Estimating Super Efficiency of Higher Education System with Reference to India

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ABSTRACT
This research aims to examine the technical efficiency (including super efficiency) of the higher education system in the different states and union territories of India. The responsibility to provide for higher education in India is shared between the central and state governments. This analysis will elucidate the higher education systems of the states and union territories, as well as the influence of various variables on efficiency assessment. This approach employs a three-step evaluation methodology: the Charnes, Cooper, and Rhodes (CCR) model, the Banker, Charnes, and Cooper (BCC) model, and the super efficiency model to identify the most efficient state or Union Territory from a group of efficient entities. The findings indicate that four units exhibit technical efficiency, achieving a score of one. The study subsequently contrasted the units to ascertain the super efficiency of the states and union territories. Only one unit (Delhi) exceeded all other efficient units in the super efficiency analysis. The analysis incorporated both human and non-human variables in the inputs for evaluating the efficiency of higher education systems on undergraduate parameters. This study will enable policymakers to identify important concerns within the higher education system and formulate effective policy solutions to address these problems and fill existing gaps.

Keywords: Efficiency, DEA, Higher Education, Human Resource, United Nations

INTRODUCTION

The best flourishes and rest perish has been adopted as the modern-day working mechanism. But what exactly is the best? In a public service industry like education, best can be described as the institution or unit that maintains the balance of vibrations between its inputs and outputs by putting only that optimum amount of pressure on the inputs that they can deliver the best results as compared to the other units, in an organised and efficient manner. Those decision-making units (DMUs) can be called as efficient that lie on the efficiency frontier and have achieved a score of 100%, but, beyond this, super efficiency allows us to find the best from the efficient units. Super-efficiency (SE) delves over and beyond the efficiency frontier (Luangpaiboon, Phinkrathok, Atthirawong, & Aungkulanon, 2024) and picks that institution that outshines the other efficient units under the established assumptions. SE allows us to evaluate the decision-making units (DMUs) against their virtual peers. It is a technique that allows us to demarcate the best performer from the better ones (Torres & Ramos, 2024). The efficient units achieve the score of 1 or 100% but the SE score is ≥ 1. This paper attempts to analyse the super efficiency of higher education system using the two-stage data envelopment analysis.

Primary education is the foundation upon which our lives are built, while tertiary education is the formidable framework that determines the course that our lives will take. Over the course of the past two decades, there has been a major rise in the population, which has led to a significant demand on the facilities that are responsible for education and healthcare administration. The need for higher education has been satisfied by increasing enrolment, both in terms of breadth and depth, as the number of people who are pursuing higher education continues to rise. On the other side, the question that needs to be answered is whether the expansion is just focused on growing quantity or whether it also contains efforts to improve quality.

Background of the Study

In September 2015, the United Nations General Assembly adopted a resolution under the name (Liu, Jungyin, Jaewoo, Heechul, & Shah, 2024) Transforming our world: the 2030 Agenda for Sustainable Development (Assembly, 2015) with 17 Sustainable Development Goals and 169 targets with an effort to

fill the void of the Millennium Development Goals. Human rights, equality, eradication of poverty and empowerment were the main agenda items to be covered through the 17 SDGs. The Goal 4 and Goal 8 of the 17 listed goals are to ensure an inclusive and equitable quality education and promote lifelong learning opportunities for all (Assembly, 2015) and to promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all(Assembly, 2015) respectively.
The UN and its member countries recognize that the path to an overall and sustained economic growth and development is not just in terms of economic stability but through quality healthcare and education. According to a report by the Asian Development Bank, higher education system in Asian countries is back against the wall with few major challenges (Bank, 2011) – providing quality education, keeping up the curriculum with changing market trends, equitable distribution of resources and equity. The rapid increase in students in the higher education sector has led to rise in the enrolment in institutions and at the same time the expansion of economic activities calls for more innovative research. Both these factors have led to squeeze financial resources of the Asian economies.
The Indian higher education system is one of the most intertwined systems encompassing universities, colleges, diploma-level institutions, and over affiliated branches of professional education, all following the same program. Here, both the central and state governments are actively working towards transforming the country into a global knowledge economy. Post-independence, education in India has been rapidly evolving, especially in the field of higher education. Education in India is a joint responsibility of the State and Centre, as evidenced by its inclusion in the concurrent list of the Indian Constitution. The Ministry of Human Resource Development, appointed by the Centre, is responsible for charting out the National Policy on Education. Moreover, State Councils are assigned the responsibility of regulating the smooth operation of intra-state higher education, while Central Advisory Board of Education (CABE) bridges the gap between the Centre and the State by attempting to harmonize the policies between them, and thereby is responsible for ensuring uniformity. Additionally, bodies such as the University Grants Commission (UGC), All India Council for Technical Education (AICTE), National Institute of Ranking Framework (NIRF), Internal Quality Assurance Cell (IQAC), and Academic Quality Assurance Committee (AQAC) regulate a number of organizations functioning under them. The central government set up University Education Commission (UEC), 1948 as one of the foundation stones of the Indian education system. Later in 1953, the University Grants Commission (UGC) was formed under the University Grants Commission Act of Parliament (1956) as a statutory body. Thereafter, Kothari Commission or the National Education Commission was set up in 1964 by the Government of India as an ad-hoc body followed by the National Policy on Education (NPE), 1968 under the co-chairmanship of Triguna Sen and Ganga Sharan Sinha followed by the National Policy on Education introduced by the then Prime Minister Mr Rajiv Gandhi in 1986 after the success of NPE 1968 (Kumar D. , 2024). The New Education Policy of 2019 was formulated under the Chairmanship of ISRO's former Chairman, K. Kasturirangan, who envisioned a complete overhaul of India's higher education system. The new National Education Policy outlined a vision for a self-reliance and resilience in the education structure of India. Despite the efforts of the governments, Indian institutions are still not able to make a position in the top 150 club of QS international universities ranking (Singh, Barve, & Shanker, 2023). Hence, it is of utmost importance to keep analysing the performance and efficiency of the Indian higher education system as it affects the future of the young generation of India. The total number of universities in India increased from 621 in 2010-11 to 1168 in 2021-22. The gross enrolment ratio (GER) has increased considerable from 19.4 in 2010-11 to 28.4 in 2021-22 (AISHE, 2022). The increasing pressure on the higher education system of India has led the researchers' attention towards performance assessment and efficiency analysis of the system. There are various methods to measure the efficiency of an education system - Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA), Free Disposal Hull (FDH), order m-frontier, Malmquist Index etc. Data Envelopment Analysis (DEA)has been extensively used in the assessment of efficiency of the higher education system globally. The present research is based on the three efficiency models - Charnes, Cooper and Rhodes (CCR) model; Banker, Charnes and Cooper (BCC) model and the super efficiency model which have been used to analyse the efficiency and super efficiency of the units to identify the most efficient higher education system.
The structure of this paper goes as follows: Section 2 discusses the literature review, research gap and objectives, section 3 deals with the models, theoretical framework and the data analysis, section 4 discusses the results followed by section 5 with conclusion and future work.

