MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 1457-1463

Quality and Efficiency Mapping of Indian Higher Education through DEA: Implications for Regional Policy

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Abstract:
When it comes to the development and progress of an economy, the education sector serves as the primary foundation supporting sustainable growth. Through higher education, individuals are transformed into skilled human resources, enabling their effective integration into society and the workforce. In recent years, considerable attention has been directed toward examining the efficiency and quality of higher education institutions, particularly in the context of the rising demand for high-quality education in India. Ensuring academic excellence requires a comprehensive understanding of the multifaceted challenges related to both quality enhancement and efficient resource utilization faced by higher education institutions (HEIs) across Indian states and Union Territories (UTs). This study employs the Data Envelopment Analysis (DEA) approach to assess the quality-oriented efficiency of higher education in Indian states and UTs for the years 2011, 2015, and 2021. By incorporating both human and non-human resources as inputs, the DEA model evaluates how effectively these resources are transformed into educational outcomes, thereby providing insights into the quality and efficiency performance of higher education across regions.

Keywords: Higher Education, DEA, Efficiency, AISHE

INTRODUCTION

Education is a transformative process that imparts knowledge, skills, and values essential for individual and societal advancement. UNESCO conceptualizes higher education as a system that develops cultural and scientific competencies while shaping individual identity, thereby converting learners into productive human capital of quality for modern economies. Beyond workforce preparation, the higher education system functions as a critical driver of quality-led economic growth, technological innovation, and social progress. Recognizing the centrality of educational quality, countries across the globe have recalibrated their higher education policies in alignment with Sustainable Development Goal 4, particularly Target 4.3, which seeks to ensure that by 2030 all women and men have equal access to affordable and quality technical, vocational, and tertiary education, including university education (UNESCO, 2014).

According to research, USA, China and India have the largest higher education systems in the world. The data published by World Bank (sourced by UNESCO Institute of Statistics) reveal that the total government expenditure on higher education as a percentage of GDP in USA was 5.4% of the GDP in the year 2022, in China it was 3.3% in 2021 and in India it was 4.6% in the year 2021. With India's growing population in the age group of 18-25, the gross enrolment ratio in Indian higher education is reached 28.4 as per the AISHE Report, 2022. Studies (Azzahra, Rahayu, Marlina, & Saeba, 2024) show that higher education has a significant positive correlation with well-being, that is an increase of 1% in higher education leading to 1% increase in well-being.

The relationship between education and economics draws its roots way back to Adam Smith (1776), followed by JS Mill, Marshall and Karl Marx. Higher education efficiency is not just about proper utilization of resources, but it also relates to a better quality of research, teaching practices and learning outcomes. This underlines that the importance of efficiency of higher education because as effective teaching practices tend to improve educational output like graduates, their employability and enrolment rates (Ford, Ingalsbe, & Hanvey, 2024). Efficiency of the education system has been a topic of discussion since the 1960's but gained momentum in the last couple of decades. India's positioning in the global playing field as the third largest hub of students in terms of population has made it a potential hotspot for higher education. Post-independence increase in the percentage of higher educational institutions has transformed radically with the establishment of prestigious institutions, sought after by students from various parts of the globe and a nation with the second-highest number of student enrolments (Shaguri, 2013). Like other nations, the Indian higher education has been paying a lot of attention towards the enrolment rates. Therefore, an assessment of efficiency takes a front seat and evaluating the performance of higher education system has become an urgent task. The government has formulated plans and policies to promote the development and growth of higher education. It becomes very important to understand the inflow and outflow of any system, be it in a public or a private system.

