGES AND DISADVANTAGES.

A review of different options in the literature in order to incorporate exogenous factors in the evaluation of efficiency allows us to make an initial distinction between methodologies using one and several stages. In one stage models, non-controllable inputs are included from the outset in the calculation of efficiencies using a DEA alone. Multi-stage models use a DEA to estimate efficiency scores in an initial evaluation without including non-discretionary inputs and then subsequently correct them to take account of the effects of such inputs. This correction can be applied directly to the scores or by modifying the original values of the variables, leading to new options within the second group.

From this perspective it seems sensible to seek a guide for selecting the most appropriate options. We will therefore examine the principal advantages and disadvantages of the options in the literature[5] combining a theoretical perspective with a more practical view according to the objective of the analysis and the characteristics of the available data set.

3.1. One stage models

One stage models (Banker and Morey, 1986; Golany and Roll, 1993; and Ruggiero, 1998) are the most frequently used option[6]. These models modify the restrictions of the standard DEA programme by incorporating the uncontrollable nature of some of the inputs used. With this modification, if the model is oriented to minimise inputs the equiproportional reduction of the entire input vector is not pursued, but only the subvector formed by controllable inputs.

The principal advantage is its lack of complexity as it simplifies the calculation of efficiency scores by incorporating all the relevant variables in a single DEA. However, this option presents some methodological problems. The first of these is that it is limited to an input-oriented approach when, if we are trying to evaluate the performance of the schools, an output-oriented approach would be more recommendable. Moreover, with this approach all the inputs are fixed and it is not possible to treat those outside the schools' control in a differentiated manner. The second issue is that the efficient units are the same as those which would be obtained by using a DEA in which all inputs were controllable by the units. This happens because the frontier is the same in both cases and, consequently, only the scores of the inefficient units are modified. The third problem, which arises from the flexibility of the technique itself, is that

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[5] This analysis sets aside other methods which try to explain possible producer inefficiencies by the influence of ambiental or environmental variables such as the models of Charnes et. al (1981), Pastor (1994) or Daraio et. al (2005).

as the number of variables increases (through the introduction of exogenous variables), the opportunities for a unit to become classified as efficient increase automatically (Nunamaker, 1985). These limitations lead us to examine the opportunities offered by multi-stage models.

3.2. Multi-stage models

Although these models have been criticised for not explicitly including the effects of exogenous factors in the first stage, the fact is that they do consider these effects implicitly in estimating efficiency scores. The key is to calculate and discount correctly the effect of these factors to obtain final efficiency scores which reflect solely the performance of the units.

In this respect, two alternative methods may be identified: a direct adjustment of the initial efficiency scores themselves by using econometric techniques (*second stage models*), or an indirect adjustment by correcting variables (inputs/outputs), according to how they are affected by non-discretionary inputs, and applying a new DEA to the adjusted values after that (*adjusted value models*).

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[6] Most of computer programmes specifically developed for DEA allow non-controllable inputs to be included automatically using this option. For a review of DEA computer programmes in the market, see Barr (2004).

3.2.1. Second stage models

These models, usually known in the literature as *regression~~s~~ or second stage analyses*, consider non-controllable inputs *(Z_j)* as explanatory variables in a regression where the dependent variable is the initial efficiency score (θ_j). In this way, the initial scores are adjusted according to the values of exogenous factors[7]:

$$\theta_j = f(Z_j, \beta_j) + u_j$$

Its main advantage compared to other multi-stage models is its simplicity as the adjustments are performed directly on the efficiency scores obtained in the first stage. Nevertheless, this fact introduces a first limitation as the correction only takes into account the radial component of inefficiency and not the possible inefficiencies derived from the existence of slacks.

Another limitation of a practical nature is that it can only be applied if there is a significant relationship between the efficiency scores and exogenous variables. Many studies assume, erroneously, that if the output depends on uncontrollable outputs, there must be a significant relationship between these factors and the efficiency score. However, this assumption does not generally turn out to be correct, as efficiency depends on several factors. As a consequence, the use of this model is conditional upon there being a significant relationship between both variables.

