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Cost efficiency in the university: A departmental evaluation model

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Abstract

This article presents a model for the analysis of cost efficiency within the framework of data envelopment analysis models. It calculates the cost excess, separating a unit of production from its optimal or frontier levels, and, at the same time, breaks these excesses down into three explanatory factors: (a) technical inefficiency, which depends on the quality of the factors consumed, the type of organization and the factor of human behaviour; (b) the availability of the fixed factors along with their level of utilization and the factors mix; and finally (c) the scale or size of the unit of production. The empirical application is carried out on the departments of the Autonomous University of Barcelona. The results show that departmental costs could be reduced on average by more than 13.46% in the long term.

JEL classification: C61; H52; I21

Keywords: Costs; Efficiency; Input output analysis; Economics of scale

1. Introduction

The environment in which Spanish universities operate has changed significantly since 2001, when the Organic Law for Universities introduced reforms into the sector. Quality improvement became a priority requirement, and this, combined with the budgetary constraints already faced by the universities for some years, has resulted in a new and more complex framework for universities to operate in. Henceforth they will require new administrative instruments capable of providing institutions with tools for allocating scarce economic resources more efficiently among departments. At the same time, such instruments should also prove useful in providing university administrators with unequivocal criteria for evaluating, and subsequently improving, the performance of the operational units, which in this case are the departments.

In this study, we propose an instrument for departmental evaluation in terms of costs that can be used to determine improvement targets both in costs and production and in quality levels. The instrument presented is a new model of cost efficiency based on Data Envelopment Analysis (DEA) methodology initially developed by Charnes, Cooper, and Rhodes (1978). The specific objectives of this model are to determine: (a) the overall

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deviation in costs of each department under analysis, understood as the difference between the observed cost and the optimal long-term cost assuming an optimal scale; (b) the factors into which this deviation can be sub-divided, distinguishing between technical inefficiency, the incorrect allocation of factors, the level of utilization of the available fixed factors or the appropriateness of the scale adopted; (c) targets for the different inputs and outputs that would lead to cost efficiency in the departments; and (d) which inefficiencies can be corrected in the short term, and which in the long term.

One of the main advantages of frontier models is their ability to evaluate the overall efficiency of a group of units on the basis of the inputs consumed and the outputs produced. For this reason, they are particularly appropriate for application to sectors with complex productive processes, such as universities, where there is a lack of information about output prices indicating the criteria for evaluating the performance of each decision making unit (DMU). In such circumstances, frontier models offer a valuable, objective tool for evaluating the public sector, which is further supported by extensive literature (see, for example, Bifulco & Bretschneider, 2001; Drake & Simper, 2003; Grosskopf, Margaritis, & Valdmanis, 1995; Pedraja-Chaparro & Salinas-Jimenez, 1996; Ray, 1991).

However, merely estimating technical efficiency as a criterion of evaluation and control is not generally sufficient in the public sector, even though administrators in the sector have traditionally neglected the conventional monetary evaluation criteria of the market economy, such as profit and profitability. The public nature of the sector does not necessarily mean that economic criteria should not or cannot be employed. In this respect, governments are increasingly administering the public sector more efficiently, effectively and economically, regardless of their political allegiances. Their aim is to cut public spending without eliminating services or prejudicing quality. The use of monetary-based criteria in the public sector generally implies an analysis from the cost perspective, since selling prices are seldom involved and, if so, they are usually pre-established. The increasing demand for control and efficiency in the administration of monetary resources has thrown doubt on technical efficiency as the most appropriate evaluation criterion. In fact, it is now well known that certain behaviors that are economically undesirable—since they do not minimize costs—and can be considered technically efficient. Thus, this paper presents a model of cost efficiency in preference to one based exclusively on measuring technical efficiency.

DEA models constitute an excellent instrument for university evaluation that is supported in various studies, although the objectives of these studies generally differ from ours. Among the authors that have written about it we can mention Beasley (1990, 1995), Athanassopoulos and Shale (1997), Sarrico, Hogan, Dyson, and Athanassopoulos (1997), Johnes and Johnes (1993), Madden, Savage, and Kemp (1997), Ahn (1987), Glass, Mckillop, and O'Rourke (1998), Emrouznejad and Thanassoulis (2005), Caballero, Galache, Gómez, Molina, and Torrico (2001, 2004), Post and Spronk (1999), Li and Reeves (1999), Korhonen (2000) and Korhonen, Tainio, and Wallenius (2001).

