Determining the Efficiency of Higher Education Institutions using Data Envelopment Analysis

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Abstract

Globalization, advancement due to technical development, and the increased financial running cost have increased the challenges that educational institutions face. The financial health of institutions can be measured using various ratio analysis tools like Liquidity ratio, Leverage ratio, Efficiency ratio, Profitability ratio, and Market Value ratio.

Cost efficiency helps to understand how well the income and funds that an institution receives have been utilized in the most effective manner. An institute is said to be technically efficient if it operates in the frontier and the associated slacks are zero (Debreu, 1951). The scale inefficiency helps in understanding if the institute is operating at increasing or decreasing returns to scale (Aly et. al, 1990). An institute is allocative efficient when the various factors of production reach a point where the marginal rate of technical substitution between the inputs equals the ratio of the corresponding input prices (Huang and Wang, 2002). The calculation of these efficiencies helps understand how well the institute functions. These efficiencies are calculated either in absolute or relative terms. The calculation in relative terms, help in benchmarking with other institution that have better efficiency, thus adopting the best practices that the institution follows.

Design / Methodology / Approach

This paper uses the non-parametric Data Envelopment Analysis (DEA) for determining the efficiency. The decision-making units (DMU) are the Higher Education Engineering and Technical institutes in Karnataka. The sample for the study has nine DMUs. The output-oriented cost efficiency, technical efficiency, scale

efficiency, and allocative efficiency are calculated. Two models, namely Overall Performance Model and Research Performance Model have been developed to calculate the various efficiencies.

Findings

The Overall Performance Model measures the various efficiencies of the institutions in terms of how efficient the inputs in terms of tuition fees, grants, and others, and total expenditure is utilized for running the institution. While Research Performance Model helps determine various efficiencies, that helps identify how well the research income and the various expenditure related to research have been effectively utilized for research.

Research Implications / Limitations

Identifying the various relative efficiencies helps to understand how the institution can learn from the best practices of other successfully running institutes. Also, it helps in framing policies that can help the institute run profitability and be more sustainable.

In the Overall Performance Model, the calculation of cost efficiency takes total income from tuition fees, grants, and others as input, while the output takes only the academic performance in terms of students placed, and successful outgoing students. This ignores the other outputs like research, skill enhancement, and others. The study is limited to technical education institutes in Karnataka where the data for input and output is available. The study could be extended to other institutions and wider scope in terms of region.

Keywords: Data Envelopment Analysis, Efficiency, Benchmarking

Introduction

Globalization, technological advancement, mushrooming of private institutions, the decline in grants and funds received from the government, rising financial costs in running institutions, and other factors have made running Higher Educational Institutes (HEIs) quite challenging. The need for continuous quality assurance, and, audits have become a norm for HEIs for it to function effectively and profitably. Cash flow statement analysis, Income statement analysis, Balance sheet analysis, and financial ratio analysis are a few of the ways to determine the financial health of an institution. The various financial ratios available include Liquidity ratio, Leverage ratio, efficiency ratio, profitability ratio, and market value ratio. The financial ratios help the institutions to track their performance and also make a comparative judgment regarding the institutions' performance (Chabotar, 1989).

The liquidity ratio shows how liquid the company is in meeting its short-term obligation by measuring the ratio of companies' cash and other current assets to the current debt. The liquidity ratio is measured through the current ratio, acid-test ratio, cash ratio, and operating cash flow ratio. Efficiency is the ability to produce the output or services with minimum resource level (Sherman, 1988). The efficiency ratio or Activity ratio measures how effectively the company has utilized its assets. Its usually measured through the Asset turn-over ratio, Inventory turn-over ratio, receivables turn-over ratio, and day sales in inventory ratio. The financial leverage ratio measures the institutions' ability to meet long-term debt obligations. This is measured through debt ratio, debt to equity ratio, interest coverage ratio, debt service coverage ratio, and debt service ratio. The profitability ratio covers the extent to which the institution has been able to make profits by the use of its capital. Gross margin ratio, Operating margin ratio, return on asset ratio, and return on equity ratio are a few ways of measuring the profitability ratio. With educational institutions going public and the availability of educational stock, the market value ratio help evaluate the current price of a publicly-held stock. Book value per share ratio, Dividend yield ratio, Earnings per share ratio, and Price-earnings ratio are a few of the ways to measure the Market Value ratio.

These financial ratios are absolute in terms and thus fail to reflect the good practices of other institutions. Data Envelopment Analysis (DEA) measures the relative efficiency. Thus, the best practices of other institutions are being analyzed. DEA analysis helps in analyzing the various types of efficiency namely technical efficiency, cost efficiency, scale efficiency, and allocative efficiency. DEA is one of the powerful tools that can be used for quality assurance in HEIs. According to the 2000 Carnegie classification, institutions are divided into – Doctoral/Research Universities, Master's college and Universities, Baccalaureate college, Associate's college, specialized institutions, and tribal colleges and universities (Shulman, L. S., 2001). In Indian perspective the doctoral, masters and graduation performs in a single university or institute.

