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ORIGINAL ARTICLE

Performance assessment of higher educational institutions in India using data envelopment analysis and re-evaluation of NIRF Rankings

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Abstract In general, each country continuously focuses on improving the performance of the education system. Our study provides suggestions regarding the improvement by taking the data in the Indian context using data envelopment analysis (DEA). To the best of our knowledge, our paper is the first study which is using the National Institutional Ranking Framework (NIRF) data. In this study, we consider 61 educational institutions of India to rank them according to their performances. The ranking is done on the basis of the efficiency scores of the institutions. To rank the efficient institutions super-efficiency DEA model is applied. Finally, some suggestions and concluding remarks are given for inefficient institutions to make them efficient.

Keywords Performance analysis · DEA · Efficiency · Ranking methods · Education sector efficiencies · Super-efficiency

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1 Introduction

Education and research play a significant role in the progress of any Nation. After The United States of America and China, India has the third-largest higher education system in the world. Currently, In India there are more than 700-degree granting institutions and 35,500 affiliated colleges with 20 million students. Among these institutions, which one is the best? This can be the question of intense debate. Data envelopment analysis (DEA) can answer this question in an imposing manner. DEA is a data-driven technique that is used to measure the performance of decision making units (DMUs). DMUs are those entities which utilize multiple inputs to produce multiple outputs. Examples include the performance assessment problems of educational institutions, hospitals, libraries, banks, transport sector, airlines, telecom companies etc. (Cooper et al. (2000)), which have earlier been reported by Bhattacharyya et al. (1997), Arya and Yadav (2018), Puri and Yadav (2013) and Nigam et al. (2012).

To measure the performances of DMUs, there are several parametric approaches like stochastic frontier and non-parametric approaches like Free Disposal Hull (FDH) and DEA are available in literature. DEA is a methodology that is most suitable for assessing the achievements of non-profitable organizations because for them, performance signals such as profitability and income do not work convincingly. Numerous approaches for evaluating different efficiency measures such as technical efficiency measure, pure technical efficiency measure, scale efficiency measure, cost efficiency measure, revenue efficiency measure, profit efficiency measure, mix efficiency measure, etc. have been developed in DEA.

There are many studies done on academic institutions. Johnes ([2006](#)) studied the odds of measuring efficiency of higher educational institutions. In this study, he applied DEA to measure the performance of over 100 higher educational institutions in England by using the data for the year 2000–01. Sinuany-Stern et al. ([1994](#)) examined the relative performance of 21 departments of Ben-Gurion University, Israel. Arcelus and Coleman ([1997](#)) considered the academic units of the University of New Brunswick, Canada. Bessent et al. ([1982](#)) analyzed the performance of community college in the USA. Tomkins and Green ([1988](#)) examined the complete performance of accounting departments of the U.K. University with input as staff number and output as student numbers. Kantabutra and Tang ([2010](#)) evaluated the performance of Thai Universities using non-parametric approach DEA. In this study, two efficiency models, the research efficiency model and the teaching efficiency model, are considered. Eckles ([2010](#)) applied the DEA model developed for National Universities to 93 National liberal arts colleges. Special attention is paid in this study, to the construction of cost per undergraduate as an input variable. It is found that 18 institutes are efficient, and 75 are inefficient. In their study, Chen and Chen ([2011](#)) mentioned the quality of Taiwanese Universities is decreasing continuously in recent years. In this study they tried to improve the performance of universities by reducing the majority of cost expenditure. Türkan and Özel ([2017](#)) analyzed the productivity of the State Universities in Turkey with the help of DEA, and the universities are ranked according to their efficiencies using a super-efficiency model. Yang et al. ([2018](#)) evaluated the performance and evolution of 64 Chinese research universities for 2010–2013 through a two-stage DEA model. They proposed several policies and suggestions to improve the performance of these universities. In studies, it is found that the efficiency scores are sensitive to the choice of the approach. In the present study, we aim to evaluate the performance of top Indian educational institutions through DEA and to analyze the results.

In recent years, to examine the performance of educational institutions many studies have been done (Bowrey and Clements [2020](#); Bornmann et al. [2020](#); Singh and Pant [2017](#); Visbal-Cadavid et al. [2017](#)). In 2015, The Ministry of Human Resource Development, launched and approved The National Institutional Ranking Framework (NIRF) to outline an approach to rank educational institutions in India. The MHRD setup a Core Committee to analyze the general parameters which can be essential in ranking of educational institutions. The committee recommended some important parameters as, "Learning, Teaching, and Resources," "Graduation Outcomes," "Inclusivity and Outreach ," "Research and Professional Practices," and "Perception." On the basis of overall recommendations of the committee a method is proposed to rank the educational institutions. In this study, we applied DEA to the data provided by NIRF and analyzed the results.

The rest of the paper is organized as follows: DEA methodology and some DEA models are described in Sect. 2. In Sect. 3, data variables and input and output variables with their relevance to the study is discussed, respectively. The Isotonicity test is conducted in Sect. 4. Section 5 is devoted to the performance assessment of educational institutions. Performance improvement technique and input-output targets are discussed in Sect. 6. Finally, some concluding remarks are given in Sect. 7.

2 Methodology

We apply two basic DEA models in this study first one is the CCR model, and the second one is the BCC model.

2.1 The CCR model

In 1978, Charnes, Cooper, and Rhodes introduced first DEA model and it is often called the CCR DEA model, which is a generalization of Farrell's ([1957](#)) technical efficiency measure.

