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Assessing the Efficiency of Academic Departments: An Application of Data Envelopment Analysis and Tobit Analysis

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Abstract. The systematic assessment of academic institutions is necessary in order to assure the achievement of their set objectives by proper utilization of the limited resources. Thus, the current paper focused on examining the efficiency of academic departments. The study has been conducted for a period of ten years. Efficiency scores of the departments have been examined through the application of CCR (Charnes, Cooper, and Rhodes) and BCC (Bankar, Charnes, and Cooper) model of data envelopment analysis. In addition to efficiency evaluation, the factors affecting efficiency have also been analysed by applying Tobit regression analysis, which helps in improving the effectiveness of departments by focusing on significant variables impacting the efficiency. It provides a guide for policy and managerial decision making.

Keywords: efficiency, academic departments, data envelopment analysis, Tobit

JEL Classification: C67, C80

1. Introduction

The present times are characterized by immense change and complexity in the structure of the higher education system due to widespread knowledge. Their evaluation can be useful in managing these instabilities. Universities are the backbone of the higher education system and provide a substantial human resource base for a country's socioeconomic development. To ensure that these universities meet their goals by making the best use of their limited resources, a rigorous evaluation of these institutions is required. When an organization's performance gaps are identified by such an evaluation, the necessary steps can be taken to close

the gaps and achieve the objectives. As a result, establishing a method to assess an organization's performance is crucial to its excellence and advancement (Askari et al., 2019). Furthermore, it is challenging for state university administrations to educate state politicians about how well their schools are performing in achieving their goals. It is the responsibility of university authorities to ensure that the available resources are utilized in such a way that improves the efficiency of the institution (Moreno and Tadepalli, 2002). However, due to the non-profit nature of higher education institutions, it is difficult to evaluate their efficiency. Moreover, these institutions are characterized by multiple input and output variables. In addition to this, there is a lack of price information for the variables in the case of these institutions. Thus, it is challenging to assess the efficiency of these institutions. However, data envelopment analysis is a non-parametric technique used to evaluate the efficiency of higher education institutions, as it does not require any price information related to input and output variables.

Improvements in education and scientific research have allowed India's development to reach a global level (Tyagi et al., 2009). According to the University Grant Commission's (UGC) 2020–21 Annual Report, an increasing number of students pursue Ph.D. degrees. In addition to research activities, student enrolment has also increased in undergraduate, postgraduate, and integrated courses. Thus, the Indian universities serve both the teaching and research motives. In the list of highest graded universities by the National Assessment and Accreditation Council (NAAC), the first name appears as Guru Nanak Dev University, Amritsar, with a score of 3.85 on the scale of 4 as per the rating in 2022. The university was established in 1969. For more than 53 years, the university has been dedicated to advancing research and education. To accomplish the university's goal of advancing education and research, the academic departments have been involved. Examining the academic departments' effectiveness is the goal of the current paper.

The study conducted by Kaur and Bhalla (2021) was also focused on the efficiency of academic departments of Guru Nanak Dev University, Amritsar. However, that study was only focused on the efficiency during one academic year. Moreover, factors of efficiency were not examined in that study. The present study examined the efficiency over a period of ten years. In addition to this, it also examined the various factors affecting the efficiency of academic departments of the university.

No doubt, efficiency studies have been carried out on academic departments and on a variety of universities. Various viewpoints provide a great deal of room for additional research. Nonetheless, a university's total efficiency is a direct result of its departments' effectiveness. Therefore, the efficiency assessment of university departments was the main emphasis of the current study.

The rest of the paper is organized as follows. Section 2 presents a literature review. Section 3 discusses research methodology, including the methods, variables, and datasets employed in the analysis. Section 4 presents the empirical findings, while Section 5 discusses implications and concludes.