This paper groups the Engineering and Technological Institute in Karnataka, India. The DEA analysis is conducted on the institutes to identify the cost efficiency, technical efficiency, and scale efficiency. The paper is set as follows, literature review followed by research methodology, followed by analysis and discussion, and finally by conclusion and scope for further studies.

Literature Review

There are various tools for quality assurance in HEIs like ranking, accreditation, league table, peer review, CIPP (Context, Input, Process, and Product), student-led evaluation, fourth-generation evaluation, and others. Data Envelopment Analysis (DEA) is one of the prominent tools used in efficiency calculation, which can be used as a quality assurance tool.

Bessent et. al (1983) evaluate the efficiency of occupational technical programs in a comprehensive community college. It demonstrates how DEA can be used in making managerial decisions for various tasks like improving programs, terminating programs, initiating new programs, or even discontinuing inefficient programs. Ranking, league table makes use of performance indicators which are aggregated by giving the weightage. But often giving value to these weights remains a challenge, especially where the market prices are not available. This challenge is being overcome by using DEA, as it uses linear programming techniques (Johnes and Johnes, 1993). Yorke (1997) clearly mentions the advantage DEA methodologies have over league tables. Cost Efficiency calculations help institutions justify their running costs and research incomes in the form of grants for their generated output in the form of number of successful leavers, number of higher degrees awarded, research publications and others (Athanassopoulos and Shale, 1997). The efficiency calculations help identify if the managerial decisions are justified or need to be changed. Efficiency calculation can be done using efficiency ratios, stochastic frontier analysis, and DEA (Robst, 2001). According to Shepherd (1953), the production and cost function are two different ways of examining the same production phenomenon. In service sectors, especially in the educational sector, it's quite difficult to model the production function, hence the duality between the production function and cost function makes it easy to empirically estimate cost function as its data are more readily available. The stochastic frontier analysis (SFA) being a parametric methodology, holds the assumption of normal distribution. But, in the service sector especially, education, the production process is largely unknown, hence using SFA requires additional assumptions which may lead to biased and inconsistent estimators. Also, the restriction of dependent variables to one makes DEA a preferred tool for efficiency calculation than SFA (Salerno, 2003). The efficiency studies in institutions can be done at any of the following three levels, namely Institution level, academic department, and non-academic or auxiliary department. But DEA studies also have their own limitation like not being able to capture the statistical noises. DEA doesn't allow hypothesis testing and assumes that every DMU operates under the same technology, which is not the condition in service sectors, especially education (Horne and Hu, 2008).

Research Methodology

Data Envelopment Analysis (DEA)

DEA is a non-parametric, linear programming frontier optimization, data-oriented approach which evaluates the performance of a collection of entities called decision-making units (DMU) were inputs are converted into outputs (Cooper, 2013). The DEA model was first introduced with the Constant Return to Scale (CRS) (Charnes et. al, 1979), which is normally used in calculating in manufacturing sectors. CRS assumption of Charnes at. al is appropriate when all DMUs are operating at an optimal scale. But, imperfect competition, govt regulation, constraints on finance and other factors may cause a DMU to not operate at optimal scale (Coelli et. al, 2005). Later this model was extended to Variable Return to Scale (VRS), which covers the service sector (Banker et. al, 1984). The CRS measures the technical efficiency, while VRS measures the pure technical efficiency. The Retention Scale Test (RTS) to determine if the underlying frontier is CRS or VRS. Compared to other parametric tools like Stochastic Frontier Analysis (SFA), and others, DEA has the merits of being able to handle multiple inputs and output simultaneously, being unit invariant, and being able to decompose the efficiency into various components. Unlike SFA, DEA need not specify restrictive functional forms (Coelli et. al, 2005). In fact, studies of benchmarking practice with DEA have identified sources of inefficiency, which otherwise were found to be efficient using other methods (Cooper et. al, 2007). DEA has a strong free disposability or monotonicity, where DMUs can freely dispose of the inputs. The convexity of DEA allows say, we have firms A, B feasible, then all the firms between A and B are also feasible. The No Free-Lunch axiom of DEA ensures that no output is possible unless some input is used. The DEA analysis can be either Input-Oriented or Output-Oriented. In Input-Oriented/ Input contraction the inputs are contracted without changing the outputs. While in output-oriented, the inputs are kept constant, while achieving maximum output. One pitfall for DEA would be its incapacity to capture the random noise or error component, which is captured in the statistical parametric analysis. In fact, DEA assumes that data are free of measurement error. The efficiency frontier or production frontier holds all the institutions referred to as DMUs that are efficient, that is Pareto Kopman efficient. Peer are real DMUs that are strongly efficient. Any other DMUs on the efficiency frontier are virtual DMUs. The DEA model can be either radial being the CRS and VRS model or non-radial. The various non-radial model includes the Additive model of Charnes et. al (1985), Russell measure of Fare & Knox Lovell (1978), Enhanced Russell graph measure of Pastor et. al (1999), Range adjusted measure of Cooper, Park & Pastor (1999), Stach based measure of Tone (1993), Geometric distance function of Portela & Thanassoulis (2005), Hyperbolic distance function of Fare, Grosskopft & Lovell (1985), Directional distance function of Chambers et. al (1996), and others. The radial slack is the radial contraction/expansion needed for the institution to be on the efficiency frontier. In other words, radial slack reflects the percentage of input reduction or output expansions necessary for the organization to become efficient.

