Quality Improvement In Education System: Data Envelopment Analysis Approach

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Research Article

Abstract: In this paper, we proposed Data Envelopment Analysis (DEA) model to the Higher Education System. This system experiencing challenges arising from both internal as well as external factors. Therefore, Data Envelopment Analysis model is one of the advanced Operations Research techniques to evaluate the relative efficiency, technical efficiency and frontier analysis. The main objective of this paper is to use linear programming method in Data Envelopment Analysis (DEA) to examine the organizational effectiveness of Technical Institutes by evaluating the overall performance measure and put forward the non-performance of education system. Finally, numerical example is given to illustrate the proposed method.

Keywords: Data Envelopment Analysis, Relative Efficiency, Higher Education System.

1. Introduction

Now a day, Higher Education System (HES) plays an essential role for socio-economic development in any country since it deals with knowledge development, education and collaborative works with industrial sector. HES play a pivotal role in a society through education, research, and public service. This is a study about organizational effectiveness of Technical Institutes (TI) within public higher education institutions. In particular, this study focuses on how to measure the effectiveness of them by integrating competing conceptions of effectiveness. The purpose of this paper is to propose a methodology based on DEA that addresses to this issue of efficiency using data from the Technical Institutes affiliated to the Dr.B.A.M.University, Aurangabad. Kováts (2006) defines three different types of efficiencies: allocative, production and dynamic efficiency. *Allocative* or *economic efficiency* is the best possible utilization or distribution of the available limited resources for maximizing usefulness (consumer welfare). *Production* or *cost efficiency* defines the requirement that the ratio of the production factors should be optimal so that maximum output could be achieved with the given inputs. *Dynamic efficiency* refers to the prospective efficiency and determines innovation, the renewal and adaptation ability of the organizations (GVH, 2007).In the present paper, we study the production efficiency of the higher education systems and relate it to certain elements of the financing mechanism and socio-economic factors. Usually, technical institutions exhibit highly process oriented and a multistate holder situation leading to difficulty in aggregating the functional variables (inputs and outputs) for the evaluation of education quality.

The major advantages of DEA are:

- it can handle multiple input and multiple output models.
- 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.
- it does not require the functional relationship between inputs and outputs.

In this study, anattempt has been made to assess the efficiency of the institutes using various quality dimensions of education through application of DEA. This study seeks to measure the relative efficiency of 7 technical institutions affiliated to Dr.B.A.M.University.

2. Literature review

The higher education sector, however, has characteristics which makes it difficult to measure efficiency: it is non-profit making; there is an absence of output and input prices; and higher education institutions (HEIs) produce multiple outputs from multiple inputs. In 1978, Charnes, Cooper and Rhodes (CCR) described a mathematical programming formulation for the empirical evaluation of relative efficiency of a Decision Making Unit (DMU) on the basis of the observed quantities of inputs and outputs for a group of similar referent DMUs. Banker (1980) and Banker, Charnes and Cooper (1984) (BCC) provided a formal link between DEA and estimation of efficient production frontiers via constructs employed in production economics. Mahapatra and Khan (2007) have suggested a methodology to find out the factors responsible for quality improvement in education sector via neural network approach. Elangovan et al. (2007) have used an Executive Support System (ESS) approach for improving the quality and productivity in maintenance engineering model. 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 organization, both in manufacturing and service industries (Anatiliy, 2007; Parkan, 2006). Pacheco and Fernandes (2003) analyzed efficiency of 35 Brazilian domestic airports using DEA and suggested the best quality implementation strategy. 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. Ramanathan (2001) studied the effect of several non-discretionary input variables which are not under direct control of management on efficiency scores. 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. Lee (2004) had examined the relative performance or organizational effectiveness of research centers and institutes within publicly funded higher education set-ups based on the Competing Values Framework (CVF) as a theoretical foundation. The CVF encompasses four representative organizational effectiveness models viz., rational goal model, open system model, human relations model and internal process model. By employing DEA methodology, this study identified the ‘best practices’ exhibited by organizations on the efficient frontier and makes recommendations regarding how ‘best practices’ could be adopted by inefficient DMUs to become more efficient. Application of DEA in Indian educational set-up is extremely limited. However, a study focuses on integration of DEA and Knowledge Management (KM) methods for evaluating the efficiency of TES in India (Wadhwaet al., 2005).