2. Review of Literature

There are a number of studies that examined the efficiency and its determinants among the higher education institutions. It has been observed that most of the studies focused on the efficiency of universities (Adamu et al., 2016; Agasisti and Pohl, 2012; Albayatey et al., 2021; Al-tyeb, 2017; Bangi, 2014; Barra et al., 2015; Foltz et al., 2012; Ismail, 2015; Kaur and Bhalla, 2021; Kempkes and Pohl, 2010; McMillan and Datta, 1998; Quiroga-Martínez et al., 2018; Sav, 2013; Selim and Bursalioglu, 2013; Selim and Bursalıoğlu, 2015; Tran and Villano, 2018; Türkan and Özel, 2017; Wildani et al., 2023; Zhang and Kim, 2018). Moreover, factors affecting departmental efficiency have been examined by Agha et al. (2011), Kounetas et al. (2011), and Sharma and Mehra (2019). Moreover, there are also some studies available that analysed the factors affecting the efficiency of different higher education institutions. These studies include Al-Bagoury (2013), Bangi and Sahay (2014), Bradley et al. (2010), Gromov (2017), Salas-Velasco (2020), Sav (2017), Soummakie and Wegener (2024), Wolszczak-Derlacz (2017), and Wolszczak-Derlacz and Parteka (2011). Thus, most of the efficiency-based studies focused on the factors affecting the efficiency of universities, and there is a dearth of literature relating to the efficiency and its determinants among the academic departments.

The efficiency has been evaluated by applying data envelopment analysis in the case of the higher education sector. After the evaluation of efficiency scores, factors affecting efficiency have been examined by using different techniques. Most of the studies employed the Tobit regression analysis to examine the factors affecting efficiency (Adamu et al., 2016; Agasisti and Pohl, 2012; Al-Bagoury, 2013; Al-tyeb, 2017; Bangi, 2014; Bangi and Sahay, 2014; Gromov, 2017; Ismail, 2015; Kempkes and Pohl, 2010; Kounetas, et al., 2011; McMillan and Datta, 1998; Sav, 2017, 2013; Selim and Bursalioglu, 2013; Selim and Bursalıoğlu, 2015; Sharma and Mehra, 2019; Türkan and Özel, 2017; Zhang and Kim, 2018). Besides this, Quiroga-Martínez et al. (2018) employed fixed-effect regression model to examine the factors affecting efficiency. Ordinary least square has been employed by Bradley et al. (2010). Another technique, i.e. multiple linear regression, has been used by Agha et al. (2011). Truncated regression has also been used to analyse the factors affecting efficiency (Barra et al., 2015; Wolszczak-Derlacz and Parteka, 2011). Foltz et al. (2012) examined the factors affecting efficiency through the application

of probit regression and Tran and Villano (2018) examined the factors affecting efficiency through the employment of fractional regression. However, it has been observed that Tobit regression analysis has been used as statistical technique in most of the studies. This is due to the censored nature of the dependent variable, i.e. efficiency scores.

The findings indicated that mean efficiency score evaluated by different studies was more than 50%. The studies, including Bangi (2014) (83.67%), Halkos et al. (2010) (84.7%), Sav (2013) (86.7% to 87.9%), and Tyagi et al. (2009) (86.8%), have recorded mean efficiency scores between 80% and 90%. Other studies experienced efficiency scores less than 80%, but none of the studies recorded a mean technical efficiency score less than 50%.

The studies related to efficiency have been conducted in various universities (Adamu et al., 2016; Agasisti and Pohl, 2012; Bangi, 2014; Barra et al., 2015; McMillan and Datta, 1998) and academic departments (Askari et al., 2019; Aziz et al., 2013; Halkos et al., 2010; Kounetas et al., 2011; Moreno and Tadepalli, 2002). Different perspectives leave a lot of scope for further exploration. However, efficient departments within a university lead to the overall efficiency of the university. Thus, the current study focused on the efficiency evaluation of specific departments within a university.

Due to a dearth of literature relating to the efficiency of academic departments and the factors affecting efficiency, the current study focused on examining the efficiency of academic departments of a state university. Moreover, as the literature reveals, most of the studies evaluating efficiency have applied data envelopment analysis and Tobit regression analysis. The detailed explanation of these techniques is presented in the next section.