Efficiency in higher education acts as an important pillar for optimal utilization of resources aimed at improving academic outcomes. Earlier only private systems were subject to such scrutiny, but with the rising pressure on the limited resources the utility of every unit being involved in the production process has started being analysed in the public sector as well. A unit can be called as efficient, if a system involves minimum combination of inputs to produce a certain level of output or produces the maximum amount of output with a minimum combination of inputs. Efficiency is calculated using a non-parametric method called as Data Envelopment Methodology (DEA) to measure the technical efficiency of a unit. This non-parametric linear programming-based method was useful in the not-for-profit (Charnes & Cooper, 1980) units as the efficiency could be calculated without taking unit price into consideration. The efficiency of a unit is calculated between 0 to 1, zero being the most inefficient and one being the most efficient unit. A unit will be considered as efficient if all slacks are zero. Slack implies an additional inefficient unit of input being put to use (Bessent & Bessent, 1980). DEA has been

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ISSN: 1053-7899
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used in broadly all categories of education sector (Athanassopoulos & Shale, 1997); (McMillan & Datta, 1998); (Sinuary-Stern, Mehrez, & Barboy, 1994). Ali Emrouznejad & Emmanuel Thanassoulis suggested a dynamic model so that the results this model can be compared using a static model for the sample set of universities in the UK. Jill Johnes (2006) applied DEA to a sample of more than 100 higher education institutions in England for 2000-01 (Chakraborty, Biswas, & Lewis, 2001); (Johnes & YU, 2008). These studies were followed by Toth in the year 2009 (Using DEA to evaluate efficiency of higher education, 2009) and by Thanassoulis et.al in the year 2011 (Costs and efficiency of higher education institutions in England: a DEA analysis, 2011). DEA has been used extensively applied to analyse the efficiency of higher education institutions in 17 European countries (Veiderpass & McKelvey, 2016) and India (Sahney & Thakkar, 2016). Barra & Zotti (2016) conducted efficiency analysis of science and technology (ST) and humanities and social sciences (HSS) on the basis of the panel data collected from 2005 to 2009 (Johnes & Tone, 2017). Methods like Data Envelopment Analysis (DEA) offer methods for benchmarking as shown in the analysis of Karnataka's higher education system, indicating an average cost efficiency of 86.20% among institutions (George, Kurien, & Nair, 2023). According to the latest NIRF reports, around 40% from the top 100 colleges in India are operating less than efficiently (De, Teli, Mandal, & Raychaudhury, 2025). In addition to the studies of efficiency and its analyses using DEA, researchers have also found learning analytics as a tool to for improving the teaching and learning experience in the higher education domain (Ifenthaler & Yau, 2022).

Following the literature review, the authors have discerned two research gaps, which informed the formulation of research objectives. The literature review indicates a lack of comprehensive research on the efficiency of higher education in Indian states and Union Territories (Sharma & Srivastava, 2024), considering both human and non-human elements. Furthermore, there is a deficiency of research utilising panel data with multistage DEA models. In light of the aforementioned literature review and identified research gaps, the authors propose the following study objectives for this paper:

a. To find the technical efficient (TE) for the states & union territories (UTs) for the years 2011, 2015 and 2021.
b. To find the pure technical efficiency (PTE) for the states & union territories (UTs) for the years 2011, 2015 and 2021.

METHODOLOGY

Data studied has been taken from the All India Survey of Higher Education (AISHE). AISHE collects data according to the states which is categorised into various variables like faculty, student enrolment of students, programs, examination results, infrastructure, and other parameters. In the current paper, the DEA model has been used to accurately assess the performance of higher education system in the Indian states and union territories. The paper employs (1978) CCR model to evaluate the performance of higher education system in the Indian states and union territories for the years 2011, 2015 and 2022 respectively using the RStudio platform for DEA modelling. Number of hostels in a state or union territory, total number of colleges per state or UT, total number of teaching and non-teaching staff respectively (Mitra & Shankar, 2009); (Cunha & Rocha, 2012); (Abd Aziz, Janor, & Mahadi, 2013); (Sagarra, Mar-Molinero, & Agasisti, 2017); (Tran & Villano, 2018); number of hostels in a state (Gourishankar & Lokachari, 2012); and number of colleges in a state. The outputs considered for the study are UG Outpass and UG Enrolment respectively (Tyagi, Yadav, & Singh, 2009); (de Guzman & Cabana, 2009); (Kumar & Thakur, 2019); (Sharma & Mehra, 2019) respectively form the input while the undergraduate pass-outs and undergraduate enrolment form the output. The modelling was carried out for 2011, 2015 and 2022. In order to run the DEA model, the data was first normalised and then technical efficiency was calculated using the Charnes, Cooper and Rhodes (CCR) model assessed under the assumptions of constant returns to scale (CRS). This study's objective is to assess the technical efficiency (TE) of higher education system in Indian states and UTs. There are two approaches to assess technical efficiency of a DMU - input-oriented approach and output-oriented approach. Input oriented approach addresses by what quantity can the inputs be reduced proportionally keeping outputs constant. According to the output-oriented approach, the measures of technical efficiency address the quantity by which outputs can be increased keeping the inputs unchanged (Coelli, Lauwers, & Van Huylenbroeck, 2005).