The remainder of this article is organized as follows. The second section describes the evaluation model on which this work is focused. The characteristics of the sample and a description of the variables are presented in Section 3. The following section outlines the most relevant results obtained in our application of the model to all the departments in the Autonomous University of Barcelona (UAB). Finally, the most significant conclusions are presented.

2. The model

With the aim of making the theoretical model as general an application as possible, we will consider the case of $k = 1, \ldots, K$ university departments. The productive process of a department k is characterized by the production of a group of $i = 1, \ldots, I$ outputs $y_k = (y_{k,1}, \ldots, y_{k,I})$ with quality levels in $q = 1, \ldots, Q$ dimensions $Q_{k,q} = (Q_{k,1} \ \ , \ldots, Q_{k,Q})$ starting from $f = 1, \ldots, F$ inputs adjustable in the long term $x_{k,f} = (x_{k,1}, \ldots, x_{k,F,})$ and $v = 1, \ldots, V$ inputs adjustable in the short term $x_{k,v} = (x_{k,1}, \ldots, x_{k,V})$ and input prices $w_{k,f} = (w_{k,1}, \ldots, w_{k,F,})$ and $w_{k,v} = (w_{k,1}, \ldots, w_{k,V})$, respectively. Consequently, the observed total costs of a department k for a level of production (y_k) and of quality $(Q_{k,q})$, is represented by

$$\mathrm{TC}_k = \sum_{v=1}^{V} w_{k,v} x_{k,v} + \sum_{f=1}^{F} w_{k,f} x_{k,f}.$$

The model breaks down total cost inefficiency (TCV_k) of department k into three factors: technical inefficiency (TEV_k), fixed factors utilization (FCV_k) and scale (SV_k). This is expressed as follows:

$$\begin{aligned} TCV_k &= TC_k - TC_k^{lr\text{-}crs} = TEV_k + FCV_k + SV_k \\ &= (TC_k - TC_k^t) + (TC_k^t - TC_k^{lr\text{-}vrs}) \\ &\quad + (TC_k^{lr\text{-}vrs} - TC_k^{lr\text{-}crs}), \end{aligned} \tag{1}$$

where

$$TC_k^t = \sum_{v=1}^{V} w_{k,v} x_{k,v}^t + \sum_{f=1}^{F} w_{k,f} x_{k,f} \tag{2}$$

is the total cost that the DMU k should achieve if it were technically efficient; $x_{k,v}^t$ is the variable inputs level associated with technical efficiency;

$$TC_k^{lr\text{-}vrs} = \sum_{v=1}^{V} w_{k,v} x_{k,v}^{lr\text{-}vrs} + \sum_{f=1}^{F} w_{k,f} x_{k,f}^{lr\text{-}vrs} \tag{3}$$

is the total cost that the DMU k should achieve if it were efficient in the long term—i.e., if it were able to change the fixed and variable input mix, while maintaining a similar scale (assuming variable returns to scale); $x_{k,v}^{lr\text{-}vrs}$ and $x_{k,f}^{lr\text{-}vrs}$ are the associated levels of variable and fixed inputs, respectively;

$$TC_k^{lr\text{-}crs} = \sum_{v=1}^{V} w_{k,v} x_{k,v}^{lr\text{-}crs} + \sum_{f=1}^{F} w_{k,f} x_{k,f}^{lr\text{-}crs} \tag{4}$$

is the cost that the DMU k should achieve if it were cost efficient in the long term and able to adapt its scale to the optimal size; $x_{k,v}^{lr\text{-}crs}$ and $x_{k,f}^{lr\text{-}crs}$ are the associated levels of variable and fixed inputs, respectively.

The scale deviation (SV_k) shows the excess in costs due to differences between the average cost of the activity that minimizes the costs globally and the frontier value relative to the level of production of the DMU k. This deviation only includes effects of scale and does not assume any type of inefficiency in the utilization of the factors, either fixed or variable. The mathematical expression of SV_k is

$$\begin{aligned} SV_k &= (TC_k^{lr\text{-}vrs} - TC_k^{lr\text{-}crs}) \\ &= \left(\sum_{v=1}^{V} w_{k,v} x_{k,v}^{lr\text{-}vrs} + \sum_{f=1}^{F} w_{k,f} x_{k,f}^{lr\text{-}vrs} \right) \\ &\quad - \left(\sum_{v=1}^{V} w_{k,v} x_{k,v}^{lr\text{-}crs} + \sum_{f=1}^{F} w_{k,f} x_{k,f}^{lr\text{-}crs} \right) \\ &= \sum_{v=1}^{V} w_{k,v} (x_{k,v}^{lr\text{-}vrs} - x_{k,v}^{lr\text{-}crs}) \\ &\quad + \sum_{f=1}^{F} w_{k,f} (x_{k,f}^{lr\text{-}vrs} - x_{k,f}^{lr\text{-}crs}). \end{aligned} \tag{5}$$

