Efficiency and Productivity Change in Spanish Public Universities, 1994-2002

Workshop "Eficiencia y Productividad"
21-22 September, 2006, León

Adela García-Aracil
Isidora Navarro-Milla
Institute for Innovation and Knowledge Management, INGENIO (CSIC-UPV)
Technical University of Valencia, Spain

Abstract

This paper examines the productivity of Spanish public universities from 1994 to 2002. The used of the Malmquist Productivity Index illustrates the contribution of efficiency and technological changes to productivity change over the period. Separate analyses of "teaching-only" and "research-only" productivity are also made. Results suggest that on average the annual productivity growth was largely attributed to technological progress rather than efficiency improvements, suggesting that most universities are operating near the best-practice frontier, although there is room for improvement in several universities. Most of the productivity gain is attributed to improvements in research productivity rather than teaching.

1. Introduction

In recent years the social demand for public accountability and transparency has been increased in almost all industrialized countries. The pressure on public budgets has lead governments to control and pursue efficiency and productivity in the allocation and management of public sector resources (Bonaccorsi & Daraio, 2005). This social concern makes the government responsible to evaluate and control the public funding institutions. Governments have started to develop evaluating systems and programs to control these institutions. Moreover these evaluating methods are useful to improve policy in a productivity and effectively way for those institutions.

There is a wide threshold of public institutions. Educational institution is interesting to study because education, even more, higher education, is one of the main economic growth sources (Denison, 1962; Verry & Layard, 1975). Numerous papers study in depth efficiency and productivity of universities. Measuring efficiency and productivity in public higher education institutions (HEI) evaluates indirectly public funding management. It will help to develop policies and improve university productivity and consequently public funding management (García-Valderrama, 1996).

Productivity in higher education has an obvious multidimensional character as it relates to both knowledge production and knowledge dissemination through its various forms of teaching, research and technology transfer (Dundar & Lewis, 1998). In this sense, measuring productivity in higher education context is complicated.

Changes in productivity growth over a period can be calculated using the Malmquist productivity change index. This approach is a particularly attractive method due to it does not require knowledge of input or output prices, nor does it require any specific behavioural assumptions of the institutions under consideration, such as cost minimization or profit or revenue maximization (Coelli & Perelman 1999; O'Donnell & Coelli 2003; Uri 2003a, 2003b; Rodríguez-Álvarez *et al* 2004; Johnes, 2005).

Worthington & Lee (2005) examine the change in productivity in the Australian universities sector between 1998 and 2003, while Flegg *et al.* (2004) examine the change in productivity in the British universities sector over the period 1980/81 to 1992/93. In both examples, the authors have used the non-parametric technique in which the selection of inputs and outputs in order to define the production function for modelling university behaviour (teaching, research and technology transfer) is complicated. Indeed, there is no definitive study to guide the selection of inputs and outputs (Tomkins & Green, 1988; Beasley, 1990, 1995; Johnes & Johnes, 1993, 1995; Glass, McKillop & Hyndman, 1995; Athanassopoulos & Shale, 1997). Most indicators are typical of the ambiguity found in education performance measurements (e.g. high degree results may be due to high entry qualifications rather than effectiveness of teaching) unable to capture the interaction among the various inputs and outputs (Gomez, 2001; Jomady, 2005) and the limitations with the selected output specification.

Studying output is found some complications. In the case of *teaching*, for example, one would prefer measures of the learning (concepts and competencies) that results from teaching such as number of students enrolled (Hanke & Leopoldseder, 1998), full-time equivalent students enrolled, student credit hours (Sinuany-Stern *et al.*, 1994), number of degrees conferred (Arcelus & Coleman, 1995), PhD graduated, among others, but indeed some problems arisen. For instance, credit hours can differ significantly among programs of full-time students (e.g. science students with labs versus humanities students) and these differences more likely reflect input differences than learning differences. Degrees awarded measure completions and a level of accomplishment or extent of learning, but they neglect the education of those who attend but do not graduate and do not recognize differences in the length of degree programs (within or across universities), such as between three and four year undergraduate programs, which the full-time equivalent enrolment capture. Cohn *et al.* (1989) remarked that graduated student represents an accumulated output for many years depending of degree time, although it is not computed the effort of non-graduated students and there are not quality criteria.

On the other hand, *research* output is also difficult to measure. Ideally, one would like an index that reflected the quality and impact of the activities undertaken and their products, but no such index exists. Publication counts are sometimes available and used as a measure of research output (Van de Panne, 1991; Sinuany-Stern *et al.,* 1994), although sometimes publication counts are difficult to obtain and are typically incomplete. For example, the publication count variable used by De Groot *et al.* (1991) in their study of the cost structure of US research universities omitted publications from the humanities. Other useful output would be books, book chapters and refereed journal articles and conference proceedings but this information is not always available. Sarafoglou & Haynes (1996) use number of articles and a citation impact factor. Tomkins & Green (1988) use both publications counts and grants. Lacking reliable and easily obtainable output measures, many studies substitute research grants, an input, as a proxy for research output (Rhodes & Southwick, 1986; Ahn *et al.*, 1988; Tomkins & Green, 1988; Cohn *et al.*, 1989; Ahn & Seiford, 1993; Dickson, 1994). Ahn *et al.* (1989) blend this approach using state funds allocated to state institutions of higher education as input and federal and private research funds as output.