3. Objectives of the study

It is evident that quality of education plays a vital role to gain an edge over its competitors and hence, efficiency of an institution must relate its performance to quality dimensions. As quality in TI characterizes multiin put and output system, its measurement through the efficiency score enables to provide not only an aggregate picture of performance of an institution in terms of quality education but also helps to reassesses its brand positioning in market-place. The relative efficiency calculated for a number of institutions helps to rank them based on their efficiency score.

4. Methodology

Data Envelopment Analysis is a linear programming procedure for a frontier analysis of inputs and outputs. DEA assigns a score of one to a unit only when comparisons with other relevant units do not provide evidence of inefficiency in the use of any input or output. DEA assigns an efficiency scoreless than one to (relatively) inefficient units. A score less than one gives a linear combination of other units from the sample could produce the same vector of outputs using a smaller vector of inputs. The score reflects the radial distance from the estimated production frontier to the DMU under consideration. The basic DEA model for ‘n’ DMUs with ‘m’ inputs and ‘s’ outputs proposed by CCR, the relative efficiency score of pth DMUs is given by

$$
\begin{aligned}
Max \quad Z_p &= \frac{\sum_{k=1}^{s} V_k Y_{kp}}{\sum_{j=1}^{m} U_j X_{jp}} \\
s.t. \quad & \frac{\sum_{k=1}^{s} V_k Y_{ki}}{\sum_{j=1}^{m} U_j X_{ji}} \le 1 \ \forall i \\
& V_k, U_j \ge 0 \quad \forall k, j
\end{aligned} \tag{1}
$$

where k = 1 to s (no. of outputs); j = 1 to m (no. of inputs); i = 1 to n (no.of DMUs); Y_{ki} = amount of output k produced by DMU i; X_{ji} = amount of input j utilized by DMU i; V_k = weight given to output k and U_j = weight given to input j.

The fractional programming shown in Equation (1) can be reduced to LPP as follows:

$$
\begin{aligned}
\text{Max } Z_P &= \sum_{k=1}^{s} V_k Y_{kp} \\
\text{s.t. } & \sum_{k=1}^{s} U_J X_{JP} = 1 \\
& \sum_{k=1}^{s} V_k Y_{ki} - \sum_{k=1}^{s} U_J X_{Ji} \le 0 \qquad \forall i \\
& V_k, U_J \ge 0 \quad \forall k, j
\end{aligned} \tag{2}
$$

This model is called CCR output oriented maximization DEA model. The efficiency score of ‘n’ DMUs is obtained by running the above LPP ‘n’ times.

5. Problem formulation

In this paper, we have taken 7 Technical institutes (Engineering Colleges) affiliated to Dr.B.A.M.University, Aurangabad. There is a mathematical approach to DEA that can be adopted which is illustrated using Linear Programming technique. In this model, we have used one input measure such as admitted student strength and two output measures, namely qualified students and students placed.

To compare these colleges and measures their performance a commonly used method is a ratio which takes output measure divides by input measure. In this case weanalyzes the effectiveness of colleges by taking these ratios.

DMU's	Students admmited	students qualified	Students placed	pass %	Placed %
	Input	Output 1	Output 2	Eff 1	Eff 2
DMU_1	620	460	318	74%	51%
DMU_2	560	466	376	83%	67%
DMU_3	420	296	262	70%	62%
DMU_4	740	571	466	77%	63%
DMU_5	590	473	465	80%	79%
DMU_6	542	300	260	55%	48%
DMU_7	360	250	160	69%	44%

The table above indicates that DMU_2 has the highest ratio of the passing percentage of students. Whereas DMU_5 has the highest ratio of students placed. As compare to these two colleges other colleges are not good. Now problem arise, when comparing these output ratios can give different picture and it is difficult to combine the entire set of ratios into a single numeric judgment. Therefore, these difficulties are solved by using DEA which interprets the ratios and provides the efficient frontier.