3. Research Methodology

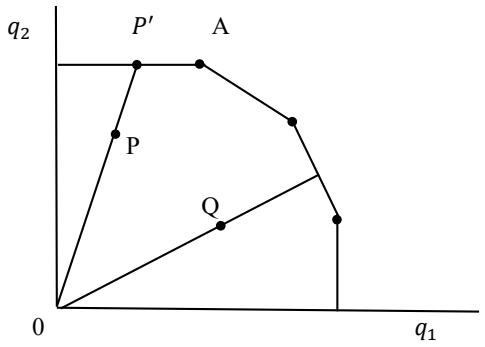
With the object of measuring the efficiency of academic departments, data envelopment analysis has been applied. In the first step, efficiency scores for the university departments have been derived, and in the second step the potential determinants of efficiency of the academic departments have been examined by regressing the efficiency scores against various institutional factors.

Step 1: Estimating the efficiency scores through data envelopment analysis

Data envelopment analysis is a linear-programming-based non-parametric technique to evaluate the relative efficiency of non-profit organizations. The organizations for which the efficiency scores are evaluated through the application of data envelopment analysis are known as decision-making units. DEA (data

envelopment analysis) requires data of input and output variables of decision-making units in order to calculate the efficiency scores. DEA was originated by Farrel in 1957. It was modified by Charnes, Cooper, and Rhodes in 1978 known as the CCR model. It assumes constant returns to scale while calculating efficiency scores. The model was further extended by Bankar, Charnes, and Cooper in 1984 known as the BCC model. This model assumes variable returns to scale while evaluating the efficiency of decision-making units. The main aim of the technique is to develop a frontier for efficient decision-making units and to find out the distance between inefficient units from this frontier. The units that lie on the efficient frontier developed by data envelopment analysis are known as efficient units.

Data envelopment analysis can be input-oriented or output-oriented. Input-oriented approach of data envelopment analysis focuses on the minimum usage of input resources to produce a given level of outputs, whereas under output orientation, DEA aims to produce maximum output with a given level of input. Output-oriented models are appropriate for higher education institutions, as input resources used in these institutions can be fixed, and they cannot influence their inputs, at least in the short run (Barra and Zotti, 2016). However, they can improve their outputs with given inputs. So, in the current case, an output-oriented model is more appropriate (Tyagi et al., 2009). Thus, output-oriented CCR and BCC models of data envelopment analysis have been employed to achieve the objectives of the present study.



Source: Coelli et al., 2005

Figure 1. *Output-oriented data envelopment analysis*

Figure 1 depicts the example of output-oriented data envelopment analysis with two outputs. The curve shows the efficient frontier. The units below the curve indicate inefficient units. For example, in the figure, P and Q indicates the inefficient units as they lie below the efficient frontier. In order to become efficient, these units must lie on an efficient frontier.

An output-oriented CCR model of data envelopment analysis can be represented mathematically as follows:

$$Max\ TE_{CRS}^{k} = \delta_k$$

subject to

$$\sum_{j=1}^{n} \omega_j y_{ij} \geq \delta y_{ik}$$

$$\sum_{j=1}^{n} \omega_j x_{rj} \leq x_{rj}$$

$$\omega \geq 0,$$

where δ_k represents the efficiency of k^{th} decision-making unit, ω denotes the weight assigned to the DMU (decision-making unit), and y_{ij} denotes the amount of i^{th} output of j^{th} decision-making unit. Similarly, y_{ik} represents the amount of i^{th} output of k^{th} DMU, x_{rj} indicates the amount of r^{th} input of j^{th} DMU. The BCC model of data envelopment analysis includes one more constraint in the above mathematical formulation. An output-oriented BCC model of data envelopment analysis can be represented mathematically as follows:

$$Max\ TE_{VRS}^{k} = \delta_k$$

subject to

$$\sum_{j=1}^{n} \omega_j y_{ij} \geq \delta y_{ik}$$

$$\sum_{j=1}^{n} \omega_j x_{rj} \leq x_{rj}$$

$$\sum_{j=1}^{n} \omega_j = 1$$

$$\omega \geq 0.$$

3.1. Input/output specification

In the case of higher education institutions, multiple input resources are utilized, which includes financial, human, and physical resources (Kantabutra and Tang, 2006; Selim and Bursalıoğlu, 2015). Financial and human resources are the most important input resources in the case of higher education institutions (Watt, 2001). Thus, in order to evaluate the efficiency of the departments, the current study uses two input variables, i.e. academic staff and non-academic staff, representing human resources, and one variable, i.e. expenditure, representing financial resources. On the other hand, the main outputs produced in higher education institutions are teaching and research. The output variables selected in the study are number of students representing teaching output and research publications and research grants representing research outputs. A number of studies also used graduates as output variable such as Aziz et al. (2013), Koksal and Nalcaci (2006), or Sagarra et al. (2016). But this variable ignores the education of those students who have attended the courses but have not graduated (McMillan and Datta, 1998). Therefore, the current study uses student enrolment variable representing teaching output.

Further, the selection of input and output measures for data envelopment analysis is based on a rule of thumb given by Banker et al. (1984), which is:

$$n/3 \geq I + O,$$

where n represents the sample size, I is the number of inputs, and O is the number of outputs. By satisfying the above condition, three input and three output variables have been considered in the present study.

Inputs:

(i) Academic staff: It comprises professors, associate professors, and assistant professors. Weights have been assigned to each category of academic staff in order to get the standardized value. The weights have been assigned with same distance between two ranks (Barra et al., 2015; Barra and Zotti, 2013; Halkos et al., 2010; Kao and Hung, 2008).
Academic staff = 1 professors + 0.67* associate professors + 0.33* assistant professors.*

(ii) Non-academic staff: The second input variable used in the present study is non-academic staff, which includes superintendent, stenographer, senior assistant, steno typist, clerk, helper, peon, waterman, and attendant.

(iii) Expenditure: Another input variable, namely expenditure, represents the salaries and operating expenses of a department.

Outputs:

(i) Number of students: Number of students comprises of students enrolled in graduation and post-graduation. Again, weights have been assigned to get standardized value (Halkos et al., 2010 and Tyagi et al., 2009).
Number of students = 1 postgraduate enrolment + 0.5* undergraduate enrolment.*

(ii) Research Publications: It represents the number of publications by a particular department.

(iii) Research grant: It constitutes the grant received by departments for different research schemes and grant received by teachers for research projects.

Step 2: Examining the determinants of efficiency through the application of the Tobit model

The efficiency scores evaluated in the first stage can be further used to examine the impact of explanatory variables. The efficiency scores ranged from 0 to 1. This accounts for limited dependent variable. Due to the censored nature of the dependent variable (efficiency scores), the Tobit regression model has been employed. Moreover, studies conducted by a large body of researchers (Adamu et al., 2016; Agasisti and Pohl, 2012; Al-Bagoury, 2013; Bangi, 2014; Bradley et al., 2010; Gromov, 2017; Kempkes and Pohl, 2010; Kounetas et al., 2011; Liu et al., 2012; McMillan and Datta, 1998; Sav, 2013, 2017; Selim and Bursalıoğlu, 2013, 2015) also suggest the application of the Tobit regression model in order to examine the factors affecting efficiency scores. The fixed-effect Tobit regression model cannot be applied due to a lack of statistics that allows the fixed effects to be conditioned out of the likelihood (Stata Press Publications, 2021). An unconditional fixed-effect model may be fit with the command of the Tobit model with individual indicator. However, these estimates are biased (Stata Press Publications, 2021).

Thus, the factors affecting technical efficiency, pure technical efficiency, and scale efficiency have been examined by applying the random-effects panel Tobit model. The random-effects panel model can be represented as the following equation:

$$y_{it} = \beta x_{it} + v_i + \varepsilon_{it}$$
$$i = 1, 2, \ldots\ldots, n$$
$$t = 1, 2, \ldots\ldots, T,$$

where y_{it} represents the dependent variable, x_{it} is the vector of independent variables, and β is the vector of coefficients of the independent variables. The error term u_{it} is split into time-varying idiosyncratic random error (ε_{it}) and time-invariant random effect (v_i):

$$u_{it} = v_i + \varepsilon_{it}$$

The measured variable for left-censored and right-censored observations is:

$$y_{it}^{*} = \begin{cases} y_{it} \; if \; y_{it} > 0 \\ 0 \; otherwise \end{cases}$$

$$y_{it}^{*} = \begin{cases} y_{it} \; if \; y_{it} < 1 \\ 0 \; otherwise \end{cases}$$

Thus, in the present study, the factors affecting technical efficiency, pure technical efficiency, and scale efficiency have been examined through the application of random-effects panel Tobit regression model.

