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Exploring the efficiency of Mexican universities: Integrating Data Envelopment Analysis and Multidimensional Scaling ☆

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ABSTRACT

National policy initiatives require the expenditure of large amounts of resources over several years. It is common for these initiatives to generate large amounts of data that are needed in order to assess their success. Educational policies are an obvious example. Here we concentrate on Mexico's "Educational Modernisation Programme" and try to see how this plan has affected efficiency in teaching and research at Mexico's universities. We use a combined approach that includes traditional ratios together with Data Envelopment Analysis models. This mixture allows us to assess changes in efficiency at each individual university and explore if these changes are related to teaching, to research, or to both. Using official statistics for 55 universities over a six year period (2007–2012), we have generated 12 ratios and estimated 21 DEA models under different definitions of efficiency. In order to make the results of the analysis accessible to the non-specialist we use models that visualise the main characteristics of the data, in particular scaling models of multivariate statistical analysis. Scaling models highlight the important aspects of the information contained in the data. Because the data is three-way (variables, universities, and years) we have chosen the Individual Differences Scaling model of Carroll and Chang. We complete the paper with a discussion of efficiency evolution in three universities.

1. Introduction

Mexico is the largest Spanish speaking country in the world, with a population of 112 million inhabitants according to the 2010 population census. It expects the demand for university education to increase in the future. There are two reasons for this. First, the number of individuals aged between 15 and 25 years old will increase under present trends [5]. Second, Mexico has been industrialising and this brings an increased interest in university education, something that is expected to result in a higher age participation rate, the proportion of individuals who attend university [11].

The Mexican government, aware of these trends, set up an "Educational Modernisation Programme" starting in 1989 [21,28]. As a result of this programme, public expenditure in Higher Education increased from 0.42% of GDP in 1990 and 1% of GDP in 2010 (OECD, 2013, Education at a Glance, table B2.3, p. 193). The modernisation plan included: financial incentives for degree quality enhancement; national planning of university places in an attempt to match supply to the needs of the country; the creation of a system of academic quality control; a "National Researchers' System" that was to provide research incentives to individuals and institutions; and the splitting of the Higher Education (HE) budget into an ordinary component with which to pay recurrent expenditure, and an extraordinary component distributed on a competitive basis [21]. The extraordinary component, which amounts to about 30% of the budget, has been aimed at improving the quality of university staff; improving university infrastructure, both in terms of lecturing and administration; widening internationalisation; purchasing better equipment; and improving the quality of undergraduate and postgraduate programmes (ANUIES 2004).

The Mexican university system is made up of a variety of institutions: there are universities financed by the central federal government, universities financed by local state governments, and private universities. In this study we analyse a sample of 55 Mexican universities over a six-year period (2007–2012): 6 federal universities, 34 local state universities, and 15 private universities.

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Using officially published data, Sagarra et al. [47] demonstrated that Mexico's policy initiative has been successful in bringing about improvements in the university system. The question still remains of whether resources are being better employed. In other words: have there been improvements in efficiency? Is it possible to assess, on the basis of published data, how the changes have affected particular institutions? Answering such questions is the aim of this study.

The present study is explicitly inserted into the stream of literature about the estimation of educational institutions' efficiency, and in particular it tries to address the challenges listed by the recent review proposed by De Witte and Lopez-Torres [7]. More specifically, we propose a methodology that combines different technologies – as efficiency scores and indicators – in order to improve the interpretability of the results.

For each individual university we have two types of information: 12 indicators (ratios) obtained from published statistics, and efficiencies obtained from 21 possible Data Envelopment Analysis (DEA) formulations. The 21 DEA models derive from all the possible combination of inputs and output available. We include 3 inputs (faculty, enrolment and first joining graduates) and 2 outputs (published papers and graduates). DEA allocates a score to each decision unit being analysed. This score depends on the inputs and outputs in the model. The estimation of a variety of specifications (combinations of inputs and outputs) makes it possible to explain in what sense any two decision units differ in the way they approach efficiency, even when the scores are equal. When the efficiency scores are different, this procedure reveals the approach to efficiency of a unit, and provides a ranking of all decision units.