CHARNES, COOPER & RHODES MODEL OF EFFICIENCY

$$min\ h_0 = \theta_0 - \epsilon\left[\sum_{i=1}^{w} s_i^- + \sum_{r=1}^{s} s_r^+\right]$$

$subject\ to$

$$0 = \theta_0 x_{i0} - \sum_{j=1}^{n} x_{ij}\lambda_j - s_i^-$$

$$y_{r0} = \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+$$

$$1 = \sum_{j=1}^{n} \lambda_j\, \mu_r \geq \epsilon$$

$$v_i \geq \epsilon$$

$$0 \leq \lambda_j, s_i^-, s_r^+ for i = 1, \ldots..w; r = 1 \ldots \ldots s; j = 1, \ldots \ldots, n$$

$$max\ y_0 \sum_{r=1}^{s} \mu_r\, y_{rv} - u_o$$

$subject\ to$

$$\sum_{i=1}^{w} v_i x_{io} = 1$$

$$\sum_{r=1}^{s} \mu_r\, y_r - \sum_{i=1}^{w} v_i x_{ij} - \mu_v \leq 0$$

Model 1, Banker et. al (1989)[46]

BANKER, CHARNES & COOPER MODEL OF EFFICIENCY

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$$min\ h_0 = \theta_0 - \epsilon\left[\sum_{i=1}^{w} s_i^- + \sum_{r=1}^{s} s_r^+\right] \qquad max \sum_{r=1}^{s} \mu_r y_{rv} - u_o$$

$$subject\ to \qquad subject\ to$$

$$0 = \theta_0 x_{i0} - \sum_{j=1}^{n} x_{ij}\lambda_j - s_i^- \qquad \sum_{i=1}^{n} v_i x_{i0=} 1$$

$$y_{r0} = \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ \qquad \sum_{r=1}^{s} \mu_r y_{rj-} \sum_{i=1}^{nw} v_i x_{ij-\mu_0 \le 0}$$

$$1 = \sum_{j=1}^{n} \lambda_j\, \mu_r \ge \epsilon$$

$$v_i \ge \epsilon$$

$$0 \le \lambda_j, s_i^-, s_r^+ \ for\ i = 1, \dots\dots w; r = 1 \dots\dots\dots s; j = 1 \dots\dots\dots, n$$

Model 2, Banker et. al (1989)

where,
j = number of DMUs (1 to n);
i = number of inputs (1 to w);
r = outputs (1 to s);
x_{ij} = amount of input i for DMU_j;
y_{ij} = amount of output r for DMU_j;
ϵ = positive constant to ensure that the inputs and outputs have a positive value;
μ_r and v_i = virtual transformations;
λ = weights;
θ_0^* = optimal value;
s_i^- and s_r^+ = slack variables.
A DMU will be fully efficient when $\theta_0^* = 1$ and all slacks are zero

RESULTS

DEA has been used by many researchers in the analysis of efficiency of educational systems over the past years. It compares the Decision-Making Units (DMUs) by assigning weights to the variables and determines the most efficient and inefficient units in which improvements can be made. Each DMU is allotted weights to make it look as efficient as possible. So, efficiency is more output achieved per unit of input (Sherman & Zhu, 2006). For this analysis, RStudio has been used. The technical efficiency of DMUs has been analysed under CRS and the pure technical efficiency has been analysed under VRS. The CCR model ignored the fact that the units could be operating at different scale, whereas the BCC model developed later, acknowledged the fact that different units operate at different scales and hence should be assessed against units of their size only (Taboada, Seruca, Sousa, & Pereira, 2020). For most cases, PTE is greater than or equal to TE.

