ALTERNATIVE APPROACHES TO INCLUDE EXOGENOUS VARIABLES IN DEA MEASURES: A COMPARISON USING MONTE CARLO

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"Alternative Approaches to Include Exogenous Variables in DEA Measures: A Comparison Using Monte Carlo"

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Abstract

The theory for measuring efficiency of producers has developed alternative approaches to include the effect of non-discretionary variables in the analysis. A review of different options in the specific literature of Data Envelopment Analysis (DEA) allows us to identify three main approaches: one-stage, two-stage and multi-stage models. Recently, some of these models have been improved through the development of bootstrap methods making it possible to make inference and to avoid bias in the estimation of efficiency scores. The aim of this paper is to test the performance of these recent models and to compare among them using simulated data from a Monte Carlo experimental design.

Keywords: Efficiency, DEA, Simulation, Monte Carlo.

1. INTRODUCTION

In the field of efficiency measurement most of the research focuses on studying the performance of producers taking into account their ability to manage the resources they can control in order to produce the maximum output feasible. However, in practice, the results of production processes also depend on the effect of another type of variables which are beyond the managers' control. Therefore, the only way the producers can correctly be evaluated is by considering the influence of those external variables on the results.

As a result, there has been a growing interest in the literature to study how the effect of exogenous variables can be included in efficiency measures, especially in those obtained with Data Envelopment Analysis (DEA). We can find papers that have addressed this issue in such different sectors as education (Ray, 1991; McCarty and Yaisawarng, 1993), health (Grosskopf and Valdamis, 1987), banking (Fried, Lovell and Vanden Eeckaut, 1993; Lozano-Vivas, Pastor and Pastor, 2002), nursing homes (Fried, Schmidt and Yaisawarng, 1999; Fizel and Nunnikhoven, 2006) or sports (Fried, Lambrinos and Tyner, 2004).

The problem has been approached using different frameworks among which researchers still do not agree to identify a preferred option (Muñiz, 2002). Hence, selecting an option among existing alternatives is a crucial decision in efficiency evaluations in which the external variables play a significant role. Moreover, this is not a simple task since the basis of each methodology is quite different and also the results obtained differ greatly (Rouse, Putterill and Ryan, 1996; Cordero, Pedraja and Salinas, 2008).

The aim of this paper is to shed some light on this issue by testing the performance of the main and most recent approaches developed in the literature about DEA using simulated data. To solve the controversy among competing techniques we employ a Monte Carlo experiment.

There have been similar attempts to deal with this issue previously, although limited to certain features. Thus, Yu (1998) focuses on comparing parametric and non-parametric approaches using a Monte Carlo experiment rather than analysing alternative non-parametric models. In contrast, Ruggiero (1998) and Muñiz *et al*. (2006) compare different approaches developed in the context of DEA using simulated data.

However, both are limited because they use a single replication instead of the large number as is usual in Monte Carlo experiments. In addition, all these papers assumed a data generation process based on a not very flexible production function, which makes it unlikely to adapt it to most of production processes that takes place in real world.

In this paper we make an effort to simultaneously overcome some of those limitations by expanding the analysis in various directions. Firstly, we perform a Monte Carlo experiment to ensure the results are adequately representative and not the result of a particular case. Secondly, we use the transcendental logarithm function proposed by Christensen, Jorgenson and Lau (1971) to generate data so that we have a more flexible production technology. Finally, we test the performance of some of the most recent models developed in the literature, some of which have never been included in this type of experiments before, such as for example the alternatives proposed by Fried, Schmidt and Yaisawarng (1999) or Simar and Wilson (2007), as well as an original combination of those alternatives we have developed.

The article is organized as follows. Section II introduces DEA and presents alternative approaches to include non-discretionary inputs in the estimation of efficiency scores with this technique. Section III describes the structure of the Monte Carlo experimental design. In Section IV the main results from the simulation analysis are reported and analyzed according to different criteria. The last section presents the conclusions.

2. DATA ENVELOPMENT ANALYSIS AND NON-DISCRETIONARY INPUTS

2.1. DEA without non-discretionary inputs

DEA methodology was introduced by Charnes, Cooper and Rhodes (1978). This non-parametric technique yields estimates of the comparative technical efficiency of a set of Decision Making Units (DMUs). The efficiency of each DMU depends on its ability to improve their results or reduce the consumption of resources while being subject to certain restrictions that reflect the activity of other units. The main advantage of this approach is that it does not impose a specific functional form on the production function, it handles multiple outputs and inputs and yields meaningful targets for improvement among inefficient DMUs.

The standard formulation of the program can take several forms according to different criteria, so it can be oriented to minimize input values or maximize output values and can also be presented as a fractional linear or dual programme[1]. In this paper, we adopt an input-oriented program with variable returns to scale (Banker, Charnes and Cooper, 1984):

$$\text{Min} \quad \theta_0 - \varepsilon\left(\sum_{r=1}^{s} s_r^+ + \sum_{i=1}^{m} s_i^-\right)$$

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

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

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0;\ s_r^+ \geq 0;\ s_i^- \geq 0 \qquad j = 1,2,\ldots\ldots, n \qquad (1)$$

where x_{ij} is the vector of inputs and y_{rj} the vector of outputs for DMU *j;* ϕ_0 is the efficiency score, ε is an infinitesimal non-Archimedean constant, λ_i are the weightings and s_i^- and s_r^+ are the inputs slacks and outputs slacks respectively. If the score 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 radial efficiency score and may be extremely useful when it comes to identifying the source of possible producer inefficiencies.