A fundamental criticism of these models is that they fail to meet the basic requirements of regressions analysis. To the extent that the efficiency scores estimated in the first stage (dependent variable in the regression), are constructed with the information from all the units making up the sample, the assumption of independence of errors will not be met and the scores will contain biases (Xue and Parker, 1999). However, this problem can be overcome by using *bootstrap* techniques (Simar and Wilson, 2003)[8].

The model proposed by those authors is very attractive if the objective is to find whether the sign is positive or negative and how much effect exogenous factors have on efficiency indicators. However, we should remember that with adjustments made using this option, scores lower than one may be obtained for all the units comprising the sample[9]. This fact, which is explained by the zero sum criterion used in the estimation of regressions, makes it impossible to construct a production frontier and, consequently, difficult to establish production objectives for the units from the set of reference (efficient) units.

3.2.2. Adjusted value models

In addition to regression or second stage models, the literature offers other more complicated multi-stage applications, based on using the total slacks (radial and non-radial components) obtained in the first stage. The objective of these models is to identify the part of the slacks which is explained by the effect of non-discretionary inputs and the part associated with producers' own technical inefficiency. This decomposition means that adjustments can be made to the values of variables (controllable inputs and outputs) allowing the effect of exogenous factors to be discounted. The last stage, which is the same in all models, consists in running a new DEA incorporating the corrected values of variables according to non-controllable inputs attributed to each unit. The new estimated scores establish exclusively the efficiency level at which each producer operates.

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[7] While some studies use ordinary least squares (Ray, 1991), others use a *Tobit* (McCarty and Yaisawarng, 1993; Kirjavainen and Loikkanen, 1998) because the efficiency scores are censored.

[8] The analytical expression of the algorithm introduced by these authors to avoid problems of bias in small samples is set out in Simar and Wilson (2003) as "algorithm 2".

[9] This is verified in the study carried out by Afonso and St. Aubyn (2005) which applies the methodology proposed by Simar and Wilson (2003) to analyse the educational results of a group of countries.

Within these models, the available options are differentiated by the technique employed in breaking down the different factors that comprise the slacks. The three stage model (Fried and Lovell, 1996) chooses a DEA, the four stage model (Fried et. al, 1999) uses censured regressions and the model proposed by Fried et. al (2002) opts for stochastic frontier regressions.

a) Three stage model with DEA (Fried and Lovell, 1996)

The mechanism used for the discomposition of different factors is a DEA which incorporates slacks as controllable inputs and non-controllable inputs as outputs. This introduces a problem of minimising inputs (slacks) subject to the value of the outputs (non-controllable inputs). In other words, the aim is to determine the extent to which the former can be reduced while taking the value of the latter to be fixed.

$$
\begin{array}{ll}
\text{min} & \beta_0 \\
\text{s.a.} & \sum_{i=1}^{I} \lambda_i x_{fi} - s^{-'} = x_{f0} \\
 & \sum_{i=1}^{I} \lambda_i \left[(1-\theta_0)x_d + s_d^+\right]_i + s^{+'} = \beta_0 \left[(1-\theta_0)x_d + s_d^+\right]_0 \\
 & \sum_{i=1}^{I} \lambda_i = 1 \\
 & \lambda_i, s_d^{+'}, s^{-'} \geq 0
\end{array}
$$

where the total slack detected in the first stage for each producer in the variable x_d is given by the expression: $\left[(1-\theta_0)x_d + s_d^+\right]_i$. As a result of this process the attainable target is obtained for each unit, taking account of how many non-discretionary inputs it has. These targets make it possible to identify what part of the slacks is explained by the influence of external effects, $\beta_0 \left[(1-\theta_0)x_d + s_d^+\right]_i$, and what is due to inefficiency, *(1-*β_0*)* $\left[(1-\theta_0)x_d + s_d^+\right]_i$.

Its principal advantage is the use of non-parametrical techniques in all stages of the analysis, which is very useful not only where there is ignorance about the productive process in sectors such as education, but also to overcome problems of bias that characterise the estimation of regressions using econometric techniques.