The dependent variables used for this study are efficiency scores under both CCR and BCC models. After analysing the existing literature, the independent variables used in the study are student : teacher ratio, the ratio of female to total students, teaching staff : non-teaching staff, professors : total teaching staff, tuition fees, operating expenses, and age. *Table 1* summarizes the explanatory variables of the departments' efficiency scores.

Table 1. *Description of the variables used as determinants of efficiency*

Variable	Symbol	Description
Student : teacher ratio	STUD	Total number of students in the department : total number of teachers in the department
Ratio of female students to total students	FEMALE	Number of female students in the department : total number of students in the department
Teaching staff : non-teaching staff ratio	TEACH	Number of teachers in the department : total number of non-teaching employees in the department
Professors : total teaching staff	PROF	Number of professors : total number of teachers in the department
Tuition fees	TUT	Fees charged by a department for teaching, instruction, or other services
Operating expenses	OEX	Ongoing costs of a department
Age	AGE	Number of years a department has been in existence

3.2. Dataset

The study is aimed at examining the efficiency of the academic departments at Guru Nanak Dev University, Amritsar. The study has been conducted for a period

of ten years between 2008-09 and 2017-18. To achieve the objective of identifying the factors affecting efficiency, the Tobit analysis can only be applied on balanced data. In order to get balanced data, two criteria have been used in selecting the sample. First of all, only departments with a continuous operation during the period of study were included in the sample. There were two demergers during the period of study. The Department of Commerce and Business Management was demerged into the Department of Commerce and the University Business School, and the Department of Computer Science and Engineering was demerged into the Department of Computer Engineering and Technology and the Department of Computer Science. These departments have been excluded from the study. Moreover, one new department, namely the Department of Education, has also been excluded from the study, as it came into existence after 2014-15. Secondly, the study focused only on departments providing degree courses. Thus, the final sample comprised of 30 academic departments that fulfil the above criteria.

4. Results of the empirical analysis

Efficiency of Academic Departments

In the first step, the efficiency scores of the departments have been assessed under the assumption of both CCR and BCC models. *Tables 2–3* represent the efficiency scores under the CCR and BCC models respectively.

It is clear from *Table 2* that heterogeneity in the results of efficiency scores under the CCR model has been observed. The mean efficiency under the assumption of constant returns to scale varied from 53.8% to 69.7%. It is also worth mentioning that only one department, i.e. the Department of Physical Education, was found to be efficient across all the years (2008-09 – 2017-18). The reason could be the lowest departmental expenditure as compared to other university departments. Also, empirical findings suggest that the Department of Food Science and Technology, Zoology, Architecture, Guru Ramdas School of Planning, Punjab School of Economics, History, Political Science, Psychology, Sociology, English, Punjabi, Sanskrit Pali, and Prakrit, Laws, Music and Guru Nanak Studies failed to achieve an efficiency score of 1 in any year of the study period. In other words, these departments were not able to produce as much output as they were expected to produce from their existing inputs.