Let us assume that the performance of a set of n DMUs $(DMU_j; j = 1, 2, 3, \ldots, n)$ is to be evaluated such that each DMU uses m inputs $(i = 1, 2, 3, \ldots, m)$ and produces s outputs $(r = 1, 2, 3, \ldots, s)$. Then the efficiency score of the kth DMU can be defined with the help of the following CCR DEA model:

Model 1

$$Max\, E_k = \frac{\sum_{r=1}^{s} v_{rk}\, y_{rk}}{\sum_{i=1}^{m} u_{ik}\, x_{ik}} \tag{1}$$

subject to,

$$0 \leq \frac{\sum_{r=1}^{s} v_{rk}\, y_{rj}}{\sum_{i=1}^{m} u_{ik}\, x_{ij}} \leq 1 \qquad \forall j = 1, 2, 3, \ldots, n;$$

$$u_{ik}, v_{rk}, y_{rj}, x_{ij} \geq 0 \qquad \forall i, r, j.$$

where y_{rj} is the amount of the rth output produced by the jth DMU; x_{ij} is the amount of the ith input used by the jth DMU; u_{ik} and v_{rk} are the weights corresponding to the ith input and rth output respectively. DMU_k is said to be CCR efficient if $E_k = 1$, otherwise CCR in-efficient. CCR model can be found in two froms: Input-Oriented and Output-Oriented CCR Model. These two forms of CCR Model are shown as follows (Table 1):

Table 1 CCR models

Output maximization multiplier model (Model 2)	Input minimization multiplier model (Model 3)
Max $E_k = \sum_{r=1}^{s} v_{rk} y_{rk}$;	Min $E_k = \sum_{i=1}^{m} u_{ik} x_{ik}$;
subject to, $\sum_{i=1}^{m} u_{ik} x_{ik} = 1$;	subject to, $\sum_{r=1}^{s} v_{rk} y_{rk} = 1$;
$\sum_{r=1}^{s} v_{rk} y_{rj} - \sum_{i=1}^{m} u_{ik} x_{ij} \leq 1$;	$-\sum_{r=1}^{s} v_{rk} y_{rj} + \sum_{i=1}^{m} u_{ik} x_{ij} \geq 1$;
$u_{ik} \geq 0, v_{rk} \geq 0$.	$u_{ik} \geq 0, v_{rk} \geq 0$.
Input oriented CCR model (Model 4)	Output oriented CCR model (Model 5)
Min θ_k	Max η_k
subject to $x_k \theta_k - \sum_{i=1}^{m} x_{ij} \lambda_{jk} \geq 0$	subject to, $\sum_{i=1}^{m} x_{ij} \lambda_{jk} \leq x_k$
$\sum_{r=1}^{s} y_{rj} \lambda_{jk} \geq y_k$	subject to, $\eta_k y_k - \sum_{r=1}^{s} y_{rj} \lambda_{jk} \leq 0$
$\lambda_{jk} \geq 0, \theta_k$ is unrestricted.	$\lambda_{jk} \geq 0, \eta_k$ is unrestricted.

2.2 The BCC model

Banker et al. (1984) extended the CCR model known as the BCC (Banker, Charnes, and Cooper) model, by adding the convexity constraint, which represents returns to scale (RTS). The BCC model calculates the PTE of each DMU. The BCC model is given as follows:

For $k = 1, 2, 3, \ldots, n$ we have

$$Min \ \theta_k \qquad (2)$$

subject to,

$$\sum_{j=1}^{n} y_{rj} \lambda_{jk} - s_{rk}^{+} = y_{rk} \quad \forall r = 1, 2, 3, \ldots, s;$$

$$\sum_{j=1}^{n} x_{ij} \lambda_{jk} + s_{ik}^{-} = \theta_k x_{ik} \quad \forall i = 1, 2, 3, \ldots, m;$$

$$\sum_{j=1}^{n} \lambda_{jk} = 1;$$

$\lambda_{jk} \geq 0 \quad \forall j = 1, 2, 3, \ldots, n; \ \theta_k$ is unrestricted in sign;
$s_{rk}^{+} \geq 0 \quad \forall r = 1, 2, 3, \ldots, s; \ s_{ik}^{-} \geq 0 \quad \forall i = 1, 2, 3, \ldots, m.$

The CCR and the BCC models work under constant returns to scale (CRS) and variable returns to scale (VRS), respectively.

CRS indicates that when we increase all the inputs by a factor of g, it leads to a g-fold increment in all the outputs as well.

VRS indicates that when we increase all the inputs by a factor of g, it leads to an h-fold ($g \neq h$) increment in all the outputs.

If $h \leq g$, then it is called decreasing returns to scale (DRS)

If $h \geq g$, then it is called increasing returns of scale (IRS)

The efficiency score under CRS is known as *overall technical efficiency (OTE)* or simply *technical efficiency (TE)* score. A DMU is said to be *CCR-efficient* if $\eta_k^* = 1$ and corresponding slacks are zero in Model 5.

Efficiency score under VRS is known as *pure technical efficiency (PTE)* score. The PTE score reflects the managerial performance to organize the inputs in the production process. A DMU is said to be *BCC efficient* if $\theta_k^* = 1$ and corresponding slacks are zero in the BCC model.

The appropriate size of a DMU reflects the *scale efficiency (SE)*. It is defined as follows:

$$The \ SE \ of \ k\text{th} \ DMU = \frac{The \ OTE \ of \ k\text{th} \ DMU}{The \ PTE \ of \ k\text{th} \ DMU} \qquad (3)$$

$$or, The \ SE \ of \ k\text{th} \ DMU$$
$$= \frac{The \ CCR \ efficiency \ score \ of \ k\text{th} \ DMU}{The \ BCC \ efficiency \ score \ of \ k\text{th} \ DMU} \qquad (4)$$

The peer count for an efficient DMU_k is the number of inefficient DMUs that became efficient with the help of DMU_k. The peer count of an inefficient DMU is 0.