2.2. DEA with non-discretionary inputs

The basic DEA model described above assumes that all the inputs are controlled by DMUs, since the solution of the programme can lead to a reduction in the number of inputs. However, in most of production processes the use of the so-called non-discretionary inputs cannot be reduced since they are exogenously fixed. In order to overcome this problem the DEA literature has developed numerous alternative approaches to include the effect of those external variables in efficiency scores. In this section, we review the structure of the main methodologies and suggest some extensions that can improve the quality of some of them. With the aim of simplifying the explanation, alternatives have been grouped into three categories: one-stage, two-stage and adjusted values models.

a) One-stage models

Following this approach non-controllable inputs are included directly in DEA to estimate efficiency scores with an additional restriction in the formulation of the standard program. The most representative model within this option is the one proposed by Banker and Morey (1986), which has been widely used by researchers due to its simple implementation[2]. Assuming variable returns to scale, the formulation for this program is:

$$\text{Min} \quad \theta - \varepsilon\left(\sum_{i=1}^{M} s_r^{+} + \sum_{r=1}^{S} s_i^{-}\right)$$

$$\text{Subject to} \quad \sum_{j=1}^{n} \lambda_j Y_j - s^{-} = Y_0$$

$$\sum_{j=1}^{n} \lambda_j X_j + s^{+} = \theta X_0$$

$$\sum_{j=1}^{n} \lambda_j Z_j + s^{f} = Z_0$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0 \qquad \forall j = 1,\dots,n$$

$$s_r^{+}, s_i^{-}, s^{f} \geq 0 \qquad (2)$$

This program does not pursue to reduce all the inputs equiproportionally, but only the subvector formed by non-discretionary inputs, which means that each DMU is only compared with those DMUs with an equal or lower value for the corresponding non-discretionary input. Hence, efficiency scores estimated using this option are worse or equal to those that would be obtained if non-controllable inputs were considered as discretionary inputs.

The principal advantage of this approach is its lack of complexity as it simplifies the estimation of efficiency scores by including all the relevant variables in a single DEA. However, this option presents some methodological problems. Firstly, it is limited to an input-oriented approach since this is the only way the program can distinguish between discretionary and non-discretionary inputs. Secondly, 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. Thirdly, it requires knowing previously whether the influence of these variables on the production results is positive or negative. Finally, the technique loses discrimination power as the number of variables included in the analysis increases regardless of whether variables have an influence on the results or not.

b) Two-stage models

This approach estimates efficiency scores with original DEA program using only the discretionary inputs. This produces a first stage measure for production that captures not only technical inefficiency but also the influence of variables that have not been included in the analysis. Subsequently, a regression analysis is used in the second stage to decompose both of them. Therefore, exogenous variables *(Z_j)* are explanatory variables and the dependent variable is the first-stage efficiency score ($\hat{\theta}_j$):

$$\hat{\theta}_j = f(z_j, \beta) + u_j \qquad (3)$$

This regression can be estimated by ordinary least squares, although the use of a Tobit regression is more widespread since the dependent variable (the efficiency score) is bounded between 0 and 1 (McCarty and Yaisawarng, 1993). From the value of estimated coefficients it is possible to identify the influential variables and their sign (positive or negative) and also to weigh the importance of each external variable in the efficiency estimate. Furthermore, the initial efficiency scores can be directly corrected in order to include the influence of the external variables (Ray, 1991).

Its main advantages are the possibility of sensitivity analysis, which allows testing different sets of external variables, and its simplicity since it only requires solving the original DEA model once as it corrects directly the initial efficiency scores. Nevertheless, this type of adjustment introduces a first limitation as it only takes into account the radial component of inefficiency and ignores possible inefficiencies derived from the existence of *slacks*[3]. But its main drawback comes from the fact that the results are bound to be biased due to the fact that efficiency scores estimated in first stage, the dependent variable in (3), depend on all observed inputs and outputs. Hence, conventional inference methods in this context are invalid as the error term u_j is correlated (Xue and Harker, 1999).

However, this problem can be overcome by using *bootstrap* methods. In this sense, there have been different proposals to address the problem[4], but the option that provides the most satisfactory solution is the methodology suggested by Simar and Wilson (2007). They describe a complete data generating process consistent with regression of non-parametric estimates in a second stage and develop two different algorithms based on the use of bootstrap methods to obtain consistent and unbiased estimates for the parameters of the regression (both algorithms are described in the Appendix).

Using the model proposed by Simar and Wilson (2007) the problems of biased can be avoided, but weaknesses also arise. First, it also ignores the non-radial component of inefficiency. Second, it assumes that inefficiency and the influence of external variables is neutral among the variables included in the initial evaluation which can be incorrect as Fried, Lovell and Vanden Eeckaut (1993) demonstrated. Thirdly and most importantly, its main purpose is to obtain a confidence interval for the parameters (β_i) in order to establish the real influence of external variables on efficiency rather than to obtain efficiency scores that include the effect of these variables. Thus, when this model is used with the latter aim, it should be assumed that scores obtained may not represent real production targets since all the units are classified as inefficient because of the structure of the model itself[5].

c) Adjusted values models

In addition to two-stage models, there are other multi-stage approaches based on the use of total *slacks* (radial and non-radial components) of each variable obtained in the first stage. These slacks arise from two distinguishable effects: the technical inefficiency of the units and the influence of the non-discretionary inputs, which have not been included in the first analysis. The objective of these models is to distinguish between them and quantify both components. Once the decomposition has been made, it is possible to make adjustments on the original values of variables in order to discount the effect of exogenous factors. Finally, by running a DEA with corrected values of the variables, it is possible to obtain new scores that establish exclusively the efficiency level at which each producer operates.