In the case of inputs although there are many kinds of them — for example, faculty, support staff, student services, libraries, computers, equipment and supplies, maintenance, buildings, etc. — they can usually be defined relatively well in terms of amounts or expenditures. Traditionally, it is used the undergraduate student number or doctoral student number (Ahn & Seiford, 1993; Athanassopoulus & Shale, 1997; Hanke and Leopoldseder, 1998; García-Aracil, 2006) for both as a teaching and a research input; academic and non-academic staff measured as the full-time equivalent or as number (Van de Panne, 1991), or by staff cost (Ahn *et al.*, 1988; Hanke and Leopoldseder, 1998). Moreover total expenditure is used like input (Ahn *et al.*, 1988) and its breakdown in R&D expenditures (Ahn, 1987), capital expenses (Johnes, 2005), library expenses (Rodhes & Southwick 1986), computer services and structures (Ahn et al; 1988, 1989, 1993), and/or space (Besset *et al.*, 1980). Variations in input quality, however, may not be easily distinguished.

It should be remarked that there are some variables with no consensus to consider them as input or as output like the case of number of undergraduate students, research income, research grants and so on. In addition, measures for assess the technology transfer are difficult to obtain, so they are not accounting in this study.

Thus, in the absence of any specific measurement to evaluate HEI, in this paper we have applied the Malmquist non-parametric approach to analyze the productivity change of the Spanish public universities from 1994 to 2002 including the following variables: as inputs we consider the total expenditure, academic staff and non-academic staff (proxy to measure teaching and research), and as output, we include number of graduates (proxy to measure education) and publication (proxy to measure research).

The remainder of the paper is organized as follows. In Section 2 presents the data descriptive; Section 3 briefly addresses the Malmquist methodology. Section 4 explains the results of the productivity analysis and Section 5 contains the concluding remarks.

2. Data Descriptive

The data set used in the present paper was collected during 2004 under the project *Advanced Quantitative Methods for the Evaluation of the Productivity of Public Sector Research* (AQUAMETH) within the framework of PRIME, a European Network of Excellence, which is supported by the Union Sixth Framework Programme (2002-2006).

Data was collected from various governmental and institutional sources from the academic year 1994/95 to 2002/03 and pertain to public universities in Spain. In 2002, there were 48 public institutions. In this study we consider 43 of them. The remaining 5 universities are excluded due to their recent creation with no data available for some years of the period considered (Pablo Olavide University, Cartagena Technical University, Miguel Hernandez University and Rey Juan Carlos University) and due to the different structure as the National Open University (UNED) has.

The AQUAMETH data set includes information for each public institution related to the accounting system based on a broad classification system of appropriations and expenditures; human resources data providing information about the academic and non-academic staff; enrolment data for undergraduate and graduate programs; institutional information on the physical resources and publications data, among others.

Next, it is presented some basic data descriptive. We select those variables related with the inputs and outputs selection according to the purpose of this study as we mentioned above: total expenses, academic and non-academic staff, graduates and publications.

The total expenses is based on a broad classification system and refers to the expenditure in academic staff, expenditure in non-academic staff, running expenses in goods and services, financial expenditures, flow of funds, capital expenses, real investment, and other expenses (financial assets plus financial liabilities). The amount is expressed in thousand euros (CRUE, 1996, 1998, 2000, 2002).

The academic and non academic staff refers to number of people that works in the university (independently of the labor they made). In Spain, the position of researchers does not exist as an independent category. The academic staff has both teaching and research duties, although there are no clear rules on research duties for academic staff. The non-academic staff is the technical and administrative staff (INE, several years).

Data concerning graduates refers to the number of people that degrees attributed between the first day of January and the last of December of each year, and corresponds to the academic year that ends up that year (CCU, 1999, 2003, 2004).

Publication refers to the number of publications that the university has published. Data is from the Web of Science consists of five databases, but it have only used three of them, Sciences Citation Index Expanded, Social Sciences Citation Index, and Arts and Humanities Citation Index. One of the problems has been found is that the year refers to the year that an article's information was entered into the database and not necessarily when the source article was published. Other additional problem is that the number of publication per public university was calculated through global counting. This implies that if in one article there are several universities being mentioned, the article is counted one time per each university. Moreover, if one article was attributed to more than one scientific field, it has been counted as many times as the number of scientific fields (Web of Science, 2005).

Table 1 presents a summary of descriptive statistics for inputs and outputs across the 43 universities by year. Sample mean, standard deviation, maximum, minimum, skewness and kurtosis are reported. As shown, in 2002 on average expenses summed to 5,488.72 thousand of euros and the academic staff was 1,898 and the non-academic staff was 959, thus, one technical and administrative staff gave support to two academics staffs. At the same time, on average, a Spanish university granted 4,538 graduates and 546 publications. Highlighting changes over the sample period, we can see that on average the expenditures decreased in 8.16 per cent (from 5,976.53 thousand of euros in 1994 to 5,488.72 thousand of euros in 2002), the academic staff increased in 23.66 per cent (from 1,535 to 1,898), the non-academic staff increased in 29.09 per cent (from 743 to 959), the number of graduates increased in 46.04 per cent (from 3,107 to 4,538) and the number of publications increased in 77.91 per cent (from 306 in 1994 to 546 in 2002). It could be said that these increases in outputs were matched by an increase in inputs, except for the fallen of total expenditures.

