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International Journal of Education Economics and Development

ISSN online: 1759-5681 - ISSN print: 1759-5673
https://www.inderscience.com/ijeed

Does PhD enrolment improve the research efficiency of educational institutes? A comparative assessment of Indian universities using data envelopment analysis

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DOI: 10.1504/IJEED.2023.10043402

Article History:
Received: 17 June 2021
Accepted: 19 October 2021
Published online: 03 April 2023

Does PhD enrolment improve the research efficiency of educational institutes? A comparative assessment of Indian universities using data envelopment analysis

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Abstract: Today, there is an increased focus on research in Indian universities. The objective of this paper is to determine the research efficiency of the universities and the effects of PhD enrolments on the same. The study uses the National Institutional Ranking Framework (NIRF) data. Two models were used to analyse and compare the research efficiency of universities. The results indicate, to increase the efficiency, the output from the PhD scholars needs to be improved. The results imply that some universities have a high count of PhD students, but their contribution to research is insignificant, resulting in poor research efficiency scores in Model 2. This study concludes that proper policy needs to be framed for minimum research outputs as part of PhD programs. Public and private universities in India should monitor the number of PhD scholars and their output.

Keywords: higher education; Indian universities; research efficiency; data envelopment analysis; DEA; NIRF.

Reference to this paper should be made as follows: Malik, S., Bharti, N. and Gupta, V. (2023) 'Does PhD enrolment improve the research efficiency of educational institutes? A comparative assessment of Indian universities using data envelopment analysis', *Int. J. Education Economics and Development*, Vol. 14, No. 2, pp.173–190.

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1 Introduction

The quality of higher education in any country determines its growth and development. Higher Education Institutes (HEI's) have an essential role in the overall growth of a nation because they are a source of higher education and research. The All India Survey of Higher Education, released by the Ministry of Human Resource Development (MHRD) of the Government of India, indicated that the total number of universities are increasing at very fast rate. In 2017–18, there were 903 universities, 39,050 colleges and 10,011 stand-alone institutions listed which grew to 993 universities, 39,931 colleges and 10,725 stand-alone institutions in 2018–2019. The data also suggests that in the year 2018–2019, there were 385 universities that were privately managed and 394 universities that were located in rural areas. The number of universities have increased by 10% in last in a year (Ministry of Human Resource Development, 2019). The growing number of institutions raises a concern about the quality of education too. Out of the 993 universities, only 385 are privately managed; the rest are supported by the government.

Reports from the MHRD indicate that the number of students enrolling in universities is increasing at a very fast rate. Total enrolment in higher education has been estimated to be 37.4 million, but the maximum enrolment (~80%) happens at undergraduate level. Interestingly, only 2.5% colleges offer PhD programmes. Only 0.5% of the total enrolment exists at the doctoral level (Ministry of Human Resource Development, 2019) At the PhD level, most enrollments are in the streams of science, engineering and technology. Doctoral students are expected to increase the research outcome of universities. Increasing the research outcome is one of the desired outcomes of the higher education system of any country. Looking at the huge investment and growing number of institutions and further, the growing concerns for maintaining quality standards in these institutions, the MHRD came up with a common framework called the NIRF in 2015. In order to enhance the quality of an institution, everyone has to maintain a desired standard of knowledge and a constant urge to effectively utilise its resources.

Nowadays, universities are facing cutthroat competition for government grants. A total grant of more than eleven thousand crore was released to academic institutions during 2018–2019. The data revealed that out of the total grants, 57.18% is allocated to central universities, 18.55% to the institutions under central universities, 4.00% to state universities and 4.48% to institutions deemed to be universities. There is an increasing pressure of improving efficiency and to achieve this, the efficient utilisation of resources must be considered. The main goal is to distribute resources to achieve the institution's

objectives and maximise the output with minimum resources. For this purpose, an overview of the universities' productivity is important for the allocation and use of financial and human resources. In this context, it was important to look at the efficiency of Indian universities who have performed well in the NIRF 2018–2019. This paper analyses the research efficiency of the top 40 universities in the NIRF 2018–2019 in two different models, i.e., with and without PhD enrolment, and see whether it actually contributes to the research efficiency or not.