The specific novelty in the estimation of models resulting from a variety of DEA specifications is that the results of the analyses can be visualised with the help of multivariate statistical analysis techniques such as Multidimensional Scaling. Indeed, although both multivariate analysis and DEA have been extensively used in the context of educational research (see [62,25,16] for a review of DEA; and [43] for MDS), their joint utilisation is new in the HE context. The present study is also innovative in the sense that it uses panel data. This study is inserted in the recent stream of the literature that explores the evolution of universities' efficiency over time (see [18] for England, and García-Aracil [10] for Spain); while previous contributions assessed the relative efficiency of universities from a static perspective, here we investigate how efficiency changed in medium-term (six years). Therefore, despite the availability of several years of data, we did not decompose the efficiency change over time in the various components, such as those proposed by recent work realised by Johnson and Ruggiero [19] – namely pure efficiency change, technological improvements and time-varying environmental conditions. Indeed, the primary focus of the present work is the combination of different approaches (DEA and ratios) in a multidimensional setting for classifying universities. A closer look to results over time is then left to future research extensions, as discussed in the last section.

Policy analysis in cases such as this one presents serious challenges. The results have to be understood by policy makers who are intelligent people but are not necessarily versed in advanced statistical or optimisation tools. Besides, there are very many universities to be studied – in this case it amounts to 55, but the total number could be much larger if all private universities had been included – and a method has to be developed that allows the assessment of change in each individual university. We present here a methodology that addresses both objectives.

We analyse the data using scaling techniques, in order to visualise the results and make them accessible to policy makers. The methodology permits the merging of qualitative and quantitative information in policy analysis. Since we deal with three-way (panel) data, the technique chosen was the Metric Individual Differences Scaling of Carroll and Chang (INDSCAL) (see [3]). We chose the metric approach rather than the ordinal version of the algorithm, in order to separate aspects that remain invariant during the studied period from aspects that changed from year to year. In this study, ratios and DEA specifications have been taken as variables, and universities as cases. The study of each individual university has taken place using the "Property Fitting" technique, a regression-based approach that shows how each university has evolved in the space of ratios and efficiencies. Although all the universities have been explored using the methods described here, we only give three examples in way of illustration: a federal university, a local state university, and a private university. Although these examples have been chosen as representative of the different university categories, the analysis has proven valid in the case of all the universities included in the data set.

After this introduction we discuss the data that was employed in the study. This is followed by a technical section that describes three way scaling models, as these are not normally found in educational research. An analysis of the data, one year at a time follows next in order to identify the main characteristics of the Mexican educational system. The results of the full analysis, with the complete data set, follow next. The paper ends with a discussion of three case studies and a conclusion.

2. Data

Data was obtained for all universities for which there was available public information during the six-year period 2007–2012. This includes 6 federal universities, 34 local state universities, and 15 private universities. The data set includes all but one federal universities, all but one local state universities, and many private universities. Together, these account for about 60% student enrolment in Higher Education in Mexico.

Private universities were included if they had submitted data in order to qualify for state support for academic improvement programmes. We still do not have data for some private universities but we do not think this is a major concern, as the private universities for which no data is available did not seek state support for academic improvement programmes. We consider that our data set is almost the whole population of the universities that should be analysed. To be on the safe side, we also estimated efficiencies using the bootstrap procedure of Simar and Wilson [53], and the results were almost identical to the results reported here.

Two data sources have been used. The first source is the "Comparative Study of Mexican Universities" [57], an on-going project that systematically collects data from Mexican Higher Education Institutions; http://www.ecum.unam.mx/. However, this comparative study did not contain disaggregated information by discipline – Health, Social Sciences, Sciences, and Humanities and Education. Such information was obtained from our second source, the Mexican National Association of Universities and Higher Education Institutions (ANUIES).

The data was converted into ratios in order to make the results independent of size. Table 1 shows and defines the ratios that were calculated from the raw data for each university. These ratios attempt to describe the employment structure of faculty staff (FTEFTot), the research productivity of faculty staff (ScopusF and ScopusEn), the composition of the student body in terms of the discipline studied (EnrolLi, EnrolMa, HealthG, SocialG, ScienceG, and HumanG), success and drop-out rates (SuccessGFj and SuccessGEn), and to account for the possibility of non-linear effects we also include a measure of university size (TotalEnrol).

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