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Changes in productivity of Spanish university libraries

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ABSTRACT

This paper analyzes productivity growth, technical progress, and efficiency change in a sample of 34 Spanish university libraries between 2003 and 2007. Data envelopment analysis and a Malmquist index are combined with a bootstrap method to provide statistical inference estimators of individual productivity, technical progress, pure efficiency, and scale efficiency scores. To calculate productivity, a three-stage service model has been developed, examining productivity changes in the relationships between the libraries' basic inputs, intermediate outputs, and final outputs. The results indicate a growth in the productivity of the libraries (relationship between basic inputs and intermediate outputs) and in the productivity of the service (relationship between basic inputs and final outputs). The growth in productivity in both relationships is due to technical progress. If the variable representing the use of electronic information resources is removed from the final output, the result is a significant reduction in productivity.

1. Introduction

The modern concept of the university library in Spain arose during the 1980s, with the aim of achieving two important objectives: the integration of the bibliographical resources of individual academic departments into a single structure and the establishment of professional management teams fully responsible for their management. Simultaneously, there was a substantial increase in budgets and in the recruitment of specialized staff to develop the technical library services [1].

In 1990, the University Library Network (REBIUN) was set up, hosting the libraries of all Spanish universities, public and private, with the goal of improving library services in general by coordinating the resources and activities of individual libraries. Since 1994, REBIUN has been responsible for the publication of relevant annual statistics.

As in other countries, at the turn of the millennium, Spanish university libraries initiated another fundamental change, aiming to become information resources management centres for students, teachers, and researchers.

The main elements of this modernisation and improvement of university library management have been the drawing up of strategic plans for the majority of libraries; the implementation of self-assessment processes using the framework elaborated by the European Foundation for Quality Management [2] or others adapted from practices in a number of other countries [3]; and the development of the digital library.

In this paper, we assess the impact of these initiatives on the productivity of a sample of 34 libraries in public universities in Spain between 2003 and 2007.

In order to compute changes in productivity, we consider the Malmquist productivity index (MPI). This method has become the standard approach to productivity measurement within the non-parametric literature.

Several past studies have measured the efficiency of libraries in depth by the application of such non-parametric statistical techniques as data envelopment analysis (DEA) [4–14]. In contrast, changes in productivity have been investigated only by Reichmann and Sommersguter-Reichmann [15], who used the MPI to measure changes between 1998 and 2004, in the USA, Germany, and Austria.

One of the crucial issues in computing the MPI is the construction of a correct production model. Our study applies a service model for university libraries, similar to the models defined by Vitalino [6] and Hammond [8]. The model is structured in three stages. At stage one, managers combine the basic resources of the library (personnel, installations, equipment, etc.) for the performance of a set of internal operations, in order to generate a set of "intermediate outputs" aimed at increasing and improving the infrastructure and the bibliographic resources to be made available to users. At stage two, these "intermediate outputs" are used by personnel, by users, or both, for the delivery and consumption of library services ("final outputs"). At stage three, the impact of these services on users and on the institution in the short and medium term is represented, and this is what we term "outcomes".

In this production model there are, therefore, five relationships that might be considered empirically, one between basic resources

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inputs and intermediate outputs, another between basic resources inputs and final outputs, third between intermediate outputs and final outputs, fourth between basic inputs and outcomes, and the fifth between final outputs and outcomes. Since it is difficult to obtain data on library outcomes, in this study we have only analysed the first three relationships.

The objective of our paper is to study productivity changes at the stages of the production model and to assess the impact of the digital library development on those changes.

In order to make the obtained MPI scores available for statistical inference, we apply a bootstrap method proposed by Simar and Wilson [16] to obtain confidence intervals and to test the hypothesis of productive growth or regress.

The paper is structured as follows: Section 2 briefly explains the methodology for calculation of the libraries' productivity; Section 3 presents the production model and the variables and data used; Section 4 reports the results of the analysis; Section 5 discusses the findings of the study and draws conclusions from them.

2. Methodology

2.1. Measurement of changes in productivity

In this study, the technique of data envelopment analysis (DEA) is used to measure the Malmquist productivity index and its components under a constant-return-scale technology (CRS).

The MPI was introduced by Caves et al. [17] and developed further in the context of performance assessments by Färe et al. [18]. They defined an input-oriented productivity index as the geometric mean of the two Malmquist indices developed a decade earlier by Caves et al. [17], referring to the technologies at time periods t and $t+1$, yielding the following Malmquist-type measure of productivity:

$$\mathrm{MPI}^{(t,t+1)} = \sqrt{\frac{D_i^t(y^{t+1},x^{t+1})}{D_i^t(y^t,x^t)}\frac{D_i^{t+1}(y^{t+1},x^{t+1})}{D_i^{t+1}(y^t,x^t)}} \quad (1)$$

where $\mathrm{MPI}^{(t,t+1)}$ is the input-oriented Malmquist index, and y represents the output vector that can be produced using the input vector x.

