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CONTENTS

Title

EVALUATING THE EFFECTIVENESS OF EDUCATIONAL INSTITUTIONS USING FRONTIER ANALYSIS

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Abstract:

The higher education system has been experimenting with management approaches to deal with challenges arising from both internal as well as external factors. In this context, it is absolutely essential to assess the quality of education offered by an educational institution with specific reference to the reliability of how and when the learning takes place. There are lots of quantitative techniques available and some work in this area has been already done. But there is a dearth of literature focusing on the relative efficiency. One advanced operations research technique which evaluates the relative efficiency is the Frontier Analysis or Data Envelopment Analysis (DEA).

This paper attempts to use Frontier Analysis to assess the effectiveness of educational institutions, specifically a set of selected institutions offering engineering education in Tamil Nadu, India. The research has identified a set of input and output parameters for each institution, from which the efficient frontiers (DMUs) are determined. The relative efficiency of the institutions are measured with respect to the efficient frontier and then analyzed. Detailed recommendations are set forth, for appropriate interventions to address the specific gaps identified through the gaps analysis. The analysis further provides useful information and opens up new avenues for future research.

Keywords: Data Envelopment Analysis, Effectiveness, Education, Relative efficiency, Frontier Analysis, DMU

Introduction:

Education System plays a pivotal role for socio-economic development in any country since it deals with knowledge development and dissemination, technology transfer, education and collaborative works with industries. The demand and opportunities in education has resulted in an overwhelming increase in number of educational technical institutes especially in the developing countries like India. The technical institutes in India are currently facing a stiff competition because of opening of the off-shore campus of foreign universities. Highly competitive environment makes quality as a key variable for attracting primary customers (students).

The conventional method adopted for assessing these institutes seems to be inadequate as it is based on summation of scores assigned to a limited number of factors like infrastructure, number of students recruited by the recruiting firms, management styles, etc. One of the major drawbacks of the conventional method is that it assigns equal weight age to all pertinent factors and is inadequate to reflect the true picture on the quality of education being imparted by an institution. For example, an institution having high score in 'quality infrastructure' and low score in 'quality faculty' may have the same overall quality with an institution having low score in 'quality infrastructure' and high score in the 'quality faculty'. Intuitionally, the later case should be treated as an efficient institution because profile of faculty plays a dominating role for imparting quality education in comparison to the adequacy of infrastructure. Further, ranking of institutions widely differ depending on sample size and criteria considered by them.

Usually, technical institutions exhibit highly process oriented and a multi- stakeholder situation leading to a difficulty in aggregating the functional variables (inputs and outputs) for the evaluation of education quality. Therefore, it is desirable to use a tool that is capable of relating customers' perception (input) to the desired performance (output) of the education system so that strategic decision-making can be made easier.

Frontier Analysis is a mathematical programming technique with a number of practical applications for measuring the performance of a set of similar units. In principle, Frontier Analysis is concerned with a number of alternative decision making units (DMU). Each of them is analyzed separately via a mathematical programming model which checks whether the DMU under consideration could improve its performance by decreasing its input and increasing its output. The improvement is pursued until the boundary of the convex hull of the other DMUs is reached. A DMU which cannot improve its performance is efficient or non-dominated. Otherwise, it is dominated by a convex combination of other DMUs. Thus, possible improvements for a particular DMU are indicated, not in an arbitrary direction, but on the basis of the performance of the more successful and efficient DMUs.

It is one such technique that aggregates the input and output components in order to obtain an overall performance measure through comparison of a group of decision units. It evaluates performance of Decision-Making Units (DMUs) by finding out the relative efficiency of the units under consideration. The DMUs can be business units (points of sales, bank branches, dealers, franchisees, etc.), government agencies, police departments, hospitals, educational institutions and even human beings on assessment of athletic, sales and student performance, etc. The major advantages of DEA may be listed as:

- it can handle multiple input and multiple output models
- it does not require the functional relationship between inputs and outputs
- it identifies the possible peers as the role models (benchmarks)
- it determines the possible sources of inefficiency
- it is independent of units of measurement of various parameters.

In this study, an attempt has been made to assess the efficiency of the institutions using various quality dimensions of education through application of DEA. This study seeks to measure the relative efficiency of 20 educational institutions in Tamil Nadu, India.

