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Relative performance of academic departments using DEA with sensitivity analysis

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ABSTRACT

The process of liberalization and globalization of Indian economy has brought new opportunities and challenges in all areas of human endeavor including education. Educational institutions have to adopt new strategies to make best use of the opportunities and counter the challenges. One of these challenges is how to assess the performance of academic programs based on multiple criteria. Keeping this in view, this paper attempts to evaluate the performance efficiencies of 19 academic departments of IIT Roorkee (India) through data envelopment analysis (DEA) technique. The technique has been used to assess the performance of academic institutions in a number of countries like USA, UK, Australia, etc. But we are using it first time in Indian context to the best of our knowledge. Applying DEA models, we calculate technical, pure technical and scale efficiencies and identify the reference sets for inefficient departments. Input and output projections are also suggested for inefficient departments to reach the frontier. Overall performance, research performance and teaching performance are assessed separately using sensitivity analysis.

1. Introduction

India's development through education and research in the scientific and technical disciplines has achieved global reach and stature. In the list of the best technical institutes in India, the first name comes into insight is a group of institutions called Indian Institute of Technology. From Kharagpur in 1950 to Roorkee in 2001, there are now seven potentially world-class institutions in this family. These institutions have international recognition. The one member of this group is the Indian Institute of Technology Roorkee, which is the successor institute of the University of Roorkee, charted in 1949 and the Roorkee College founded in 1847, which was later renamed as the Thomason College of Civil Engineering. It is worth mentioning that the Roorkee College was the first engineering college established in the British Empire. This institute has the glorious past over 160 years and has been acclaimed for its excellence in education, research and training. The institute has three types of academic programs, namely, Undergraduate (UG) Programs (Bachelor of Technology degree in different disciplines), Postgraduate (PG) Programs (Master of Technology degree in different disciplines and Master in Business Administration degree) and Doctoral Programs (Ph.D.). Nineteen academic departments offer these programs.

The purpose of this paper is to assess the relative performance of these departments based on the multiple criteria. Second objective is to measure how efficiently the departments work in the institute and to identify efficient and inefficient performers. Thirdly, we apply sensitivity analysis to test the robustness of results and assess the performance of departments for different activities like research and teaching.

In the literature, several approaches are applied for measuring efficiency like performance indicators, parametric methods (such as ordinary least square method, stochastic frontier method) and non-parametric methods (such as DEA and Free Disposal Hull). Each method has its strengths and weaknesses. The ratio style performance indicators can work well only when a single input and single output are involved. But in multi-input and multi-output context, it is unable to draw right inferences. Parametric methods require explicit functional form for technology as well as distribution of inefficiency. But non-parametric methods do not require any functional form and work well with multiple inputs and outputs.

The paper applies data envelopment analysis (DEA) methodology as it is the most suited methodology for measuring the performance of non-profit organization such as academic

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departments. It is particularly appropriate when the researcher is interested in investigating the efficiency of entities that convert multiple inputs into multiple outputs. Here such an entity is academic department.

The paper is organized as follows: Section 2 comprises methodology and brief survey of literature of DEA in education sector. Section 3 describes the application procedure of DEA. Description of inputs and outputs and models used in the paper is also given. Section 4 gives information about data collection and computation. The overall performance of the departments is discussed in Section 5. Section 6 explains the teaching and research performance of the departments and robustness of the estimated efficiency scores using sensitivity analysis. Efficiency measurement of engineering departments estimated separately is also given in this section. In the last section, conclusions are given.

2. Methodology

DEA is developed by Charnes, Cooper, and Rhodes (1978) and extended by Banker, Charnes and Cooper (1984). It is used for measuring efficiency in the cases where multiple input and output factors are observed and when it is not possible to turn these into one aggregate input or output factor. The DEA methodology is especially adequate to evaluate the efficiency of non-profit entities that operate outside the market, since for them performance indicators, such as income and profitability, do not work satisfactorily.