In addition, the distributional properties of all five variables are shown in Table 1. They appear non-normal. Given that the sampling distribution of skewness is normal with mean 0 and standard deviation of $\sqrt{T/6}$ where T is the sample size, many of the series are significantly skewed. Since these are also positive they signifying the greater likelihood of observations lying above the mean than below. Across each of the years in the sample period, the most highly skewed variables are graduates and publications. The kurtosis or degree of excess, across some variables is also large, thereby indicating leptokurtic distributions with extreme observations. Given the sampling distribution of kurtosis is normal with mean 0 and standard deviation of $\sqrt{T/24}$ where T is the sample size, then many estimates are once again statistically significant at any conventional level. Graduates and publications are again highly leptokurtic.

Table 1. Descriptive statistics for inputs and outputs across the 43 universities by year.

Year	Statistics	Expenses *(thousand €)*	Academic Staff *(number)*	Non-acad. Staff *(number)*	Graduates *(number)*	Publications *(number)*
1994	Mean	5,976.53	1,535.09	743.04	3,107.44	306.98
	Std.desviation	4,368.68	1,095.32	579.81	3,215.15	334.10
	Minimum	939.18	285.00	135.19	459.00	7.00
	Maximum	20,324.80	5,491.00	2,899.96	18,534.00	1,562.00
	Skewness	1.24	1.42	1.68	2.97	1.87
	Kurtorsis	1.53	2.62	3.50	12.06	4.06
1995	Mean	6,770.77	1,784.12	771.49	3,441.49	360.74
	Std.desviation	4,919.13	1,344.59	588.12	3,583.68	396.98
	Minimum	932.93	367.00	136.00	573.00	18.00
	Maximum	22,654.28	7,352.00	2,984.00	21,367.00	1,873.00
	Skewness	1.19	1.99	1.71	3.27	1.99
	Kurtorsis	1.40	5.83	3.71	14.53	4.56
1996	Mean	7,010.14	1,846.44	797.53	3,782.40	392.91
	Std.desviation	4,846.34	1,293.54	596.60	3,692.18	420.93
	Minimum	1,289.54	385.00	183.00	765.00	18.00
	Maximum	22,608.63	6,727.00	3,017.00	22,050.00	1,995.00
	Skewness	1.33	1.76	1.84	3.16	2.00
	Kurtorsis	1.50	3.61	3.59	13.78	4.57
1997	Mean	6,396.16	1,902.23	841.07	4,090.30	418.74
	Std.desviation	4,271.65	1,310.39	630.01	3,746.72	436.53
	Minimum	1,352.85	411.00	198.00	846.00	39.00
	Maximum	20,250.61	7,112.00	3,203.00	21,902.00	2,239.00
	Skewness	1.20	1.78	1.64	2.94	2.23
	Kurtorsis	1.36	4.63	3.48	11.67	6.44
1998	Mean	6,303.56	1,805.98	838.86	4,216.02	461.88
	Std.desviation	4,121.59	1,182.53	605.00	3,470.14	457.58
	Minimum	1,484.87	362.00	201.00	856.00	51.00
	Maximum	19,632.44	6,019.00	3,282.00	20,559.00	2,218.00
	Skewness	1.16	1.33	1.79	2.72	1.94
	Kurtorsis	1.41	2.48	5.36	10.90	4.23
1999	Mean	6,038.64	1,869.56	883.98	4,271.81	492.44
	Std.desviation	3,789.43	1,205.73	623.27	3,371.48	462.92
	Minimum	1,507.77	379.00	205.00	996.00	65.00
	Maximum	18,383.07	6,019.00	3,303.00	19,240.00	2,312.00
	Skewness	1.16	1.33	1.79	2.33	1.94
	Kurtorsis	1.28	2.03	4.35	8.17	4.67
2000	Mean	5,310.00	1,944.40	927.40	4,218.67	491.35
	Std.desviation	3,229.42	1,206.75	652.86	3,160.19	462.29
	Minimum	1,391.79	379.00	202.00	832.00	52.00
	Maximum	15,836.95	6,035.00	3,504.00	16,870.00	2,346.00
	Skewness	1.13	1.25	1.82	1.88	2.07
	Kurtorsis	1.20	1.85	4.60	4.95	5.24
2001	Mean	5,368.72	1,902.35	969.35	4,206.53	526.12
	Std.desviation	3,270.08	1,197.24	664.40	3,037.45	473.23
	Minimum	1,306.64	415.00	140.00	977.00	74.00
	Maximum	16,241.30	6,021.00	3,509.00	16,095.00	2,482.00
	Skewness	1.21	1.39	1.66	1.80	2.15
	Kurtorsis	1.45	2.23	3.82	4.45	6.03
2002	Mean	5,488.72	1,898.37	959.19	4,538.00	546.14
	Std.desviation	3,357.24	1,181.64	651.24	3,209.23	467.33
	Minimum	1,247.61	419.00	217.00	1,083.00	86.00
	Maximum	16,805.48	6,021.00	3,509.00	15,770.00	2,518.00
	Skewness	1.26	1.38	1.81	1.35	2.15
	Kurtorsis	1.66	2.38	4.47	2.11	6.44
94-02	Mean Variation	- 8.16%	23.66%	29.09%	46.04%	77.91%