Technical Efficiency (TE)

Farrell (1957) defines technical efficiency in terms of the radial reduction in inputs or the radial augmentation of outputs that is possible. Debeu (1951) states that an institution is technically efficient if it operates on the efficiency frontier and furthermore that all associated slacks are zero, that is the resources are fully utilized. Technical efficiency can be attributed to managerial efficiency because it is attributable to managerial expertise as management controls the inputs and outputs. Technical efficiency contains three components Mix Inefficiency, Pure Technical Efficiency (PTE), and Scale Efficiency (SE). Pure Technical efficiency is VRS efficiency which is attributable only to managerial performance devoid of scale effect. Mix Inefficiency is due to the wrong composition of inputs or outputs. Efficiency attributed only to managerial performance devoid of scale effect is referred to as PTE. VRS measure of efficiency measures the PTE. Input-oriented Radial Technical efficiency (θ) for input contraction reduces all the inputs and technology while maintaining the output constant. Output-Oriented Radial Technical efficiency (Φ) measures the efficiency while augmenting the outputs for the same level of inputs.

Output Oriented Technical efficiency (VRS) can be calculated as below

$$\Phi^* = \underset{\lambda j \Phi}{\text{Max}} \; \Phi$$

Subject to

$$\sum_{j=1}^{n} \lambda_j X_{ij} <= X_{i0} \quad ; \quad i=1,\ldots..m \quad \text{-------- Condition-1}$$

$$\sum_{j=1}^{n} \lambda_j Y_{rj} >= \Phi Y_{r0} \quad ; \quad i=1,\ldots..s \quad \text{-------- Condition-2}$$

$$\sum_{j=1}^{n} \lambda_j = 1 \quad ; \quad \lambda_j >=0; \quad j=1,\ldots\ldots..n \quad \text{-------- Condition-3}$$

Were, X – Input;

Y – Output;

j – No. of DMU's;

λ – weights

Cost Efficiency (CE)

Cost efficiency is referred to as Overall efficiency, using cost as input. Once the objective of a DMU is cost minimization, then a measure of cost efficiency is provided by the ratio of the minimum feasible costs to the actual costs (Farrell, 1957). It reflects the ability to produce the current outputs at the minimum costs, given the current price level at each DMU. Cost efficiency can be calculated as the product of pure technical efficiency, scale efficiency, and allocative efficiency. For a particular institute to be cost-efficient, the institute must be able to choose the right mix of inputs . That is the resources must be used in the right way (Fare et. al, 1985). The traditional Fare et. al (1994) cost efficiency DEA model assumes market perfection in inputs and their prices are the same across all the DMUs. That is it assumes factor inputs are homogeneous across firms, factor prices are exogenously given and factor prices are measured and known with full certainty. While Tone (2002) cost efficiency considers the heterogeneous nature of inputs, prices are not constant and are not exogenous but vary across firms. While measuring cost efficiency using isocost, it is defined as the distance from the minimum isocost to the DMU.

ISBN: 978-93-83302-64-2

Tone (2002) can be calculated as below

$$\min_{\lambda_j \; \bar{X}} \text{ Cost Efficiency} = \sum_{i=1}^{m} \bar{X}_{i0}$$

Subject to

$$\sum_{j=1}^{n} \lambda_j \bar{X}_{ij} \leq \bar{X}_{i0} \quad ; \quad i=1,.....m \qquad \text{-------- Condition-1}$$

$$\sum_{j=1}^{n} \lambda_j Y_{rj} \geq Y_{r0} \quad ; \quad i=1,.....s \qquad \text{-------- Condition-2}$$

$$\sum_{j=1}^{n} \lambda_j = 1 \quad ; \quad \lambda_j \geq 0; \quad j=1,........n \qquad \text{-------- Condition-3}$$

Were, $\bar{X}_{ij} = W_{ij} * X_{ij}$;

W_{ij} – Price of input i at DMUj

Allocative Efficiency (AE)

A firm is allocative efficient if it employs factors of production up to the point where the marginal rate of technical substitution between any of the inputs equals the ratio of corresponding input prices (Huang and Wang, 2002). Allocative efficiency reflects the distance between the actual and minimum cost at which an institution may secure its output once any technical inefficiency of the unit has been eliminated (Fare et. al, 1992). It can be calculated as the ratio of cost efficiency to technical efficiency.