Its main weakness is the impossibility of applying a downwards correction for units classed as efficient in the initial estimation. This appears inappropriate if these units have a relatively high level of non-controllable inputs, which involves a practical requirement when it comes to selecting the technique used in the process related to the characteristics of the available data set[10].

b) *Four stage model (Fried et. al, 1999)*

To distinguish the different effects incorporated in slacks, this model uses a system of equations formed by *n* Tobit regressions, one for each variable. The dependent variables are the total slacks of each output obtained in the initial DEA and the regressors are the exogenous factors:

$$ITS_j^k = f\left(Z_j^k, \beta_j, u_j^k\right)$$

where ITS_j^k represents total slacks obtained in the first stage, Z_j^k is a vector representing non-controllable inputs, β_j is a vector of coefficients and u_j^k is the error term.

From an applied perspective, its output-oriented approach is especially appropriate for including the effect of non-discretionary inputs in the educational sector as this technique only corrects output values -the only variables influenced by these factors-. It can also correct the scores

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[10] This is a decisive factor in the decision of its promoters to abandon it, as described in Fried et. al (2002).

of units considered efficient in the first stage if these have high values of exogenous factors.

The similarity of this method with second stage models means that it shares certain of their limitations. One is of a practical kind, such as the fact that there has to be a significant relationship between the slacks and exogenous variables so that it can be used and another, which is more important, of a methodological nature to do with problems of bias in the estimation of regressions[11]. While the former difficulty affects the possibility of applying it to certain samples, the latter can be overcome by using a bootstrap when estimating the equations system of the original regressions, though this is an option undeveloped in the literature.

c) *Three stage model with stochastic frontier (Fried, Lovell, Schmidt and Yaisawarng, 2002)*

The model's starting point is that the total slacks obtained in the first stage have three sources: producer inefficiency, the influence of exogenous factors and random noise. To separate these three components, a stochastic frontier is estimated in the second stage with the slacks as dependent variable, the non-controllable inputs as independent variables and a composed error term which differentiates between the effects of inefficiency and statistical noise. The stochastic frontier regression takes the following functional form:

$$s_{ni} = f^n(z_i;\beta^n) + v_{ni} + u_{ni} \qquad n = 1,\ldots., N \quad i = 1,\ldots.., I$$

where $s_{ni} = x_{ni} - X_n\lambda \geq 0$ are the total slacks of the outputs (inputs), $f^n(z_i;\beta^n)$ are the deterministic frontiers of feasible slacks, $z_i = \left[z_{i1},\ldots\ldots z_{ki}\right]$, are the variables of exogenous factors, β^n are the vectors of the parameters to be estimated and, finally, $v_{ni} + u_{ni}$ represent the errors, with

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[11] The slacks can also be calculated using the information of the units making up the sample, with the requirement for independence of errors not being fulfilled.

the first component representing random noise $\left[v_{ni} \approx N\left(0, \sigma_{vn}^{2}\right)\right]$ and the second ($u_{ni} \geq 0$) representing technical inefficiency. These regressions can be estimated through maximum likelihood, if some assumptions are made.

The stochastic nature of the proposed method allows the incorporation in the analysis of the effect of factors not included in it (random noise). This option also corrects the scores of those units considered as efficient in first stage in the case that they have favourable exogenous resources. Finally, it is also useful in identifying possible extreme values or outliers.

With respect to the disadvantages, we may note the excessively favourable criterion it uses to adjust the initial efficiency scores (worse placed unit in all dimensions), which produces final scores remote from the real production possibilities, as well as problems of bias in the estimations given the shortage of independence amongst the composed errors.

An analysis of the different options does not allow us to conclude that any one is better than the others. While some can be rejected, such as one stage models or second stage models not incorporating the proposal of Simar and Wilson (2003), choosing between adjusted value multi-stage models imposes certain requirements such as the need to make specific corrections in order to overcome methodological problems or the fulfillment of some requirements in the available sample.

In this way, using the four stage model with our proposed extension to avoid problems of bias is only possible if there is a significant relationship between the initial scores and exogenous variables; whereas the three stage model with DEA requires prior exploration of the data to avoid problems of overestimation in the scores. Finally the three stage stochastic model allows to detecting the effect of other factors not included in the analysis (random noise). However, using this model is not advisable because it sets non-real targets for the units (too easy to achieve) and also requires improvements – not yet developed in the literature- to eliminate biases from the estimation.