3. Methodology

The methodology employed in this paper to study productivity growth in the Spanish public Universities from 1994 to 2002 is the nonparametric Malmquist index. This productivity growth method is superior to alternative indexes such as the Törnqvist index or the Fisher Ideal index, because Malmquist index is based only on quantity data and makes no assumptions regarding university's behavior (Grifell-Tatjé & Lovell 1996).

Several different decompositions of the Malmquist index have been proposed in the literature. One of them is that proposed by Fare *et al.*, (1994) which assumes constant returns to scale (CRS) technology. Other is that proposed by Ray & Desli (1997), which does not require the CRS assumption. Simar & Wilson (1998) & Zofío & Lovell (1998) extend the Ray & Desli (1997) decomposition, more concretely, the technical change component further decomposed into a "pure" technical change of the frontier plus a residual measure of the scale change of the technology. This residual measure evaluates the separation between the CRS and the variable returns to scale (VRS) technologies.

In this study, we assume constant returns-to-scale to start with, and calculate the total productivity change and decomposed into technological (or technical) change and technical efficiency change which is formed by "pure" efficiency change and scale efficiency change.

Furthermore, for studying productivity by Malmquist, it is necessary to construct a nonparametric envelopment frontier over the data points such that all observed points lie on or below the production frontier. There are two analysis options: input orientation which reduces the inputs without dropping the output levels, and output orientation which raises outputs without increasing the inputs. In education, the universities may be given a fixed quantity of resources (e.g., state financial resources, academic and non-academic loads) and asked to produce as much output as possible. Thus, we assume an output orientation.

The output-based Malmquist productivity change index *(M)* specified by Färe *et al.* (1994) may be formulated as:

$$M_o^{t+1,t}(y_t, x_{t,} y_{t+1,} x_{t+1}) = \left[\frac{D_o^t(y_{t+1}, x_{t+1})}{D_o^t(y_{t,} x_t)} * \frac{D_o^{t+1}(y_{t+1}, x_{t+1})}{D_0^{t+1}(y_t, x_t)} \right]^{1/2}$$

where the subscript *O* indicates an output-orientation, *M* is the productivity of the most recent production point (x_{t+1}, y_{t+1}) (using period $t + 1$ technology) relative to the earlier production point (x_t, y_t) (using period *t* technology), D_0 are output distance function which is the reciprocals of Farrell's (1957) technical efficiency measures. The output distance function, it is defined on the output set *P(x),* as:

$$D_o(x,y)\text{:min } \{\theta\text{: } (y/\theta) \in P(x)\}$$

where θ is the corresponding level of efficiency. The output distance function seeks the largest proportional increase in the observed output vector *y* provided that the expanded vector (y/θ) is still an element of the original output set (Grosskopf *et al.*, 1995). If the university is fully efficient, so that it is on the frontier, $D_o(x,y)= \theta =1$, where as $D_o(x,y)= \theta <1$ indicates that the institution is inefficient.

An equivalent way of writing the Malmquist index is:

$$M_o^{t+1,t}(y_t, x_{t,} y_{t+1,} x_{t+1}) = \frac{D_o^{t+1}(y_{t+1}, x_{t+1})}{D_0^t(y_t, x_t)} \left[\frac{D_o^t(y_{t+1}, x_{t+1})}{D_o^{t+1}(y_{t+1,} x_{t+1})} * \frac{D_o^t(y_t, x_t)}{D_0^{t+1}(y_t, x_t)} \right]^{1/2}$$

or *M=E*P* where *M* is the product of a relative efficiency change *E* under constant returns to scale which measures the degree of catching up to the best-practice frontier for each observation between time period *t* and time period $t + 1$ (term outside the square bracket) and a measure of technical progress *P* (the two ratios in the square bracket) as measured by shifts in the frontier of technology (or innovation) measured at period $t + 1$ and period t (averaged geometrically). Applying at the same data CRS assumption (without convexity constraint) and VRS (with convexity constraint), measures of overall technical efficiency *(E)* and "pure" technical efficiency *(PT)* are obtained. Dividing the overall technical efficiency *(E)* by "pure" technical efficiency change *(PT)* then yields a measure of scale efficiency change *(S)*.

Recalling that M indicates the degree of productivity change, then if $M>1$ then productivity gains occur, whilst if $M<1$ productivity losses occur. Regarding changes in efficiency, technical efficiency increases (decreases) if and only if E is greater (less) than one. An interpretation of the technological change index is that technical progress (regress) has occurred if P is greater (less) than one.