LITERATURE REVIEW

The concept to efficiency analysis goes back to the 1950s when the economists understood how important it was to measure the input utility and output being produced using a certain proportion of inputs. Farrell (1957) mentioned the importance of understanding the theoretical and practical efficiency of industries so that the economic growth can be aligned with the important industries. He gave the efficiency model for single input, single output case. But in practical situations the production process in any industry or economy involves multiple variables. Farell's model was later developed into a nonlinear and nonconvex model by Charnes, Cooper and Rhodes (1978). Their model provided a fresh direction to the calculation of efficiency specially for the not-for-profit units that are involved in the public programs. This model came to be known as the CCR model. The LP models given by Charnes, Cooper and Rhodes (1978) provided a method for finding out the extremal relations that lie on the boundary rather in the interior of the observed data. Bessent and Bessent(1980) used the model given in 1978 for comparing the relative productivity of schools by employing least square and CCR model. The authors could identify the efficient schools from the inefficient ones. The Pareto-efficient frontier model (1985) was analysed and the new Data Envelopment Analysis method was constructed and the authors found that the non-Archimedean constructs were not required. The CCR model worked under the assumption of constant returns to scale. But later Banker, Charnes and Cooper (1984) modified the CCR model to be used under the variable returns to scale. This was the BCC model. These models were further developed as additive and multiplicative. But surprisingly the units that were found to be efficient under additive model were not necessarily efficient under the multiplicative model (1988). The earlier theories were extended (1991) so that DEA can include zero inputs and outputs along with zero virtual multipliers (shadow prices). Charnes et.al (1992) added the concept of stability or sensitivity of an organization to the existing model. The additive model yielded a particular region of stability where the unit's classification remained unchanged. Later the differences in the CCR, BCC, additive and multiplicative models respectively were listed (1994).

Thanassoulis(1993) compared the regression and DEA results for single input and single output use for hypothetical hospital to find the differences in the models and found that DEA outperformed the regression results. DEA was used to (1994) find the best performer amongst a sample of secondary schools for role-model identification. Through this study the schools could get a target for improvement also reflect upon the individual outcomes. Seiford and Zhu (1998) developed the sensitivity analysis for the CCR, BCC and additive models respectively. The sensitivity analysis would find that when simultaneous variations in the data considered for all units, till what level can the efficient units in the data set tolerate the disturbances before becoming inefficient.

DEA gained importance with the researchers and policy makers of all segments. Its uses could be seen extensively in the not-for-profit sectors like banking (1999), education and healthcare. (Emrouznejad & Thanassoulis), (2006) suggested a dynamic model and compared its results with the static models for the set of UK Universities. The paper suggested solution for the issue of inter-temporal input–output dependence by using input–output 'paths' mapped out by operating units over time as the basis of assessing them. Johnes worked extensively on the application of DEA to the education sector. The researcher applied DEA (2006) to more than 100 higher education institutions in England for the data set of 2000-01 using the inputs - quantity and quality of undergraduates, the quantity of postgraduates, expenditure on administration, and the value of interest payments and depreciation for quantity and quality of undergraduate degrees, the quantity of postgraduate degrees and research. Bootstrapping technique used in the paper suggested that there were major differences between the most and least efficient higher education institutions in England. The teaching efficiency of 2547 Economics graduates from UK Universities was assessed using DEA for the data set of 1993 (2006). The efficiency was split into two components - university at which the student studied, and the other to the student himself. The results showed that the efficiencies that were derived as an aggregate of the institution and individual level components were misleading. Therefore, the author suggested that it the unit of an analysis in a DEA is very crucial. Johnes and Yu (2008) examined the relative research efficiency for 109 Chinese regular universities in 2003 and 2004 using inputs variables - staff, students, capital and resources and output variables - impact and productivity of research. This study was followed by Toth (2009) and Thanassoulis et.al (2011).