3 Data and variables

In the present work, we have considered 61 top educational institutions (established before the year 1980) of India as DMUs. The data has been collected from the website of NIRF (2018). Since the data has been collected from the Indian Govt. website , there is no necessity to cross-check the data. We have two types of variables in our study,

(a) Output variables,
(b) Input variables.

The detailed explanation of the variables is given in the follwing sub-section.

3.1 Selection of input and output variables

The selection of input and output variables is totally depends on the decision-maker. In the education sector, there is a great fluctuation in the opinions of decision-makers. Some decision-makers may consider A as input while some other may consider A as output. In DEA, an input variables set used for evaluating the performance of DMUs in the field of education is always picked apart due to its conductive nature. In our present study, we evaluate the performance of different institutions. We define input and output variables for each department as follows:

Input variables (NIRF 2018): We have considered two input variables for our study. Each input and the reason why it is a correct choice for input is explained below:

(i) *Student-Faculty ratio*: For any institute, it is necessary that the student-faculty ratio should not be very high. According to the World Report and the U.S. News, it is beneficial to attend the smaller schools for better participation in classes. If you are in a large class where there are hundreds of students then it will be difficult for the professor to notice every student. So the choice of student-faculty ratio as an input in our study is quite relevant to our study. Breu and Raab (1994), Colbert et al. (2000) and Ray and Jeon 2008 also used faculty to student ratio as input variable in their study.

(ii) *Financial resources*: Funds are needed for any institution to run its activities smoothly. The choice of financial resources is quite relevant to our study because every institute needs some money to perform activities like salary to the staff, to pay the electricity bill, water supply bill and many other activities. Allocation of financial support depends upon the number of research papers published in journals and conference proceedings, the number of students enrolled in each program. Arcelus and Coleman (1997), Abbott and Doucouliagos (2009), and Tyagi et al. (2009) also treated financial resources as input variable in their study.

Output variables (NIRF 2018): For our study, we have considered four output variables as Number of students who got the placement or went for higher studies, Number of publications, Patent details, and Perception. The choice of output variable totally depends on decision-maker. But the choices of output variables must be appropriate. The following shows the relevance of the output variables taken.

(i) *Growth Index*: According to Blessinger (2017) one aim of education (at any level) is to teach students models, theories, and principles that have been developed over time through research and scholarships, in order for the students to develop higher levels of critical and creative thinking. In each institute, there are two types of students one who prefers placements after completion of courses of study and others who want to go for higher studies. By considering these two choices of students, we have constructed an index, called growth index. In this index, we have considered both kinds of students and we have weighted them equally because this is an individuals' choice either he wants placement or want to go for higher study. Tyagi et al. (2009) also used this type of index in their research. The growth index is defined as, *Growth Index (G.I.) = The number of placed students + The number of students went for higher studies.*

(ii) *Publicatons*: The research is an important work of any institute. The choice of publications as an output variable is quite relevant to our study because higher the publications of any institution will mimic the involvement of that institution in research. Thursby (2000) and Kao and Hung (2008) also used publications as an output variable in their studies.

(iii) *Patent details*: An intellectual property that entitles its holder to a limited time in making, selling, and using inventions for a limited period is called a patent. This average period is usually 20 years. Copyrights are honored by the exchange of public disclosure of the composer. At each institute, students work in their own labs and do specific activities for social welfare. It can easily be assumed that if any institution has a high number of patents then that institution is doing well in the field of most important inventions. Therefore the selection of copyright data as output variants is appropriate in our study.

(iv) *Perception*: This is a very interesting output variable which we are going to consider in this study. NIRF has given some marks to each institute according to the following factors:

1. Peer Perception: Employers and Research Investors (PREMP): PREMP is done through an online survey. In a time-bound fashion, the survey is conducted over a large category of Officials of Funding agencies in

Govt., Professionals from Reputed Organizations, Employers and Research Investors, NGOs, private sectors, etc.

2. Peer Perception: Academics (PRACD): PRACD is done with the help of a survey conducted over a large category of academics to confirm their choice for graduates of various educational institutions.

3. Public Perception (PRPUB): In response to advertisements, online data is collected from the general public. Based on collected data, PRPUB is done. PRPUB confirms the choice of the general public for choosing institutions for their friends and wards.

4. Competitiveness (PRCMP): By counting the number of PG and Ph.D. students admitted to top institutions in the previous year, PRCMP is calculated.

When an institution performs well, public opinion for that institute will be positive and the opinion creates a perception for that institution. So the choice of perception as an output variable is quite relevant to our study because the perception for any institution depends on its performance.

4 The isotonicity test

Isotonicity test is based on the fact that with every increase in input, the output should not decrease i.e., the correlation coefficient between each input and output should be positive (Golany and Roll 1989). The correlation coefficients of all inputs-outputs for the years 2016–17 and 2017–18 are given in Table 2. Since all correlation coefficients are positive, the isotonicity test is passed.

5 Performance analysis for input and output based assessment

The TE, PTE, and SE scores are calculated for 61 Indian educational institutions for the years 2016–17 and 2017–18. The results are shown in Tables 3 and 4. The output-oriented DEA model is applied to evaluate the performances of educational institutions. There is not found any general significant pattern of distribution of efficiency scores for all the institutions.

5.1 TE estimates

The TE or OTE score is evaluated under CRS. With the help of the TE score, we can know the reason of the inefficiencies of the institutions. The score is affected by two factors.

(i) Configuration of input and output,
(ii) Size of operations.