4. EMPIRICAL APPLICATION

In this section we estimate the level of technical efficiency in a group of Spanish high schools in the Extremadura region. The sample comprises eighty public schools in the region for which we have a great deal of information for the 2001-2002 school year on the non-discretionary inputs (obtained from student surveys), the results achieved by pupils in a standard test and the schools' productive factors.

This information is used to estimate the efficiency scores of the schools without including the information about their non-controllable inputs. Subsequently, once the results have been analysed and taking into account the characteristics of the sample, we select an appropriate model to discount the effect of non-controllable inputs and obtain a new estimation of the schools' efficiency.

4.1. Variables

The results achieved by pupils in the University Entrance Exam are used as an output. All students who wish to go to a Spanish University (public or private institutions) must make this commom exam on completing their secondary education. Two variables have been constructed using this information. The average mark of pupils passing the exam (MARKS), as an indicator of a qualitative nature, and the percentage of pupils who pass the exam compared to those enrolling in a university course (ACCEPTED).

As controllable inputs, the two variables most often used in the literature as being representative of the factors managed by the schools are chosen[12]. The total number of teachers in the school per 100 pupils (TEACHERS) and the total current cost per student excluding school personnel costs during the year (COSTS)[13].

The usual difficulty of an absence of available information on the non-controllable inputs has been overcome in our study through a survey of the pupils of all the schools evaluated. These gave twenty-two variables offering information on a large variety of circumstances which may affect pupils' academic performance. Following an exhaustive analysis, eleven of these were selected, all of which are statistically related to the representative variables of the output. These variables are also associated with the factors that the literature identifies as most influential on the student such as the socio-economic and family environment, their own abilities or the influence of class mates (peer group effect). The variables, defined as the percentage of pupils who fulfil certain requirements, are listed in Table 1 of the Annex.

In any case, given the number of variables, which is still high, and the fact that none of them represents the factors addressed in the literature and mentioned above particularly accurately, we decided to use Principal Component Analysis (PCA)[14]. This technique makes it possible to summarise all the information available in a lower number of variables with minimum loss of information. These are the variables which will finally be incorporated in the evaluation of efficiency as representative variables of so-called non-controllable inputs.

PCA allows us to identify three components which cover 78% of the original information (see Annex, Table 2). Next, looking at the rotated

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[12] Bessent et. al (1982), Smith and Mayston (1987), McCarty and Yaisawarng (1993) or Muñiz (2002) amongst others.

[13] We should point out that, taking into account the type of variables used, the concept of efficiency to be measured is not strictly technical efficiency as one input (costs other than personnel) is expressed in monetary terms, but they are very close to it. However, this cannot be considered as allocative efficiency as we do not include the price of inputs which are clearly unknown in this field.

[14] Smith and Mayston (1987) were the first to recommend using this technique to reduce the number of non-discretional factors in the evaluation of the efficiency of schools.

component matrix, we can verify which variables are associated with each of the variables. Table 3 in the Annex shows that the first factor is comprised of five variables concerning family incomes, level of education and profession of the fathers (in other words, those determining the student’s socio-economic environment). The second is comprised of four variables representing pupils' ability, meaning variables related to their academic record and the opinion that parents have about their academic potential. Finally, the third factor is made up of two variables which offer us information about the characteristics of class mates or peer group effect such as those relating to the pupils’ aspirations or their efforts to keep their studies up to date.

In summary, for the empirical application we used two variables for school output (MARKS and ACCEPTED), two offering information about inputs controlled by the schools (TEACHERS and COSTS) and three representing non-discretionary inputs (the three components obtained from the eleven variables described above). Table 1 lists the principal statistichs for these variables.

Table 1: Statistical information about the variables

	MINIMUM	MAXIMUM	AVERAGE	STANDARD DEV
MARKS	50.28	72.52	59.59	4.0987
ACCEPTED	12.50	86.42	40.33	14.0819
TEACHERS	7.68	13.21	9.64	1.1490
COSTS	65.63	543.86	161.19	66.8621
COMP 1	0.00	4.60	1.3050	1.0000
COMP 2	0.00	5.06	2.6922	0.9993
COMP 3	0.00	5.27	1.8900	1.0000

4.2. Results obtained with a standard DEA analysis

In this section we assess the schools' efficiency by applying a standard DEA, i.e. using only discretional inputs. As explained earlier, the approach is to maximise outputs and we consider variable returns to scale both to eliminate possible inefficiencies to do with the size of the schools and because it is the correct option in cases where ratios are used in inputs or in outputs (Hollingsworth and Smith, 2003).