Table 2. *Efficiency scores (CCR) of the departments (from 2008-09 to 2017-18)*

Departments (DMUs)	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
1 Chemistry	1	0.81	0.903	0.672	1	0.869	1	0.896	0.819	0.83
2 Mathematics	0.886	1	1	0.721	0.444	1	0.939	0.606	0.57	0.587
3 Physics	1	1	1	0.658	0.743	0.785	0.626	0.461	0.528	0.717
4 Pharmaceutical Sciences	0.613	0.952	0.857	0.703	0.417	1	1	1	0.891	1
5 Food Science and Technology	0.913	0.668	0.714	0.425	0.67	0.952	0.998	0.527	0.811	0.525
6 Biotechnology	1	0.826	1	1	1	1	1	1	1	1
7 Botanical and Environmental Sciences	1	1	0.766	1	0.969	0.916	1	1	1	1
8 Human Genetics	0.689	0.703	1	1	0.706	0.63	0.689	0.419	0.587	0.575
9 Microbiology	1	1	1	1	1	1	1	0.887	0.912	0.705
10 Molecular Biology and Biochemistry	0.355	0.502	0.609	0.789	0.716	1	1	0.753	0.837	0.475
11 Zoology	0.881	0.641	0.665	0.628	0.832	0.822	0.848	0.913	0.757	0.586
12 Electronics Technology	1	1	1	1	0.676	1	0.728	1	1	1
13 Architecture	0.314	0.279	0.458	0.269	0.259	0.157	0.343	0.336	0.355	0.323
14 Guru Ramdas School of Planning	0.255	0.372	0.392	0.312	0.192	0.298	0.199	0.19	0.233	0.239
15 Punjab School of Economics	0.803	0.548	0.685	0.431	0.332	0.809	0.475	0.748	0.705	0.578
16 History	0.167	0.1	0.152	0.195	0.175	0.272	0.328	0.311	0.497	0.244
17 Library and Information Science	1	1	1	0.409	0.342	0.783	0.792	0.646	1	0.951
18 Political Science	0.505	0.383	0.382	0.388	0.517	0.673	0.664	0.564	0.889	0.665
19 Psychology	0.482	0.421	0.69	0.407	0.25	0.377	0.214	0.362	0.55	0.347
20 Sociology	0.384	0.399	0.575	0.388	0.607	0.416	0.311	0.391	0.446	0.549
21 School of Social Science	1	1	1	1	1	0.792	1	1	1	1
22 English	0.427	0.385	0.331	0.27	0.21	0.303	0.192	0.249	0.197	0.229
23 Hindi	0.178	0.6	0.501	0.303	0.265	0.652	0.283	0.534	0.288	1
24 Punjabi	0.287	0.211	0.317	0.281	0.212	0.374	0.196	0.406	0.39	0.554
25 Sanskrit, Pali, and Prakrit	0.126	0.529	0.228	0.137	0.135	0.517	0.067	0.442	0.076	0.162
26 Physical Education	1	1	1	1	1	1	1	1	1	1
27 Laws	0.556	0.641	0.562	0.498	0.2	0.38	0.497	0.722	0.737	1
28 Music	0.213	0.269	0.217	0.213	0.263	0.473	0.466	0.489	0.552	0.704
29 Guru Nanak Studies	0.483	0.289	0.261	0.148	0.269	0.662	0.516	0.379	0.403	0.337
30 Sports Medicine and Physiotherapy	1	0.9	1	0.785	0.74	1	1	0.701	0.949	0.647
Mean	0.651	0.648	0.675	0.568	0.538	0.697	0.646	0.631	0.666	0.651
Percentage of efficient departments	33.33%	26.67%	33.33%	23.33%	16.67%	26.67%	30%	20%	20%	26.67%