Models following this approach differ among themselves by the technique used in the second stage to decompose different factors that comprise the *slacks*. Thus, Fried and Lovell (1996) and Muñiz (2002) choose a DEA so that they have a totally non-parametric model whereas *Fried, Schmidt and Yaisawarng* (1999) and *Fried et al.* (2002) opt for a semi-parametric model based on the use of regressions.

On the one hand, non-parametric models run a separate DEA with an input orientation for the slack of each variable (inputs and outputs). Non-discretionary inputs are included as outputs and the slacks as inputs. In this way, the aim is to determine to what extent the *slacks* can be reduced while taking the value of the non-discretionary inputs to be fixed. As a result of this process the attainable target is obtained for each unit, taking into account the values of non-discretionary inputs, and the original values of variables can be corrected prior to running a final DEA with those adjusted values in a third stage.

The main advantages of this model derived from the use of DEA in all the stages, due to the fact that it does not require assuming any functional form and it also avoids potential problems of bias which can arise in the estimation of regressions using econometric techniques. However, it involves some weaknesses as well, such as possible bias related to the deterministic nature of the method, the impossibility to distinguish the different importance of the set of non-controllable inputs or the loss of discrimination power that arises when a high number of non-controllable inputs is included in DEA[6]. Moreover, there is an additional limitation from a methodological point of view, which is the fact that the units classified as efficient in first stage cannot become inefficient after including non-discretionary variables in the analysis[7].

On the other hand, semi-parametric models estimate a separate regression for each *total slack* (*TS*) of the inputs or the outputs (depending of the orientation of DEA in first stage) using non-discretionary inputs as explanatory variables:

$$T\hat{S}_j^k = f\left(Z_j^k, \beta_j^k\right) + u \qquad j = 1, 2, \ldots, N \qquad k = 1, 2, \ldots, K \tag{4}$$

The coefficients ($\hat{\beta}_j$) from (4) and (5) should be estimated using Tobit since *slacks* are also censored at zero. They provide a helpful information since it is possible to establish the direction and relative weight of each non-controllable input on the slacks separately. Thus, different effects among slacks can be detected and even it could happen that some external factors have influence on some *slacks* but not others.

In addition, these coefficients can be used to predict new *slacks* for each variable taking into account the influence of non-controllable inputs on each DMU. Thus, it is possible to correct original values of variables using these predicted values by subtracting to the original value of each output the difference between the highest predicted value and the predicted value for each DMU or by adding it in the case of inputs. Finally, as well as the former model, a new DEA is run with the adjusted variables.

The process described was suggested by Fried, Schmidt and Yaisawarng (1999) and it is known as the four-stage model[8]. From the theoretical point of view this is an attractive option, since it allows to measure the influence of each external variable considered and to take it into account to estimate efficiency scores, which, furthermore, can be interpreted as production targets for the units. However, the second stage of this model shares the problem of bias with its two-stage counterpart since total *slacks* are also estimated by taking the information of the whole sample so it is not fulfilled the assumption of independence in the errors.

To the best of our knowledge this problem has not been dealt with in the literature, even though the solution seems to be straightforward when using bootstrap. In this sense, following the algorithm 1 proposed by Simar and Wilson (2007) we could estimate unbiased regressions to predict total *slacks*[9], although for a correct application of the procedure to compute bootstrap in our context it is necessary to introduce some slight variations:

- Replacing the inefficiency score $\hat{\theta}_j$, estimated in the first stage (dependent variable in Simar and Wilson (2007)), by the estimated value of total *slacks* $T\hat{S}_j$ for each variable. This includes the radial and non-radial inefficiency component.
- Modifying the truncation point of the normal distribution from $(1 - z_j \hat{\beta}_j)$ in Simar and Wilson (2007) to $-z_j \hat{\beta}_j$.

Using *bootstrap* in the second stage estimation will allow us to obtain a confidence interval for the regression parameters. These values can be used to identify which exogenous variables are influencing over each total *slack* variables and the positive or negative strength of this influence. With this new framework we enhance the Fried, Schmidt and Yaisawarng (1999) model through the use of bootstrap providing more precise and robust regressions whose coefficients can be employed to predict new *slacks* for the third stage achieving more accurate technical efficiency scores for DMUs.

3. EXPERIMENTAL DESIGN

In this section we compare the performance of alternative approaches studied in previous section using a Monte Carlo experimental design in which the underlying production technology is known, so that we can compare alternative estimated efficiency scores with the true level of efficiency.

This statistical instrument has been widely used in the context of efficiency measurement especially in last years. Bowlin *et al*. (1985), Banker *et al.* (1987), Gong and Sickels (1992), Banker, Gadh and Gorr (1993) and Thanassoulis (1993) pioneered the use of this instrument to test the efficiency measures obtained with parametric and non-parametric approaches. In more recent years several Monte-Carlo experiment papers have focused on DEA issues: Pedraja, Salinas and Smith (1997) analyze the benefits of weights restrictions, Zhang and Bartels (1998) investigate the effect of sample size on mean efficiency scores, Pedraja, Salinas and Smith (1999) study the quality of the data envelopment analysis model, Holland and Lee (2002) measure the influence of random noise and Steinmann and Simar (2003) assess the comparability of estimated inter-group mean efficiencies.