The results in Table 3 in the Annex show eight efficient units (HS 12, 18, 24, 31, 44, 52, 56 and 71), which can in turn be divided into two groups. The first (HS 12, 31, 56 and 71) comprises units which have achieved the best results in the University Entrance Exam, and the second (HS 18, 24, 44 and 52) represents those with lower input values. With regards to the inefficient units, those with the lowest scores are those with the worst results in the University Entrance Exam (HS 10, 37, 53 or 64), or those which, in spite of having greater resources, achieved mediocre results (HS 15, 48 or 62).

This initial evaluation would be correct if all the schools had pupils with similar characteristics, which is not true in the light of the information contained in Table 1. Therefore it is necessary to include these variables in the evaluation process.

Given the analysis performed in the previous section, and taking into account that our aim is to obtain scores which discriminate between efficient and inefficient units in order to set production and consumption targets, the choice between the different current methodologies for incorporating exogenous variables is limited to the three stage model with DEA and the four stage model. The choice of the latter was based on the characteristics of the sample.

In this context we verify that the units classified as efficient in the first stage have a high level of non-controllable inputs (see Annex, Table 5). This fact makes it necessary to adjust the efficiency scores of these units as their good results are due, to a large extent, to the higher quality of their pupils. This situation eliminates choosing the three stage model as it would continue to consider these units as efficient following the adjustment process.

Below we test the existence of a significant relationship between the slacks obtained in the first stage and non-controllable inputs, a necessary requirement to enable us to apply the proposed extension to the four stage model. The results in Table 2 confirm this relationship for all variables (*p-values* for the three components are very close to 0) both in the estimation of the initial Tobit regressions and the estimations performed using a 10,000 iteration bootstrap process. As a result, for the first time in the literature, we use an extended four stage model to estimate the efficiency of schools.

Table 2: Results of the Tobit regressions

	Dependent Variable			
Dependent Variable	***Slacks* Accepted**	***Slacks* Marks**	***Slacks* Accepted (Bootstrap)**	***Slacks* Marks (Bootstrap)**
Constant	30.9050** (2.6931)	21.6691** (1.7208)	30.9112** (2.6790)	21.6763** (1.7084)
CP1	-3.1547** (0.7406)	-2.7603** (0.4732)	-3.1539** (0.7402)	-2.7671** (0.4748)
CP2	-3.8893** (0.7416)	-1.7736** (0.4739)	-3.8794** (0.7401)	-1.7690** (0.4712)
CP3	-2.1842** (0.7411)	-1.3464** (0.4735)	-2.1956** (0.7375)	-1.3497** (0.4733)

Note: The standard errors of the estimated parameters are shown in brackets. The subscores ** indicate that the parameter estimated is significant at 5 per cent level.

4.3. Results from incorporating the effect of non-discretionary inputs

Comparing the scores obtained from the four stage model with the initial scores allows us to draw some conclusions (Table 4). Firstly, there is an increase in average efficiency. More units benefit from the inclusion of non-discretional inputs than those which are negatively affected and the efficiency gains outstrip the losses (see Annex, Table 4).

Table 3: Differences between the initial DEA and the extended four stage model

	Efficient units	**Average efficiency**	**Percentage of units with a difference > 5%**	**Spearman's coefficient**
Initial DEA	8	84.96	57.5	0.714
Modified 4 stage	12	89.25		

Secondly, the number of efficient units increases to twelve, as a consequence of five becoming efficient (HS 22, 25, 34, 42 and 78), and one (HS 24) no longer being efficient. The new efficient centres have been benefited in the second estimation because the scores assigned to each unit are constructed taking into account additional resources, thus implying that all the units are evaluated according to their true productive potential.

As with the units which become efficient, there are others, which though they do not reach the frontier, clearly move closer to it. This is the case with the schools like HS 28, 33 ó 36. All were negatively affected in the first evaluation which ignored the type of pupils in each school. However, by applying the four stage methodology, all increase their score and are amongst the ten best inefficient units.