* 2011: Goa, Chandigarh, Delhi, Uttar Pradesh, Bihar, Sikkim, Arunachal Pradesh, Jharkhand and Gujarat show high to full efficiency. Tamil Nadu is fully efficient in some years. Rajasthan, Odisha and Madhya Pradesh are moderately efficient. While Puducherry, Punjab, Maharashtra and Mizoram have very low efficiency scores.

* 2015: Goa, Chandigarh, Delhi and Tripura are fully efficient. Efficiency levels drop for Gujarat and Madhya Pradesh, Andhra Pradesh, Jammu and Kashmir and Karnataka. Nagaland has low efficiency scores. Efficiency scores also decrease after Telangana enters the list.

* 2021: Maharashtra, Telangana, Karnataka, Tamil Nadu and Goa showed mixed results with potential scale issues. Bihar remains fully efficient. Chandigarh and Uttar Pradesh are consistent

Table 1: Year wise and Zone wise TE and PTE for 2011, 2015 and 2021

West Zone	**TE - 2011**	**PTE - 2011**	**TE – 2015**	**PTE – 2015**	**TE – 2021**	**PTE – 2021**
Rajasthan	0.806	0.807	0.871	0.986	0.759	0.259
Madhya Pradesh	0.753	0.754	0.494	0.511	0.722	0.314
Gujarat	0.809	0.913	0.438	0.687	0.62	0.254
Maharashtra	0.488	0.745	0.381	0.75	0.463	0.766
Goa	1	1	1	1	0.254	1
South Zone	**TE - 2011**	**PTE - 2011**	**TE – 2015**	**PTE – 2015**	**TE – 2021**	**PTE – 2021**

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Andhra Pradesh	0.588	0.702	0.378	0.432	0.443	0.443
Karnataka	0.324	0.376	0.273	0.335	0.271	0.988
Kerala	0.355	0.366	0.281	0.348	0.314	0.278
Tamil Nadu	0.467	1	0.452	0.9	0.349	1
Puducherry	0.092	0.152	0.122	0.148	0.212	0.467
Telangana	---	---	0.532	0.532	0.493	0.493
North Zone	**TE - 2011**	**PTE - 2011**	**TE – 2015**	**PTE – 2015**	**TE – 2021**	**PTE – 2021**
Jammu & Kashmir	0.766	0.781	0.419	0.491	0.445	0.425
Himachal Pradesh	0.653	0.68	0.299	0.344	0.425	0.402
Punjab	0.474	0.503	0.38	0.38	0.259	0.212
Chandigarh	1	1	1	1	0.753	0.753
Uttarakhand	0.982	1	0.48	0.482	0.386	0.386
Haryana	0.552	0.587	0.335	0.373	0.402	0.62
Delhi	1	1	1	1	1	0.564
Uttar Pradesh	1	1	0.937	1	0.864	1
East Zone	**TE - 2011**	**PTE - 2011**	**TE – 2015**	**PTE – 2015**	**TE – 2021**	**PTE – 2021**
Bihar	1	1	1	1	1	1
Sikkim	1	1	0	1	0.441	0.441
Arunachal Pradesh	1	1	1	1	0.423	0.423
Nagaland	0.535	0.537	0.242	0.245	0.407	0.354
Manipur	0.527	0.527	0.516	0.516	0.431	0.985
Mizoram	0.16	0.718	0.24	0.348	0.354	0.68
Tripura	0.667	0.859	1	1	0.659	0.659
Meghalaya	0.779	0.783	0.525	0.628	0.68	0.431
Assam	0.764	0.798	0.47	0.616	0.564	0.564
West Bengal	0.87	0.963	0.715	0.939	0.975	1
Jharkhand	1	1	0.767	0.94	0.988	0.445
Odisha	0.56	0.583	0.354	0.447	0.467	0.407
Chhattisgarh	0.519	0.533	0.42	0.507	0.564	0.564