2 Status of higher education in Indian universities

India is known for its quality education in the past. Since the Vedic period, the Indian education system was acknowledged for its quality. In the present context, it is one of the largest systems in the world in terms of the number of institutions. The Indian university system originated in the British Colonial era (Chaudhary, 2010). It is important to note that there has been multi-fold increase in the total number of academic institutions in India. At the time of Independence, the total number of universities was only 20, which reached 1,047 at the end of 2018–2019 Table 1.

Table 1 Status of universities and colleges in India

Year	*Universities*	*Colleges*
1947–48	20	500
1950–51	28	578
1960–61	45	1819
1970–71	93	3227
1980–81	123	4738
1990–91	184	5748
2000–01	266	11,146
2010–11	523	33,023
2018–19	1047	41935

Source: Compiled from various annual reports of the UGC

Table 2 Types of universities in India

Type of universities	*As of January 2018*
Central	48
State public	384
State private	290
Institutes of national importance	103
Deemed universities	123
Universities established through state legislations	3
Total	*951*

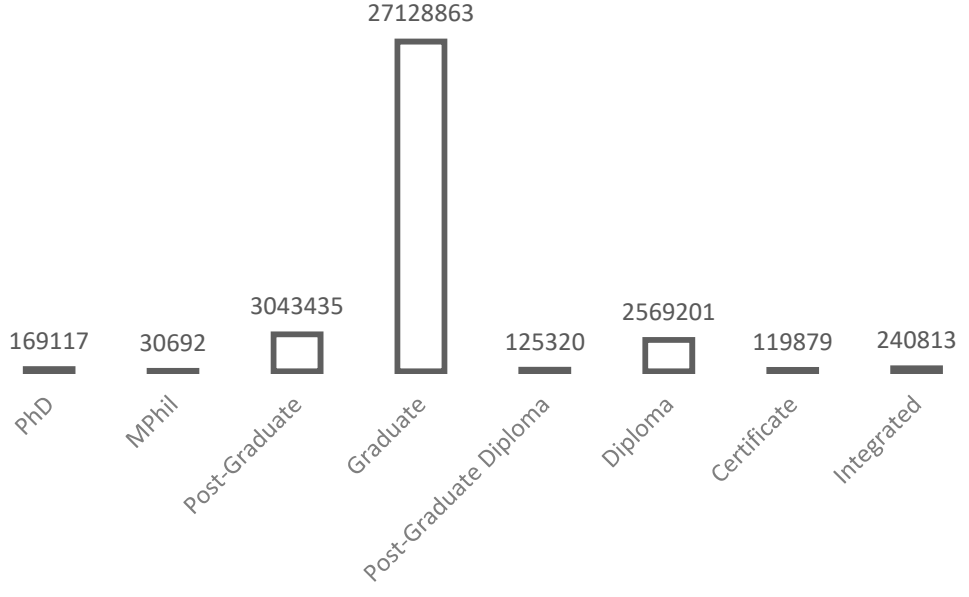
Source: UGC Annual report 2018

Since Independence, several committees emphasised the need of maintaining such quality in the higher education sector. If we look at the classification of universities based on

their funding sources, it is evident that a large percentage of Indian universities are publicly funded Table 2. As of 2018, apart from 123 deemed universities (12.9%) out of the total 953 universities, all were government funded.

The data on the progression of expenditure of the UGC shows that it grew from 26.6 million in 1955 to 115136.0 million in 2018–2019, which is approximately 4,328 times. The data on enrolment to various courses suggest that PhD enrolment is just 0.51% of the total enrolments in India (Ministry of Human Resource Development, 2019). This data clearly indicates that more than 90% of the enrolment is done at just graduate level and below.