In all these papers the process is similar. First, a production function is defined, inputs are generated from a random distribution and then output is derived from the former function. Then, true inefficiency is introduced according to a distribution assumption and the observed output and inputs, subject to inefficiency behaviours, are used by different methodologies to estimate efficiency scores. Finally, estimated values are compared with the true efficiency to test the quality of alternative methods.

Obviously, the accuracy of this process improves as long as the function defined can reproduce the analyzed process. So, assuming that production technology is usually unknown in most of complex production processes, using a flexible functional form, usual criteria in the distribution of variables as well as considering different types of inputs (controllable and non-controllable) seem to be desirable options.

To our knowledge, Yu (1998) is the only previous paper in which a Monte Carlo experiment has been used to examine how alternative approaches deal with the exogenous variables. Nevertheless, only two alternative approaches are compared: a one-stage procedure in which those variables are incorporate directly in estimating the frontier function and a two-stage procedure in which a regression analysis is used to account for those variables. Moreover, the main purpose of this experiment were not to compare the former approaches, but the stochastic frontier method and DEA, i.e. it focused on identifying differences between parametric and non-parametric approaches instead of comparing alternatives within one of these approaches.

In addition to this paper, we can also find two articles with similar purpose and structure. Ruggiero (1998) and Muñiz *et al.* (2006) use a simulation analysis to compare alternative approaches to deal with non-discretionary inputs as well. Actually, they do compare different alternatives based on the use of DEA like one-stage, basic two-stage and three-stage models studied in previous section, as well as original methodological options proposed by Ruggiero (1998) and Yang and Paradi (2006). However, their results should be interpreted cautiously since they only use a single replication instead of the large number that is usually conducted in Monte Carlo experiments.

Although conclusions drawn from those papers are extremely helpful for our aim, they present some limitations. First, none of them fulfils the requirement of using a flexible functional form, since Yu (1998) uses the CRESH (Constant Ratio of Elasticity of Substitution Homothetic) function introduced by Hanoch (1971), whereas Ruggiero

(1998) and Muñiz *et al.* (2006) use the Cobb-Douglas function. Second, the two-stage model tested in those papers has a problem of bias as we comment in the previous section. Third, the four-stage approach has not been analyzed in any of those studies. In this paper, we attempt to overcome these limitations, since we define a more flexible function and include in comparison the enhanced two-stage model proposed by Simar and Wilson (2007) as well as an extension of the four-stage model to avoid bias in the estimation of regressions.

As indicated, the first step in Monte Carlo experiments is to specify the true underlying production technology. With this aim, it must be assumed that all the DMUs are homogeneous and have the same production function, but the levels of efficiency and the influence of external variables are different. Thus the observed production of each unit can be defined by the following function:

$$Y = f(x) + u \qquad (6)$$

$$u = g(z) + W + v \qquad (7)$$

where Y represents the output, x is a vector of inputs, $f(x)$ is the production technology, u represents the observed inefficiency from the production frontier without considering non-controllable inputs; z is a vector of exogenous variables; $g(z)$ indicates the effect of those variables on the observed inefficiency; W represents the efficiency level due to managerial performance and v is a random term which captures statistical random noise.

In our experiment, the production technology is assumed to be a *translog* functional form, since this specification fulfils a set of desirable characteristics such as its flexibility or to be easy to derive. In the most simple case (two inputs), this function is defined by the following expression:

$$\ln(y) = \beta_0 + \beta_1 \ln x_1 + \beta_2 \ln x_2 + \frac{1}{2}\beta_{11}[\ln x_1]^2 + \frac{1}{2}\beta_{22}[\ln x_2]^2 + \beta_{12} \ln x_1 \ln x_2 - u \qquad (8)$$

We have fixed the values of the parameters in the following way: $\beta_0 = 1$; $\beta_1 = \beta_2 = 0.3$; $\beta_{11} = \beta_{22} = \beta_{12} = 0.1$, so that we have a function with variable returns to scale. Both inputs are generated from a random uniform distribution with the same interval: $X_1 \sim \mathrm{U}(1,50)$ and $X_2 \sim \mathrm{U}(1,50)$.

The observed inefficiency (u) is a composited term within which there are three components: the effect of external variables, inefficiency level without the influence of external variables and random noise. We defined this term as in Battesse and Coelli (1995):

$$u = \ln\left(\frac{1}{\exp(-W) + g(z) + v}\right)$$ where:

- $g(z)$ is defined as the sum of the effect of two variables ($g(z) = Z_1 + Z_2$). Those variables are both generated uniformly and independently from a distribution between –0.25 and +0.25, so that their effect on observed inefficiency can be both positive (benefits production) or negative (harms production).

- *W* represents inefficiency in the case that all the units were affected on the same way by external variables or, which is the same, in the case these variables does not exist or have no influence on efficiency. The inefficiency component is drawn randomly and independently from a half-normal distribution which takes absolute values from $W \sim N|0;0.3|$. It is also assumed that 20 % of DMUs belong to production frontier, i.e. $W = 0$, so these DMUs are classified as efficient[10].

- The noise component v is drawn randomly and independently from a normal distribution $N|0;0.02|$. In practice this random noise is observed as included on inefficiency by means of a slightly increase or decrease in production.