To calculate the indices, it is necessary to solve several linear programs to maximize the function with the premises. Assume there are N universities and that each university consumes varying amounts of K different inputs to produce M outputs. The *ith* university is therefore represented by the vectors $x_i y_i$ and the $(K \times N)$ input matrix X and the $(M \times N)$ output matrix Y represent the data of all universities in the sample. The first two linear programs are where the technology and the observation to be evaluated are from the same period, and the solution value is less than or equal to unity. The second two linear programs occur where the reference technology is constructed from data in one period, whereas the observation to be evaluated is from another period. The following linear programs are used:

$$\left[D_0^{t+1}(y_{t+1}, x_{t+1})\right]^{-1} = \max_{\theta,\lambda} \theta$$

s.t. $\theta y_{i,t+1} + Y_{t+1}\lambda \geq 0$,

$$x_{i,t+1} - X_{t+1}\lambda \geq 0$$

$$\lambda \geq 0$$

$$\left[D_0^{t}(y_t, x_t)\right]^{-1} = \max_{\theta,\lambda} \theta$$

s.t. $\theta y_{i,t} + Y_t \lambda \geq 0$,

$$x_{i,t} - X_t \lambda \geq 0$$

$$\lambda \geq 0$$

$$\left[D_0^{t+1}(y_t, x_t)\right]^{-1} = \max_{\theta,\lambda} \theta$$

s.t. $\theta y_{i,t} + Y_{t+1}\lambda \geq 0$,

$$x_{i,t} - X_{t+1}\lambda \geq 0$$

$$\lambda \geq 0$$

$$\left[D_0^{t}(y_{t+1}, x_{t+1})\right]^{-1} = \max_{\theta,\lambda} \theta$$

s.t. $\theta y_{i,t+1} + Y_t \lambda \geq 0$,

$$x_{i,t+1} - X_t \lambda \geq 0$$

$$\lambda \geq 0$$

This approach can be extended by decomposing the constant returns-to-scale technical efficiency change into scale efficiency and pure technical efficiency components. Further details on the interpretation of these indices may be found in Charnes *et al.*, (1993), Lovell (2003), Worthigton & Lee (2005).

4. Results

To evaluate Spanish public universities, first, we analyze a “general model” taking into account as input total expenses, number of academic and non-academic staff, and as outputs graduates and publications. Then, in order to understand better the sources of the productivity changes two additional specifications of university productivity are examined. The first one focuses on “teaching-only” productivity and the second one “research-only” productivity. Variable definitions in both instances are identical to the “general model”, but the “teaching-only” specification removed the output publications and the “research-only” specification removed the output graduates. Ideally, it would be better if the rest of variables could have been split along the lines of research-related and teaching-related, but this was not possible.

The Malmquist index and its decomposition for each of the three models are presented in Table 2 by year and by university. Three primary issues are addressed in the computation of Malmquist indices of productivity growth over the sample period. The first is the measurement of productivity change over the period (see column *M* in Table 2). The second is to decompose changes in productivity into what are generally referred to as a "catching-up" effect (technical efficiency change) (see column *E* in Table 2) and a "frontier shift" effect (technological change) (see column *P* in Table 2). The third is that the "catching-up" effect is further decomposed to identify the main source of improvement, through either enhancements in "pure" technical efficiency (see column *PT* in Table 2) or increases in scale efficiency (see column *S* in Table 2). It should be remarked that these indexes (and any resulting percentage changes) are relative, that is, a university may be more or less efficient, or more or less productive, but only in reference to the other forty-two universities.

Table 2 shows that the "general-model" had an annual mean increase in total factor productivity *(M)* of 4.6 percent for the period 1994 to 2002 across the university sector. Given that productivity change is the sum of technical efficiency and technological change, the major cause of productivity improvements can be ascertained by comparing the values of the efficiency change and technological change. That is, the productivity gains described can be the result of efficiency gains, technological improvements, or both. In our case, the overall improvement in productivity over the period is composed of an average efficiency increase (movement towards the frontier) of 0.6 per cent, and average technological progress (upward shift of the frontier) of 4.0 per cent annually. The technical efficiency can be further decomposed into pure technical efficiency (0.5) and scale efficiency (0.1). Clearly, across all Spanish public universities the sustained improvement in productivity over the period 1994-2002 is the result of a sustained expansion in the frontier relating inputs to outputs rather than any improvements in efficiency.

In the analysis by years, the high mean productivity improvement was in academic year 1996/1997 with 10.5 per cent, which was composed of 7.9 per cent improvement in efficiency (the highest in the period analyzed) and 2.4 per cent of technological gain. In turn, most of the technical efficiency gain was composed of an improvement in both pure technical efficiency (5.6 per cent) and scale efficiency (2.2 per cent). By way of comparison, the high technological improvement was well spread across the sector in the academic year 2001/2002 (26.2 per cent), but with a fallen in efficiency (-16.4 per cent).