Scale Efficiency (SE)

In frontier efficiency analysis, scale efficiency is derived from the ratio of the CRS and VRS measures of technical efficiency. If scale inefficiency exists (SE not equal to 1 or SE <1), the source of inefficiency makes it operate at either increasing or decreasing returns to scale (Aly et. al, 1990). Return to scale reflects the change in the proportion of the increase in output when there is an increase in input. Accordingly, increasing return to scale is when the output increases by a larger portion than the increase in input during the production process. Increasing returns to scale are often associated with start-ups or new institutions. Decreasing return to scale is when there is a less proportionate increase in output for the increase in output. Decreasing return to scale is often equated with a higher level of institutional bureaucracy. In scale inefficiency happens when the institution is not operating at CRS.

In our current study, we are analyzing the various efficiency of Engineering and Technological Institutions in Karnataka using Data Envelopment Analysis. Hence, the DMU for our study will be the individual Engineering and Technological Institution. In the study, two models are created for measuring efficiency.

MODEL-1: OVERALL PERFORMANCE MODEL: This model measures the overall output-oriented cost efficiency, technical efficiency, and scale efficiency. The inputs and output variables used for the DEA analysis in the overall performance model is in Table 1. This model measures cost efficiency by taking the income and expenditure incurred as input and the output is measured as the outgoing students and those being placed. The argument is how effectively the institution can use its input to cater to the needs of the outgoing students. Technical efficiency takes labor in the form of the number of teaching and non-teaching staff as input to cater to the needs of the outgoing students. The calculation of scale efficiency helps identify if inefficiency is due to inappropriate unit size.

MODEL-2: RESEARCH PERFORMANCE MODEL: This model measures the institutions' output-oriented cost efficiency, technical efficiency, and scale efficiency with respect to research. The input and output variable for the DEA analysis used in the Research performance model is shown in Table 1. The Research Performance Model helps to find how effective the institution has been, given their resource allocation decisions and the abilities of the students to achieve outcomes as graduates, especially in terms of research. Research Income in the form of grants can be taken as either input or output. The justification for it to be input is that grants received by the institution are spent on research assistance and other facilities. The justification for it to be output is that the value of the grant reflects the market value of the research being conducted (Johnes and Johnes, 1993). In the Research Performance Model, research income is considered as input.

The argument for including both income and expenditure as input variables is justified in the literature (Athanassopoulos and Shale, 1997). While calculating the cost efficiency the inputs being considered are general academic expenditure and research income.

Table 1

Input and Output variables of the DEA analysis in the Overall Performance Model and Research Performance Model.

MODEL	Efficiency calculated	Variables
Overall Performance Model	Cost efficiency	**Input -1**: Total Income **Input-2**: Total Expenditure **Output-1**: No. of outgoing students placed **Output-2**: No. of outgoing students
	Technical Efficiency Scale Efficiency	**Input-1**: Total No. of teaching and non-teaching staff **Output-1**: No. of outgoing students placed **Output-2**: No. of outgoing students
Research Performance Model	Cost Efficiency	**Input-1**: Research Income **Input-2**: Expenditure on library, computing services, and maintenance of infrastructure **Output-1**: No. of Publication & Patent **Output-2**: No. of students for the academic year
	Technical Efficiency Scale Efficiency	**Input-1**: Total full-time equivalent faculty recognized as a research guide **Input-2**: Total number of academic staff with Ph. D. **Output-1**: No. of Publication & Patent **Output-2**: No. of students for the academic year

ISBN: 978-93-83302-64-2

Since the DEA is a relative approach, outliners in data may alter the shape of the best practice frontier and distort the efficiency scores of institutions using similar input/output proportions (Salerno, 2003). To address this issue, it is essential that the institutions are grouped for analysis in the right manner. In our study, we take five variables as listed in Table 2 from the NAAC (National Assessment and Accreditation Council) data filed by the respective institutions. One institute is taken as the base institute. The K Distance of other institutes from the base institute is calculated using the variables 1-5 as coordinates. Thus, institutes are ranked based on the K distance from the base institute. This helps in grouping those institutes that resemble each other and avoids the issue of outliners.

Table 2

Variables used for grouping of Institutes

Variable Number	Variable Description (for the institute)
Variable-1	Total number of programs
Variable-2	Total number of students year-wise
Variable-3	Total number of outgoing students
Variable-4	Total expenditure
Variable-5	Total grants

The population for the study is the Engineering and Technological Institutions in Karnataka, India which have NAAC Accreditation. National Assessment and Accreditation Council (NAAC) is a quality assurance body that assesses and accredits Higher Education Institutions (Welcome to NAAC, 2023).