From those three components, the value of observed inefficiency u (defined between 0 and 1) is estimated. If the sum exceeds one, u takes the value one, since distribution is censored. For example, a DMU belonging to the frontier [exp(-W)=1], can become inefficient because of the effect of external variables or the random noise, while a inefficient DMU [exp(-W)<1] can be observed as efficient after including the Zs or/and the random term.

After defining the values of the inputs, beta parameters and the efficiency term u, the observed output logarithm $\ln(y)$ can be obtained by replacing those values in (8). Finally, we can derive *y* using exponential function. Once the output (Y), the inputs (X_1 and X_2) and the external variables (Z_1 y Z_2) are generated, alternative approaches are applied to this simulated sample data set to estimate efficiency scores (W) for individual DMUs and those scores are then compared with the real efficiency.

We have considered two alternative sample sizes for the experiment (50 and 400 observations). In this way, we can test how the relation between the number of observations and the number of variables included in DEA can affect the results for each methodology. Each experiment is repeated 100 times in order to ensure the results are representative.

Finally, as a recap of the contents of section 2, we present the four models we are going to compare in this experiment: the model proposed by Banker and Morey (1986) as representative of the one-stage approach; the enhanced model proposed by Simar and Wilson (2007) to overcome the problem of bias in a two-stage approach; the totally non-parametric three-stage approach proposed by Muñiz (2002) and the enhanced semi-parametric four-stage approach (Fried, Schmidt and Yaisawarng, 1999) in which bootstrap methods are used to estimate regressions. We have opted for using an input-oriented DEA program with variable returns to scale.

4. RESULTS

In this section, we comment the main results obtained in the simulation analysis performed. Since we have real efficiency as the essential reference, we have compared separately the efficiency scores estimated with alternative approaches with real efficiency scores in every replication, although we only display the mean values for different indicators selected. Those indicators can be deduced from the objectives usually pursued in efficiency evaluations of a group of decision making units (DMUs).

Table 1 reports the average and standard deviation of real efficiency and estimated scores for each of the four alternative approaches. According to these values, it seems that scores obtained with models that use regressions to correct initial scores (two-stage and four-stage) are closer to real efficiency when a small sample is considered while the three-stage model is nearer when a larger sample is used. Otherwise, one-stage approach overestimates efficiency, particularly when sample size is small (50 units), due to the fact that this model, in which a single DEA is used to obtain efficiency scores, has problems to distinguish between efficient and inefficient there is a high number of variables but not many observed units, so it is common that the number of efficient units increases when additional variables (non-discretionary inputs in this case) are included in analysis. Something similar occurs when totally non-parametric three-stage models is used to measure efficiency in small samples, although, in this case, the number of efficient units is not so high because non-discretionary inputs are not included in first stage but in a following one.

Table 1: Mean efficiency and standard deviation

	50 DMUs		400 DMUs	
	Mean	S. D.	Mean	S. D.
Real Efficiency	82,77	15,09	84,15	14,19
One-Stage	94,05	12,06	87,57	17,46
Two-Stage	78,20	10,99	75,11	15,27
Three-Stage	86,13	18,67	83,64	21,72
Four-Stage	82,61	15,03	80,35	15,24

Table 2 reports the rank correlation coefficient between the true and measured efficiency, in which a higher value suggests better performance in measuring efficiency. According to this coefficient, the approach with a better performance is again the four-stage model, followed by one-stage, third-stage and two-stage model. In addition, we can notice that as expected the rank correlation coefficient increases when the number of observations is higher.

Table 2: Spearman´s Rank Correlation Coefficient

	50 DMUs	400 DMUs
One-Stage	0,506**	0,617**
Two-Stage	0,317*	0,291*
Three-Stage	0,527**	0,577**
Four-Stage	0,631**	0,725**

** Coefficient is significant at 1 per cent.
* Coefficient is significant at 5 per cent.

Finally, two indicators have been calculated from the specific values of individual efficiency scores: the mean absolute deviation (MAD) between true and measured efficiency (reported in Table 3) and the percent of DMUs for which measured efficiency was less than 10% deviation from real efficiency (reported in Table 4). In first of them a lower MAD indicates that the measure is closer to the real efficiency, while in the latter a higher value means the same.

Table 3: Mean absolute deviation

	50 DMUs	400 DMUs
One-Stage	12,86	10,11
Two-Stage	15,82	17,78
Three-Stage	12,11	14,35
Four-Stage	9,11	8,28

Table 4: Percent of units with a less than 10% deviation from real efficiency

	50 DMUs	400 DMUs
One-Stage	51,48	61,77
Two-Stage	32,09	34,31
Three-Stage	46,53	44,37
Four-Stage	66,88	67,62

Once again, the four-stage approach obtains the best results (lowest values in first indicator and higher values in the second one) as it seems to be the best option among the approaches discussed in the context of our experimental design. In contrast, two-stage approach has the worst performance in both cases and independently of sample size which in addition to its inability to identify efficient units lead us to conclude that this is not a satisfactory option to include non-discretionary inputs in efficiency measurement. Finally, the values obtained with one-stage and three-stage for both indicators are similar in the case of 50 DMUs, but not in the case of 400 DMUs in which the results of the three-stage approach become worse.