Figure 1 Status of PhD enrolment in India



Source: AISHE Report: 2018–19

3 Review of literature

This section will explore the literature on various aspects of efficiency in higher institutes. HEI's always struggle with the evaluation of the research performance of faculty. Mostly, the number of publications is given more weightage. A recent study pointed out that while monitoring research of a faculty, the number of publications receives too much weight, whereas the implication of research and creativity is ignored (Stremersch et al., 2021). In a previous study on efficiency of higher institutes, four criteria, i.e., academic efficiency, research efficiency, teaching efficiency and consulting efficiency, were used to evaluate the total efficiency (Sahney and Thakkar, 2016).

Ranking has become very important for management institutes. A study in this regard pointed out that most of these rankings rely on technical efficiencies, which are misleading at times and scale efficiencies should be preferred for the same (Debnath and Shankar, 2009). In a study on government institutes, it was concluded that most of the institutes were inefficient (Kaur and Bhalla, 2017).

However, it needs to be noted that measurement of efficiency of universities is challenging due to their distinct characteristics. In the case of non-profit organisations such as universities, the distribution of monetary values to inputs and outputs is complicated because the universities generate several outputs (count of publications, citations and patents, etc.) for multiple inputs (university expenditure, number of faculty members, etc.). There are a number of methods available to measure the efficiency of universities such as data envelopment analysis (DEA) and stochastic frontier analysis (SFA). SFA is suited for data that has a certain level of uncertainty and not for those with numerous inputs and outputs. DEA follows a distance function approach and is able to handle several inputs and outputs for calculating the efficiency of decision making units (DMUs) such as clinics and hospitals, public schools, professional associations and research institutions. It does not take efficiency distribution and no prior information is needed on the prices of inputs and outputs. The scores can provide efficient and high-performing universities in an effective manner. Benchmarking turns out to be beneficial for the efficiency of individual universities. The combination of inputs and outputs is chosen on the basis on previous research and by the authors' understanding of what they think is necessary to identify the efficiencies of universities. There are abundant studies that measure the efficiency of higher education institutions using DEA. The nonparametric methods are used more as compared to the use of traditional parametric estimation models in the available literature. One of the first studies in this regard was by Lopes and Lanzer (2002) and Moreno and Tadepalli (2002) to analyse the efficiency of academic departments in a university. Various inputs and outputs like the salaries of the teaching staff and faculty, space allocated, equipment budget, credit house and number of students were taken into account. Initial studies to measure the efficiency of different universities were conducted by Abbott and Doucouliagos (2003) and Johnes (2006) in Australia and England. Flegg et al. (2004) did a multi-period DEA where technical efficiencies were calculated over a period of ten years.

The study revealed the causes of variations in efficiency and decomposes technical efficiency into pure technical efficiency, congestion efficiency and scale efficiency. Laureti et al. (2014) used a stochastic frontier approach to analyse the efficiency of teaching activities in the universities in the Italian region. Nazarko and Saparauskas (2014) did a study on the research strength of Polish universities. Their study revealed that Polish universities are relatively weaker in research. In the Indian context, Tyagi et al. (2009) studied nineteen departments of Indian Institute of Technology Roorkee through DEA and sensitivity analysis. The study concludes that out of nineteen departments, seven departments achieved technical efficiency and the staff needs to be utilised more efficiently. Factors like the staff, operating costs, research and number of students were taken into account. Kulshreshtha and Nayak (2015) examined the efficiency of eight Indian higher technical educational institutions during 2001–2005. The study suggests that how institutions can utilise the full potential of the existing

educational inputs. A state-level study in India by Gourishankar and Lokachari (2012) used an educational development efficiency (EDE) model. The study used the data from 28 states and seven union territories and concluded that South Indian states are efficient in the utilisation of the inputs. Some of the studies have also applied DEA and revealed interesting results. In a study on HEI's in European countries Wolszczak-Derlacz and Parteka (2011) revealed that higher the number of students in a academic institution, the higher is the level efficiency including a positive impact on women. A recent study conducted on higher educational institutes in China reported that various disciplines have different levels of journals. We need different approaches for analysing the research efficiency of different disciplines. This research paper proposed a model for mixed type of DMUs (Ma et al., 2021).