As per (Golany and Roll, 1989), the sufficient sample size or the No. of DMUs can be calculated as below

n>= 2(m+s).

were, n – Total no. of DMUs

m – Total no. of inputs

s - Total No. of outputs

In the current study, the total no. of inputs and outputs are two. Hence the DMU size must be greater than or equal to eight. Here, we have taken the sample size as nine.

The data for grouping of institutes as per Table 2 and input and output variables for the DEA analysis for both the models as per Table 1, are taken from the NAAC data submitted by the institution and the financial data available on the institution website.

Analysis & Discussion

The analysis for the study is done in various steps as discussed below.

Step 1: Grouping of institutions

The institutions are grouped as per the variable in Table 2 using K Distance (Euclidean distance). DMU-1 institution is taken as the base institution. For other institutions, Euclidean distance is calculated from the base Institute using the five variables as coordinates. This follows the Fixed Base calculation as shown in Figure 1 below.

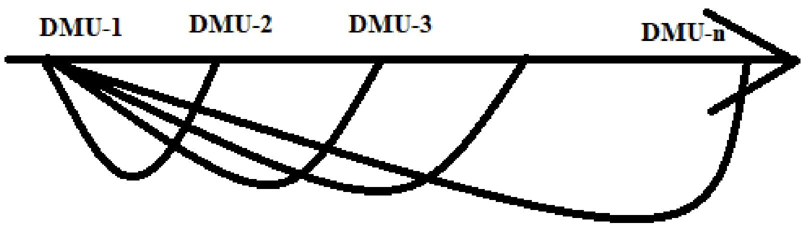

Figure-1: Fixed Base Calculation

Since the variables are of different scales and units, normalization of data needs to be done to ensure the data accuracy. Table 3 shows the ranking of all the DMUs as per the Euclidean distance.

Table 3

Grouping of Institution based on the Euclidean Distance (K Distance)

DMUs	Euclidean distance	Ranking as per the Euclidean distance
1	0	1
2	0.752672463	2
3	0.878498937	3
4	1.237167354	4
5	1.248221634	5
6	1.334995574	6
7	2.582269697	7
8	2.930688265	8
9	5.923815036	9

Step 2: Calculation of cost efficiency, technical efficiency, and scale efficiency for the Overall Performance Model

Table 4 depicts the values of the input and output variables used for the Overall Performance Model. All the efficiency calculation for the DMUs for the Overall Performance Model is shown in Table 5,6.

Figure – 2 plots the cost efficiency of the Overall Performance Model.

Figure – 3 plots the technical efficiency (CRS) of the Overall Performance Model.

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Figure - 4 Plots the pure technical efficiency (VRS) of the Overall Performance Model.

Table 4

Inputs and outputs for cost-efficiency, technical efficiency, and scale efficiency calculation for Overall Performance Model

DMU	Cost-efficiency Input-1	Cost efficiency Input-2	Technical efficiency Input-1	Output-1	Output-2
1	181813334	115611162	116	239	601
2	120302684	128605644	144	206	446
3	294667498	208584458	243	403	711
4	392078335	396507228	226	277	628
5	471420806	418865782	306	375	743
6	589038658	500769349	645	438	647
7	464889592	538336097	361	396	1243
8	851140374	603863278	435	895	1449
9	859301125	836964629	604	1286	1912

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Table 5

Calculation of Cost Efficiency, references, and targets for the DMUs for Overall Performance Model

DMU	***Cost Efficiency***	***References***	***Targets***
1	1.0000		
2	1.0000		
3	1.0000		
4	0.6022	DMU1 DMU7 DMU9 0.47381 0.37073 0.15546	Output-1: 460 Output-2: 1043
5	0.6449	DMU1 DMU9 0.5796 0.4204	Output-1: 680 Output-2: 1152
6	0.5384	DMU3 DMU9 0.53502 0.46498	Output-1: 814 Output-2: 1269
7	1.0000		
8	0.9736	DMU1 DMU9 0.32314 0.67686	Output-1: 948 Output-2: 1488
9	1.0000		
Mean	0.8621		

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Table 6:

Calculation of technical Efficiency, references, targets, and scale efficiency for the DMUs for the Overall Performance Model