6. Results

We are interpreting two ratios for problems involving two outputs and a single input by using simple graphical analysis. This involves a plot of the two ratios for each college as shown in figure 1.

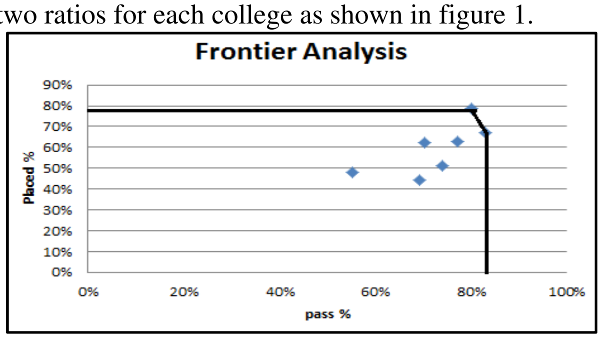

Figure 1: *Graphical Representation for Efficient Frontier*

The positions on the graph represented by DMU_2 and DMU_5demonstratealevel of performance which is superior to all other colleges. Mathematically the efficient frontier is the convex hull of the data. The efficient frontier, derived from the example of best practice contained in the data considered, represents a standard of performance that the colleges are not on the efficient frontier, they can try to achieve.InDEA the efficient frontier envelopes all the data is available. It can be seen that DMU_2 and DMU_5 have efficiencies of 100%.

To quantify the efficiency scores of the inefficient DMU's, consider DMU_3 and DMU_6 in figure 1. It is seen that, with respect to both of the ratios DMU_5 dominates both DMU_3 and DMU_6.

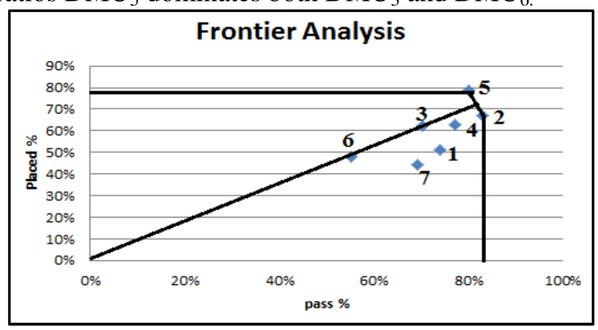

Figure 2: *Analysis of inefficient (DMU_3 and DMU_6) with respect to Efficient.*

The figure 2 shows that the point corresponding to students pass =79% and students placed =71% lies on the efficient frontier from the origin through the current position of DMU_3.This is the point where the line from the origin through DMU_3 meets the efficient frontier. In DEA the concept of the reference set can be used to identify best performing college with which compared a poorly performing college.

To evaluate the efficiency of DMU_3 such as

Maximize E_3

Subject to

$$E_1 = (460W_{pass} + 318W_{placed})/(620W_{intake})$$
$$E_2 = (466W_{pass} + 376W_{placed})/(560W_{intake})$$
$$E_3 = (296W_{pass} + 262W_{placed})/(420W_{intake})$$
$$E_4 = (571W_{pass} + 466W_{placed})/(740W_{intake})$$
$$E_5 = (473W_{pass} + 465W_{placed})/(590W_{intake})$$
$$E_6 = (300W_{pass} + 260W_{placed})/(542W_{intake})$$
$$E_7 = (250W_{pass} + 160W_{placed})/(360W_{intake})$$
$$0 \le E_i \le 1, \text{ i=1,2,…..7}$$
$$W_{pass} \ge 0$$
$$W_{placed} \ge 0$$
$$W_{intake} \ge 0$$

Where E_1 to E_7 is the efficiency of DMU_1 to DMU_7 respectively (expressed a fraction)

W_{pass} is the weight attached to number of students passed

W_{placed} is the weight attached to number of students placed

W_{intake} is the weight attached to number of students admitted

The above optimization problem is a nonlinear problem and hence difficult to solve numerically. In fact it can be converted into a Linear Programming problems.