5. CONCLUSIONS

This paper has analyzed the differences among alternative approaches usually employed in economic literature to include the effect of non-discretionary inputs in efficiency measures using DEA. Specifically, four models with a quite different methodological basis have been tested. Thus, the one-stage model (Banker and Morey, 1986) uses a single modified DEA program; the enhanced two-stage model (Simar and Wilson, 2007) uses the estimated parameters from a regression analysis to correct directly efficiency scores; the three-stage model (Muñiz, 2002) uses a totally non-parametric process to discount the effect of these variables on the scores obtained and the four-stage model (Fried, Schmidt and Yaisawarng, 1999), enhanced by using bootstrap methods to make inference, uses a semi-parametric process with the same aim.

In order to test the performance of those models a Monte Carlo study has been conducted. In contrast to other previous studies we use a *translog* function to generate data in which non-discretionary inputs have been included as a component of observed inefficiency (Battese and Coelli, 1995). Two different sample sizes have also been considered: 50 and 400 DMUs. True efficiency measures have been compared with efficiency scored obtained with alternative approaches according to different criteria.

The results show that estimates obtained with the enhanced four-stage model are the closest to real efficiency according to the values of indicators calculated for both sample sizes. Among the other alternatives, the results obtained with the three-stage approach seem to be better with a small sample size whereas the one-stage model is superior when a larger sample size is considered. Finally, two-stage model obtains the worst results due to its own structure which is focused on identifying external variables that really have influence on the results of production process rather than worrying about how to construct a boundary frontier taking them into account.

These results lead us to conclude that rarely used four-stage model can be employed as a good tool to deal with exogenous variables in economics contexts in which those variables have a significant influence on results.

Notes

1. For an overview, Cooper, Seiford and Zhu (2004) or Fried, Lovell and Schmidt (2008).
2. Most of computer software programs developed for estimating DEA includes this option among their utilities (Barr, 2004).

3. Fried, Schmidt and Yaisawarng (1999) point out that this fact can slant the estimation of the parameters and lead the research to deceptive conclusions about the influence of each external variable on efficiency.

4. Xue and Harker (1999) and Hirschberg and Lloyd (2002) also suggest methods to avoid the problem of correlation among DEA scores, but they both use a *naive bootstrap* which is inconsistent in the context of non-parametric efficiency estimation (Simar and Wilson, 1999a and 1999b).

5. The results obtained by Afonso and St. Aubyn (2006) and Prado and García-Sánchez (2007) using this methodology in different contexts (education and municipal services, respectively) confirm this assumption.

6. This assumption is based on the results obtained in the simulation analysis performed in Muñiz *et al.* (2006), in which efficiency scores estimated with this model are further from true efficiency as the number of variables included in evaluation increases.

7. This limitation was decisive for its promoters to give up exploring the possibilities of this model as described in Fried *et al.* (2002)

8. Using a stochastic frontier is another option (Fried *et al.*, 2002), although it may overestimate efficiency scores since it introduces an excessively favorable criterion to correct the initial scores by assuming that random noise has a positive effect on each DMU.

9. We use algorithm 1 because it is not straightforward to apply step 3.3. in algorithm 2 with an input oriented DEA as we are working with total instead of radial slacks. This is because the total slack is censored at zero instead of one, which imposes limitations to recalculate the new input values to perform a new DEA.

10. We have maintained the same percent of units in both sample sizes in order to homogenize the comparison despite this percent usually decreases in so far as the number of observations increases (Pedraja, Salinas and Smith, 1999).

11. In order to facilitate the interpretation of this ratio we present data used to obtain the values of first column in Table 2:

	Correct (C)	Failure (F)	Total (T=A+F)	Ratio (C/T)*100
One-Stage	9,40	26,12	35,52	26,46
Two-Stage	0,00	0,00	0,00	0,00
Three-Stage	6,75	15,38	22,13	30,51
Four-Stage	5,87	7,02	12,89	45,54

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References

Afonso, A., M. St. Aubyn. 2006. Cross-country Efficiency of Secondary Education Provision: a Semi-parametric Analysis with Non-discretionary Inputs. *Econ. Model*. **23** (3) 476-491.

Banker, R. D., A. Charnes, W. W. Cooper. 1984. Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Sci.* **30** 1078–1092.

Banker, R.D., R. C. Morey.1986. Efficiency Analysis for Exogenously Fixed Inputs and Outputs. *Oper. Res.* **34** (4). 513-521.

Banker, R., A. Charnes, W. W. Cooper, A. Maindiratta. 1987. A Comparison of Data Envelopment Analysis and Translog Estimates of Production Frontiers Using Simulated Observations from a Known Technology. Dogramaci, A. and R. Fare, eds. *Applications in Modern Production Theory Inefficiency and Productivity*, Kluwer Academic Publishers, Boston, MA, 33-55.

Banker, R., V. Gadh, W. Gorr. 1993. A Monte Carlo Comparison of Two Production Frontier Estimation Methods: Corrected Ordinary Least Squares and Data Envelopment Analysis. *Eur. J. Operat. Res.* **67**. 332-343.

Barr, R. 2004. DEA Software Tools and Technology: A State-of-the-Art Survey. Cooper, W. W., L. Seiford, J. Zhu (eds.) *Handbook on Data Envelopment Analysis.* Kluwer Academic Publishers. Boston, MA.

Battese, G., T. Coelli. 1995. A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Emp. Econ.* **20**. 325-332.

Bowlin, W., A. Charnes, W. W. Cooper, H. Sherman. 1985. Data Envelopment Analysis and Regression Approaches to Efficiency Estimation and Evaluation. *Annals Operat. Res.* **2**. 113-138.