DMU	Technical efficiency (CRS)	References (CRS)	Targets (CRS)	Pure Technical efficiency (VRS)	References (VRS)	Targets (VRS)	Scale efficiency
1	1.0000			1.0000			1.0000
2	0.6867	DMU1 DMU9 0.82827 0.07934	Output-1: 300 Output-2: 650	0.6888	DMU1 DMU9 0.94262 0.05738	Output-1: 299 Output-2: 676	0.9970
3	0.7859	DMU1 DMU9 0.57919 0.29108	Output-1: 513 Output-2: 905	0.7879	DMU1 DMU9 0.73975 0.26025	Output-1: 511 Output-2: 942	0.9975
4	0.5903	DMU1 DMU9 1.49075 0.08787	Output-1: 469 Output-2: 1064	0.7005	DMU1 DMU9 0.77459 0.22541	Output-1: 475 Output-2: 896	0.8426
5	0.5848	DMU1 DMU9 1.29087 0.25871	Output-1: 641 Output-2: 1270	0.6685	DMU1 DMU9 0.61066 0.38934	Output-1: 646 Output-2: 1111	0.8748
6	0.3189	DMU9 1.06788	Output-1: 1373 Output-2: 2041	0.3406	DMU9 1	Output-1: 1286 Output-2: 1912	0.9364
7	0.6646	DMU1 3.11207	Output-1: 744 Output-2: 1870	0.9871	DMU1 DMU9 0.49795 0.50205	Output-1: 765 Output-2: 1259	0.6732

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8	0.9705	DMU1 DMU9 0.49634 0.62488	Output-1: 922 Output-2: 1493	0.9938	DMU1 DMU9 0.34631 0.65369	Output-1: 923 Output-2: 1457	0.9765
9	1.0000			1.0000			1.0000
Mean	0.7335			0.7964			0.9220

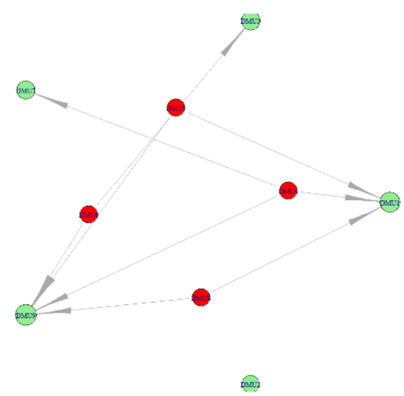

Figure – 2:
Cost efficiency plot of the Overall Performance Model

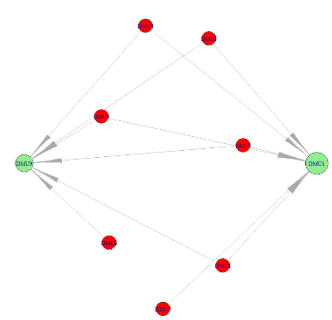

Figure – 3:
Technical efficiency (CRS) plot of the Overall Performance Model

ISBN: 978-93-83302-64-2

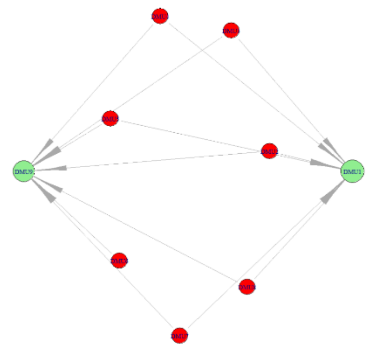

Figure – 4:

Pure Technical efficiency (VRS) plot of the Overall Performance Model

The average cost efficiency for the Overall Performance Model for the academic year was 86.20 %. DMUs 1,2,3,7,9 is cost-efficient as they lie in the cost-efficiency frontier. Only five DMUs (Institutions) are found to have unit scale efficiency score, meaning that they are cost-efficient. The DMU-6 is the least cost-efficient having a cost-efficiency of 53.83%. The reference DMUs for inefficient DMU-6 are DMU-3 and DMU-9. DMU-6 can become cost-efficient if it increases its output-1(No. of outgoing students placed) by 814 from 438 and output-2 (No. of outgoing students) by 1269 from 647, without increasing its input (total income and total expenditure). This is a radial movement and we are considering the radial DEA. The same can be analyzed about the references for inefficient DMUs 4,5, and 8. Table 5 gives the references for these DMUs and the target outputs they must achieve in order to be cost-efficient.

In total, out of 9 institutions, only 2 institutions (22.2%) were CRS technically efficient and VRS technically efficient. Under the VRS assumption, the average technical efficiency score (Pure Technical Efficiency) for the DMUs is 79.64%. This implies that on average DMUs could have used 20.23% fewer resources to produce the same amount of output. Under the CRS assumption, the average Technical Efficiency is found to be 86.21%, which is less than the average of Pure Technical Efficiency. These findings imply that on average the DMUs should contract their input by about 20.23% - 13.79% in order to operate efficiently. The average Scale Efficiency is 92.20% which means that on average the actual scale of production has diverged from the most productive scale size by 7.81%. DMUs 1 and 9 have Scale Efficiency as unity, which means they are operating at the most productive scale size (Constant Return to Scale). For DMUs 1 and 9, technical efficiency and pure technical efficiency will be the same. Table 6 gives the references for the DMUs and the target they must achieve in order to be efficient (either CRS or VRS).