The deviation in the utilization of fixed factors (FCV_k) is the deviation in cost due to differences between the cost that unit k should achieve if it would be efficient in the long term, maintaining a similar scale, and the minimum cost if it would be technically efficient.

$$\begin{aligned} FCV_k &= (TC_k^t - TC_k^{lr\text{-}vrs}) = \left(\sum_{v=1}^{V} w_{k,v} x_{k,v}^t + \sum_{f=1}^{F} w_{k,f} x_{k,f} \right) \\ &\quad - \left(\sum_{v=1}^{V} w_{k,v} x_{k,v}^{lr\text{-}vrs} + \sum_{f=1}^{F} w_{k,f} x_{k,f}^{lr\text{-}vrs} \right) \\ &= \sum_{v=1}^{V} w_{k,v} (x_{k,v}^t - x_{k,v}^{lr\text{-}vrs}) \\ &\quad + \sum_{f=1}^{F} w_{k,f} (x_{k,f} - x_{k,f}^{lr\text{-}vrs}). \end{aligned} \tag{6}$$

If a high level of substitutability among the different inputs existed, FCV_k would also show the impact that wrong decisions in the composition of the mix of factors can have on cost minimization. In other words, by considering input prices, it is possible for FCV_k to detect a non-optimal mix of factors. Consequently, in this situation it could also be considered an indicator of allocative inefficiency.

Finally, the technical inefficiency deviation (TEV_k) measures the increase in total costs caused by an excessive consumption of factors. This may occur in situations of management incompetence, errors of organization or lack of incentives, which can be explained partially by the lack of competition, according to Leibenstein's (1966) X-efficiency theory. It is expressed as

$$\begin{aligned} TEV_k &= (TC_k - TC_k^t) = \left(\sum_{v=1}^{V} w_{k,v} x_{k,v} + \sum_{f=1}^{F} w_{k,f} x_{k,f} \right) \\ &\quad - \left(\sum_{v=1}^{V} w_{k,v} x_{k,v}^t + \sum_{f=1}^{F} w_{k,f} x_{k,f} \right) \\ &= \sum_{v=1}^{V} w_{k,v} (x_{k,v} - x_{k,v}^t). \end{aligned} \tag{7}$$

A prerequisite for calculating the above deviations is the gathering of the intermediate optimal total costs, denoted as TC. For each one, we use an ad hoc DEA model. TC_k^t is calculated by solving the following linear program for each department:

$$\min \gamma_k - \varepsilon\left(\sum_{v=1}^{V} S_{s,v} + \sum_{i=1}^{I} S_{k,i}\right)$$

s.t.

$$\begin{aligned}
&\gamma_k \cdot x_{k,v} - \sum_{s=1}^{K} z_s \cdot X_{s,v} - S_{k,v} = 0 && v = 1,\ldots,V,\\
&x_{k,f} - \sum_{s=1}^{K} z_s \cdot X_{s,f} = 0 && f = 1,\ldots,F,\\
&-y_{k,i} + \sum_{s=1}^{K} z_s \cdot y_{s,i} - S_{k,i} = 0 && i = 1,\ldots,I,\\
&-Q_{k,q} + \sum_{s=1}^{K} Z_s \cdot Q_{s,q} = 0 && q = 1,\ldots,Q,\\
&\sum_{s=1}^{K} Z_s = 1,\\
&\gamma_k, Z_s, S_{s,v}, S_{k,i},
\end{aligned} \tag{8}$$

where ε[1] is a non-Archimedean constant. The linear program (8) is very similar to other usual formulations of DEA programs for calculating technical efficiency (see Cooper, Seiford, & Tone, 2000, for further details). The objective is to determine the maximum reduction of the variable inputs maintaining the observed levels of production and quality. Quality has been introduced as an output (Adler & Berechman, 2001; Dismuke & Sena, 2001; Olesen & Petersen, 1995). Their associated constraints have an equal sign, under the supposition that university quality cannot be modified in the short term. Variable returns to scale (VRS) are also supposed, in order to eliminate the potential scale effect, thus ensuring comparisons between departments of similar size.