The following table describes the literature analysed for different input-output factors used in past studies to determine and evaluate the performance of higher education institutions:

3.1 Decision making units (DMUs)

As an assumption, DMUs should be homogenous and must fulfil three rules. First, they should have similar activities; second, they should have similar inputs to produce similar outputs; and third, they should work within the same scenarios. All the universities selected in this study are homogenous units. In the context of research efficiency of universities, the same resources as the teaching staff and operating expenses are used to create similar outputs.

3.2 Gaps in the literature

The literature review indicated that several studies were conducted on the efficiency of various sectors, but the scholars have largely neglected the education sector in general and research. A thorough review of the literature suggested that there have been several studies on the efficiency of educational institutes, including government, Management institutes, etc. Still, no analysis has tried to explore the research contribution of universities. In this context, this study attempts to analyse the research efficiency of the top 40 universities of India. The data used in this research of top 40 Indian Universities is obtained from the NIRF 2018 ranking of universities in India. The indicators considered for DEA's calculation of the efficiency scores referred as inputs and outputs of the institutions. For the calculation of research output, we have considered the total count of publications, the total count of citations, total count Ph.D. students, and sponsored research projects. As inputs for the DEA, annual operational expenditure, number of faculty members are considered.

For the selection of top universities, NIRF ranking was nowhere used in literature. This paper attempts to use the NIRF ranking and see whether the top universities of India are contributing enough for promoting research.

Table 4 Input-output variables for higher education institutions

S. no.	*Variables*	*Source*
	Input variables	
1.	Market share of UG and PG applicants 1. Graduation rates 2. Attraction of PG and PhD students 3. Classes of degrees	(Sahney and Thakkar, 2016; Aziz et al., 2013; Agasisti and Johnes, 2009; Singh and Ranjan, 2017; Tse and Yew, 2011; Kaur and Bhalla, 2017; Cunha and Rocha, 2012; Arcelus and Coleman, 1997; Beasley, 1995)
2.	Teaching quality 1. Qualification 2. Experience 3. Workload (credits per faculty) 4. Teacher-student ratio	(Sahney and Thakkar, 2016; Aziz et al., 2013; Abramo et al., 2011; Agasisti and Johnes, 2009; Singh and Ranjan, 2017; Tse and Yew, 2011; Kaur and Bhalla, 2017; Cunha and Rocha, 2012; Arcelus and Coleman, 1997; Martínez et al., 2018; Kumar and Thakur, 2019; Avkiran, 2001; Sreekumar and Mahapatra, 2011; Kumar et al., 2018; Pietrzak et al., 2016; Johnes and Yu, 2008; Johnes, 2006; Guironnet and Peypoch, 2018)
3.	Research 1. Papers in national conference 2. Papers in international conferences 3. Publications in national journals 4. Publications in international journals 5. Projects completed and in hand	(Sahney and Thakkar, 2016; Aziz et al., 2013; Abramo et al., 2011; Tse and Yew, 2011; Kumar and Thakur, 2019; Sreekumar and Mahapatra, 2011; Kumar et al., 2018; Pietrzak et al., 2016; Johnes and Yu, 2008)
4.	Administration 1. Transparent and timely services to the institute 2. Staff-student ratio 3. Number of electives 4. Perks	(Sahney and Thakkar, 2016; Aziz et al., 2013; Singh and Ranjan, 2017; Cunha and Rocha, 2012; Arcelus and Coleman, 1997; Martínez et al., 2018; Kumar and Thakur, 2019; Avkiran, 2001; Johnes, 2006)
5.	Infrastructure 1. Computing/ internet availability 2. Furniture 3. Air-conditioned rooms 4. Class-size 5. Student accommodation 6. Medical facilities 7. Gymnasium 8. Banking facilities 9. Other recreational facilities	(Sahney and Thakkar, 2016; Aziz et al., 2013; Agasisti and Johnes, 2009; Tse and Yew, 2011; Cunha and Rocha, 2012; Arcelus and Coleman, 1997; Beasley, 1995; Kumar and Thakur, 2019; Sreekumar and Mahapatra, 2011; Kumar et al., 2018; Johnes and Yu, 2008; Johnes, 2006; Guironnet and Peypoch, 2018)

Table 4 Input-output variables for higher education institutions (continued)