Table 2. Malmquist index by year and by Spanish public universities

	General Model					Teaching Model					Research Model				
Year/index	E	P	PT	S	M	E	P	PT	S	M	E	P	PT	S	M
94-95	4.6	-1.2	4.2	0.4	3.4	4.2	-1.4	4.8	-0.6	2.8	8.4	3.0	7.7	0.6	11.6
95-96	2.7	4.3	4.3	-1.5	7.1	0.7	6.0	2.5	-1.7	6.7	-1.1	8.5	4.9	-5.7	7.2
96-97	7.9	2.4	5.6	2.2	10.5	12.8	-2.6	7.2	5.2	9.8	19.1	-5.2	13.8	4.7	12.8
97-98	0.8	7.5	-4.0	5.0	8.4	-2.8	10.1	-5.8	3.2	7.0	0.7	17.0	0.6	0.1	17.7
98-99	1.0	-0.3	1.6	-0.6	0.7	2.8	-3.5	2.7	0.1	-0.8	10.0	0.2	6.7	3.1	10.2
99-00	-1.2	2.1	0.2	-1.4	0.9	0.6	-0.5	2.0	-1.4	0.0	-4.2	6.5	-5.8	1.7	2.0
00-01	7.6	-6.0	3.2	4.3	1.1	5.8	-5.9	3.4	2.3	-0.4	13.8	-3.5	7.2	6.2	9.9
01-02	-16.4	26.2	-10.2	-6.9	5.5	-21.7	35.1	-15.2	-7.7	5.7	1.5	3.8	4.2	-2.7	5.3
All years	0.6	4.0	0.5	0.1	4.6	-0.2	4.0	0.0	-0.1	3.8	5.7	3.6	4.8	0.9	9.5