Once the optimal value γ_k^* is calculated, the variable inputs level associated with technical efficiency can be calculated as $x_{k,v}^t = \gamma_k^* \cdot x_{k,v}$.The frontier level of the long-term costs ($TC_k^{\text{lr-vrs}}$) without scale changes is obtained from the following program:

$$TC_k^{\text{lr-vrs}} = \min \sum_{v=1}^{V} w_{k,v} x_{k,v}^{\text{lr-vrs}} + \sum_{f=1}^{F} w_{k,f} x_{k,f}^{\text{lr-vrs}} - \varepsilon\left(\sum_{i=1}^{I} S_{k,i} + \sum_{q=1}^{Q} S_{k,q}\right)$$

s.t.

$$\begin{aligned}
&x_{k,v}^{\text{lr-vrs}} - \sum_{s=1}^{K} Z_s \cdot x_{s,v} = 0 && v = 1,\ldots,V,\\
&x_{k,f}^{\text{lr-vrs}} - \sum_{s=1}^{K} z_s \cdot x_{s,f} = 0 && f = 1,\ldots,F,\\
&-y_{k,i} + \sum_{s=1}^{K} z_s \cdot y_{s,i} - S_{k,i} = 0 && i = 1,\ldots,I,\\
&-Q_{k,q} + \sum_{s=1}^{K} z_s \cdot Q_{s,q} = 0 && q = 1,\ldots,Q,\\
&\sum_{s=1}^{K} z_s = 1,\\
&x_{k,v}^{\text{lr-vrs}}, x_{k,f}^{\text{lr-vrs}}, z_s, S_{k,i}, S_{k,q} \geqslant 0.
\end{aligned} \tag{9}$$

Linear program (9) determines the levels of both the variable inputs ($x_{k,v}^{\text{lr-vrs}}$) and the fixed inputs ($x_{k,f}^{\text{lr-vrs}}$) that minimize the long-term total costs. The difference between the optimum cost obtained by (8) and by (9) can be assigned to adjustments in the long run changeable costs and/or changes in the mix of possible substitutable costs. In this way, it can reflect aspects relating to the fixed capacity utilization and/or allocative ones respectively.

Finally, the minimum total cost ($TC_k^{\text{lr-crs}}$), assuming a technological environment with constant returns to scale (CRS), is given by:

$$TC_k^{\text{lr-crs}} = \min \sum_{v=1}^{V} w_{k,v} x_{k,v}^{\text{lr-crs}} + \sum_{f=1}^{F} w_{k,f} x_{k,f}^{\text{lr-crs}} - \varepsilon\left(\sum_{i=1}^{I} S_{k,i} + \sum_{q=1}^{Q} S_{k,q}\right)$$

s.t.

$$\begin{aligned}
&x_{k,v}^{\text{lr-crs}} - \sum_{s=1}^{K} z_s \cdot x_{s,v} = 0 && v = 1,\ldots,V,\\
&x_{k,f}^{\text{lr-crs}} - \sum_{s=1}^{K} z_s \cdot x_{s,f} = 0 && f = 1,\ldots,F,\\
&-y_{k,i} + \sum_{s=1}^{K} z_s \cdot y_{s,i} - S_{k,i} = 0 && i = 1,\ldots,I,\\
&-Q_{k,q} + \sum_{s=1}^{K} z_s \cdot Q_{s,q} - S_{k,q} = 0 && q = 1,\ldots,Q,\\
&x_{k,f}^{\text{lr-crs}}, x_{k,v}^{\text{lr-crs}}, z_s, S_{k,i}, S_{k,q} \geqslant 0.
\end{aligned} \tag{10}$$

The principal difference between (9) and (10) is that (10) permits the use of reference units of very different sizes to that analyzed. The reference units in (9) are those departments that obtain an output

[1]The constant ε is an infinitesimal $0<\varepsilon<1/N$ for all positive integer N. For calculating we usually assign to it a value of 10^{-6}.

equal to or greater than the one analyzed at a lower cost, while in (10), the reference units could also be departments with a lower output in absolute terms at a lower cost or a higher output at a greater cost. In both cases, the model could choose them as reference units, once they were rescaled to obtain an equal or greater output at an equal or lower cost than the one analyzed. This means that both programs refer to the long run situation, because they admit the possibility of adjusting the fixed factors to achieve greater cost efficiency. However, from (10) we can deduce results that would infer changes in the long run, albeit of a more structural nature, because they may imply substantial changes in the size of the analyzed departments in order to obtain the lowest average cost.

3. Sample and variables

The empirical application of the model described above was carried out on departments of the Autonomous UAB. The UAB consists of a total of 46 departments, although complete information was available for only 42 of these.