Table 3. *Efficiency scores (BCC) of the departments (from 2008-09 to 2017-18)*

Departments (DMUs)	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
1 Chemistry	1	1	1	1	1	1	1	1	1	1
2 Mathematics	0.913	1	1	0.723	0.586	1	0.939	0.606	0.603	0.589
3 Physics	1	1	1	1	1	1	0.894	0.689	0.754	1
4 Pharmaceutical Sciences	0.646	0.965	0.938	0.737	0.495	1	1	1	0.988	1
5 Food Science and Technology	0.95	0.748	0.741	0.66	0.818	1	1	0.631	0.815	0.566
6 Biotechnology	1	0.839	1	1	1	1	1	1	1	1
7 Botanical and Environmental Sciences	1	1	0.829	1	0.976	1	1	1	1	1
8 Human Genetics	0.712	0.739	1	1	0.855	0.709	0.718	0.458	0.59	0.596
9 Microbiology	1	1	1	1	1	1	1	0.891	1	0.716
10 Molecular Biology and Biochemistry	0.37	0.507	0.611	0.791	0.74	1	1	0.761	0.876	0.475
11 Zoology	1	0.658	0.673	0.646	0.846	0.822	0.873	0.944	0.979	0.609
12 Electronics Technology	1	1	1	1	1	1	1	1	1	1
13 Architecture	0.38	0.36	0.514	0.432	0.439	0.181	0.482	0.403	0.502	0.621
14 Guru Ramdas School of Planning	0.375	0.537	0.524	0.465	0.408	0.323	0.315	0.286	0.324	0.347
15 Punjab School of Economics	0.804	0.709	0.726	0.65	0.743	0.935	0.896	0.996	0.761	0.794
16 History	0.215	0.128	0.152	0.222	0.271	0.276	0.345	0.343	0.534	0.251
17 Library and Information Science	1	1	1	0.617	0.363	0.986	0.825	0.743	1	1
18 Political Science	0.518	0.448	0.448	0.446	0.549	0.705	0.667	0.606	0.968	0.675
19 Psychology	0.586	0.474	0.71	0.438	0.351	0.387	0.286	0.364	0.685	0.351
20 Sociology	0.463	0.414	0.592	0.434	0.703	0.479	0.326	0.397	0.492	0.565
21 School of Social Science	1	1	1	1	1	1	1	1	1	1
22 English	0.527	0.475	0.331	0.332	0.365	0.345	0.316	0.345	0.253	0.266
23 Hindi	0.205	0.729	0.509	0.304	0.282	0.758	0.355	0.586	0.296	1
24 Punjabi	0.376	0.327	0.439	0.461	0.468	0.462	0.46	0.5	0.462	0.56
25 Sanskrit, Pali, and Prakrit	0.629	0.692	0.246	1	0.143	0.661	0.083	0.493	0.078	0.177
26 Physical Education	1	1	1	1	1	1	1	1	1	1
27 Laws	0.78	0.774	0.636	0.67	0.4	0.477	0.845	1	1	1
28 Music	0.216	0.271	0.224	0.215	0.306	0.605	0.533	0.507	0.559	0.714
29 Guru Nanak Studies	0.504	0.393	0.282	0.156	0.397	0.725	0.519	0.391	0.433	0.342
30 Sports Medicine and Physiotherapy	1	0.988	1	0.83	1	1	1	0.826	0.966	0.653
Mean	0.706	0.706	0.704	0.674	0.65	0.761	0.723	0.692	0.731	0.696
Percentage of efficient departments	36.67%	30%	36.67%	33.33%	26.67%	43.33%	36.67%	26.67%	30%	36.67%

The findings of the efficiency scores under the BCC model have been presented in *Table 3*. The mean efficiency under variable returns to scale varied from 65% to 73.1%. The Department of Chemistry, Electronics Technology, School of Social Sciences and Physical Education have been rated as efficient in all the years considered in the study, i.e. from 2008-09 to 2017-18. This indicates that these departments are producing the expected outputs by optimally utilizing their existing resources. It has also been observed that the pure technical efficiency score of 1 has never been attained by the Department of Architecture, Guru Ramdas School of Planning, Punjab School Economics, History, Political Science, Psychology, Sociology, English, Punjabi, Music and Guru Nanak Studies in any of the academic years (2008-09 to 2017-18). Thus, there is no proper utilization of resources in these departments.

Determinants of Efficiency Scores of the Academic Departments

After assessing the efficiency differences among various academic departments, we examine the various institutional factors affecting their efficiency. The factors affecting efficiency have been examined with the help of the Tobit regression model. Before running the models, assumptions have been checked. The data has been found normal. While checking the multicollinearity between the independent variables, it has been found that the values fall within the limits (1.106 to 1.816), indicating that there is no multicollinearity problem. Values greater than 10 indicate collinearity problem. However, the values for all variables were below 10. Moreover, the data were also free from autocorrelation. The findings of the Tobit regression under both the CCR and BCC models are presented in *Table 4*.