DEA provides comparative efficiency of the units to be evaluated. The units analyzed are called Decision Making Units (DMUs). The performance of DMUs is assessed using the concept of efficiency and productivity, which is the ratio of total outputs to total inputs. Efficiencies are estimated relative to the best performing DMU (or DMUs). The best-performing DMU is assigned an efficiency score of unity and performance of other DMUs vary between 0 and 1 relative to this best performance. More detailed theoretical introduction of DEA may be found in Coelli, Prasada Rao, and Battese (1998), Cooper, Seiford, and Zhu (2004), Ramanathan (2003) and Thanassoulis (2001). The mathematical formulation of DEA is given in Appendix A.

DEA provides some useful information to policy makers that may be helpful to improve the performance of a DMU. We can find input slacks (quantity of access resource used) and/or output slacks (deficient output produced). DEA also identifies the reference set, also known as the peer group. A peer group contains two or more efficient DMUs for an inefficient DMU. Thus, an efficient DMU may be a peer for one or more inefficient DMUs. A DMU, which appears frequently as a peer for more inefficient DMUs or has a high peer count, is considered as an example of good performance.

2.1. Literature survey

In recent years, several studies have been undertaken to analyze the efficiency for academic departments in universities. Each study differs in its scope and meaning. Among them, some important studies are briefly reviewed as below.

Bessent, Bessent, Charnes, Cooper, and Thorogood (1983) used DEA in measuring the relative efficiency of education programs in a community college in USA. Educational programs (DMUs) were assessed on outputs such as revenue from state government, number of students completing the program, and employer satisfaction with training of students. These outputs represented significant planning objectives. Input included were student contact hours, number of full time equivalent instructors, square feet of facilities for each program and direct instructional expenditure. The author demonstrated how DEA could be used in improving programs, terminating programs, initiating new programs or discontinuing inefficient program.

Tomkins and Green (1988) studied the overall efficiency of UK University accounting departments. They ran a series of six efficiency models of varying complexity where staff number was an input and students number an output. The results indicated that different configurations of multiple inputs and outputs produced substantially stable efficiency scores. Beasley (1990) studied productive efficiency of Chemistry and Physics departments in UK, where financial variables such as research income and expenditure were treated as inputs. Outputs consisted of numbers of undergraduate and postgraduate students as well as research ratings. In a follow up study, Beasley (1995) analyzed the same data set in an effort to determine the research and teaching efficiencies jointly, where weight restrictions were used. Johnes and Johnes explored various models in measuring the technical efficiency of economics departments in UK in terms of research output. They discussed the potential problems in choosing inputs and outputs. The authors also provided a good guide to interpreting efficiency scores.

Stern, Mehrez, and Barboy (1994) examined the relative efficiency of 21 academic departments in Ben-Gurion University, Israel. Operating costs and salaries were taken as inputs while grants, publications, graduate students and contact hours were used as outputs. The analysis suggested that the operating cost should be reduced in 10 departments. Nunamaker (1985) investigated the effect of changing the variables-mix on DEA scores. Arcelus and Coleman (1997) investigated how a particular fixed budget formula affected the input/output structure of academics units of University of New Brunswick, Canada.

3. Research design

3.1. Selection of DMUs

The first step in research design is to decide the DMUs to be compared. Two factors influence the selection of DMU for a study. These two factors are – homogeneity and number of DMUs. The DMUs must be homogeneous units. They should perform the same tasks and should have similar objectives. The inputs and outputs characterizing the performance of DMUs should be identical, except for differences in intensity or magnitude.

We select the departments of IIT Roorkee for our study. They are homogeneous because they perform the same task and have similar objectives. We mean that all the department use academic, non-academic staff and operating costs for teaching and research purposes.

The number of DMUs to be compared depends upon the objective of the study and on the number of homogeneous units whose performance in practice has to be compared. However, some considerations have been specified in the selection of the number of DMUs. The number of DMUs is expected to be larger than the product of number of inputs and outputs in order to discriminate effectively between efficient and inefficient DMUs (Avkiran, 2001; Darrat, Topuz, & Yousef, 2002). Therefore, we take three inputs and three outputs with 19 academic departments in our study. In literature many of authors (like Arcelus & Coleman, 1997; Beasley, 1990; Johnes & Johnes, 1993, 1995; Stern et al., 1994; Tomkins & Green, 1988) have evaluated the performance taking academic departments as DMUs.

3.2. Selection of inputs and outputs

The next step in research design is to determine inputs and outputs for the DMUs to be compared. The criteria of selection of