The data obtained corresponds to the 1996–98 period. A period exceeding 1 year was chosen essentially because scientific research requires a development process lasting for more than one year. Specifically, a three-year period was used because that is the duration of most of the projects of more than 1 year supported by the different institutions and organisms that fund a large part of public research in Spain. This longer period also avoids the distortion of the results through potential anomalies in the data for a single year.

After reviewing the literature on nonparametric frontier models applied to higher education, it was concluded that no agreement has been reached on which inputs and outputs should be used to evaluate efficiency in university departments. However, there is a common denominator in the majority of the studies reviewed: the departments' main activities are teaching and research. A dual approach to these two items has been selected: in the first place, a quantitative approach (production); and in the second place, a qualitative approach, based on the conviction that both views should be considered in an attempt to obtain a reliable image of reality.

In order to choose the outputs, a list of the most frequently used outputs encountered in the literature examined was presented to a group of university administrators. After several interviews guided by the authors, and taking into account the available information, the following outputs were finally selected as the most representative of the productive process at UAB:

- *New "research segments" awarded*. This variable measures the quantity and quality of the scientific production of the departments. "Research segments" are the result of the evaluation process made by a government committee that evaluates the research carried out by Spanish university staff. This evaluation is carried out by subcommittees grouped according to academic affinities, in order to ensure that the evaluation is conducted by specialists in each scientific field. Six-year "research segments" are evaluated on the basis of the quantity and scientific quality of their publications and salary complements are granted to lecturers in consequence. Obviously, a professor can be awarded more than one "research segment" in the course of his/her academic career. Hence, departments with more senior lecturers would probably have a larger number of "research segments" than departments with younger staff. In order to avoid the influence of this fact in the results, the number of new "research segments" awarded over the three year period of the study as a percentage of those eligible instead of total "research segments" awarded was considered. There is also widespread recognition in Spain that the number of "research segments" conceded differs significantly among disciplines. For this reason, the number of "research segments" has been divided by the percentage of segments conceded over the number of applications for segments in each scientific field.[2]
- *Teaching load*. To measure the teaching load, the departments used the total number of credits granted. For a department, "k" that conducted "j" subjects, the calculation will be $\sum_{i=1}^{j} s_i c_i$, where s_i is the number of registered students for subject "i" and c_i are the credits[3] for the subject "i". In this way the number of students that receive instruction as well as the duration of the course are considered.

[2]These percentages were obtained from the 2002 report of the National Research Activity Evaluation Committee. The full report can be seen at http://www.univ.mecd.es.

[3]One credit is equal to 10 class hours.

- *Quality teaching*. There are different ways of determining teaching quality (see Astin, 1985; George, 1982), but taking into account the scarcity of information and the difficulty of adopting other approaches, in this work teaching quality was measured by the opinions of its users—i.e. the students. The reason for using this indicator was the difficulty encountered in obtaining homogeneous information from the departments. The average scores obtained by each department in the satisfaction questionnaire that students complete at the end of each semester were used to determine the opinion of the students about the quality of their learning.

Another alternative would have been to use a compound measure of quality and production, like in the case of research, for teaching activity. Designing an index involves assigning explicit weights to each variable. Unfortunately, as there are no official sources for such weights either in the university or in Spain in contrast to the case of research activity, it was considered more reliable to use a DEA model to assign weights to each department, based on Pareto's efficiency criteria. The origin of the question lies in whether any trade-off quantity/quality is acceptable a priori for the teaching activity, or whether the weights assigned to each one of those outputs should be restricted (Pedraja-Chaparro, Salinas-Jimenez & Smith, 1997). Our opinion is that in our case it is not necessary to make this restriction. The departments do not have the capacity to decide how to prioritize one of these variables over the other. In this sense, it must be taken into account that the departmental teaching load is imposed by the number of students to be served, hence, individual departments have very little room for manoeuvring (Table 1).

With regard to the inputs, the main budget items on which the departments allocates funds have been selected, distinguishing between those that are potentially adjustable over the short or long term. The inputs selected were the following:

- *Expenditure on temporary hired teaching and research staff*. This includes all spending relating to the contracting of such staff in the department. This input is considered variable (adjustable in the short to medium term).
- *Operational expenditure*. This item measures the normal operational costs of the department, such as photocopies, office supplies, telephone, fax, computer maintenance, expenses for visiting researchers, expenses for reading of doctoral theses, etc. Expenses particular to departments that conduct experiments such as instruments, maintenance of laboratories, specialized equipment, etc. have been excluded. This input is also considered variable.
- *Expenditure on permanent teaching and research staff*. This item includes spending related to permanent staff, who are civil servants with a working life-long contract. As this spending cannot be adjusted in the short or medium term, this input is considered fixed (adjustable solely in the long term).