S. no.	*Variables*	*Source*
	Output variables	
1.	Review by externals (magasines etc.) 1. Citations in citation indexes 2. Patents and inventions 3. Rankings 4. Consultancies 5. Grants to the institute	(Sahney and Thakkar, 2016; Aziz et al., 2013; Abramo et al., 2011; Agasisti and Johnes, 2009; Tse and Yew, 2011; Kaur and Bhalla, 2017; Cunha and Rocha, 2012; Beasley, 1995; Kumar and Thakur, 2019; Avkiran, 2001; Sreekumar and Mahapatra, 2011; Kumar et al., 2018; Pietrzak et al., 2016; Johnes and Yu, 2008; Johnes, 2006; Guironnet and Peypoch, 2018)
2.	Placements of students	(Sahney and Thakkar, 2016; Tse and Yew, 2011; Kumar and Thakur, 2019; Avkiran, 2001; Sreekumar and Mahapatra, 2011; Kumar et al., 2018)
3.	Membership, prizes and medals	(Sahney and Thakkar, 2016; Tse and Yew, 2011; Sreekumar and Mahapatra, 2011)
4.	Success rate and time taken 1. Doctoral 2. Postdoctoral	(Sahney and Thakkar, 2016; Tse and Yew, 2011; Cunha and Rocha, 2012; Arcelus and Coleman, 1997; Kumar and Thakur, 2019; Avkiran, 2001; Johnes, 2006; Guironnet and Peypoch, 2018)

4 Research questions and objectives of the study

In the emerging context of the increasing number of Indian universities but very small percentage of PhD enrolment in them, this study raises an important question of whether PhD enrolment affects the research efficiency of Indian universities. The objectives of the study are:

- To analyse the impact of PhD enrolment on the research efficiency of the top 40 Indian universities as per the NIRF
- To suggest recommendations for improving the research outcomes of Indian universities

5 Methodology

5.1 Selection of variables

In DEA, a good mix of inputs and outputs plays a very significant role. Universities' relative efficiency greatly depend on the combination of the input-output variables considered in the study. Different combinations of inputs and outputs will result in different efficiency scores of DMUs. Various literature referred to the application of DEA for higher education institutions that have chosen a variety of combinations of inputs and outputs. There is no fixed rule for the selection of variables in this sector. Teaching and research are the two main objectives of universities and accordingly, the variables have been chosen in this study. On the basis of the literature review of output and input variables used in other studies, the following indicators are used for the selection of inputs and outputs:

5.1.1 Number of faculty members

This includes the number of full-time equivalent teachers viz. professors and lecturers. This input is a human capital measure. The role of faculty members in every university is to do research and to teach. This input was used in studies carried out by Aziz et al. (2013), Visbal-Cadavid et al. (2017), Tyagi et al. (2009), Worthington and Lee (2008), Johnes (2006) and Kaur and Bhalla (2017).

5.1.2 Annual operational expenditure

The amount of annual operational expenditure reflects financial resources other than the salaries of staff members that are used for the purpose of teaching and research. Operating expenditure is based on the number of faculty members and students. This input was included in the studies by Aziz et al. (2013), Visbal-Cadavid et al. (2017), Tyagi et al. (2009) and Duan (2019).

5.1.3 Total count of PhD graduates (till 2016–17)

Universities receive funds on the basis of the number of PhD graduates contributing to the research activity of the university. This output was the part of the studies conducted

by Johnes (2006), Kaur and Bhalla (2017), Duan (2019), Aziz et al. (2013) and Visbal-Cadavid et al. (2017).

5.1.4 Total amount of the research grant (sponsored research project amount)

All faculty members and PhD graduates are expected to do research in accordance with the university's objective. The total amount of the research grant is an indicator of the university's research operation. The larger the research grant amount, the higher the number of faculty members and students involved in research work. The same output was referred in works by Johnes (2006), Agasisti and Johnes (2009), Duan (2019) and Aziz et al. (2013).

5.1.5 Total count of publications

In addition to teaching, faculty members and research students are also supposed to publish research papers and articles, write books and present studies at seminars. This reflects the performance in research activities. This output has been used in the research of Aziz et al. (2013) and Visbal-Cadavid et al. (2017).