Data envelopment analysis (DEA), which was initially developed as a method for performance measurement, has been used in a great number of research articles for the purpose of comparing efficiency of units that involve more than one input and output. Some variables may act as inputs in one case but as outputs in others (Cook and Zhu, 2007). Like student enrolment can be used as an input as well output referred to these variables as flexible measures. Another paper, (Amirteimoori & Emrouznejad, 2011) proposed a model in which each flexible measure was considered either as an input or an output for maximizing the technical efficiency of the units being studied. Higher education systems are under excessive pressure and scrutiny in all countries. This leads the policy makers towards rigorous examination of efficiency of the educational institutions using various permutations and combinations of inputs and outputs variables. In (2014) output oriented CCR model was applied by the authors to analyse the input, output and efficiency of 19 universities of Poland. Education is one typical example where the market pricing or cost pricing cannot be calculated especially in case of public institutions (2016), (2017). In (2017)Johnes and Tone, used DEA models with slack based min- (SBM-min) and max- models (SBM-max) to find the efficiency for higher education institutions in England for the data set of 2013–2014. Results showed that the results were sensitive to the methodology as well as the variable combinations.

Huan and Fangtao(2017) used DEA to analyse the efficiency of variables for the panel data in the education and technology sector of 53 countries. There was significant growth found in East Asia, especially in Japan, Korea, Taiwan and some other developing countries. They also concluded that efficiency of science and technology sector has a positive effect on the balanced overall development of any country.

DEA was also combined with machine learning language to enhance the usage of the model. Sahney and Thakkar (2016) evaluated the technical efficiency of selected institutes of national importance in India by using DEA-AHP model. A panel data of four institutes was considered over a period of five years to assess the academic, research, teaching and consulting efficiency of the institutes. The DEA-AHP model helped to chalk out critical parameters that are important to the policymakers. Ali et. al(2017) estimated the efficiency of 15 academic department of a government PG College, Gopeshwar, Chamoli, Uttarakhand, 2011-2012. They calculated the technical efficiency (TE), overall technical efficiency (OTE) and pure technical efficiency (PTE) of the government colleges. The authors found that 8 out of 15 teaching departments were scale efficient, while only 4 out of 15 research departments has scale efficiency equal to 1. But there can be cases when the data is not as crisp or precise as we found in the previous studies. The possibility of considering the box-uncertainty in data was highlighted in (Dehnokhalaji, Khezri, & Emrouznejad, 2022). They assumed that the inputs and outputs are present in the form of intervals. This application was used to find the efficiency of a hospital in East Virginia. Loganathan and Subrahmanya(2023) studied and compared the graduation, research and entrepreneurship outcomes of 28 Indian universities that were also delivering entrepreneurship support to students with pedagogical outcomes using a slack-based data envelopment analysis (DEA). They found that very few universities were fully efficient in all the three missions, namely, graduation, research and entrepreneurship. According to their study, private universities have developed a graduation orientation and can shift to the entrepreneurial without a research base. Further in (Tran, Pham, Nguyen, & Do, 2023) the economic efficiency of 172 Vietnamese higher education institutions from 2012–2016 was examined using the Data Envelopment Analysis (DEA) approach. The authors sorted the institutions into public and private, multidisciplinary and mono-disciplinary, non-autonomy and autonomy, non-international and international categories and then compared the efficiencies. The study suggested that the operational efficiency of 172 institutions had decreased during the said period. The paper suggests that public universities had lower efficiency as they operate in the absence of market mechanism. Mogha(2023) also analysed the performance of 7 academic departments in a private university using the data set of 2014-15 using dual CCR model in DEA with academic and non-academic staff as inputs and total enrolled students, total outpass, total number of students placed and research index as output. According to the paper four academic departments were found to be technically efficient with and average efficiency score of 0.899 while remaining three were working at increasing returns to scale and hence were inefficient. Along with education, DEA has also been used extensively in the healthcare sector (Jung, Son, Kim, & Chung, 2023).

The technical efficiency of higher education institutions with respect to labor market outcomes for recent graduates by employing an analysis of distinct three methodologies was studied by Wu et. al (2024). They used a sample of recent graduates of Colombian universities between 2007 and 2011. They used Data Envelopment Analysis (DEA), Free Disposal Hull (FDH), and order-m estimator. Their study showed that estimation technique affects the results when super-efficient DMUs exist. The order-m technique showed superiority over DEA and FDH. Although, the absence of SE DMUs made the efficiency rankings from the different methodologies consistent. Cong (2024) used the super-efficiency SBM model on provincial-level panel data from 2013 to 2021 from the Chinese mainland to measure research efficiency of university. This paper analysed the effect of institutional support both formal and informal on the research efficiency of university. DEA has been used with Malmquist index in both input – and output - oriented models for analysing the efficiency of government expenditure for two most crucial social sector that is education and nutrition for the years 2014-15 (2024). Education is a sector that has homogeneous as well as heterogenous variables that affect the results and need to be considered at the time of study (Dixit, Singh, & Sardar, 2024). Heterogeneity of variables was discussed in (Srivastava, Aggarwal, & Bansal, 2024). Zhao et. al (2024) used a three-division network DEA to find the efficiency of three departments in the Chinese education system - Scientific and technological (S&T), R&D and TT.