Departments can make decisions about the permanent or temporary hired teaching and research staff mixed with different strategic implications on cost and quality. Likewise, a part of the operational expenditure depends on this mix, because it directly affects printing expenses, paper, doctoral thesis reading, congress assistance, etc. Therefore, in this case, deviation on fixed factors utilization will also reflect a number of aspects very closely related to allocative efficiency and the optimum mix between permanent and temporary professors.

The inputs correspond to the division of costs instead of physical inputs, as it appears in the formulation of the model. As a consequence, we are

Table 1
Descriptive statistics of inputs and outputs, 1996-98

Input/output	Max.	Min.	Mean	Std. dev.
Costs permanent staff (€)	5,943,164.50	774,611.28	2,774,205.22	1,383,666.78
Costs temporary hired staff (€)	2,561,641.50	216,316.83	929,524.69	585,391.73
Operational costs (€)	592,781.29	81,333.60	285,386.30	180,413.87
New research segments awarded (% of those eligible)	87.03	31.87	58.68	24.18
Teaching load	401,977.50	13,239.00	139,822.96	87,968.05
Teaching quality	7.00	5.43	6.17	0.41

assuming that the purchase prices of the different inputs are the same for all departments. In our case, this assumption does not simplify reality, but adjusts to it. All departments of the university must make their purchases through suppliers that have previously been officially approved by the purchasing department of the university. For this reason, the price of purchases should be similar for all the departments. In the case of the costs of the teaching staff, the assumption is again plausible. Wages for professors at Spanish public universities are determined by the government (as happens in other countries).

It is well known that DEA methodology is not appropriate for analyzing heterogeneous units. The evaluation of departments belonging to the same university cannot be exempt of this problem, as they are subject to departmental-specific constraints that make it difficult to compare them. It is noteworthy that departments with a high level of experimental research require larger and more specialized equipment to carry out their normal research and teaching tasks, implying the need for greater financial resources for investment and maintenance than other departments with less experimentation. In fact, this aspect (with different objectives) has been highlighted in other studies focusing on Spanish universities, such as that of Caballero et al.(2004). It would be unfair to ignore this circumstance in the evaluation of the departments, which conduct the most experiments using special equipment. This has been the reason why these kinds of costs have been excluded from operational costs. A second aspect that contributes to the varied results is the scientific activities of the departments. It is well known that scientific production of different areas of knowledge is not directly comparable. Likewise, departments with more senior professors have greater opportunities for undertaking high quality research tasks. We believe this problem is resolved on its own and by the construction of the output "new research segments awarded".

4. Results

The results presented in this section are constrained by the conditions laid down by the UAB vice-chancellor's office: the presentation of the results in aggregate form was an essential prerequisite for supplying the information requested.

Table 2 depicts the average values of the cost deviations of the model. Overall, one can see that the average total cost deviation (TCV) is 13.46%; in other words, there is a potential cost saving of this amount in the long term, after making the necessary scale adjustments. However, from the management perspective, it is useful to differentiate how much of this potential saving would be achievable in the short or long term. The technical deviation indicates the cost excess that can be corrected in the short term, while the sum of the deviation due to the utilization of fixed capacity, together with the scale deviation, indicates excess costs that can be reduced in the long term.

Specifically, it can be seen that the long-term factors are the causes of a cost excess of 10.90% on average. By way of contrast, the factors of short-term inefficiency—or, in other words, factors attributable to more operational aspects—are only responsible for 2.56% of the total cost excess of the departments, which suggests that improvements should focus on structural rather than temporary factors. In the case under analysis, the structural factors are closely linked to the composition of the research and teaching staff and the size of the departments. Among the long-term factors leading to cost inefficiency, the most significant is the utilization of fixed capacity (FCV) with 7.43%, rather than scale deviation (SV).

A detailed analysis at departmental level showed that departments with a higher proportion of temporary hired staff generally achieve better results. Table 3 shows that the staff from the most efficient departments is composed, on average, of 57.33% temporary staff, while in the more inefficient departments, this percentage is 48.56%. The application of the Mann–Whitney non-parametric test confirmed that the difference between the two figures is statistically significant (p-value = 0.023).