Step 3: Calculation of cost efficiency, technical efficiency, and scale efficiency for the Research Performance Model

Table 7 depicts the values of the input and output variables used for the Overall Research Model.

The efficiency calculation for the DMUs for the Research Performance Model is shown in Table 8,9.

Figure – 5 plots the cost efficiency of the Research Performance Model.

Figure – 6 plots the technical efficiency (CRS) of the Research Performance Model.

Figure - 7 Plots the pure technical efficiency (VRS) of the Research Performance Model.

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Table 7

Inputs and outputs for cost-efficiency, technical efficiency, and scale efficiency calculation for the Research Performance Model

DMU	Cost-efficiency Input-1	Cost efficiency Input-2	Technical efficiency Input-1	Technical efficiency Input-2	Output-1	Output-2
1	3100000	23122232	20	23	62	2056
2	3971000	32930000	8	26	70	1529
3	12925200	84837000	18	20	103	2656
4	6687000	65013000	63	77	191	3038
5	2405000	79525500	21	42	71	2826
6	2171000	48456000	0	56	37	2515
7	1780400	111711000	52	71	91	4634
8	7610000	57339000	70	96	336	5304
9	71675000	242252600	53	118	134	6866

ISBN: 978-93-83302-64-2

Table 8

Calculation of Cost Efficiency, references, and targets for the DMUs for the Research Performance Model

DMU	Cost Efficiency	References	Targets
1	1.0000		
2	0.5909	DMU1 DMU7 DMU8 0.76493 0.03245 0.20262	output-1: 118 output-2: 2797
3	0.4888	DMU8 DMU9 0.91703 0.08297	output-1: 319 output-2: 5433
4	0.6449	DMU1 DMU7 DMU8 0.01225 0.14885 0.83890	output-1: 296 output-2: 5164
5	0.8062	DMU1 DMU7 DMU8 0.34556 0.62552 0.02892	output-1: 88 output-2: 3762
6	1.0000		
7	1.0000		
8	1.0000		
9	1.0000		
Mean	0.8368		

ISBN: 978-93-83302-64-2

Table 9

Calculation of technical Efficiency, references, targets, and scale efficiency for the DMUs for the Research Performance Model

DMU	Technical efficiency (CRS)	References (CRS)	Targets (CRS)	Pure Technical efficiency (VRS)	References (VRS)	Targets (VRS)	Scale efficiency
1	0.6885	DMU3 DMU6 1.11111 0.01389	output-1: 115 output-2: 2986	0.7383	DMU3 DMU9 0.96939 0.03061	output-1: 103 output-2: 2784	0.9326
2	1.0000			1.0000			1.0000
3	1.0000			1.0000			1.0000
4	0.5156	DMU2 DMU3 0.40909 3.31818	output-1: 370 output-2: 9438	0.6877	DMU3 DMU8 0.25 0.75	output-1: 278 output-2: 4642	0.7498
5	0.7178	DMU3 DMU6 1.16667 0.33333	output-1: 132 output-2: 3937	0.8473	DMU3 DMU6 DMU9 0.67593 0.15741 0.16667	output-1:98 output-2: 3335	0.8472
6	1.0000			1.0000			1.0000
7	0.5606	DMU3 DMU6 2.88889 0.23611	output-1: 306 output-2: 8266	0.9561	DMU3 DMU9 0.47959 0.52041	output-1:119 output-2: 4846	0.5863
8	0.7881	DMU2 DMU3 1.06494 3.41558	output-1: 426 output-2: 10700	1.0000			0.7881
9	0.6555	DMU3 DMU6 2.94444 1.05556	output-1: 342 output-2: 10475	1.0000			0.6555
	0.7696			0.9144			0.8399