Dynamic ranking model was used in the score-driven framework for analysing the research efficiency of higher education systems at country level by examining scientific publications and its relation to good governance (Holý, 2024).
Saavedra-Caballero (2024) studied technical efficiency of Colombian universities using a sample of graduates between 2007 and 2011 using Data Envelopment Analysis (DEA), the Free Disposal Hull (FDH) model, and order-m estimator. Results revealed that the estimation technique affects the results when super-efficient decision-making units are present, with the order-m technique demonstrating superiority over DEA and FDH. Efficiency assessments not only help to identify the efficient units from the inefficient ones but also help policy makers to demarcate the changes that need to be brought about to meet the growing demands of the society. Different models have been developed to measure efficiency of social sector like stochastic frontier analysis (SFA), free disposal hull (FDH), data envelopment analysis (DEA), and Malmquist index among others. Of these methods DEA is the most widely used model especially for the performance measure of social sectors. In addition to those mentioned above, the key contributors in the efficiency analysis of higher education are (Lindsay, 1982), (Athanassopoulos & Shale, 1997), (Johnes J. , 2006), (Bougnol & Dulá, 2006), (Tóth, 2009), (Thanassoulis, Kortelainen, & Johnes, G. & J, 2011), (Nazarko & Šaparauskas, 2014), (Mikušová, 2017), etc.
According on the aforementioned literature review, several research gaps were discovered. Much has been stated and examined regarding higher education institutions in India and worldwide; nevertheless, certain critical elements remain understudied, as mentioned below:
a. The impact of number of colleges and number of hostels as an important factor affecting the efficiency have not been included in the research papers.
b. Also, the CCR models do not facilitate sorting the top performer from the good ones. So it is important that we use a tool that separates the best one from a set of efficient institutions.
Based on these research gaps, the authors have proposed the following objectives:

1. To find the technical efficiency of higher education institutions of different states and UTs of India through the CCR model by using total teaching staff, total non-teaching staff, number of colleges and number of hostels in a state as input variables.
2. To find the pure technical and scale efficiencies of higher education institutions of different states and UTs through the BCC model by using total teaching staff, total non-teaching staff, number of colleges and number of hostels in a state as an input.
3. To sort the most efficient from the efficient ones using the super efficiency model.

METHODOLOGY

We employed the non-parametric DEA three-stage models to analyse the dataset. This study initially employed the traditional Charnes, Cooper, and Rhodes (CCR) model to evaluate the technical efficiency of the units under constant returns to scale (CRS), followed by the application of the Banker, Charnes, and Cooper (BCC) model to assess pure technical efficiency under the assumption of variable returns to scale (VRS). Subsequently, the third model of super efficiency was employed to identify the most efficient unit of all.

Theoretical Framework

The concept of analysing efficiency started from Pareto's work followed by (Farrell, 1957). This was further developed by Charnes, Cooper and Rhodes (1978) into a model that was called as the CCR Model of DEA or the CRS model. Although there are different other models used to measure the efficiency – Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA), Free Disposal Hull (FDH), order m-frontier, Malmquist Index. Of these we would be using the DEA methodology in this paper. DEA is the most widely used method in the direction of efficiency analysis for education, healthcare and banking systems. DEA has two major advantages over the other methods, one it doesn't need assumptions and two it doesn't need mathematical formulations.
In general terms, we can understand efficiency as the sum of weighted output divided by the sum of weighted input.

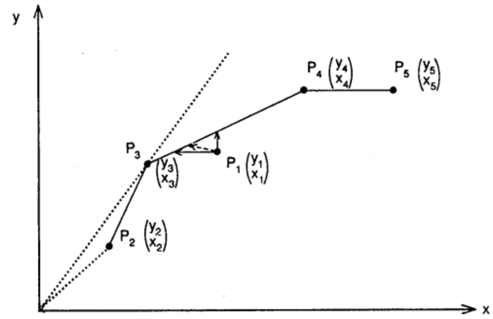

Figure 1: Efficiency evaluation for one output and one input. (Source: Banker et.al (1989))

In the above figure, P1 to P5 denotes the efficiency points for outputs y_j, inputs x_j and DMU_{sj}, where j=1 to 5.
But in practice, there isn't just one or two inputs or outputs at play. Specially in the education systems, there may be several heterogeneous variables at play. Those institutions can be called as efficient that use minimum inputs to produce one unit of output. Efficiency can be technical or allocative/price efficiency. Technical efficiency is a measure of the extent to which an institution efficiently allocates the physical inputs at its disposal for a given level of output. The most efficient DMUs fall on the isoquant while the inefficient ones are either below or above the isoquant.
The second type of efficiency is allocative or price efficiency that takes into account the cost aspect of the units. The efficiency is measured by the distance of the DMU from the isoquant. Most efficient units with efficiency equal to 1 will lie on the isoquant, while the inefficient ones will either lie below or above the isoquant. In case of education system being a non-profit institution in general, the price or cost aspect is most of the times difficult to calculate hence we take into analysis the technical efficiency of the higher education institutions (HEI). The model was improved upon by Banker, Charnes, & Cooper (1984) who included the assumption of variable returns to scale (VRS). The efficiency under VRS assumption is termed as the Pure Technical Efficiency (PTE). In the long run, education systems tend to function under constant returns to scale (Salerno, 2003). There is the third type of efficiency called as the scale efficiency which is the ratio of TE/PTE. In most cases there isn't much difference in the efficiency ratio of DMUs when calculated under the assumption of CRS and VRS respectively except that the constant returns to scale assumption lowers the efficiency scores and variable returns to scale assumption yields higher efficiency scores.