5.1.6 Total count of citations

Total count of citations indicates the standard of university-generated research content. The higher the count of citations, the higher the research efficiency of the institution (Visbal-Cadavid et al., 2017).

5.2 Choice of orientation

Within DEA, there are two orientation preferences: the orientation of inputs and outputs. The objective of input orientation is to decrease the input at the specified output level, whereas the goal of output orientation is to improve the output at the available input level. This analysis will use input orientation as the inputs are modifiable by the university in comparison with outputs. The university can control annual operational expenditure and number of faculty members but it cannot control the number of publications, citations, PhD students and the sponsored research project amount. Aziz et al., (2013), Katharaki and Katharakis (2010) and Agha et al. (2011) have used the same orientation.

5.3 Data envelopment analysis

Most basic model of DEA, i.e., the CCR model, is a non-parametric technique (Charnes et al., 1978). It is used to measure the performance of public sector non-profit organisations. Charnes's CCR model and Banker's BCC model are the frequently used in the field of Data Envelopment Analysis. The returns distinction between these two is returns to scale. The consideration of BCC model is variable returns to scale (VRS), while with CCR model it is constant returns to scale (CRS) (Agasisti and Johnes, 2009). The output returned from DEA is not absolute for a particular DMU but it is relative to the other DMUs (Debnath andand Shankar, 2009). DEA returns an efficiency score to each DMU, where the perfect score of 1 can be interpreted for an efficient unit and a

score less than 1 can be interpreted for relatively inefficient units. The study uses CCR model for analysis. DEA scores are computed using a multi stage approach.

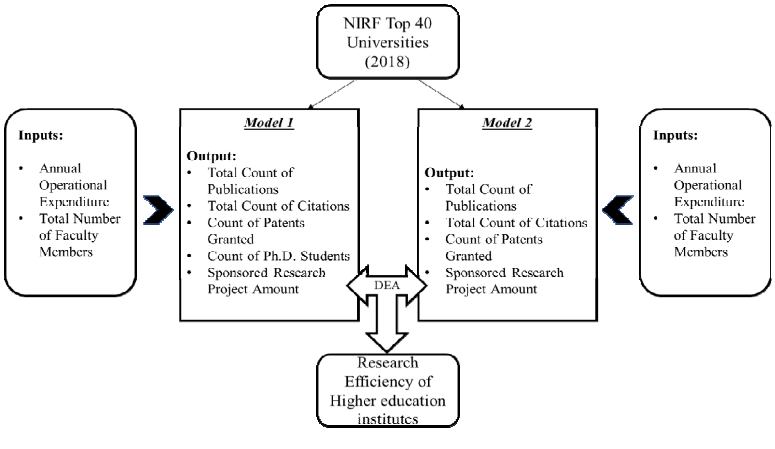
5.4 DEA Models

To assess the research efficacy of institutions with different parameters, a sensitivity analysis of the DEA model was conducted. There are two models described, using the same inputs but with different output combinations. Model 1 consists of all the five outputs namely 'total count of publications', 'total count of citations', 'count of patents granted', 'count of PhD students', and 'sponsored research project amount' and two inputs, 'annual operational expenditure' and 'total number of faculty members'. Model 2 includes all the outputs except the number of PhD students and same number of inputs. Both the models are summarised in the Table 5.

Table 5 Proposed DEA models

Variables	*Model 1*	*Model 2*
Inputs:		
Annual operational expenditure	√	√
Total number of faculty members	√	√
Outputs:		
Total count of publications	√	√
Total count of citations	√	√
Count of patents granted	√	√
Count of PhD students	√	
Sponsored research project amount	√	√

Figure 1 The conceptual framework



5.5 Data and sample

The sample size of this study is the top 40 Indian universities ranked by NIRF. The data collected was for the year 2018 and was obtained from the website of NIRF. In this study, DEA-Solver software has been used to calculate the research efficiency scores of all 40 universities. The conceptual framework of the paper is provided in Figure 1.