It has been observed that the random model is better, as reflected by rho and the likelihood ratio (LR) test under both the CCR and BCC models. If the value of rho is zero, it indicates that the panel level component is unimportant. In the present model, rho is not equal to zero. Thus, the panel model is better than the pooled model. Moreover, the probability value (Prob > Chi2) indicates that the overall model is fit. The student : teacher ratio (STUD) reveals the significant positive impact on technical efficiency at 1% level of significance, which indicates that the efficiency of a department increases when teachers serve more students. The results are supported by Bradley et al. (2010) and Sharma and Mehra (2019), as significant positive relationship was found between efficiency and STUD in these studies. The relationship between efficiency and the ratio of female students to total students (FEMALE) was found as insignificant. Similar findings were revealed by Sharma and Mehra (2019). Positive association has been observed between teaching staff : non-teaching staff ratio (TEACH) and the efficiency of the university departments, which is significant at 1% level of significance. This implies that a greater proportion of teaching staff as compared to non-teaching staff leads to increase in efficiency. A negative relationship has been found between professors : total teaching staff and efficiency of the departments.

This may be attributed to the lower level of commitment of experienced teachers (professors) as compared to new teachers (assistant professors) towards teaching and research activities. In addition to this, tuition fees (TUT) have a negative impact on efficiency scores. The results are found consistent with the study conducted by Sav (2013). Positive relationship has been found between operating expenses and efficiency of academic departments. Age (AGE) also suggests a negative association with efficiency, which is statistically significant at 1% level of significance. This indicates that younger departments were found to be more efficient as compared to departments operating for a longer period of time. Barra et al. (2015), Kounetas et al. (2011), and Wolszczak-Derlacz (2017) also found significant negative association between age and efficiency. The findings imply that the university departments should focus on statistically significant variables in order to achieve higher efficiency.

Table 4. *Results of the panel Tobit regression*

Explanatory variables		CCR Model			BCC Model		
Variable name	Symbol	**Coeff.**	**Std. Err.**	**P > Z**	**Coeff.**	**Std. Err.**	**P > Z**
Student : teacher ratio	STUD	.0166*	.0025	0.000	.0200*	.0034	0.000
Ratio of female students to total students	FEMALE	-.0023	.0950	0.981	.0045	.0986	0.964
Teaching staff : non-teaching staff ratio	TEACH	.0914*	.0256	0.000	.0747*	.0279	0.007
Professors : total teaching staff	PROF	-.2849*	.1034	0.006	-.2704**	.1085	0.013
Tuition fees	TUT	-9.38e-09*	2.48e-09	0.000	-4.47e-09	3.65e-09	0.221
Operating expenses	OEX	6.28e-08**	2.66e-08	0.018	9.42e-08*	3.28e-08	0.004
Age	AGE	-.0093*	0.0031	0.002	-.0118*	.0034	0.000
Constant		.576319	.1551524	0.000	.7237	.1698	0.000
Prob. > chi2			0.000			0.000	
Rho			.6430			.6523	
LR test (Prob.)			0.000			0.000	
Censored observations			77			101	
Uncensored observations			223			199	

*Note: * and ** indicate significance at 1% and 5% level of significance respectively.*

5. Conclusions

The present study examined the efficiency and factors affecting the efficiency of academic departments of a state university through the application of data envelopment analysis and Tobit regression model. It has been observed that several of the departments operated efficiently during the study period. However,

in case of the inefficient departments, the faculty members and administrators can redirect their efforts to areas that require attention. In addition to this, the identification of factors affecting academic departments' efficiency also helps in improving the effectiveness of departments by focusing on significant variables. The departments can improve their efficiency by increasing the student : teacher ratio, the teaching : non-teaching staff ratio, and operating expenses. However, an increased number of professors as compared to total teaching staff leads to a decrease in the efficiency of the departments. It has also been observed that an increase in tuition fees leads to less efficient departments. This may be due to the increased pressure among the students to pay greater fees, which ultimately results in their lower efficiency. Departments operating for a long period of time have also been found less efficient. This may be attributed to the lower level of commitment of older departments towards teaching and research activities as compared to newly established departments. It is important for the departments to focus on the significant variables in order to improve their efficiency. Moreover, the findings of the study enable administrators to make informed policy decisions such as allocating additional resources to either reward high-performing units or support struggling ones. In addition to this, identifying inefficiencies within an academic unit presents a valuable opportunity for the faculty and administrators to redirect their efforts towards areas requiring improvement. The present study also provides a way for other universities to examine their performance in terms of efficiency.

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