CCR MODEL OF EFFICIENCY UNDER CRS

$$min\hbar_0 = \theta_0 - \epsilon \left[\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right]$$

subjectto

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

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

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

$$v_i \geq \epsilon$$

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

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

subjectto

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

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

Model 1, Banker et. al (1989)

BCC MODEL OF EFFICIENCY UNDER VRS

$$min\hbar_0 = \theta_0 - \epsilon \left[\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right]$$

subjectto

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

subjectto

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

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

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

$$\nu_i \ge \epsilon$$

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

Model 2, Banker et. al (1989)

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

This paper is based on the input oriented CCR and BCC model calculating TE and PTE respectively. But like every methodology this too has its shortcoming. The CCR model cannot differentiate between the efficient DMUs as to how efficient a DMU is as compared to other efficient ones. So, we will employ the super efficiency analysis in the second step of the DEA analysis. In this model, the scores of inefficient units remain less than 100% or unity but the score of efficient units exceeds 100% or 1. The first input oriented super efficiency DEA model was given by (Andersen & Petersen, 1993) and well explained by Josef Jablonsky (2006).

minimise θ

subject to

$$\sum_{j=1,\neq q}^{n} x_{ij}\lambda_j + s_i^- = \theta x_{iq}, \qquad i = 1,2,\ldots,m$$

$$\sum_{j=1,\neq q}^{n} y_{ij}\lambda_j - s_i^+ = y_{iq}, \qquad i = 1,2,\ldots,r$$

$$\boldsymbol{\lambda}, \mathbf{s}^+, \mathbf{s}^- \ge 0$$

Model 3 (Jablonsky, 2006)

Where, each DMU uses m inputs to achieve r outputs; x_{ij} denotes the inputs vector and y_{ij} denotes output vectors respectively; λ denotes weights; s- and s+ are slacks associated with virtual input and outputs. The efficiency scores for inefficient DMUs are the same as those obtained from the CCR model, while the scores for efficient DMUs are greater than or equal to 1.

Data Analysis

The current study presents data obtained from the All India Survey of Higher Education (AISHE) exclusively for the year 2021-22. Based on the available data, we have classified the states and union territories as DMUs, resulting in a total of 32 units that have been included in the study. Some UTs like Lakshwadeep had to be dropped due to lack of sufficient data. The analysis of the performance and efficiency of our higher education systems not only facilitates the classification of the institution as either efficient or inefficient, but also enables the periodic modification of policies. If the policies just prioritise the growth of enrolment and the number of institutions, it detrimentally affects the calibre of graduates and the quality of human resources provided by the higher education system to the job market. Six variables have been selected for the study based on the research gap identified from the literature review. Out of six, 2 are outputs and 4 are input variables.

Input Variables

Total Teaching Staff: The variable total teaching staff represents the total number of teachers in the state. It includes teachers from all groups – professor and equivalent, readers and associate professors, lecturers/assistant professors, demonstrator/tutors, temporary teachers and visiting teachers in a state. According to AISHE, the total number of teachers in India in the year 2021-22 was 15,97,688 which was 46,618 more than the previous year (AISHE, 2022). Teaching staff counts as the human resource input in the process of imparting education and hence it has been included by researchers in the efficiency analysis of higher education ((Abbott & Doucouliagos, 2003), (Mitra Debnath & Shankar, 2009), (Tyagi, Yadav, & Singh, 2009), (Cunha & Rocha, 2012), (Agasisti, Barra, & Zotti, 2016), (Kaur, 2021), (Lee & Johnes, 2022)).

Total Non-Teaching Staff: Non-teaching staff is the backbone of an educational system. The operations and administrative and all other related duties are taken care of by the non-teaching staff. Although they are not directly teaching or grooming the students but the quality and quantity of non-teaching staff determines how smoothly an educational institution runs. The total non-teaching staff in the year 2021-22 was 12,08,446. Both teaching and non-teaching staff have accorded their place in the research of efficiency of higher education. See (Abbott & Doucouliagos, 2003), (Tyagi, Yadav, & Singh, 2009), (Anderson, Antellius, & Sund, 2010), (Abd Aziz, Janor, & Mahadi, 2013), (Agasisti, Barra, & Zotti, 2016), (Singh & Ranjan, 2018), (Sharma & Mehra, 2019), (Kaur, 2021), (Lee & Johnes, 2022).

Number of hostels in a state: Infrastructure plays a very crucial role in deciding the functioning of any institution. Our third variable in this paper is the availability of hostels for students in a state. Migration of students from one to another for the sake of higher studies is common. Most students or parents prefer to send their wards to a new location so that they can explore Hostel availability implies how convenient it is for outstation students to find an accommodation. In case of lack of seats in the hostels the students then turn towards accommodations in paying guest which is generally costlier than the institution hostels. Not much attention has been given to the inclusion of number of hostels in a state as an important infrastructural factor in determining the efficiency of the institutions. The data has been taken from (AISHE, 2022).

Number of Colleges in a State: In this variable we include the number of colleges in a state and those that have registered themselves with AISHE. This includes the affiliated and constituent colleges of Central and State Public Universities. Number of colleges in a state means how the student population will get divided. In some states the college density is very high, that is the number of colleges per lakh population. This means that those states have more capacity to enrol students as compared to others. Enrolling more students implies equivalently more outpass numbers of graduates. Some states like Uttar Pradesh, Karnataka, Rajasthan, Tamil Nadu have very high number of colleges.

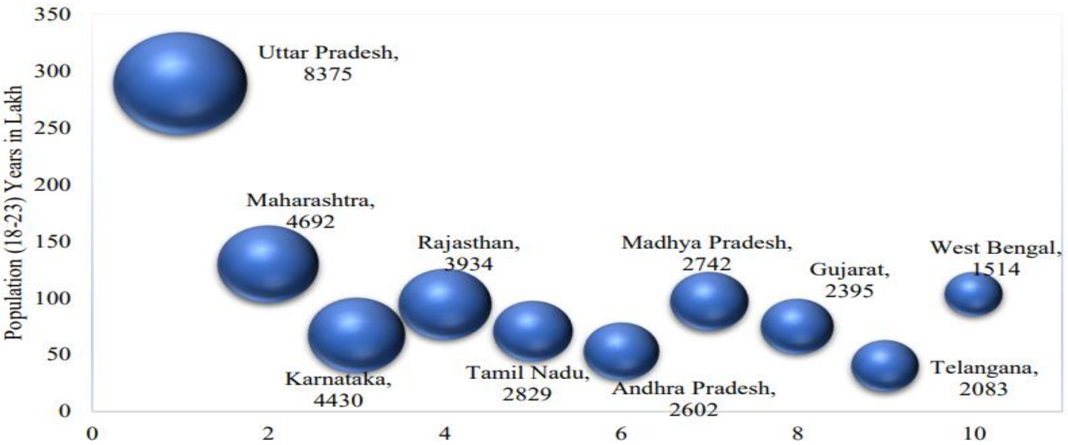

Figure 2: Number of Colleges and Eligible Population (18-23 Years) in Top 10 States (Bubble size indicating the number of colleges) (AISHE, 2022).