Charnes, A., W. W. Cooper, E. Rhodes. 1978. Measuring the Efficiency of Decision Making Units. *Eur. J. Operat. Res.* **2** (6). 429-444.

Christensen, L.R., D. W. Jorgenson, L. J. Lau. 1971. Conjugate Duality and the Transcendental Logarithmic Production Function. *Econometrica.* **39**. 255-256.

Cooper, W., L. Seiford, J. Zhu. 2004. *Handbook on Data Envelopment Analysis.* Kluwer Academic Publishers, Boston, MA.

Cordero, J.M., F. Pedraja, J. Salinas. 2008. Measuring Efficiency in Education: an Analysis of Different Approaches for Incorporating Non-Discretionary Inputs. *Appl. Econ.* Forthcoming.

Fizel, J. L., T. S. Nunnikhoven. 2006. Technical Efficiency of For-Profit and Non-Profit Nursing Homes. *Manag. Dec. Econ*., **13** (5). 429-439.

Fried, H.O., C. A. K. Lovell, P. Vanden Eeckaut. 1993. Evaluating the Performance of US Credit Unions, *J. Banking Finance*. **17**. 251-265.

Fried, H.O., C. A. K. Lovell. 1996. *Searching for the Zeds.* Paper presented in II Georgia Productivity Workshop.

Fried, H., S. Schmidt, S. Yaisawarng. 1999. Incorporating the Operating Environment into a Nonparametric Measure of Technical Efficiency. *J. Product. Anal.* **12**. 249-267.

Fried, H., C. A. K. Lovell, S. Schmidt, S. Yaisawarng. 2002. Accounting for Environmental Effects and Statistical Noise in Data Envelopment Analysis. *J. Product. Anal*, **17**(1/2). 157-174.

Fried, H., J. Lambrinos, J. Tyner. 2004. Evaluating the performance of professional golfers on the PGA, LPGA and SPGA tours. *Eur. J. Operat. Res.* **154** (2). 548-561.

Fried, H.O., C. A. K. Lovell, S. Schmidt. 2008. *The Measurement of Productive Efficiency and Productivity Growth.* Oxford University Press, New York.

Gong, B. H., R. Sickles. 1992. Finite Sample Evidence on the Performance of Stochastic Frontiers and Data Envelopment Analysis Using Panel Data. *J. Economet.* **51**. 259-284.

Grosskopf, S., V. Valdmanis. 1987. Measuring hospital performance: a non-parametric approach. *J Health Econ.* **6**. 89–107.

Hanoch, G. 1971. CRESH Production Functions. *Econometrica.* **39** (5). 695-712.

Hirschberg, J., P. Lloyd. 2002. Does the Technology of Foreign-Invested Enterprises Spill Over to Other Enterprises in China? An Application of Post-DEA Bootstrap Regression Analysis. Lloyd, P.J., X. Zang (eds.). *Modelling the Chinese Economy*, Edward Elgar Press, London.

Holland, D. S., S. T. Lee, S. T. 2002. Impacts of Random Noise and Specification on Estimates of Capacity Derived from Data Envelopment Analysis. *Eur. J. Operat. Res.* **137**. 10-21.

Mccarty, T., S. Yaisawarng. 1993. Technical Efficiency in New Jersey School Districts. Fried, H., C. A. K. Lovell, S. Schmidt (eds.). *The Measurement of Productive Efficiency: Techniques and Applications.* Oxford University Press, New York.

Muñiz, M. 2002. Separating Managerial Inefficiency and External Conditions in Data. *Eur. J. Operat. Res.*, **143**. 625-643.

Muñiz, M., J. Paradi, J. Ruggiero, Z. Yang. 2006. Evaluating Alternative DEA Models Used to Control for Non-Discretionary Inputs. *Comput. Operat. Res.* **33**. 1173-1183.

Pedraja, F., J. Salinas, P. Smith. 1997. On the Role of Weight Restrictions in Data Envelopment Analysis. *J. Product. Anal*. **8**. 215-230.

Pedraja, J. Salinas, P. Smith. 1999. On the Quality of the Data Envelopment Analysis Model. *J. Oper. Res. Soc.*, **50**. 636-644.

Prado, J. M., I. M. García-Sánchez. 2007. Efficiency Evaluation in Municipal Services. An Application to the Street Lighting Service in Spain, *J. Product. Anal.* **27**. 149-162.

Ray, S.C. 1991. Resource Use Efficiency in Public schools: A Study of Connecticut Data. *Management Sci.* **37 (**12). 1.620-1.628.

Rouse, P., M. Putterill, D. Ryan, D. 1996. *Methodologies for the Treatment of Environmental Factors in DEA*, Working Paper, Department of Accounting and Finance, University of Auckland, New Zealand.

Ruggiero, J. 1998. Non-discretionary inputs in Data Envelopment Analysis. *Eur. J. Operat. Res.* **111**. 461-469.

Simar, L., P. W. Wilson. 1999a. Some Problems with the Ferrier/Hirschberg Bootstrap Idea, *J. Product. Anal.*, **11**. 67-80.

Simar, L., P. W. Wilson. 1999b. Of Course We Can Bootstrap DEA Scores! But Does it Mean Anything? Logic Trumps Wishful Thinking. *J. Product. Anal.*, **11**. 93-97.