The TE score tells us that which institute is on the efficiency frontier and which is not. If TE score for any institution is 1, then it is called relatively efficient with respect to other institutions and lies on the efficiency frontier. If the TE score is less than 1 for any institution, then it is called relatively inefficient and lies below the efficiency frontier. From Table 3 , it is clear that DMUs D_3, D_4, D_5, D_{13}, D_{21}, D_{43}, D_{55}, D_{57}, D_{58} and D_{61} are technically efficient and form the CRS efficiency frontier for the year 2016–17 as they have TE score 1. Table 4 says that DMUs D_1, D_3, D_{10}, D_{19}, D_{23}, D_{25}, D_{42} and D_{55} are efficient in the year 2017–18. DMUs D_3 and D_{55} are the DMUs which are efficient for both the years. These institutions are the best examples for all the remaining inefficient institutions. We can call them as the 'global leaders' for inefficient institutions. The DMUs D_{13} and D_{19} have the highest peer count in the years 2016–17 and 2017–18 respectively. The higher peer count represents the robustness of the DMU with respect to other DMUs. So, the institutions with highest peer counts are role models for all other

Table 2 Correlation coefficient matrices for the years 2016–17 and 2017–18

	2016–17						2017–18					
	x_1	x_2	y_1	y_2	y_3	y_4		x_1	x_2	y_1	y_2	y_3	y_4
x_1	1						x_1	1					
x_2	0.13	1					x_2	0.13	1				
y_1	0.19	0.46	1				y_1	0.2	0.49	1			
y_2	0.004	0.52	0.39	1			y_2	0.001	0.27	0.15	1		
y_3	4.18	0.24	2.7	0.67	1		y_3	0.0001	0.30	0.0002	0.32	1	
y_4	0.03	0.31	0.32	0.43	0.35		y_4	0.0001	0.36	0.006	0.39	0.87	1

x_1 = Student-faculty ratio, x_2 = Financial resources, y_1 = growth Index, y_2 = Publications, y_3 = Patent details, y_4 = Perception

Table 3 Efficiency scores, RTS, Peer Count, and Ranks for the year 2016–17

Code	Year → Institute Name (DMU)	City	TE	PTE	2016–17 SE	RTS	Sup-Eff	PC	Rank
D_1	Indian Institute of Science	Bengaluru	0.915	1	0.915	DRS	0.915	0	**12**
D_2	IIT Madras	Chennai	0.983	1	0.983	IRS	0.983	0	**11**
D_3	IIT Bombay	Mumbai	1	1	1	CRS	2.0144	15	**1**
D_4	IIT Delhi	Delhi	1	1	1	CRS	1.1819	15	**8**
D_5	IIT Kharagpur	Kharagpur	1	1	1	CRS	1.1187	12	**9**
D_6	Jawaharlal Nehru University	New Delhi	0.455	0.491	0.925	IRS	0.455	0	**45**
D_7	IIT Kanpur	Kanpur	0.748	0.758	0.986	IRS	0.748	0	**18**
D_8	IIT Roorkee	Roorkee	0.824	0.842	0.978	IRS	0.824	0	**16**
D_9	Banaras Hindu University	Varanasi	0.742	0.872	0.852	DRS	0.742	0	**20**
D_{10}	Anna University	Chennai	0.894	1	0.894	DRS	0.894	0	**14**
D_{11}	University of Hyderabad	Hyderabad	0.732	0.795	0.921	IRS	0.7317	0	**21**
D_{12}	IIT Guwahati	Guwahati	0.593	0.612	0.97	IRS	0.593	0	**33**
D_{13}	Jadhavpur University	Kolkata	1	1	1	CRS	1.6047	37	**3**
D_{14}	University of Delhi	Delhi	0.54	0.77	0.701	DRS	0.54	0	**38**
D_{15}	Savitribai Phule Pune University	Pune	0.299	0.314	0.95	DRS	0.299	0	**55**
D_{16}	Aligarh Muslim University	Aligarh	0.361	0.431	0.837	DRS	0.361	0	**52**
D_{17}	Manipal Acad. of Higher Edu.	Manipal	0.931	0.97	0.941	IRS	0.913	0	**13**
D_{18}	Jamia Millia Islamia	New Delhi	0.649	0.702	0.923	IRS	0.6486	0	**30**
D_{19}	Calcutta University	Kolkata	0.683	0.782	0.873	DRS	0.683	0	**26**
D_{20}	King George's Med. University	Lucknow	0.141	0.208	0.675	DRS	0.141	0	**61**
D_{21}	Vellore Inst. of Technology	Vellore	1	1	1	CRS	1.4878	20	**6**
D_{22}	Birla Inst. of Tech. and science	Pilani	0.692	0.738	0.938	IRS	0.692	0	**24**
D_{23}	IIT(ISM) Dhanbad	Dhanbad	0.386	0.39	0.988	DRS	0.3856	0	**50**
D_{24}	University of Madras	Chennai	0.673	1	0.673	IRS	0.6732	0	**28**
D_{25}	Institute of Chemical technology	Mumbai	0.46	0.467	0.986	IRS	0.461	0	**44**
D_{26}	NIT Tiruchirapalli	Tiruchirapalli	0.503	0.51	0.985	DRS	0.5026	0	**41**
D_{27}	Punjab University	Chandigarh	0.399	0.469	0.85	DRS	0.3986	0	**48**
D_{28}	IIM Calcutta	Kolkata	0.371	0.505	0.734	IRS	0.3706	0	**51**
D_{29}	Andhra University	Vishakhapattanam	0.592	0.726	0.815	DRS	0.5915	0	**34**
D_{30}	NIT Rourkela	Rourkela	0.613	0.617	0.994	IRS	0.6129	0	**32**
D_{31}	IIES and Tech., Shibpur	Howrah	0.589	0.59	0.999	CRS	0.5894	0	**36**
D_{32}	Osmania University	Hyderabad	0.678	0.678	1	CRS	0.6779	0	**27**
D_{33}	Tezpur University	Tezpur	0.349	0.375	0.931	IRS	0.3489	0	**53**
D_{34}	Kerala University	Tiru. puram	0.317	0.319	0.992	IRS	0.3166	0	**54**
D_{35}	Visva Bharati	Kolkata	0.73	0.734	0.994	IRS	0.7295	0	**22**
D_{36}	Tata Inst. of Social Science	Mumbai	0.669	0.672	0.995	IRS	0.6692	0	**29**
D_{37}	Thapar inst. of Engg. and Tech.	Patiyala	0.59	0.595	0.992	IRS	0.5898	0	**35**
D_{38}	GB Pant Uni. of Aggr. and Tech.	Pant Nagar	0.47	0.807	0.583	IRS	0.4704	0	**43**
D_{39}	NIT Surathkal	Surathkal	0.526	0.531	0.99	IRS	0.5261	0	**39**
D_{40}	Punjab Aggricultural Uni.	Ludhiyana	0.402	0.724	0.556	IRS	0.4024	0	**47**
D_{41}	Gauhati University	Guwahati	0.159	0.162	0.979	DRS	0.1589	0	**59**
D_{42}	PSG College of Technology	Coimbatore	0.864	0.961	0.898	DRS	0.8637	0	**15**
D_{43}	Birla Inst. of Technology	Ranchi	1	1	1	CRS	1.2438	6	**7**
D_{44}	University of Kashmir	Srinagar	0.239	0.28	0.854	IRS	0.2388	0	**57**
D_{45}	Sri Venkateswara University	Trirupati	0.476	0.481	0.989	IRS	0.4759	0	**42**
D_{46}	CCS Haryana Aggr. uni.	Hisar	0.398	1	0.398	IRS	0.3983	0	**49**
D_{47}	University of Jammu	Jammu Tawi	0.203	0.227	0.895	IRS	0.2034	0	**58**