In the case of the unit that goes from being efficient to inefficient the opposite applies. The first DEA, in which not all the resources are taken into account, benefits this school as it is one of those which have better quality students. However, it can be seen in the subsequent evaluation that the school was not in fact maximising its results given its set of non-controllable factors.

Many others also obtain a score which is appreciably lower following the correction made using the four stage model, causing significant changes in the final classification of schools. The most noticeable are those affecting units 20, 50 and 59 which are noteworthy for having a set of non-discretionary inputs which are clearly higher than the others.

Finally, although the corrections to values are not too significant, a considerable number of units modify their scores. More than half change their score by more than 5% (Table 3). This changes the final ranking of the units as can be seen by the value of the Spearman coefficient range (0.714).

5. CONCLUSIONS

This study offers a detailed analysis of the advantages and disadvantages of the options proposed in the literature for incorporating the effect of non-controllable inputs when estimating efficiency scores. Their incorporation is essential in areas like education where output depends to a large extent on factors, such as socio-economic characteristics of the students and their families, which are outside of the schools' control.

Once certain options which are unsuitable from a methodological perspective have been discarded, it is impossible to say that one model is better than the rest in overall terms. The choice will be affected by the specific objectives of the study and the characteristics of the available sample.

These conclusions were followed in estimating the efficiency of a group of Spanish high schools, applying a four stage model proposed by Fried et. al (1999) and adding a bootstrap to avoid problems of bias in the estimations. This approach, which had not been used in the field of education until now, can be considered as a very suitable option to identify the efficient units once the non-discretionary inputs have been included in the analysis.

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ANNEX

Table 1: Definition of the representative variables of non-discretionary inputs.

Name of variable	Definition
PASSALL	Pupils who passed all their subjects last year
NOREPEAT	Pupils who have never repeated a year
RECORD	Pupils who passed all subjects between June and September last year with high marks
HOURS	Pupils who studied for more than 10 hours a week
ASPIRATION	Pupils wishing to study at university
CONFIDENCE	Pupils whose parents have confidence in their academic success
INCOMES	Pupils whose parents have high incomes
FATHEREDUC	Pupils whose father has a university education
MOTHEREDUC	Pupils whose mother has a university education
FATHERJOB	Pupils whose father is a qualified professional
MOTHERJOB	Pupils whose mother is a qualified professional

Table 2: Principal Components Analysis for non-discretionary inputs

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	5.145	46.777	46.777	5.145	46.777	46.777
2	2.364	21.489	68.265	2.364	21.489	68.265
3	1.092	9.927	78.192	1.092	9.927	**78.192**
4	.665	6.048	84.241			
5	.459	4.169	88.409			
6	.371	3.373	91.782			
7	.271	2.465	94.247			
8	.208	1.887	96.135			
9	.193	1.757	97.892			
10	.152	1.381	99.273			
11	.079	.727	100.000			

Table 3: Rotated Factor Matrix

	COMPONENT		
	1	**2**	**3**
PASSALL	0.107	**0.780**	0.374
NOREPEAT	0.072	**0.690**	0.482
RECORD	0.085	**0.883**	0.126
HOURS	0.057	0.088	**0.909**
ASPIRATION	0.255	0.416	**0.505**
CONFIDENCE	0.274	**0.773**	-0.194
INCOMES	**0.888**	0.112	0.166
FATHEREDUC	**0.915**	0.205	0.037
MOTHEREDUC	**0.916**	0.250	-0.042
FATHERJOB	**0.899**	0.020	0.190
MOTHERJOB	**0.901**	0.114	0.049

Rotation Method: Varimax with Kaiser Normalization.