Literature Review:

Identification of inputs and outputs in a service sector is really a challenging task as they are not well defined. In this context, Mahapatra and Khan (2007) have suggested a methodology to find out the factors responsible for quality improvement in education sector via neural network approach [12]. Elangovan et al. (2007) have used an Executive Support System (ESS) approach for improving the quality and productivity in maintenance engineering model [8]. However, DEA approach enables the management to frame right kind of policy for improvement of quality through identification of inefficiencies in certain dimensions in an organisation, both in manufacturing and service industries (Anatiliy, 2007; Parkan, 2006). Pacheco and Fernandes (2003) analysed efficiency of 35 Brazilian domestic airports using DEA and suggested the best quality implementation strategy [2]. Lin et al. (2005) determined the efficiency for a shipping industry using financial indicators through DEA so that Quality Improvement Programme (QIP) can be implemented[10]. Recent studies reveal that DEA has been successfully applied to education sector but each study differs in its scope, meaning and definition. [1] In one such study, the policy for Italian universities has been derived based on computation of Technical Efficiency (TE) using DEA with various input and output specifications (Agasisti and Bianco, 2006). A comparative study on efficiency of private universities and public universities in the

USA using DEA has been carried out by Rhodes and Southwick (1986) considering each individual university as a DMU[18]. Tomkins and Green (1988) have used DEA to test the performance of individual departments of a university considering both teaching and research activities and compared the results with the ranking obtained by means of elemental analysis of staff/student ratio[19]. McMullen (1997) applied DEA in order to assess the relative desirability of Association to Advance Collegiate Schools of Business (AACSB) accredited MBA programmes [12]. McMillan and Datta (1998) used DEA to assess the relative efficiency of 45 Canadian universities and found that a subset of universities comprising of three categories such as comprehensive with medical school, comprehensive without medical school and primarily undergraduate universities are regularly found to be efficient. In an attempt to compare the performance of selected schools in the Netherlands, Ramanathan (2001) studied the effect of several non- discretionary input variables which are not under direct control of management on efficiency scores[15]. Calhoun (2003) employed DEA to compare relative efficiencies of private and public Institutions of Higher Learning (IHL) using a sample of 1323 four-year old institutions and introduced a new way for clustering institutions based on revenue management. Data envelopment analysis (DEA), occasionally called frontier analysis, was first put forward by Charnes, Cooper and Rhodes in 1978[5]. It is a performance measurement technique which, can be used for evaluating the *relative efficiency* of *decision-making units* (*DMU's*) in organizations. Examples of such units to which DEA has been applied are: banks, police stations, hospitals, tax offices, prisons, defense bases (army, navy, air force), schools and university departments. One advantage of DEA is that it can be applied to non-profit making organizations. Since the technique was first proposed much theoretical and empirical work has been done. Many studies have been published dealing with applying DEA in real-world situations. Obviously there are many more unpublished studies, e.g. done internally by companies or by external consultants.

Data envelopment analysis (DEA), occasionally called frontier analysis is a performance measurement technique which can be used for evaluating the *relative efficiency* of *decision-making units* (*DMU's*) in organizations [17]. A DMU is a distinct unit within an organization that has flexibility with respect to some of the decisions it makes, but not necessarily has complete freedom with respect to these decisions.

Research Methodology:

The paper initially illustrates DEA by taking a sample of 20 Engineering Colleges in Tamil Nadu, India using a graphical (pictorial) approach to DEA. This is very useful when attempting to explain DEA to those in the management area. There is a mathematical approach to DEA that can be adopted which is illustrated using Linear Programming technique. Our analysis uses 2 output measures, namely pass percentage of students and students placed and 2 input measures namely, intake of students and faculty in the various Engineering Colleges.

From the Table 1, it can be inferred that, for the college C 4 in one year, there were 142 faculty, 4246 students admitted out of which 3116 students passed and 2555 students got placed. (Table 1)

To compare these colleges and measure their performance a commonly used method is *ratios* which takes output measure and divides it by the corresponding input measure. In this case, we analyze the effectiveness of colleges by taking *inputs* and converting them (with varying degrees of efficiency) into *outputs*. Hence there are two ratios.(Table 2)

From the Table 2, eff11 is the ratio of Students passed / faculty, eff12 is the ratio of students placed / faculty and so on. This is usually the efficiency parameter on the students pass percentage w r t faculty and the placement status w r t faculty. Since we have multiple inputs and outputs (2 each in our case), it is very difficult to conclude on the efficiency of the colleges using ratios.