Table 3 continued

Code	Institute Name (DMU)	City	TE	PTE	SE	RTS	Sup-Eff	PC	Rank
					2016–17				
D_{48}	NIT Warangal	Warangal	0.442	0.442	1	CRS	0.4423	0	**46**
D_{49}	Madurai Kamraj university	Madurai	0.811	1	0.811	IRS	0.8114	0	**17**
D_{50}	KL Edu. Fondation and Uni.	Veddeswaram	0.743	0.749	0.992	DRS	0.743	0	**19**
D_{51}	KLE Acad of High. edu. and Res	Belagavi	0.299	0.362	0.824	DRS	0.2985	0	**56**
D_{52}	Uni. of Aggr. Sciences	Dharwad	0.511	0.743	0.688	IRS	0.5114	0	**40**
D_{53}	Guru Nanak dev Uni.	Amritsar	0.588	0.59	0.997	DRS	0.5882	0	**37**
D_{54}	North Eastern Hill Uni.	Shillong	0.143	0.146	0.978	IRS	0.1428	0	**60**
D_{55}	Dayalbagh edu. Inst.	Agra	1	1	1	CRS	1.5378	15	**4**
D_{56}	Banasthali Vidyapeeth	Banasthali	0.691	0.7	0.987	DRS	0.6912	0	**25**
D_{57}	Bharti Vidyapeeth	Pune	1	1	1	CRS	1.7768	3	**2**
D_{58}	Thiagarajar College of Engg.	Madurai	1	1	1	CRS	1.0329	1	**10**
D_{59}	College of Engg.	Pune	0.646	0.646	1	CRS	0.641	0	**31**
D_{60}	Cochin Uni. of Sci. and Tech.	Cochin	0.712	0.758	0.94	IRS	0.7124	0	**23**
D_{61}	Delhi Technical Uni.	Delhi	1	1	1	CRS	1.4933	10	**5**
		Mean	**0.6296**	**0.6925**	**0.9164**				

TE = Technical efficiency score, PTE = Pure technical efficiency score, SE = Scale efficiency score, RTS = Returns to scale, Sup-Eff = Super-efficiency score, PC = Peer count

institutions. The institutions D_1, D_2, D_3, D_4, D_5, D_7, D_8, D_9, D_{10}, D_{13}, D_{19}, D_{21}, D_{24}, D_{42}, D_{55}, D_{56}, D_{58}, D_{60} and D_{61} have TE scores above average for both the years. So, their performances can be considered relatively satisfactory from the other institutions which score below average. The institutions D_{12}, D_{14}, D_{15}, D_{20}, D_{27}, D_{28}, D_{30}, D_{31}, D_{33}, D_{34}, D_{37}, D_{38}, D_{39}, D_{40}, D_{41}, D_{44}, D_{45}, D_{46}, D_{47}, D_{48}, D_{52}, D_{53} and D_{54} have TE score below average for both the years. So, their performance can be considered very poor in this period.

5.2 PTE estimates

The PTE score is evaluated under VRS. The BCC model is used to determine PTE score. The reason for using BCC model is that by this we can understand whether inefficiency in any institution is due to unfavorable size or inefficient use of resources. The PTE is a measure which tells us that how efficiently the DMU converts its multiple inputs into outputs. The results of PTE are shown in Tables 3 and 4. It is easy to see that many institutions which have low CRS scores have better PTE scores. In comparison with CCR model more number of institutions have PTE scores 1. Out of 61 institutions, 9 institutions D_1, D_2, D_3, D_{10}, D_{21}, D_{46}, D_{49}, D_{55} and D_{58} are pure technically efficient and form VRS frontier for both years. The institutions D_1, D_2, D_3, D_4, D_5, D_7, D_8, D_9, D_{10}, D_{11}, D_{13}, D_{17}, D_{19}, D_{21}, D_{23}, D_{42}, D_{46}, D_{55}, D_{58}, D_{60} and D_{61} have PTE score above average for both the years means they are

utilizing their resources effectively for both the years. The institutions D_{12}, D_{15}, D_{20}, D_{27}, D_{28}, D_{30}, D_{32}, D_{33}, D_{34}, D_{36}, D_{37}, D_{39}, D_{41}, D_{44}, D_{47}, D_{48}, D_{51}, D_{53}, D_{54} and D_{59} have PTE scores below average for both the years which means they are not using their resources effectively. These institutions must utilize their resources wisely so that they can achieve higher efficiency scores.