This MPI is composed of four input-oriented distance functions. Two are measures of the technical efficiency in the t and $t+1$ periods: $D_i^t(y^t,x^t)$ and $D_i^{t+1}(y^{t+1},x^{t+1})$; the other pair indicates cross-period distance functions. The first of these, $D_i^t(y^{t+1},x^{t+1})$, gives the efficiency measure using the observation at period $t+1$ relative to the frontier technology at period t. The second, $D_i^{t+1}(y^t,x^t)$, uses the observation at period t relative to the frontier technology at period $t+1$. A more detailed explanation of this methodology is given by Coelli et al. [19].

An important feature of the DEA-derived MPI is that the calculated productivity can be decomposed into two mutually exclusive indices [18], one reflecting the change in efficiency and the other the change in the frontier of the production possibility set (that is, an index of technical change). This differentiation of the origin of the changes in productivity is potentially very valuable to library managers for the establishment of policy [20]. The relevant components are obtained by reformulating the index in Eq. (1) as follows:

$$\mathrm{MPI}^{(t,t+1)} = \frac{D_i^{t+1}(y^{t+1},x^{t+1})}{D_i^t(y^t,x^t)}\sqrt{\frac{D_i^t(y^{t+1},x^{t+1})}{D_i^{t+1}(y^{t+1},x^{t+1})}\frac{D_i^t(y^t,x^t)}{D_i^{t+1}(y^t,x^t)}} \quad (2)$$

The ratio outside the square root measures efficiency change (EFCH) between time periods t and $t+1$. The geometric mean of the two ratios inside the square root captures the technical change (TECH) between the two periods, evaluated at the input–output levels (x^t, y^t) at time period t and the levels (x^{t+1}, y^{t+1}) at time period $t+1$.

Improvements in productivity are signified by MPI values greater than 1, and means that lower amounts of input are required to obtain a given level of output. An index of less than 1, correspondingly, signifies a reduction in productivity.

The MPI can be defined using an output-oriented approach or an input-oriented approach. In the present study, an input-oriented measure of MPI change is the most appropriate because library managers have a greater capacity to reduce the inputs used to produce outputs than to control the amount of service delivered by the library.

In relation to the returns to scale assumption used to estimate the distance functions, we use CRS as the reference technology for calculating the Malmquist index, regardless of the form of the technology underlying the production unit's activity. This is because the computation of the Malmquist index in the presence of non-constant return to scale does not accurately measure the productivity change, as shown by Grifell-Tatjé and Lovell [21]. The fundamental problem is that the imposition of a variable return scale (VRS) technology creates a systematic bias in the productivity measurement derived.

However, due to the fact that the most appropriate technology for libraries efficiency analysis is VRS, we follow the recommendations given in Fare and Grosskopf [22], who propose the use of a MPI decomposition including a change in scale efficiency terms in order to consider deviations from constant returns to variable returns to scale (VRS).

The EFCH calculated under the assumption of CRS technology can be further decomposed into pure technical efficiency change (PEFCH) and scale efficiency change (SEFCH). Pure technical efficiency change is calculated relative to variable return technology and is defined as the ratio of its own-period distance functions under VRS, and indicates whether a production unit has moved closer to or further away from its own-period best practice:

$$\mathrm{PEFCH} = \frac{D_{i,\mathrm{VRS}}^{t+1}(y^{t+1},x^{t+1})}{D_{i,\mathrm{VRS}}^t(y^t,x^t)} \quad (3)$$

Scale efficiency change (SEFCH) is constructed as the ratio of the distance function under CRS to the distance function under VRS, and captures the changes in the deviation between the variable-return and constant-return-to-scale technology:

$$\mathrm{SEFCH} = \frac{D_{i,\mathrm{CRS}}^{t+1}(y^{t+1},x^{t+1})/D_{i,\mathrm{VRS}}^{t+1}(y^{t+1},x^{t+1})}{D_{i,\mathrm{CRS}}^t(y^t,x^t)/D_{i,\mathrm{VRS}}^t(y^t,x^t)} \quad (4)$$

In summary, the MPI is in the form:

$$\mathrm{MPI} = \mathrm{TECH} \times \mathrm{PEFCH} \times \mathrm{SEFCH}$$

where MPI represents the change in productivity, TECH is technical change, PEFCH is pure efficiency change and SEFCH is scale efficiency change.

2.2. Application of bootstrapping techniques

In order to compare the productivity changes, we need to determine appropriate confidence intervals for the indices obtained in each step of the production model and to determine whether these indices are significant.

Bootstrapping, introduced by Efron [23], is a resampling method used to construct an empirical distribution of a given variable. This technique is used frequently in econometrics in order to approximate statistical variance, to construct confidence intervals, or to make hypothesis tests over parameters of interest in order to make inference over the empirical distribution of data.

For the bootstrapping of productivity indices, we use the non-parametric envelopment estimators introduced by Simar and Wilson [16] which allows the construction of confidence intervals