One problem with comparison using ratios is that different ratios can give a different picture and it is difficult to combine the entire set of ratios into a single numeric judgment. For instance, when we consider C2 and C4; C2 is (83 / 73) = 1.13 times only as efficient as C4 at the pass percentage of students but (75 / 60) = 1.25 times as efficient at the percentage of students placed. To combine these figures into a single judgment is very difficult. This problem of different ratios giving different pictures would be especially true if there is an increase the number of colleges (and/or increase the number of input/output measures).

Thus it is very difficult to interpret the values corresponding to college C 5 from these ratios. This is where it is essential to get into a better technique called Frontier Analysis or Data Envelopment Analysis which interprets the ratios and provides the efficient frontier.

Results and Discussion:

One method of interpreting different ratios, at least for problems involving just two outputs and a single input, is a simple graphical analysis. This involves a plot of the two ratios for each college as shown in figure 1.

The first figure gives the position of efficiency with respect to faculty and the second figure gives the efficiency with respect to Student intake. From the figure it was observed that a clear efficient frontier cannot be determined using graphical analysis, as it gives only a partial picture of the effectiveness of the colleges. It is important to note that DEA can only give *relative efficiencies* - efficiencies relative to the data considered. It does not, and cannot give absolute efficiencies.

In words, DEA while evaluating any number of Decision making units (DMU's), and with any number of inputs and outputs requires the inputs and outputs for each DMU to be specified. It defines efficiency for each DMU as a weighted sum of outputs [total output] divided by a weighted sum of inputs [total input]; where all efficiencies are restricted to lie between zero and one (i.e. between 0% and 100%). It uses the numerical value for calculating the efficiency of a particular DMU. Weights are chosen to maximise its efficiency, thereby presenting the DMU in the best possible light.

To calculate the efficiency of the other colleges the only step is to change what is to be maximized (e.g. maximize $E_{C\ 5}$ to calculate the efficiency of C 5). This is exactly the association of non-negative weights with each input and output measure. As the optimization problem is a nonlinear problem and hence difficult to solve numerically, it can be converted into a linear programming problem by algebraically substituting for all efficiency variables in order to give an optimization problem expressed purely in terms of weights by introducing an additional constraint and setting the denominator of the objective function equal to one (technically this can be done as the above nonlinear problem has one degree of freedom - multiplying all the weights by a (positive) scale factor would leave the solution value unchanged)

Once the LP has been solved to generate optimal values for the weights then the efficiency of the college being optimized optimizing for, C 2 in this case, can be easily calculated using $E_{C\ 2}$=((2024W_{pass} + 1836W_{placed})/(2444W_{intake}). Here that the numerator of (2024W_{pass} +

1836W_{placed})/(2444W_{intake}) is known as the *weighted output* for C 2 and the denominator is know as the *weighted input* for C 2

This can be extended for all the other institutions to determine the respective efficiencies. The entire formulated linear programming problem can be solved using Solver. The Solver screenshot for this analysis is given at the end of the article.

From the Solver screenshot , it was observed that the efficiency of the different colleges are given in highlighted column . It shows that C 1, C 3, C13 and C 16 have 1.00 as the efficiency value and the other colleges are less than 1.00. The relative efficiency can be further analyzed to improve the performance.

Conclusion:

This paper set out as a contribution to current educational systems for assessing the effectiveness of educational institutions. A sample of 20 institutions in Tamil Nadu, India were analyzed for effectiveness using Data Envelopment Analysis(DEA)/Frontier analysis. The efficient frontier were identified and the relative efficiency of the colleges were established using graphical analysis initially and then the case was formulated as an Linear Programming Problem which was solved using Solver. As this research is confined only to two inputs measure and two output measures, it cannot be generalized unless it is extended to more inputs and output measures. This study provides scope for further research using multiple input and output measures to assess the effectiveness of educational institutions in the service sector and other industrial sectors.