ISBN: 978-93-83302-64-2

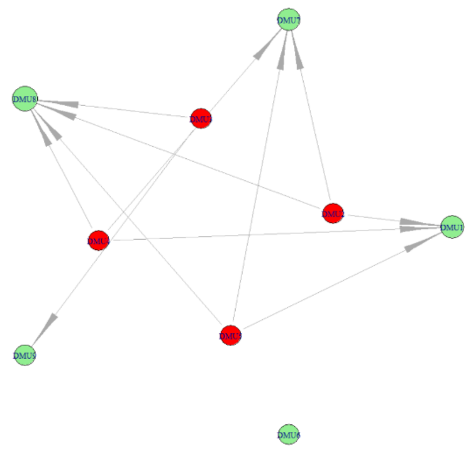

Figure – 5:
Cost efficiency plot of the Research Performance Model

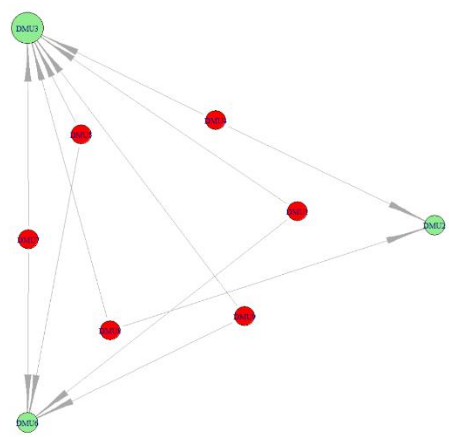

Figure – 6:
Technical efficiency (CRS) plot of the Research Performance Model

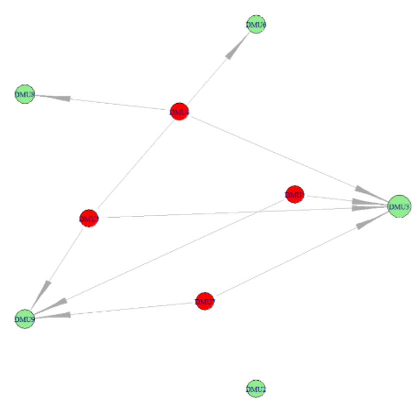

Figure – 7:
Pure Technical efficiency (VRS) plot of the Research Performance Model

ISBN: 978-93-83302-64-2

The average cost efficiency for the Research Performance Model for the academic year was 83.68 %. DMUs 1,6,7,8,9 is cost-efficient as they lie in the cost-efficiency curve. The DMU-3 is the least cost-efficient having a cost-efficiency of 48.88%. The reference DMUs for inefficient DMU-3 are DMU-8 and DMU-9. DMU-3 can become cost-efficient if it increases its output-1(Publication and Patent details) by 319 from 103 and output-2 (No. of students for the academic year) by 5433 from 2656, without increasing its input (Research income and expenditure on library, computing services, and maintenance of infrastructure). The same can be inferred about inefficient DMUs 2, 4, and 5. Table 8 gives the references for these DMUs and the target outputs they must achieve in order to be cost-efficient.

In total, out of 9 institutions, only 3 institutions (33.3%) were CRS technically efficient. While 5 institutions (55.56%) out of 9, were VRS technically efficient. Under the VRS assumption, the average technical efficiency score (Pure Technical Efficiency) for the DMUs is 91.43%. This implies that on average DMUs could have used 8.57% fewer resources to produce the same amount of output. Under the CRS assumption, the average Technical Efficiency is found to be 76.95%, which is less than the average of Pure Technical Efficiency. These findings imply that on average the DMUs should contract their input by about 8.57% - 23.05% in order to operate efficiently. The average Scale Efficiency is 83.99% which means that on average the actual scale of production has diverged from the most productive scale size by 16.01%. DMUs 2,3 and 6 have Scale Efficiency as unity, which means they are operating at the most productive scale size (Constant Return to Scale). For DMUs 2,3, and 6 the technical efficiency and pure technical efficiency are the same. DMU-4 is the least technically efficient both in CRS and VRS. It can become efficient by increasing its output keeping the inputs constant. This would require managerial decisions to be taken. Table 9 gives the references for the DMUs and the target they must achieve in order to be efficient (either CRS or VRS).

Conclusion & Scope for Further Studies

DEA study for efficiency is a non-parametric linear programming tool, which helps to decompose the efficiency into various components like cost efficiency, technical efficiency, and scale efficiency. Technical efficiency helps to identify what managerial decisions need to be taken to make it more effective. Cost efficiency helps to determine how effectively the institution is running with its limited cost. Even though educational institutions are non-profitable, the tough competition makes institutions minimize the cost and run profitably. The scale efficiency helps identify if the institution is running at constant, decreasing, or increasing return to scale. In fact, in the long run, competitive firms or institutions adjust their scale to the point that they are operating at a constant return to scale. However, the service sector is usually assumed to be operating at a Variable return to scale.

In the present study, performance indicators like the number of outgoing students and the number of outgoing students placed have been used as output for the DEA analysis. This ignores the fact that the placement and the degree may be due to the high entry qualification rather than the effectiveness of teaching. For the Research Performance Model, taking the number of publications poses a problem as academicians who try to publish articles in low-impact journals, may have a good number of publications, but the quality and the contribution to research will be minimal. This is not being captured in the efficiency study (Avkiran, 2001).

In the Overall Performance Model, it's assumed that the income of the institution is being spent on the salary of teaching and non-teaching staff. The infrastructure count is not taken into consideration and hence the income and expenditure are void of infrastructure maintenance and enhancement. In the Research Performance Model, the infrastructure count is not taken into consideration.

The present study is limited to technical and engineering institutions in Karnataka, India, that are NAAC accredited and have financial data. But this study can be extended to further geographical areas considering the macro factors also.

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