	General Model					Teaching Model					Research Model				
University/index	E	P	PT	S	M	E	P	PT	S	M	E	P	PT	S	M
Almeria	1.8	7.0	0.3	1.5	8.9	5.0	4.4	6.1	-1.0	9.5	4.0	5.9	2.2	1.9	10.2
Cadiz	-0.9	5.2	-1.6	0.7	4.2	-4.6	4.8	-4.8	0.2	0.0	5.4	5.5	6.0	-0.6	11.2
Cordoba	1.5	3.5	1.3	0.2	5.0	-7.2	4.8	-7.5	0.4	-2.7	-0.8	2.6	-0.3	-0.5	1.8
Granada	-1.9	4.8	-1.1	-0.8	2.9	2.2	6.1	1.1	1.1	8.4	1.1	3.8	-0.6	1.8	5.0
Huelva	3.7	2.6	2.7	1.0	6.4	2.3	3.5	2.2	0.1	5.8	27.3	3.3	26.3	0.8	31.5
Jaen	4.6	3.4	3.4	1.1	8.1	-7.1	3.8	-2.7	-4.5	-3.6	24.0	5.2	23.1	0.7	30.4
Malaga	-1.6	3.8	-2.1	0.5	2.2	-1.8	4.2	-2.5	0.8	2.3	1.4	2.5	1.3	0.1	3.9
Sevilla	2.0	5.2	4.6	-2.5	7.3	-1.8	4.7	-2.0	0.2	2.9	4.2	4.0	1.4	2.8	8.4
Zaragoza	-1.5	4.2	-1.5	0.0	2.6	2.6	3.6	0.8	1.7	6.2	2.4	3.9	2.1	0.3	6.3
Oviedo	3.0	4.7	3.0	0.0	7.9	-0.9	4.9	-1.4	0.5	4.0	5.0	2.1	5.2	-0.2	7.3
Balearic Island	-9.2	4.9	-8.0	-1.3	-4.7	-5.1	4.4	0.0	-5.1	-0.9	-5.4	4.8	-8.3	3.2	-0.9
La Laguna	0.7	5.6	0.6	0.1	6.4	1.5	4.4	2.0	-0.5	6.0	2.4	4.6	2.7	-0.3	7.1
Gran Canaria	3.4	4.3	3.7	-0.3	7.8	2.1	3.5	2.1	0.1	5.7	7.4	3.0	8.3	-0.8	10.6
Cantabria	1.7	3.8	2.6	-0.9	5.6	4.4	5.7	4.2	0.2	10.4	1.9	2.5	3.5	-1.5	4.5
Aut. Barcelona	3.9	6.1	3.7	0.2	10.2	-2.9	3.9	0.0	-2.9	0.9	1.7	4.8	0.8	0.9	6.6
Barcelona	0.0	3.4	0.0	0.0	3.4	3.5	6.4	1.9	1.6	10.1	1.9	3.7	0.0	1.9	5.6
Girona	5.8	6.0	5.9	-0.1	12.2	-2.1	3.3	-0.2	-1.9	1.1	16.6	5.7	17.2	-0.5	23.2
Lleida	-2.2	3.4	0.0	-2.2	1.2	3.7	2.6	2.7	1.0	6.4	8.0	4.1	13.6	-4.9	12.4
Tech. Catalonia	4.3	2.9	4.2	0.0	7.3	-12.2	5.6	-11.2	-1.1	-7.3	7.9	2.5	7.8	0.2	10.7
Pompeu Fabra	7.3	2.6	5.1	2.1	10.1	2.1	4.4	0.8	1.3	6.6	26.8	3.9	22.6	3.4	31.7
Rovira i Virgili	2.0	3.3	1.8	0.1	5.4	0.1	4.6	-1.4	1.5	4.7	7.1	3.1	6.7	0.3	4.0
Castilla la Mancha	-0.9	4.9	-1.4	0.5	4.0	1.4	3.7	1.3	0.1	5.2	5.1	3.9	4.0	1.1	9.2
Alicante	-5.8	4.1	-6.1	0.3	-2.0	-0.7	2.4	-1.8	1.1	1.7	-1.8	2.5	-2.2	0.4	0.6
Jaume I	0.4	4.4	-2.0	2.4	4.8	0.1	4.5	0.0	0.1	4.6	3.0	3.6	-1.2	4.2	6.8
Tech. Valencia	-3.0	2.1	-3.0	0.0	-1.0	3.4	4.4	3.6	-0.3	7.9	1.7	2.1	1.3	0.4	3.8
Valencia	-1.7	3.5	-1.1	-0.5	1.7	-1.8	3.2	-2.6	0.8	1.4	1.4	3.3	0.4	1.0	4.8
Burgos	-1.8	4.2	-2.5	0.8	2.3	-2.7	3.2	-2.8	0.1	0.3	28.0	3.0	21.1	5.7	31.8
Leon	-0.7	2.7	-1.5	0.8	2.0	2.3	4.8	2.2	0.1	7.2	0.5	2.1	-0.1	0.6	2.6
Salamanca	3.9	5.7	3.5	0.4	9.9	2.8	3.3	3.2	-0.4	6.2	1.9	3.2	2.2	-0.3	5.2
Valladolid	-0.9	4.6	-1.1	0.1	3.6	4.3	3.0	2.1	2.2	7.5	3.7	3.9	4.3	-0.6	7.7
Extremadura	2.6	6.2	1.1	1.5	9.0	9.6	2.2	10.9	-1.2	12.0	1.3	4.9	1.6	-0.2	6.3
A Corunya	1.6	3.8	1.5	0.1	5.4	-1.2	3.1	-2.5	1.3	1.9	9.8	2.5	9.3	0.5	12.6
Santiago.	-0.3	2.0	-0.6	0.4	1.8	-1.5	2.4	-1.1	-0.4	0.9	3.7	2.5	3.4	0.3	6.3
Vigo	3.8	4.6	3.3	0.5	8.6	-5.0	2.7	-4.9	0.0	-2.4	11.9	3.4	10.1	1.6	15.6
Alcala	-4.3	4.1	-5.2	0.9	-0.4	2.1	2.8	0.0	2.1	4.9	-3.4	3.2	-4.2	0.7	-0.3
Aut. Madrid	0.0	4.5	0.0	0.0	4.5	-0.5	3.8	-0.3	-0.1	3.3	0.0	4.3	0.0	0.0	4.3
Carlos III	3.5	3.2	1.5	1.9	6.9	5.1	4.5	4.7	0.3	9.8	10.1	3.3	2.9	7.1	13.8
Comp. Madrid	-4.8	4.5	0.0	-4.8	-0.5	-3.6	2.4	-4.2	0.7	-1.2	-1.9	4.2	-4.5	2.8	2.3
Tech. Madrid	9.5	2.3	10.8	-1.2	12.0	1.8	4.7	5.3	-3.3	6.6	9.2	3.0	7.0	2.0	12.4
Murcia	-2.1	3.2	-2.1	0.1	1.1	-1.3	4.7	-1.4	0.1	3.4	0.9	2.5	1.1	-0.2	3.4
Public Navarra	0.3	2.7	-0.9	1.2	3.0	-2.2	3.8	-0.4	-1.8	1.6	19.8	1.8	17.8	1.6	21.9
Basque Country	-0.9	2.2	-0.3	-0.6	1.2	2.5	4.9	2.2	0.2	7.4	0.2	4.2	0.7	-0.5	4.4
La Rioja	2.0	2.5	0.0	2.0	4.5	-3.3	3.8	-2.3	-1.0	0.4	3.6	4.9	0.0	3.6	8.7
All universities	0.6	4.0	0.5	0.1	4.6	-0.2	4.0	0.0	-0.2	3.8	5.7	3.6	4.8	0.9	9.5

Looking at the results by universities, the University of Girona had a mean productivity improvement of 12.2 per cent (first-ranked) which was composed of 5.8 per cent improvement in efficiency (moving towards the efficient frontier) and 6.0 per cent technological gain (movement in the frontier). Both figures moves closed. Technical efficiency was composed of an improvement in pure technical efficiency (5.9 per cent) with a fallen of the scale efficiency (-0.1 per cent). The Technical University of Madrid was ranked second in terms of productivity (12.0 per cent) comprising a 2.3 per cent technological gain and a 9.5 per cent improvement in efficiency, which is composed by 10.8 per cent of pure efficiency change and -1.2 percent of scale efficiency. The University Autonoma of Barcelona was third-ranked with a productivity gain of 10.2 per cent attributed 6.1 per cent to technological progress and 3.9 per cent to improvements in efficiency.

At the other end of the scale are universities with a low level of total factor productivity over the period. For example, productivity fell on average by 4.7 percent at University of Balearic Island, 2.0 percent at University of Alicante, 1.0 percent at the Technical University of Valencia and 0.4 percent at the University Complutense of Madrid. In all of these instances, the decline in productivity was the result of inefficiency (negative result in efficiency change column), rather contraction in their best-practice frontier (negative result in technological change column).