Output Variables:

Undergraduate enrolment: Undergraduate enrolments are almost 80% of the total enrolments in the educational institutions. Therefore, the paper is focused on the data analysis from the numbers of undergraduate courses only. The total undergraduate enrolment in all states for the year 2021-22 was 34117845. The undergraduate enrolments have been increasing at a compounded annual growth rate of 4.1 (AISHE, 2022). Undergraduate enrolment have been taken into consideration by many researchers like (Abbott & Doucouliagos, 2003), (Agasisti, Barra, & Zotti, 2016)(Anderson, Antellius, & Sund, 2010),(Kumar & Thakur, 2019), (Jablonsky, 2006)(Johnes J. , 2006)(Kaur, 2021), (Sharma & Mehra, 2019), among others.

Undergraduate Passout: Our second output is the passout number of undergraduate courses. The number of passouts in the year 2021-22 was 7750734. This variable has been explored by (Abbott & Doucouliagos, 2003), (de Guzman & Cabana, 2009), (Cunha & Rocha, 2012), (Abd Aziz, Janor, & Mahadi, 2013), (Agasisti, Barra, & Zotti, 2016), (Kumar & Thakur, 2019), (Kaur, 2021), among others.

RESULTS AND DISCUSSIONS

The efficiency of all 32 units were estimated using the 3 models – CCR, BCC and Super Efficiency using the RStudio platform. Technical efficiency (TE) was calculated using the CCR model, pure technical efficiency (PTE) was calculated using the BCC model and super efficiency was calculated after analysing the TE and PTE. We estimated the efficiency scores using input orientation and considered slacks to exist that is true.

Table 1: Efficiency scores for CRS and VRS Models

States/UTs	TE (CRS)	PTE (VRS)	SE	States/UTs	TE (CRS)	PTE (VRS)	SE
Andhra Pradesh	0.377	0.434	0.870	Maharashtra	0.338	0.985	0.343
Arunachal Pradesh	0.518	0.518	1.000	Manipur	0.418	0.418	1.000
Assam	0.510	0.559	0.912	Meghalaya	0.741	0.975	0.760
Bihar	1.000	1.000	1.000	Mizoram	0.165	0.165	1.000
Chandigarh	1.000	1.000	1.000	Nagaland	0.265	0.405	0.655
Chhattisgarh	0.356	0.556	0.641	Odisha	0.345	0.457	0.754
Delhi	1.000	1.000	1.000	Puducherry	0.150	0.150	1.000
Goa	0.386	0.386	1.000	Punjab	0.226	0.249	0.907
Gujarat	0.477	0.612	0.780	Rajasthan	0.555	0.805	0.689
Haryana	0.394	0.394	1.000	Sikkim	0.000	0.000	0.000
Himachal Pradesh	0.402	0.428	0.939	Tamil Nadu	0.320	1.000	0.320
Jammu and Kashmir	0.432	0.447	0.967	Telangana	0.479	0.479	1.000
Jharkhand	0.883	1.000	0.883	Tripura	1.000	1.000	1.000
Karnataka	0.200	0.272	0.735	Uttar Pradesh	0.778	1.000	0.778
Kerala	0.308	0.308	1.000	Uttarakhand	0.377	0.378	0.997
Madhya Pradesh	0.678	0.763	0.889	West Bengal	0.821	1.000	0.821

(Source: Authors' calculation)

According to Ali Emrouznejad(2000), a DMU can be called efficient if it produces maximum quantities of outputs using any given level of inputs or uses minimum quantity of inputs to produce a given level of output. Using this frontier the concept and the index of technical inefficiency can be defined.

The definition of efficiency says that units producing maximum output with least inputs should be considered as efficient. The units that achieved 100% efficiency under CRS assumption are Bihar, Chandigarh, Delhi and Tripura. If we look at the number of colleges per lakh population in these units we will find that there are 7 colleges per lakh population in Bihar, 15 colleges per lakh population in Chandigarh, 8 colleges per lakh population in Delhi and Jharkhand respectively and 11 colleges per lakh population in Tripura. The average enrolment per college in Bihar is 2088, in Chandigarh it is 1888, in Delhi the average enrolment is 1752, in Jharkhand it is 1848 and in Tripura the average enrolment is 1387. It is very clear from the numbers that there is a lot of pressure on the human and non-human resources in these states. Bihar has the highest pupil teacher ratio (PTR) in the country. The PTR in Bihar is 69. It means that there one teacher per 69 students in the HEI of Bihar. In Delhi also the PTR is 49. The national average PTR is 26. In Jharkhand the PTR is 58. According to a quantitative study, these states that have attained 100% efficiency. It also means that they are over utilizing their inputs to fulfil the requirement of maximum enrolment and to attain a certain passout percentage. Colleges are being pushed to increase their seats for undergraduates while the faculty hiring is still in the loom. Table 2 shows the average efficiency of the units considered under evaluation. The number and percentage of units (out of 32) that have the efficiency in the different ranges have been shown.