5.3 SE estimates

TE can be decomposed into two components;

(i) PTE
(ii) SE

The first component of PTE is obtained by estimating the frontier under VRS. It is called pure technical efficiency because it is an evaluation of technical efficiency without scale efficiency. Thus, we can understand that PTE is used to evaluate the managerial performance of any DMU. The ratio of TE to PTE is called the scale efficiency (SE). Thus, SE represents the expertise of the management that how effectively it uses its resources. For our study, we can say that SE provides us the idea to decide the size of the institution. If the SE score is 1 for any department, then we can say that the institute is operating at optimal scale size and there is no antagonistic impact of scale size on the institution's efficiency. If the SE score is below 1, then the institute size is not perfect. It is either too big or too small. Tables 3 and 4 shows that the institutions D_3 and D_{55} have

Table 4 Efficiency scores, RTS, Peer Count and Ranks for the year 2017–18

| | Year → | | | | 2017–18 | | | | |
Code	Institute Name (DMU)	City	TE	PTE	SE	RTS	Sup-Eff	PC	Rank
D_1	Indian Institute of Science	Bengaluru	1	1	1	CRS	4.95	30	**1**
D_2	IIT Madras	Chennai	0.864	1	0.864	DRS	0.86	0	**12**
D_3	IIT Bombay	Mumbai	1	1	1	CRS	1.20	3	**6**
D_4	IIT Delhi	Delhi	0.554	0.65	0.853	DRS	0.55	0	**24**
D_5	IIT Kharagpur	Kharagpur	0.652	0.678	0.963	DRS	0.65	0	**17**
D_6	Jawaharlal Nehru University	New Delhi	0.639	0.915	0.699	IRS	0.64	0	**20**
D_7	IIT Kanpur	Kanpur	0.915	0.921	0.993	DRS	0.91	0	**10**
D_8	IIT Roorkee	Roorkee	0.576	0.612	0.941	IRS	0.58	0	**22**
D_9	Banaras Hindu University	Varanasi	0.88	0.896	0.982	DRS	0.88	0	**11**
D_{10}	Anna University	Chennai	1	1	1	CRS	1.12	11	**7**
D_{11}	University of Hyderabad	Hyderabad	0.396	0.759	0.522	IRS	0.40	0	**40**
D_{12}	IIT Guwahati	Guwahati	0.403	0.435	0.927	IRS	0.40	0	**39**
D_{13}	Jadhavpur University	Kolkata	0.782	0.786	0.996	DRS	0.78	0	**13**
D_{14}	University of Delhi	Delhi	0.377	0.53	0.711	DRS	0.38	0	**41**
D_{15}	Savitribai Phule Pune University	Pune	0.42	0.444	0.947	IRS	0.42	0	**36**
D_{16}	Aligarh Muslim University	Aligarh	0.726	0.729	0.995	IRS	0.73	0	**15**
D_{17}	Manipal Acad. of Higher Edu.	Manipal	0.453	0.806	0.562	DRS	0.45	0	**31**
D_{18}	Jamia Millia Islamia	New Delhi	0.483	0.502	0.962	IRS	0.48	0	**28**
D_{19}	Calcutta University	Kolkata	1	1	1	CRS	1.63	43	**4**
D_{20}	King George's Med. University	Lucknow	0.055	0.102	0.545	DRS	0.06	0	**61**
D_{21}	Vellore Inst. of Technology	Vellore	0.77	1	0.77	DRS	0.77	0	**14**
D_{22}	Birla Inst. of Tech. and science	Pilani	0.438	0.457	0.959	DRS	044	0	**34**
D_{23}	IIT(ISM) Dhanbad	Dhanbad	1	1	1	CRS	4.64	34	**2**
D_{24}	University of Madras	Chennai	0.548	0.694	0.79	IRS	0.55	0	**25**
D_{25}	Institute of Chemical technology	Mumbai	1	1	1	CRS	2.05	6	**3**
D_{26}	NIT Tiruchirapalli	Tiruchirapalli	0.705	0.708	0.995	DRS	0.70	0	**16**
D_{27}	Punjab University	Chandigarh	0.258	0.343	0.752	DRS	0.26	0	**50**
D_{28}	IIM Calcutta	Kolkata	0.353	0.353	0.999	CRS	0.35	0	**45**
D_{29}	Andhra University	Vishakhapattanam	0.57	0.586	0.973	IRS	0.57	0	**23**
D_{30}	NIT Rourkela	Rourkela	0.451	0.469	0.961	DRS	0.45	0	**32**
D_{31}	IIES and Tech., Shibpur	Howrah	0.4181	0.465	0.899	0.42	IRS	0	**37**
D_{32}	Osmania University	Hyderabad	0.485	0.541	0.897	DRS	0.49	0	**27**
D_{33}	Tezpur University	Tezpur	0.421	0.507	0.831	IRS	0.42	0	**35**
D_{34}	Kerala University	Tiru. puram	0.295	0.491	0.601	IRS	0.30	0	**47**
D_{35}	Visva Bharati	Kolkata	0.454	0.465	0.977	IRS	0.45	0	**30**
D_{36}	Tata Inst. of Social Science	Mumbai	0.376	0.508	0.742	IRS	0.38	0	**42**
D_{37}	Thapar inst. of Engg. and Tech.	Patiyala	0.357	0.364	0.981	IRS	0.36	0	**43**
D_{38}	GB Pant Uni. of Aggr. and Tech.	Pant Nagar	0.285	0.447	0.638	IRS	0.29	0	**48**
D_{39}	NIT Surathkal	Surathkal	0.409	0.412	0.992	IRS	0.41	0	**38**
D_{40}	Punjab Aggricultural Uni.	Ludhiyana	0.264	0.313	0.846	IRS	0.26	0	**49**
D_{41}	Gauhati University	Guwahati	0.13	0.134	0.975	IRS	0.13	0	**46**
D_{42}	PSG College of Technology	Coimbatore	1	1	1	CRS	1.01	1	**8**
D_{43}	Birla Inst. of Technology	Ranchi	0.356	0.357	0.996	DRS	0.36	0	**44**
D_{44}	University of Kashmir	Srinagar	0.255	0.257	0.992	DRS	0.26	0	**51**
D_{45}	Sri Venkateswara University	Trirupati	0.229	0.232	0.987	DRS	0.23	0	**55**
D_{46}	CCS Haryana Aggr. uni.	Hisar	0.24	1	0.24	IRS	0.24	0	**54**
D_{47}	University of Jammu	Jammu Tawi	0.095	0.097	0.981	IRS	0.10	0	**58**