Focusing on the "teaching-model", Table 2 shows that there was an annual mean increase in total factor productivity *(M)* of 3.8 per cent for the period 1994 to 2002, which was composed of an improvement in technological change (4.0 per cent) and a fallen of the technical efficiency change (-0.2 per cent). It could be said that Spanish universities improvements in teaching only productivity are sustained by the expansion in the frontier rather than improvements in efficiency.

In the analysis by years, the high mean teaching only productivity improvement was in academic year 1996/1997 with 9.8 per cent, which was composed of 12.8 percent improvement in efficiency (the highest in the period analyzed) and -2.6 per cent of technological loss. By way of contrast, the high technological improvement was in the academic year 2001/2002 (35.1 per cent), but this has been offset by a decrease in teaching efficiency (-21.7 per cent).

In the analysis by university, the first ranked university was the University of Extremadura with a teaching only productivity of 12.0 per cent which was composed of 9.6 per cent improvement in efficiency and 2.2 per cent technological gain. Moreover it is one of the few universities that the improvement in efficiency change was higher than the technological one. Technical efficiency was composed of improvement in pure technical efficiency (10.9 per cent) with a fallen of the scale efficiency (-1.2 per cent). The University of Cantabria was ranked second in terms of teaching only productivity (10.4 percent) comprising a 5.7 per cent technological gain and a 4.4 per cent improvement in efficiency which was composed by 4.2 per cent of pure efficiency change and 0.2 per cent of scale efficiency. The University of Barcelona was the third-ranked with a productivity gain of 10.4 percent attributed 5.7 per cent to technological progress and 4.4 per cent to improvements in efficiency: 4.2 due to pure efficiency change and 0.2 due to scale efficiency.

The lowest level of the teaching only productivity factor over the period is observed at the University of Catalonia (-7.3 per cent) due to the decrease of efficiency (-12.2 per cent) cause mainly for the decrease in pure efficiency change (-11.2 per cent) and scale efficiency (-1.1 per cent). The University of Jaen, the University of Cordoba and the University of Vigo have reduced their teaching only productivity in 3.6, 2.7 and 2.4, respectively, mainly due to an increase in inefficiency.

With regards of the “research-model”, Table 2 shows that the annual mean increase in research only productivity was 9.5 per cent for the period 1994 to 2002, which was composed on an average efficiency increase of 5.7 per cent, and average technological progress of 3.6 per cent annually. The increment of the technical efficiency was decomposed into pure technical efficiency (4.8 per cent) and scale efficiency (0.9 per cent). It seems that Spanish universities improvements in research only productivity are sustained by both expansions in the frontier and movements towards the efficiency frontier.

In the analysis by years, the highest mean research only productivity was in academic year 1997/1998 with a 17.7 per cent, which was composed of 0.7 per cent improvement in efficiency and 17.0 percent to technological gain. However, the lowest increased in research only productivity was in academic year 1999/2000 with a 2.0 per cent.

Looking at the results of universities, the best-ranked performers were University of Burgos (31.8 per cent), Pompeu Fabra University (31.7 per cent), University of Huelva (31.5 per cent) and University of Jaen (30.4 per cent), while the worst-ranked performers were University of Balearic Island (-0.9 per cent) and University of Alcala (-0.3 per cent).

5. Conclusions

This paper examines the productivity of Spanish public universities from 1994 to 2002, through the used of the Malmquist Productivity Index illustrating the contribution of efficiency and technological changes to productivity change over the period. Three different specifications are made to assess Spanish public universities: “general-model”, “teaching-only” and “research-only” model. The inputs included in the analysis are total expenses, academic and non-academic staff and the outputs are graduates and publications. Variable definitions for "teaching-only" and "research-only" models are identical to the "general model", but the "teaching-only" specification removed the output publications and the "research-only" specification removed the output graduates.

The results indicate that annual productivity growth average 4.6 per cent across all universities, with a range between -4.7 per cent and 12.2 per cent, and were largely attributed to technological progress (4.0 per cent) rather than efficiency improvements (0.6 per cent). Gains in scale efficiency appear to have played only a minor role in productivity gains (0.1 per cent). The fact that there is little contribution for the technical efficiency suggests that most universities are operating near the best-practice frontier.

The separate analysis of teaching-only and research-only productivity indicate that annual productivity growth averaged 3.8 per cent and 9.5 per cent, respectively, suggesting that most productivity growth was associated with improvements in research rather than teaching. In turn, the increase in teaching productivity is mainly sourced from technological gains and very little efficiency improvements, whereas the research gains are mostly associated with the removal of inefficiency rather than technological improvements. The interpretation of these results should be taken with care due to the overlap in teaching and research related inputs. It is clear that much of the overall productivity improvement in universities over this period is associated with gains in research productivity. Of this, most can be accounted for by universities catching up to the frontier through pure technical efficiency improvements rather than the frontier expanding over time. By way of contrast, improvements in teaching productivity have been more modest and largely linked with technological improvements, but this has been offset by a decrease in teaching efficiency. Giving the lower level of inefficiency, further gains will rely on technical innovations. This remains a challenge to the higher education sector.

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