In Spanish universities there are two kinds of profiles for temporary professor. On one hand, there are full-time contractual positions for those

Table 2
Descriptive statistics of cost deviations (% of observed total cost)

	TEV	FCV	SV	TCV
Mean	2.56	7.43	3.47	13.46
Maximum	24.06	38.87	27.33	42.75
Minimum	.00	.00	.00	.00
Std. dev.	5.43	9.13	6.46	21.81
Number of efficient departments	26	19	15	15

Table 3
Academic staff structure in the long-term for efficient and inefficient departments (% of total staff)

		Mean	Max.	Min.	Std. dev.
Efficient departments ($n = 19$)	Permanent staff (PS)	41.67	67.39	27.08	10.35
	Temporary staff (TS)	57.33	72.92	32.61	10.35
	% TS full time	68.97	82.56	43.28	28.46
	% TS part time	31.03	49.58	21.41	28.46
Inefficient departments ($n = 23$)	Permanent staff (PS)	57.44	77.86	29.49	12.42
	Temporary staff (TS)	48.56	67.07	30.87	12.42
	% TS full time	49.67	65.72	39.38	27.78
	% TS part time	50.33	75.33	45.94	27.78

professors that want to develop their careers entirely within the university. On the other hand, there are part-time contractual positions for those professors whose professional activity is developed outside the university but collaborate with the university in teaching tasks, contributing their professional experience.

Within the part-time contractual positions, the departments have the autonomy to decide what personnel structure they prefer. It has even been observed that they are able to employ monetary resources initially destined for permanent placements in order to cover new temporary places. Table 3 breaks down the results for each of these sub-categories, expressing the percentage over the total temporary staff.

The analysis of Table 3 reveals that in the efficient departments, the temporary hired staff is mainly made up of professors hoping to consolidate their professional career in the university. Specifically, you can observe that 68.97% of the temporary staff is full time, contrary to the inefficient departments, where this percentage is approximately 50%. Again, the Mann–Whitney test confirms that the difference between both calculations is statistically significant with a p-value of 0.043. There may be various reasons for this, and to determine them would require a more detailed study that is beyond the scope of current research. However, the first explanation of this result that comes to mind might be that in these departments there is strong competition among the temporary staff to earn stable posts. Such competition may lead to an increase in the production of scientific publications at a reduced cost, since these researchers receive lower salaries than the permanent staff.

These results posed the following question: Should the university contract more temporary than permanent professors? From the results, an affirmative response can be deduced. However, we believe that we should be cautious in this assertation because other factors which we define here below can exist, which can influence the obtained conclusion and should be object of a future study, which is outside the scope of this article. The first of these factors is the fact that temporary professors work hard in order to consolidate their position. Perhaps their performance would not be the same if this would not be the case. The second factor is the possibility that these results mean that a system of adequate incentives for permanent professors does not exist in the Spanish universities. Higher education salaries in Spain are under national or regional governmental control, giving rise to relative similarity among identically ranked professors. The monetary incentives for teaching or research, in relation to the effort required to achieve them, are extremely limited, especially in the case of the latter. So, it would seem that the results point towards the need to create a more efficient incentive and motivation system than the current one, thus guaranteeing that professors will maintain a high performance level once they have obtained a permanent position.

In recent years some members of successive governing boards at UAB have expressed their concern for the need to re-think the current departmental structure of the university, with the aim of balancing the size of departments. This research casts some light on this question, for the results show that an inappropriate size or scale in departments leads to a mere 3.47% excess in costs. Consequently, a restructuring of these characteristics would not probably appear to be a priority from the cost savings perspective.

In fact, the intensity vectors obtained from the model (10) indicate that the particularly inefficient university departments are mainly those that have expanded in size, which suggests that average costs are lower in smaller departments. In the literature, contradictory results can be observed, but most sources conclude that there are increasing returns to scale. However, the majority of the studies analyze economies of scale at university rather than departmental level. There is little research on returns of scale for departments. Some examples of the research that has found that universities can reap benefits from scale economies are Koshal and Koshal (1999), Cohn, Rhine and Santos (1989), Dundar and Lewis (1995) and Hashimoto and Cohn (1997). Nevertheless, other studies that also take universities as the analysis unit reached the opposite conclusion (Avkiran, 2001).

As stated in the introduction, the Spanish university system is currently immersed in a process of cost rationalization, accompanied by a reduction in the number of students in many disciplines, as a result of the low national birth rate sustained through time, a characteristic that can only be inverted as a secondary consequence of immigration. Given these circumstances, universities are turning their priorities towards quality improvement and increased production of scientific research, without the injection of additional financial resources in the system. As a result, the model proposed in this paper may prove to be a useful tool in determining where the quantity and quality of research production should be increased, without modifying or reducing costs.