Table 4 continued

Code	Institute Name (DMU)	City	TE	PTE	SE	RTS	Sup-Eff	PC	Rank
	Year →				2017–18				
D_{48}	NIT Warangal	Warangal	0.254	0.262	0.968	DRS	0.25	0	**52**
D_{49}	Madurai Kamraj university	Madurai	0.529	1	0.529	IRS	0.53	10	**26**
D_{50}	KL Edu. Fondation and Uni.	Veddeswaram	0.445	0.47	0.947	DRS	0.44	0	**33**
D_{51}	KLE Acad of High. edu. and Res	Belagavi	0.905	0.103	0.921	DRS	0.09	0	**59**
D_{52}	Uni. of Aggr. Sciences	Dharwad	0.312	0.43	0.726	IRS	0.31	0	**46**
D_{53}	Guru Nanak dev Uni.	Amritsar	0.127	0.207	0.616	DRS	0.13	0	**57**
D_{54}	North Eastern Hill Uni.	Shillong	0.07	0.07	0.999	CRS	0.07	0	**61**
D_{55}	Dayalbagh edu. Inst.	Agra	1	1	1	CRS	1.30	27	**5**
D_{56}	Banasthali Vidyapeeth	Banasthali	0.643	0.719	0.895	DRS	0.64	0	**19**
D_{57}	Bharti Vidyapeeth	Pune	0.242	0.453	0.535	DRS	0.24	0	**53**
D_{58}	Thiagarajar College of Engg.	Madurai	0.946	1	0.946	IRS	0.95	0	**9**
D_{59}	College of Engg.	Pune	0.48	0.493	0.973	DRS	0.48	0	**29**
D_{60}	Cochin Uni. of Sci. and Tech.	Cochin	0.6	0.969	0.619	IRS	0.60	0	**21**
D_{61}	Delhi Technical Uni.	Delhi	0.647	0.701	0.922	DRS	0.65	0	**18**
		Mean	**0.5201**	**0.6039**	**0.8661**				

TE = Technical efficiency score, PTE = Pure technical efficiency score, SE = Scale efficiency score, RTS = Returns to scale, Sup-Eff = Super-efficiency score, PC = Peer count

SE scores 1 for both years. Hence these institutes are operating at optimal scale size for both the years. All other institutes are not able to maintain good scores consistently.

5.4 Returns to scale (RTS)

The RTS depict whether the size of a DMU is too large or too small. Tables 3 and 4 show the institutions operating under CRS, IRS and DRS. If any institute is operating at IRS or DRS, then the efficiency of these institutes can be increased by adjusting their sizes. If any institute is operating at CRS, its efficiency cannot be improved because it is utilizing its resources efficiently. Tables 3 and 4 show that in the year 2016–17, the institutions D_2, D_6, D_7, D_8, D_{11}, D_{12}, D_{17}, D_{18}, D_{22}, D_{24}, D_{25}, D_{28}

5.5 Ranking

In DEA, the DMU with efficiency score 1 is called the efficient DMU. To rank all those DMUs which have efficiency 1, we can apply any super-efficiency technique available in literature. Andersen and Petersen (1993), Du et al. (2010), and Noura et al. (2011) proposed super-efficiency models in their studies. In this study, we apply the super-efficiency model proposed by Andersen and Petersen (1993). We have shown rankings of DMUs in Tables 3 and 4. The ranking is done according to the efficiency scores of DMUs.

5.6 Descriptive statistics of efficiency scores

The descriptive statistics of TE, PTE, and SE scores are shown in Table 5. From this table, we find that out of 61 institutions 51 and 53 are technical inefficient in the year 2016–17 and 2017–18 respectively. In the year 2016–17, the average TE (ATE) score of all institutions is 0.6296, i.e., 62.96%. The TE score has a range between 0.141 and 1. The average technical inefficiency (ATI) is 37.04%. While in the year 2017–18, the ATE score of all institutions is 0.5201, i.e., 52.01%. The TE score has a range between 0.055 and 1. ATI is 47.99%.

Table 5 indicates that the average PTE (APTE) scores for all institutions are 0.6925 and 0.6039 for the years 2016–17 and 2017–18 respectively. In the year 2016–17, the PTE score varies between 0.146 and 1. The average pure technical inefficiency (APTI) is 30.75%. It means that 30.75% of APTI out of 37.04% of ATI is due to inappropriate management of institutes in utilizing resources. The remaining part of ATI is due to the fact that the institutions are not operating at their optimal size. While in the year 2017–18, the PTE score has the range between 0.07 and 1. APTI is 39.61%. It means that 39.61% of APTI out of 47.99% of ATI is due to inappropriate management of institutes in utilizing resources. The remaining part of ATI is due to the fact that the institutions are not operating at their optimal size.