6 Results and discussion

Table 6, which provides descriptive statistics of the data, is given below.

Table 6 Descriptive statistics of the data

Parameter	*Annual operational expenditure (in million Indian Rs) (2016–17)*	*Total number of faculty members*	*Total count of publications*	*Total count of citations*	*Count of patents granted (For 2014, 2015, 2016)*	*Total count of PhD students (till 2016–17)*	*Sponsored research project amount (in million Indian Rs.)*
Max	13,160	2,586	14,971	80,148	116	5,432	3,912
Min	500	115	628	1,219	0	178	2
Average	3,060	750	4,323	19,399	8	1,426	473
SD	2,507	515	3,471	16,443	23	1,193	724

Table 7 displays the research performance scores in each model obtained by the various universities.

Model 1 includes all five outputs: count of publications, count of citations, count of patents granted, PhD students and sponsored research project amount. The universities that have achieved efficiency scores equal to 1 were regarded as efficient ones. The results showed that out of the 40 universities, only six were identified as efficient. This means that they are efficient in utilising their resources to produce all the defined outputs, compared to the others. There is a considerable difference between efficient universities and poor universities in the quality ratings. The Table 8 indicates the top 10 universities on the basis of their research efficiency, according to DEA analysis for model 1.

Model 2 includes all the outputs except the number of PhD students. As a result, only three universities were identified as efficient: the Indian Institute of Science, Bharathiar University and the Institute of Chemical Technology were the only universities. This indicates that the number of PhD students significantly contributes to the research efficiency scores. Universities such as Gauhati University, Kerala University, Jawaharlal Nehru University and Osmania University have high count of PhD students and had higher scores in model 1; however, they decreased significantly in model 2 where only the count of publications, count of citations, count of patents granted and sponsored research project amount were considered. As mentioned, the number of PhD students was chosen as an output because PhD students contribute to the research activity of the universities. However, it should be noted that some universities have a high count of PhD

students but their contribution to research is insignificant, resulting in poor research efficiency scores in model 2.

Table 7 Research efficiency scores

Serial no.	*Decision making unit*	*Model 1*	*Model 2*
1	Indian Institute of Science	1	1
2	Jawaharlal Nehru University	0.967	0.284
3	Banaras Hindu University	0.358	0.225
4	Anna University	0.941	0.899
5	University of Hyderabad	0.877	0.693
6	Jadavpur University	1	0.922
7	University of Delhi	0.468	0.377
8	Amrita Vishwa Vidyapeetham	0.199	0.199
9	Savitribai Phule Pune University	0.272	0.27
10	Aligarh Muslim University	0.282	0.175
11	Manipal Academy of Higher Education	0.124	0.124
12	Jamia Millia Islamia	0.318	0.216
13	Bharathiar University	1	1
14	Calcutta University	0.581	0.581
15	King George's Medical University	0.162	0.162
16	Vellore Institute of Technology	0.421	0.408
17	Birla Institute of Technology and Science	0.281	0.281
18	University of Madras	0.77	0.561
19	Institute of Chemical Technology	1	1
20	Panjab University	0.383	0.305
21	Bharath Institute of Higher Education and Research	0.31	0.31
22	Andhra University	0.464	0.183
23	Jamia Hamdard	0.36	0.36
24	Siksha `O` Anusandhan	0.157	0.143
25	Tamil Nadu Agricultural University	0.256	0.256
26	Homi Bhabha National Institute	0.481	0.479
27	Alagappa University	1	0.402
28	Osmania University	0.924	0.337
29	Tezpur University	0.61	0.591
30	Kerala University	0.749	0.209
31	Visva Bharati	0.418	0.243
32	Tata Institute of Social Sciences	0.599	0.294
33	Thapar Institute of Engineering and Technology	0.473	0.473
34	G. B. Pant Universtiy of Agriculture and Technology	0.198	0.15
35	Mahatma Gandhi University	0.622	0.304

Table 7 Research efficiency scores (continued)