In this context, and assuming cost minimization, it may be helpful to examine the potential increases achievable in the long term in the different outputs, especially scientific activity. Teaching quality has also become an objective of improvement for university management. In Table 4 we show descriptive statistics that correspond to the increases that should be reached in the different outputs over the long term. The target increase for each output in each department is calculated in the expression $\sum_{s=1}^{K} z_s^* y_{s,i}$, where z_s^* represents the optimum value of the variables of intensity in (9).

Table 4
Potential increases in outputs associated with long-term cost minimization (% of current level)

	New research segments awarded	Teaching load	Quality teaching
Mean	48.67	.39	3.32
Max.	212.43	12.29	21.87
Std. dev.	39.58	2.31	4.61

The results depicted in Table 4 show that once costs are minimized in the long term, there is on average a margin for increasing current teaching levels by .39%. This reduced percentage was predictable a priori, since the size of the teaching staff in each department has traditionally been determined in Spanish universities in accordance with the amount of teaching needed (Caballero et al., 2004).

Similarly, potential significant increases in teaching quality have not been detected once long term costs have been minimized (only 3.32%). However, the output associated with scientific activity is the one that presents the greatest need for improvement. The average increase that should be reached in the new research segments awarded is 48.67%, which should notably improve the quantity and quality of scientific production. Hence, the results indicate that teaching activity is found at comparable levels of efficiency among the different departments of the UAB while the opposite occurs in research. One explanation for this result, could be that Spanish universities have made a huge effort during the last decades to satisfy the growing demand for university education. In many cases, this has led to conditional hiring policies, which give precedence to professors who can cover teaching needs without taking research activity into account.

5. Conclusions

This paper has presented a general model for the evaluation of the cost efficiency of any type of organization, based on data envelopment analysis methodology. The main contribution of the model is that it quantifies the difference between the observed cost of the units under analysis and the cost that they would achieve assuming long-term cost minimization and optimal scale. The model therefore outlines a target that is achievable in the long term. However, in order to make this objective easier to attain in successive stages, the model attributes the difference between each of the two costs to different factors, each of which can be corrected in the short or long term. To be more precise, technical inefficiency is the explanatory factor of the total cost deviation attributable to the short term, while the factors attributable to the long term are the inappropriate utilization of the capacity available and an inappropriate scale from the cost minimization perspective.

The empirical application of the model on 42 departments at UAB showed that the management of their economic resources is generally correct in the short term (2.56% optimal reduction possible), and that improving it would mainly require adjustments only achievable in the long term. These assertions are based on the fact that long-term factors largely explain the total cost deviation of 13.46%.

Analysis of the results referring to the long term revealed two interesting questions that should, in the authors' opinion, be considered by the university authorities:

Firstly, departments with a large proportion of temporary professors striving to make a university career were shown to be more efficient. At first sight, the solution would be to increase the proportion of temporary staff in order to improve efficiency. However, we should be cautious in the interpretation of this conclusion as it can be due to other factors, for example the inexistence of a sufficient system of incentives for the professors, which already have permanent positions, as we have noted in the previous section.

Secondly, the results show that an inappropriate size or scale in departments leads to a mere 3.47% excess in costs. Consequently, the resizing of departments would not appear to be a priority from the cost savings perspective. However, if it were implemented, administrators should bear in mind the fact that the particularly inefficient university departments are mainly those that have expanded, while average costs are lower in smaller departments. From the perspective of improving outputs over the long term, the results suggest that while teaching activity develops in an efficient way in general, a clear opportunity and need exist to increase the quantity and quality of scientific production.

One difficulty in any research that evaluates different university departments is the handling of the heterogeneous nature of the sample. In our case, we have not used control variables, as we could have done, for example, for the level of experiments conducted. In its place, we have chosen to use variables that, apart from obviously representing the productive process, were directly comparable among departments. The advantage of using this method is directly associated with the reduced size of the initial sample. Using control variables generally implies segregating the sample into subsamples, reducing the discriminating power of the DEA. The solution applied in this case has made possible to achieve some meaningful insights. Another limitation that we found was in measuring the teaching quality in the different departments. The use of evaluations by the students is not ideal and could be improved, but unfortunately the authors did not have access to a better homogenous measure of teaching quality.

Finally, we can mention that the future line of investigation will consist of extending the dynamic setting of the model of deviations in costs that we have presented in this article.

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