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Table 1 Details pertaining to Selected Sample of Colleges

Colleges	Faculty	Student Intake	Students Passed	Students Placed
	Input 1	*Input 2*	*Output 1*	*Output 2*
C 1	100	2477	2168	1754

C 2	95	2444	2024	1836
C 3	90	2870	2243	2131
C 4	142	4246	3116	2555
C 5	120	2578	1779	1686
C 6	110	1958	1336	466
C 7	60	1291	1086	1053
C 8	75	2019	894	586
C 9	73	1105	477	353
C 10	120	3162	2689	2003
C 11	140	2060	1580	1000
C12	80	1200	1062	900
C13	110	2010	1960	1800
C14	125	2300	2120	1935
C15	140	2620	2500	2010
C16	115	2200	2100	2000
C17	90	1700	1620	1510
C18	85	1800	1650	1400
C19	135	2050	1950	1875
C20	105	1995	1850	1745

Table 2 Ratios for efficiency

Colleges	Faculty	Student Intake	Students Passed	Students Placed				
	Input 1	*Input 2*	*Output 1*	*Output 2*	*Eff 11*	*Eff 21*	*Eff 12*	*Eff 22*
C 1	100	2477	2168	1754	22	18	0.9	0.7
C 2	95	2444	2024	1836	21	19	0.8	0.8
C 3	90	2870	2243	2131	25	24	0.8	0.7
C 4	142	4246	3116	2555	22	18	0.7	0.6
C 5	120	2578	1779	1686	15	14	0.7	0.7
C 6	110	1958	1336	466	12	4	0.7	0.2
C 7	60	1291	1086	1053	18	18	0.8	0.8
C 8	75	2019	894	586	12	8	0.4	0.3
C 9	73	1105	477	353	7	5	0.4	0.3
C 10	120	3162	2689	2003	22	17	0.9	0.6
C 11	140	2060	1580	1000	11	7	0.8	0.5
C 12	80	1200	1062	900	13	11	0.9	0.8
C 13	110	2010	1960	1800	18	16	1.0	0.9
C 14	125	2300	2120	1935	17	15	0.9	0.8
C 15	140	2620	2500	2010	18	14	1.0	0.8

C 16	**115**	**2200**	**2100**	**2000**	**18**	**17**	**1.0**	**0.9**
C 17	**90**	**1700**	**1620**	**1510**	**18**	**17**	**1.0**	**0.9**
C 18	**85**	**1800**	**1650**	**1400**	**19**	**16**	**0.9**	**0.8**
C 19	**135**	**2050**	**1950**	**1875**	**14**	**14**	**1.0**	**0.9**
C 20	**105**	**1995**	**1850**	**1745**	**18**	**17**	**0.9**	**0.9**

Solver screenshot for this analysis is given below:

Colleges	Faculty	Student Intake	Students Passed	Students Placed	Weighted O/p	Weighted I/p	Efficiency	Working
	Input 1	*Input 2*	*Output 1*	*Output 2*				
C 1	100	2477	2168	1754	1.000000002	1.000000001	1.00	1.17109E-09
C 2	95	2444	2024	1836	0.94799764	0.972343165	0.97	-0.02434552
C 3	90	2870	2243	2131	1.057570336	1.057570336	1.00	-2.3981E-10
C 4	142	4246	3116	2555	1.439741131	1.599202749	0.90	-0.15946162
C 5	120	2578	1779	1686	0.838492382	1.103003372	0.76	-0.26451099
C 6	110	1958	1336	466	0.57157411	0.911441899	0.63	-0.33986779
C 7	60	1291	1086	1053	0.513588847	0.551993555	0.93	-0.03840471
C 8	75	2019	894	586	0.402390042	0.789656964	0.51	-0.38726692
C 9	73	1105	477	353	0.217627841	0.55705629	0.39	-0.33942845
C 10	120	3162	2689	2003	1.227783276	1.246629212	0.98	-0.01884594
C 11	140	2060	1580	1000	0.708568952	1.05377319	0.67	-0.34520424
C12	80	1200	1062	900	0.492815852	0.607777472	0.81	-0.11496162
C13	110	2010	1960	1800	0.919623433	0.924230501	1.00	-0.00460707
C14	125	2300	2120	1935	0.993827553	1.05417453	0.94	-0.06034698
C15	140	2620	2500	2010	1.152221218	1.191496599	0.97	-0.03927538
C16	115	2200	2100	2000	0.990499079	0.990499079	1.00	-1.439E-10
C17	90	1700	1620	1510	0.761712691	0.769826787	0.99	-0.0081141
C18	85	1800	1650	1400	0.765797458	0.77487926	0.99	-0.0090818
C19	135	2050	1950	1875	0.921046209	1.031772851	0.89	-0.11072664
C20	105	1995	1850	1745	0.871354634	0.901000489	0.97	-0.02964585
Weight	0.00391	0.00025	0.00040	0.00007				