Table 5 Descriptive Statistics of TE, PTE, and SE Scores for all 61 Institutions

Years →	2016–17			2017–18		
Descriptive statistics	TE	PTE	SE	TE	PTE	SE
NI	61	61	61	61	61	61
NEIs	10	16	13	8	13	8
NIIs	51	45	48	53	48	53
Average	0.6296	0.6925	0.9106	0.5201	0.6039	0.8661
SD	0.2557	0.2588	0.1295	0.2795	0.2909	0.1718
Min	0.141	0.146	0.398	0.055	0.07	0.24
Q_1	0.442	0.491	0.873	0.055	0.43	0.77
M	0.646	0.726	0.978	0.453	0.53	0.947
Q_3	0.141	1	0.995	0.705	0.915	992
Max	1	1	1	1	1	1
(AI %)	37.04	30.75	8.94	47.99	39.61	13.39

NI = Number of institutions, *NEIs* = Number of efficient institutions, *NIIs* = Number of inefficient institutions, *SD* = Standard deviation, *AI* = Average inefficiency = $((1 - AE) \times 100)$, *ATI* = Average technical inefficiency, *ASI* = Average scale inefficiency, *APTI* = Average pure technical inefficiency; *ATE* = Average technical efficiency, *Max* = Maximum, *Min* = Minimum, Q_1 = First quartile, *M* = Median, Q_3 = Third quartile

The average scale efficiency (ASE) scores are 0.9106 and 0.8661 for all institutions in the years 2016–17 and 2017–18 respectively. In the year 2016–17, the SE score ranges between 0.398 and 1. The average scale inefficiency (ASI) score is 8.94%. While in the year 2017–18, the SE score of all institutions ranges between 0.24 and 1. The ASI score is 13.39%.

6 Efficiency improvements for inefficient DMUs

In DEA, there are mainly two ways to make inefficient DMU_k as efficient DMU.

(i) *Input reduction*: Reduce inputs of DMU_k while maintaining the levels of outputs of DMU_k.
(ii) *Output augmentation*: Increase outputs of DMU_k while maintaining the levels of inputs of DMU_k.

Percentage change in outputs and inputs can be calculated as follows:

%*age change in s*th *output of* DMU_k

$$= \frac{Change \ in \ sth \ output \ of \ DMU_k}{Actual \ sth \ output \ of \ DMU_k} \times 100$$

%*age change in m*th *intput of* DMU_k

$$= \frac{Change \ in \ mth \ input \ of \ DMU_k}{Actual \ mth \ input \ of \ DMU_k} \times 100$$

where change in the *m*th input of DMU_k = Actual *m*th input of DMU_k –Target of the *m*th input of DMU_k; change in the *s*th output of DMU_k = Target of the *s*th output of DMU_k –Actual *s*th output of DMU_k.

In the present study, output-oriented DEA model is applied. The average increase in outputs which is needed for inefficient DMUs to become efficient is given in Table 6 for the years 2016–17 and 2017–18 as follows:

7 Conclusions

This paper evaluates the performance efficiencies of educational institutions in India with the help of DEA. The main objective of our study is to analyze the year-wise performances of Indian educational institutions. In this study, we have considered 61 institutions and calculated TE, PTE, and SE scores for these institutions for the years 2016–17 and 2017–18. We have used 2 inputs (Student-faculty ratio, financial resources,) and 4 outputs (Growth index, Publications, Patent details, Perception) for our study.

The DEA results indicate that only 10 institutions in the year 2016–17 and 8 in the year 2017–18 are found to be technically efficient. To rank the technically efficient institutions, we applied the super-efficiency technique. Consequently, the institutions are ranked (see Tables 4 and 5). Finally, our study gives the following concluding remarks and suggestions which policymakers can use to improve the performance efficiencies of the institutions.

(i) In the year 2016–17, all 61 institutions on average are 30.75% managerial inefficient and 8.94% scale inefficient. While in the year 2017–18, all 61 institutions are 39.61% managerial inefficient and 13.39% scale inefficient. Thus, more efforts

Table 6 Average (%age) increase in outputs for the years 2016–17 and 2017–18

Years →	2016–17	2017–18
Average increase in y_1 in (%)	14.308	0
Average increase in y_2 in (%)	16.059	5.373
Average increase in y_3 in (%)	73.764	157.855
Average increase in y_4 in (%)	55.832	77.310
Average increase in all outputs (%)	**39.991**	**60.1345**

should be made to improve managerial efficiency of all institutions as compared to scale efficiency in both the years.

(ii) Output target summary is shown in Table 6. In the year 2016–17, the outputs 1, 2, 3 and 4 of inefficient institutions should be increased by the amount 14.308%, 16.059%, 73.764% and 55.832% respectively to make them efficient. While in the year 2017–18, the outputs y_1, y_2, y_3 and y_4 of inefficient institutions should be increased by the amount 0%, 5.373%, 157.855% and 77.310% respectively to make them efficient.

(iii) The efficient institutions form efficiency frontier and known as best performing institutions. In the year 2016–17; D_3, D_4, D_5, D_{13}, D_{21}, D_{43}, D_{55}, D_{57}, D_{58} and D_{61} while in the year 2017–18; D_1, D_3, D_{10}, D_{19}, D_{23}, D_{25}, D_{42} and D_{55} are efficient in the year 2017-18. DMUs D_3 and D_{55} are the efficient institutions.

(iv) On the basis of TE score, it can be seen that the DMU D_3 and D_1 are the best performing institutions for the years 2016–17 and 2017–18 respectively while D_{20} is the worst performing institution for both the years.

(v) On the basis of peer count D_{13} in 2016–17 and D_{19} in 2017–18 are highly robust institutions.

We can develop fuzzy DEA models to deal with the uncertainty present in data in real-life situations in future work.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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