Section 1 (of Table 2) shows the number of efficient units under CRS assumption. There is 1 DMU that has efficiency between 0 and 0.1, 2 units have efficiency between 0.1 and 0.2, 3 units have efficiency between 0.2 and 0.3, 9 units have efficiency between 0.3 and 0.4. Same numbers have been shown as a percentage from 32 units. Section 2 (of Table 2) shows the number of efficient units under the assumption of VRS.

Table 2: Number of DMUs in each range of efficiency score

Section 1			Section 2		
Efficiency Range	Number of Units Out of 32 in the Efficiency Range	% of Units Out of 32 in the Efficiency Range	Efficiency Range	Number of Units Out of 32 in the Efficiency Range	% of Units Out of 32 in the Efficiency Range
Under the assumption of CRS			**Under the assumption of VRS**		
0<=E<0.1	1	3.1	0<=E<0.1	1	3.1
0.1<=E<0.2	2	6.2	0.1<=E<0.2	2	6.2
0.2<=E<0.3	3	9.4	0.2<=E<0.3	2	6.2
0.3<=E<0.4	9	28.1	0.3<=E<0.4	4	12.5
0.4<=E<0.5	5	15.6	0.4<=E<0.5	7	21.9
0.5<=E<0.6	3	9.4	0.5<=E<0.6	3	9.4
0.6<=E<0.7	1	3.1	0.6<=E<0.7	1	3.1
0.7<=E<0.8	2	6.2	0.7<=E<0.8	1	3.1
0.8<=E<0.9	2	6.2	0.8<=E<0.9	1	3.1
0.9<=E<1	0	0	0.9<=E<1	2	6.2
E=1	4	12.5	E=1	8	25

(Source: Authors' Calculation)

Under CRS methodology and input oriented efficiency, the number of firms with efficiency equal to 1 are 4 out of 32 and the mean efficiency is found to be 0.497. Under the assumption of VRS methodology and input oriented efficiency, the number of firms with efficiency equal 1 are 8 out of 32, having the mean efficiency of 0.598.

We applied the super efficiency model, given by (Andersen & Petersen, 1993) and (Jablonsky, 2006), to identify the most efficient unit from those achieving the score 1, and the result is shown below in Table 3.

Table 3: Super Efficiency of States and UTs

States/UTs	Super Efficiency (SE)	States/UTs	Super Efficiency (SE)
Andhra Pradesh	0.4341	Maharashtra	0.9851
Arunachal Pradesh	0.5175	Manipur	0.4181
Assam	0.5589	Meghalaya	0.9749
Bihar	1.9739	Mizoram	0.1646
Chandigarh	Inf	Nagaland	0.4045
Chhattisgarh	0.5563	Odisha	0.4572
Delhi	8.4517	Puducherry	0.1496
Goa	0.386	Punjab	0.2494
Gujarat	0.6124	Rajasthan	0.8048
Haryana	0.3938	Sikkim	Inf
Himachal Pradesh	0.4282	Tamil Nadu	1.0691
Jammu and Kashmir	0.4467	Telangana	0.4794
Jharkhand	1.012	Tripura	1.2009
Karnataka	0.2724	Uttar Pradesh	Inf
Kerala	0.3078	Uttarakhand	0.3782
Madhya Pradesh	0.7631	West Bengal	1.0012

(Source: Authors' Calculation)

As per the result obtained and shown in Table 3, Bihar, Jharkhand, Tamil Nadu, Tripura and West Bengal are marginally more efficient than 100%, but Delhi has surpassed all other DMUs with super efficiency score of 8.45. Figure 3 and 4 show the comparison for 4 years data for the units achieving more than 100% efficiency in the super efficiency analysis. In Bihar, Tamil Nadu and West Bengal the enrolment numbers are much higher as compared to Delhi. Although the outpass numbers shown in blue colour are somewhat similar to Delhi. In Delhi, the enrolment is not as high as Bihar, Tamil Nadu and West Bengal.