Table 4: Efficiency scores and rankings

	Standard DEA	***Ranking***	**Four Stages Model**	***Ranking***
HS 1	83.44	*46*	92.19	*25*
HS 2	76.43	*71*	87.38	*47*
HS 3	87.20	*26*	88.29	*44*
HS 4	75.88	*72*	82.64	*70*
HS 5	84.23	*39*	89.57	*38*
HS 6	90.17	*19*	89.05	*41*
HS 7	85.12	*33*	82.86	*69*
HS 8	93.46	*11*	93.68	*20*
HS 9	85.85	*30*	91.58	*27*
HS 10	69.99	*79*	78.47	*77*
HS 11	92.38	*14*	86.23	*54*
HS 12	100.00	*4*	100.00	*2*
HS 13	77.92	*67*	84.40	*61*
HS 14	79.59	*59*	84.06	*64*
HS 15	75.44	*74*	84.03	*65*
HS 16	85.05	*34*	87.31	*48*
HS 17	92.30	*15*	96.17	*14*
HS 18	100.00	*5*	100.00	*8*
HS 19	79.86	*56*	90.08	*37*
HS 20	84.94	*35*	78.53	*76*
HS 21	82.68	*51*	92.26	*24*
HS 22	89.01	*22*	100.00	*5*
HS 23	79.41	*63*	84.44	*60*
HS 24	100.00	*2*	93.03	*21*
HS 25	93.49	*10*	100.00	*10*
HS 26	83.58	*45*	89.54	*39*
HS 27	84.65	*37*	90.14	*36*
HS 28	82.75	*49*	96.27	*13*
HS 29	83.11	*47*	86.36	*53*
HS 30	80.96	*54*	88.73	*42*
HS 31	100.00	*8*	100.00	*11*
HS 32	85.64	*31*	90.78	*29*
HS 33	83.98	*40*	96.08	*15*
HS 34	90.07	*20*	100.00	*9*
HS 35	83.88	*41*	90.24	*35*
HS 36	79.41	*64*	95.41	*16*
HS 37	69.33	*80*	75.22	*79*
HS 38	85.43	*32*	90.55	*33*
HS 39	81.83	*52*	87.53	*46*
HS 40	83.77	*43*	86.58	*51*
HS 41	80.44	*55*	88.51	*43*
HS 42	91.50	*17*	100.00	*4*
HS 43	89.23	*21*	94.48	*18*
HS 44	100.00	*1*	100.00	*1*

HS 45	91.33	*18*	94.82	*17*
HS 46	79.43	*61*	83.25	*68*
HS 47	88.67	*23*	89.22	*40*
HS 48	74.47	*77*	81.75	*71*
HS 49	77.36	*68*	74.13	*80*
HS 50	83.78	*42*	79.71	*74*
HS 51	82.68	*50*	84.86	*59*
HS 52	100.00	*6*	100.00	*7*
HS 53	74.58	*76*	83.90	*67*
HS 54	88.01	*24*	92.07	*26*
HS 55	86.53	*28*	90.59	*31*
HS 56	100.00	*7*	100.00	*6*
HS 57	84.58	*38*	90.40	*34*
HS 58	86.66	*27*	91.13	*28*
HS 59	92.49	*13*	84.10	*63*
HS 60	79.80	*58*	92.34	*23*
HS 61	81.66	*53*	78.38	*78*
HS 62	75.74	*73*	86.73	*50*
HS 63	83.01	*48*	86.41	*52*
HS 64	74.14	*78*	80.45	*73*
HS 65	79.81	*57*	85.75	*56*
HS 66	75.25	*75*	79.17	*75*
HS 67	84.77	*36*	87.58	*45*
HS 68	76.86	*70*	86.87	*49*
HS 69	80.54	*55*	85.27	*58*
HS 70	77.95	*66*	84.19	*62*
HS 71	100.00	*3*	100.00	*3*
HS 72	79.56	*60*	86.21	*55*
HS 73	77.10	*69*	85.48	*57*
HS 74	92.11	*16*	92.47	*22*
HS 75	87.45	*25*	94.17	*19*
HS 76	78.34	*65*	80.69	*72*
HS 77	83.67	*44*	90.64	*30*
HS 78	95.73	*9*	100.00	*12*
HS 79	93.24	*12*	83.95	*66*
HS 80	85.91	*29*	90.56	*32*
Average	**84.96**	**-**	**89.25**	**-**