Simar, L., P. W. Wilson. 2007. Estimation and Inference in Two-Stage, Semi parametric Models of Production Processes. *J. Economet,* **136**. 31-64.

Steinmann, L., L. Simar. 2003. On the Comparability of Efficiency Scores in Nonparametric Frontier Models. *Discussion Paper 0318,* Institut de Statistique, Université Catholique de Louvain, Belgium.

Thanassoulis, E. 1993. A Comparison of Regression Analysis and Data Envelopment Analysis as Alternative Methods for Assessing Performance, *J. Operat. Res. Soc.* **44**. 1129-1145.

Xue, M., P. T. Harker. 1999. *Overcoming the Inherent Dependency of DEA Efficiency Scores: A Bootstrap Approach.* Working Paper, Wharton Financial Institutions Center, University of Pennsylvania, Philadelphia, PA.

Yang, Z, J. Paradi. 2006. Cross Firm Bank Branch *Benchmarking* Using "Handicapped" Data Envelopment Analysis to Adjust for Corporate Strategic Effects. *Proceedings of the 39th Hawaii International Conference on System Sciences*. Hawaii-IEEE.

Yu, C. 1998. The Effects of Exogenous Variables in Efficiency Measurement. A Monte Carlo Study. *Eur. J. Operat. Res.*, **105**. 569-580.

Zhang, Y., R. Bartels. 1998. The Effect of Sample Size on the Mean Efficiency in DEA with an Application to Electricity Distribution in Australia, Sweden and New Zealand. *J. Product. Anal.* **9**. 187-204.

Appendix

Simar and Wilson (2007) describe a data generation process which is consistent with regression of non-parametric, DEA efficiency estimates on some covariates in a second stage. For this aim, they assume that the *true* efficiency scores depend on the external variables, so that it can be written as:

$$\theta_j = \psi(z_j, \beta) + u_j \geq 1 \qquad (1)$$

where ψ is a smooth, continuous function and β a vector of parameters, u_j is a truncated normal random variable, distributed $N(0, \sigma_\varepsilon^2)$, with left-truncation at $1 - \psi(z_j, \beta)$.

The scores obtained in the first stage ($\hat{\theta}_j$) are considered as an estimate for θ_j. They propose two bootstrap procedures for the two-stage efficiency estimation problem.

Algorithm 1 involves the following steps:

1. The computation of $\hat{\theta}_j$ for all n decision units using original data.
2. Use the method of maximum likelihood to obtain an estimate $\hat{\beta}$ of β as well as an estimate $\hat{\sigma}_\varepsilon$ of σ_ε from $\hat{\theta}_j = f(z_j, \beta) + u_j$, considering it is a truncated regression.
3. The computation of *L (e.g. L=2000)* bootstrap estimates for β and σ_ε in the following way:
   3.1. For each j = 1,…, n, draw u_j from the $N(0, \sigma_\varepsilon^2)$ distribution with left-truncation at $1 - z_j\hat{\beta}$.
   3.2. Compute $\theta_j^* = z_j\hat{\beta} + u_j$ again for each j = 1,…., n.
   3.3. Use the maximum likelihood method to estimate the truncated regression of θ_j^* on z_j, yielding a bootstrap estimates $(\hat{\beta}^*, \hat{\sigma}_\varepsilon^*)$
4. Use the bootstrap values and the original estimates $\hat{\beta}$ and $\hat{\sigma}_\varepsilon$ to construct estimated confidence intervals for each element of β and σ_ε.

***Algorithm 2*:**

1. The computation of $\hat{\theta}_j$ for all n decision units using original data.
2. Use the method of maximum likelihood to obtain an estimate $\hat{\beta}$ of β as well as an estimate $\hat{\sigma}_\varepsilon$ of σ_ε from $\hat{\theta}_j = f(z_j, \beta) + u_j$, considering it is a truncated regression.
3. The computation of L_1 bootstrap estimates for β and σ_ε in the following way:
   3.1. For each j = 1,…, n, draw u_j from the $N(0, \sigma_\varepsilon^2)$ distribution with left-truncation at $1 - z_j\hat{\beta}$.

   3.2. Compute $\theta_j^* = z_j\hat{\beta} + u_j$ again for each j = 1,…., n.

   3.3. Set $x_j^* = x_j$ and modify output measure: $y_j^* = y_j \dfrac{\hat{\theta}_j}{\theta_j^*}$ for all j = 1,….,n.

   3.4. Compute $\hat{\theta}_j^*$ using non-parametric techniques using x_j^* and y_j^*.

4. Compute the bias-corrected output inefficiency estimator as $\hat{\hat{\theta}}_j = 2\hat{\theta}_j - \overline{\hat{\theta}}_j^*$ where $\overline{\hat{\theta}}_j^*$ is the bootstrap average of $\hat{\theta}_j^*$.
5. Use the maximum likelihood method to estimate the truncated regression of $\hat{\hat{\theta}}_j$ on z_j, yielding a bootstrap estimates $(\hat{\hat{\beta}}, \hat{\hat{\sigma}})$.
6. Replace $\hat{\theta}_j$ with $\hat{\hat{\theta}}_j$ in algorithm 1 and continue from step 2 onwards by computing L_2 times three steps (6.1 – 6.3).
7. Use the bootstrap values and the original estimates $\hat{\hat{\beta}}$ and $\hat{\hat{\sigma}}_\varepsilon$ to construct estimated confidence intervals for each element of β and σ_ε.

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