Serial no.	*Decision making unit*	*Model 1*	*Model 2*
36	Shanmugha Arts Science Technology and Research Academy	0.61	0.61
37	JSS Academy of Higher Education and Research	0.237	0.213
38	Punjab Agricultural University	0.274	0.274
39	Gauhati University	1	0.167
40	Sri Ramachandra Medical College and Research Institute	0.185	0.185

Table 8 Top 10 universities according to model 1

Research efficiency ranking	*Decision making units*	*Research efficiency score*
1	Indian Institute of Science	1
2	Bharathiar University	1
3	Institute of Chemical Technology	1
4	Jadavpur University	1
5	Alagappa University	1
6	Gauhati University	1
7	Jawaharlal Nehru University	0.967
8	Anna University	0.941
9	Osmania University	0.924
10	University of Hyderabad	0.877

Table 9 Top 10 universities according to DEA analysis according to Model 2

Research efficiency ranking	*Decision making units*	*Research efficiency score*
1	Indian Institute of Science	1
2	Bharathiar University	1
3	Institute of Chemical Technology	1
4	Jadavpur University	0.922
5	Anna University	0.899
6	University of Hyderabad	0.693
7	Shanmugha Arts Science Technology and Research Academy	0.61
8	Tezpur University	0.591
9	Calcutta University	0.581
10	University of Madras	0.561

To identify the specific areas of improvements for the universities which were not able to achieve high levels of research efficiency, input output slack analysis was performed. In model 1 and 2, DMU 25, 38 and 40 had the highest output slack values in the 'total number of pulications'. For the output 'total count of citations' DMU 8 and 11 had the highest slacks. So, DMU 8 and 11 should focus on increasing citations to become efficient as compared to peers. DMU 11 also had a high output slack for 'count of PhD

students' and 'no. of patents granted'. DMU 3 also had a high slack for 'no. of patents granted'. DMU 14 should focus on getting 'sponsored research projects' in order to achieve research efficieny. As far as the input slacks are concerend, DMU 25 should decrease the input 'total number of faculty members' in order to be efficient.

(Refer to Table 7 for DMU numbers)

7 Conclusions

This study has evaluated the efficiency of Indian universities based on the NIRF using DEA. The research uses 40 DMUs and the analysis was done on data collected for the year 2018. Two inputs namely annual operational expenditure and total number of faculty members – and five outputs; and count of publications, count of citations, patents granted, PhD students and the sponsored research projects – are used. The research proposed two models to fulfil the objectives and the output variable 'number of PhD scholars' is dropped in the second model. The mean efficiency achieved in the first model is 0.53, with six efficient DMUs. When the output variable 'number of PhD scholars is dropped in the second model, the mean efficiency decreases to 0.39, with only three efficient DMUs. Thus, Model 2, where one of the variables was dropped, was used to determine this.

8 Limitations

The study relies on secondary data, and the data is not verified with the concerned universities. This study was conducted based on the NIRF ranking of 2018, and data was collected from the NIRF website only. Certain universities may not have performed in this particular year but have yielded better research outputs in previous years or even in later years. It will be good to conduct a study with data from multiple years for more efficient results. However, this paper is limited to only one year of data and does not claim any generalisation on the performances of these universities across years. However, the research and citations data of the 2018 NIRF rankings consider the last three years of publications and citations data. Another limitation of this study is that it has been conducted on top 40 universities only. Another analysis can be performed on a larger set of universities for better results.

9 Recommendation and future directions for research

It is observed that in Indian context, the PhD programmes are not closely monitored. Many times, the students take several years to complete their PhD and that too without any sufficient research outcomes. The quality of research done in the PhD programmes is poor. Based on the above results, it is recommended that public and private universities in India should monitor the number of PhD scholars and their output. The universities should also encourage and motivate their scholars to focus more on publications that mainly affect efficiency. We can also conclude that merely the classical method of increasing cost efficiency through increasing the number of PhD scholars, which can be normally achieved, would not be an effective method to actually increase the research

output of the Indian universities. The universities should promote research that has strong policy and managerial implications. Similar studies can be done for various years to showcase the trends in research efficiency. A primary study can also be designed with a combination of qualitative as well as quantitative study to explore the research efficiency of various universities.

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