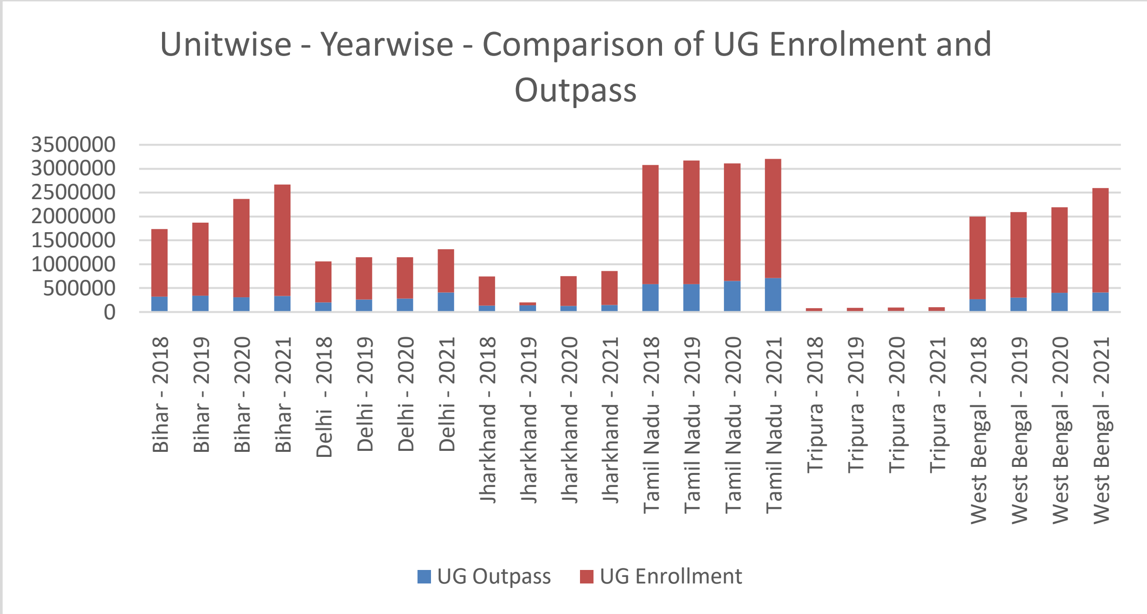

Figure 3: Author's compilation showing a comparison of number of undergraduate enrolments and outpass for 4 years from 2018-21 for the units achieving more than 100% efficiency in the SE analysis.

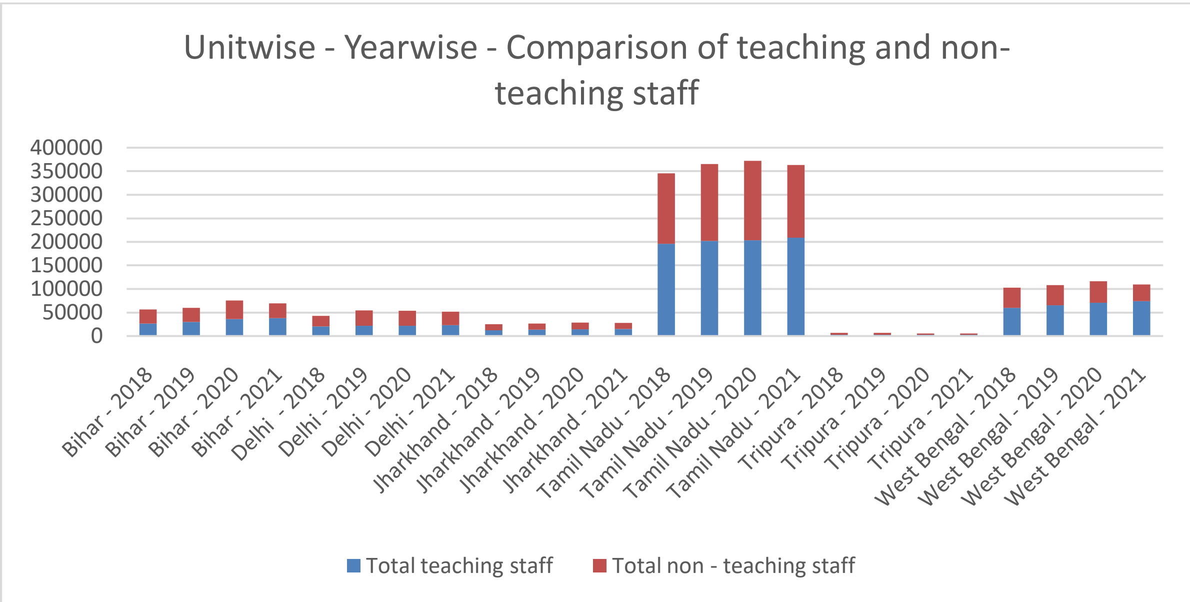

Figure 4: Author's compilation showing a comparison of number of teaching and non-teaching staff for 4 years from 2018-21 for the units achieving more than 100% efficiency in the SE analysis.

CONCLUSION AND FUTURE WORK

In this paper, we stressed upon the importance of non-human resources on the efficiency of the higher education systems and the pressure that is being put on the human resources in some states. Data revealed that some states lacked proper infrastructure in terms of human and non-human resources and hence were over utilizing them. The impact of number of colleges and availability of hostel as an important factor affecting the efficiency have not been included in the literature. We identified few gaps and proposed to identify the top performing units from the others by involving three models - CCR model for finding the technical efficiency and BCC model to find the pure technical efficiency. We used the TE and PTE score to find the scale efficiency which is the ratio of both. Thereafter we sorted the most efficient unit from the efficient ones using the super efficiency model, as proposed by Andersen & Petersen (1993) and (Jablonsky, 2006).

The aim of our central and state governments is to bring more and more students under the umbrella of higher education system through enrolments. This also means that the human as well as non-human infrastructure needs to be enhanced at an equivalent pace in order to keep up with the rising pressure of students. Delhi is the most efficient of all units with super efficiency score of 8.4. Through the 3-model analysis (CCR, BCC, & SE) done in this paper the authors aim to draw the attention of the policy makers towards this direction. Although Delhi has some unsaid advantages as it is the national capital, yet the other states and UTs can follow the working model of higher education in Delhi to some extent.

Finally, there are some limitations and possible extensions of this research paper. A one-size-fits-all approach can be unjust for the analysis of the states of different sizes and different peculiarities. Attention should be given to the policy analysis, fund allocation, recruitment patterns of each state or UT. The state governments should decide their own trajectory for the short and long term. Involving the public institutions in the market mechanism and limiting the independence of the private players can be worked upon by a coordinated effort of players are multiple fronts. It is also important to acknowledge the limitations of the SE analysis, the variable and software selection can affect the result remarkably. So, it is important to keep in view the previous studies that have been performed in the same field.

This paper does not close the gates for further discussion rather intends to draw the attention of policy makers towards a different direction. The units that have achieved 100% efficiency also need to keep monitoring their policies to keep up with the ever-rising population of India. This study is a spirited call to revisit the policies motive with which we are shaping the higher education and graduates of India and to reassess how the higher education system of states and UTs and of India on the whole can be evolved to make our graduates fit for the working market.

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