(Source: Authors' Calculations)

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DISCUSSION

The analysis of efficiency of higher education has been the favourite topic of the academic group. In this context, universities are recognized as multiproduct organizations that employ inputs collectively to generate outputs. Regarding the output aspect, the inclination is towards the number of graduates (in terms of teaching). For the easiness of understanding the states and UTs have been categorised into zones – North, South, East and West (Singh & Ranjan, 2018). In the west zone, Goa can be seen performing at 100% efficiency in the years 2011 and 2015 whereas it is locally efficient in the year 2021. Other states, that is Rajasthan Madhya Pradesh, Gujarat and Maharashtra need to optimise their resource utilization in order to improve the efficiency score.

In the south zone, Tamil Nadu is only locally efficient with PTE = 1 in 2011 and 2021. All other states, can be found to be functioning at a very low efficiency level. The number of colleges per lakh population is more than 50 colleges in the southern states, we can conclude that there are more resources than needed in these states and hence they have under-utilised inputs. The North zone seems to be performing really well, with two union territories – Chandigarh and Delhi performing at 100% efficiency level in 2nd and 3rd years respectively. Uttar Pradesh had 100% efficiency in 2011 and was locally efficient in the years 2015 and 2021 respectively. In the eastern zone, Bihar can be seen at 100% efficiency in all states. This can be accounted for the over utilization of resources in the states like Bihar and Jharkhand where the pupil teacher ratio stands at 69 and 58 in the year 2021-22 respectively. These states are examples where the human and non-human resources are being consistently over utilised. These inefficiencies demand significant traction as they obstruct the system's performance, give way to socioeconomic inequalities hence impacting national development objectives. Under the pressure to meet the benchmark of enrolling x-number of students and showing y-number of students passed out the HE systems have not been able to pay the required amount of attention on the quantum of pressure that is being exerted on the human as well as non-human resources. Sometimes the resources are diverted from productive to non-productive endeavours as well. The higher education system in India is impacted by significant regional disparities that fundamentally affect institutional efficiency and student outcomes (Sabu & Roy, 2025) resulting from disparities in government funding, faculty mobility, and infrastructural landscape across states and union territories.

CONCLUSION AND FUTURE WORK

Building on the work of Kaur (2021) on the technical efficiency of higher education across Indian states, this study adopts a two-phase approach with a strong emphasis on quality-driven efficiency enhancement. In the first phase, the quality and efficiency performance of higher education in Indian states and Union Territories (UTs) was analysed using input-based measures, leading to several policy-relevant insights. The findings underscore the need for systematic quality assessment (Banitalebi, Estaji, & Brown, 2025) alongside increased recruitment of qualified faculty in both public and private institutions to strengthen instructional quality. Further, faculty training programs must be aligned with national quality standards to ensure that educators are adequately equipped to develop the skills and competencies required by future generations (Delcker, Heil, & Ifenthaler, 2025). Ensuring job stability for teaching and non-teaching staff, particularly in private institutions, is critical for maintaining continuity and consistency in educational quality and preventing disruptions to academic sessions. Additionally, bringing private institutions under closer governmental oversight would help establish uniform quality benchmarks across the higher education system. Finally, fostering a quality-oriented research culture through partnerships with reputed publishers and renowned journals is essential for enhancing academic excellence and long-term quality outcomes in higher education.

Finally, we outline some limitations of this paper. First, it would not be very apt to judge the systems based on the across-the-board results. The policies in place, grants and funding from the state and central governments, stability of the state governments, whether the state or UT is a border area or not are few of the many factors that should be considered while analysing the efficiency of the higher education systems.

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