Table 5: Non-discretionary inputs for each high school

	PC1	**PC2**	**PC3**		**PC1**	**PC2**	**PC3**
HS 1	1.0808	1.4951	1.0187	**HS 41**	0.2187	2.7987	2.3335
HS 2	1.4212	0.6059	0.1967	**HS 42**	0.6686	2.1311	2.1477
HS 3	1.8614	3.1401	2.1468	**HS 43**	0.3599	3.7343	2.2877
HS 4	0.7276	2.7477	2.0753	**HS 44**	1.9076	1.8234	2.4579
HS 5	1.4026	3.1588	1.3687	**HS 45**	1.1824	4.3392	1.3264
HS 6	1.9669	2.4983	3.4984	**HS 46**	0.3398	3.6254	2.7528
HS 7	2.2588	2.6491	3.1852	**HS 47**	1.0450	3.9637	1.8646
HS 8	0.8083	2.3982	5.2743	**HS 48**	0.3185	3.4848	0.6267
HS 9	0.6896	3.2240	3.3473	**HS 49**	1.0532	4.0855	2.9011
HS 10	0.4224	1.8592	1.4136	**HS 50**	2.0677	4.3398	1.3995
HS 11	4.6013	1.0401	2.0900	**HS 51**	1.4411	2.7152	2.2873
HS 12	1.3850	3.9275	2.4113	**HS 52**	3.1948	3.6682	1.6367
HS 13	0.0000	3.3721	2.1315	**HS 53**	0.5786	1.7482	1.7943
HS 14	1.5857	2.0269	1.3725	**HS 54**	1.2085	2.6764	2.2443
HS 15	1.0413	0.6457	2.3220	**HS 55**	1.3972	2.8984	2.3295
HS 16	0.9165	4.4271	1.5982	**HS 56**	3.6352	5.0613	1.6067
HS 17	1.3560	3.8398	1.4263	**HS 57**	0.9291	3.0304	1.1858
HS 18	2.4432	2.3563	1.7231	**HS 58**	1.5084	2.2075	1.4870
HS 19	0.2991	3.2500	0.2965	**HS 59**	4.4237	2.5879	2.4581
HS 20	2.5508	2.6287	4.0942	**HS 60**	1.4312	1.8256	1.9502
HS 21	0.5152	2.7861	1.1598	**HS 61**	1.9006	3.7419	1.8804
HS 22	0.3016	3.1860	1.6239	**HS 62**	0.9679	1.1688	0.0288
HS 23	0.5144	2.4602	3.0751	**HS 63**	0.5758	3.5621	2.3229
HS 24	3.5859	3.3580	2.3960	**HS 64**	0.9592	2.4005	1.2170
HS 25	0.5770	2.6935	3.0344	**HS 65**	0.8750	3.1157	1.0487
HS 26	0.8750	2.3512	2.2104	**HS 66**	1.4877	0.6579	3.1975
HS 27	1.0462	3.4355	1.1760	**HS 67**	1.8478	2.4793	1.4155
HS 28	0.7177	0.0000	1.2093	**HS 68**	0.2757	2.8287	0.0000
HS 29	0.4964	3.1566	2.4382	**HS 69**	2.4651	1.9489	0.1295
HS 30	1.2993	3.0063	0.5576	**HS 70**	0.0480	2.0493	3.7129
HS 31	2.0975	3.5235	2.1756	**HS 71**	1.4361	2.8011	2.0229
HS 32	0.0925	3.0095	3.6040	**HS 72**	0.9623	1.6753	2.2555
HS 33	0.1048	2.8841	0.9020	**HS 73**	1.0699	2.1929	0.4935
HS 34	0.8876	1.5343	2.9837	**HS 74**	2.6558	3.1612	2.0677
HS 35	1.5845	2.1841	1.3469	**HS 75**	0.9686	2.0025	2.8209
HS 36	0.5419	0.7101	0.1403	**HS 76**	0.8843	4.7554	0.3874
HS 37	0.7452	1.6108	2.3759	**HS 77**	1.6583	1.4129	1.2149
HS 38	2.0752	3.1690	0.9027	**HS 78**	0.1629	3.6564	1.9776
HS 39	0.2346	3.4821	2.6125	**HS 79**	3.7948	2.3542	2.1048
HS 40	0.6136	2.7154	2.5032	**HS 80**	2.7672	2.1222	0.4030
Average	**1.3050**	**2.6922**	**1.8900**	**Average**	**1.3050**	**2.6922**	**1.8900**

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