- Algebraically substitute for all efficiency variables, to give an optimization problem expressed purely in terms of weights.
- Introduce an additional constraints setting the denominator of the objective function equal to one

Thus for DMU_3, the corresponding LPP is

$$Maximize \quad (296W_{pass} + 262W_{placed}) / 420W_{intake}$$

$$subject\ to$$

$$420W_{intake} = 1$$
$$0 \le (460W_{pass} + 318W_{placed}) \le 1$$
$$0 \le (466W_{pass} + 376W_{placed}) \le 1$$
$$0 \le (571W_{pass} + 466W_{placed}) \le 1$$
$$0 \le (473W_{pass} + 465W_{placed}) \le 1$$
$$0 \le (300W_{pass} + 260W_{placed}) \le 1$$
$$0 \le (250W_{pass} + 160W_{placed}) \le 1$$
$$W_{pass} \ge 0$$
$$W_{placed} \ge 0$$
$$W_{intake} \ge 0$$

The above is a linear program after rearrangement as follows

$$Maximize \quad (296W_{pass} + 262W_{placed})$$

$$subject\ to$$

$$420W_{intake} = 1$$
$$(460W_{pass} + 318W_{placed}) \le 1$$
$$(466W_{pass} + 376W_{placed}) \le 1$$
$$(571W_{pass} + 466W_{placed}) \le 1$$
$$(473W_{pass} + 465W_{placed}) \le 1$$
$$(300W_{pass} + 260W_{placed}) \le 1$$
$$(250W_{pass} + 160W_{placed}) \le 1$$
$$W_{pass} \ge 0$$
$$W_{placed} \ge 0$$
$$W_{intake} \ge 0$$

Once this LP has been solved to generate optimal values for the weights then the efficiency of the college being optimized, optimizing for, DMU_3 in this case,can be easily calculated using $E_3 = (296W_{pass}+262W_{placed})/(420W_{intake})$. Here that the numerator is known as the weighted output for DMU_3 and the denominator is known as the weighted input for DMU_3.This can be extended for all the other colleges to find out the respective efficiencies. The entire formulated linear Programming problems can be solved using solver and efficienciesresult shown as below.

DMU's	BCC score	CCR score	Scale efficiencies	RTS
DMU1	0.92	0.89	0.97	-1
DMU2	1.00	1.00	1.00	0
DMU3	1.00	0.86	0.86	1
DMU4	1.00	0.93	0.93	-1
DMU5	1.00	1.00	1.00	0
DMU6	0.69	0.67	0.98	1
DMU7	1.00	0.83	0.83	1

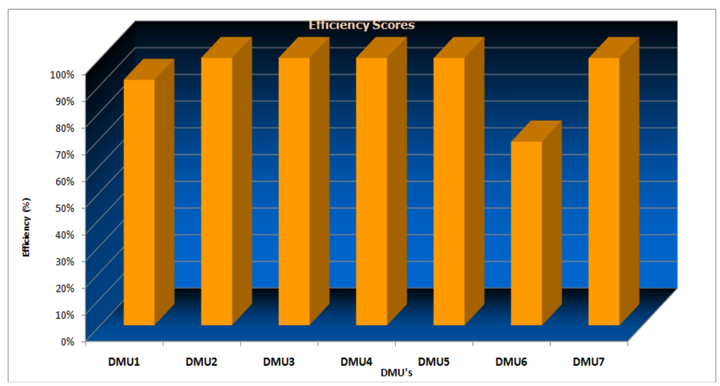

Figure 3: *BCC score efficiencies*

7. Conclusion

This paper is a contribution to current educational systems for assessing the effectiveness of educational institution. A sample of 7 Technical colleges affiliated to DR.B.A.M. University, Aurangabad was analyzed for effectiveness using DEA. The efficient frontiers were identified and the relative efficiency of the other colleges were established using graphical analysis initially and then the case was formulated as an Linear Programming Problems.We observed that, in the sample of seven technical collegesDMU1,DMU6 and DMU7gives 100% efficient and its returns scale increased, the DMU6 found poor efficient. This study provides scope for further research using multiple input and output measures to assess the effectiveness of non technical institutions.

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