

Jñānābha, Vol. 55(2) (2025), 257-266

RELATIVE RESEARCH PERFORMANCE ASSESSMENT OF ACADEMIC DEPARTMENTS WITH SENSITIVITY ANALYSIS: A DEA APPROACH

Imran Ali^{1*}, Roshan Lal Keshtwal², Susheel Kumar³ and Gaurav Varshney⁴

¹Department of Mathematics, Dharmanand Uniyal Government Degree College, Narendranagar (Tehri Garhwal), Uttarakhand, India-249175

²Department of Mathematics, V.S.K.C. Government Postgraduate College, Dakpathar, Dehradun, Uttarakhand, India-248125

³Department of Mathematics, Deshbandhu College Kalkaji, New Delhi, India-110019

⁴Department of Mathematics, Sridev Suman Uttarakhand University, Pt. L.M.S. Campus Rishikesh (Dehradun), Uttarakhand 249201, India

Email: ali.imranmath@gmail.com^{*1}, rlkeshtwal@gmail.com², skahlawatt@gmail.com³, gauravdips@gmail.com⁴

(Received: March 27, 2025; In format: May 13, 2025; Revised: December 05, 2025;

Accepted: December 09, 2025)

DOI: <https://doi.org/10.58250/jnanabha.2025.55228>

Abstract

Data Envelopment Analysis (*DEA*) is a non-parametric linear programming technique. So, for to find the error analysis and robustness (stability) of the result the statistics hypothetical approach is very complicated and for this, in this study we apply the concept of sensitivity analysis. In this research work we assess the relative research performance of fifteen academic departments of *HEI* (Higher educational Institute) of Uttarakhand (India) using *DEA* technique. For to assess the research performance of all 15 PG departments we have been taken 3 input and 2 output variables by omitting alternatively these parameters we define 4 models in this study. In this study, only two departments, namely, Education and Zoology out of fifteen are best performer in all activities Ph.D. programs as well as others like publications etc. To understand the results more accurately and also for to search robustness (stability) of the research efficiency results, sensitivity analysis has been used in this research article.

2020 Mathematical Sciences Classification: 90C05, 90C31, 90C90.

Keywords and Phrases: *DEA*, Research performance, Departments, *LPP*, Sensitivity analysis.

1 Introduction

Education is important for the full development and sustained growth of any nation. The future of any country is secure in the hands of skilled persons. So, in these days the role of education has become more crucial and cannot be neglected by any nation. For economic and social development of any nations education is compulsory. In this study we have been taken 15 PG departments of Government College of Uttarakhand, for to measure the relative research performance of 15 academic departments (acad. depts.) using *DEA* technique with sensitivity analysis. Presently college is affiliated to Sri Dev Suman Uttarakhand Vishwavidhyalay (*SDSUV*), Badshahithaul, Uttarakhand. In general research activity is negligible in Degree College but Govt. PG College, Gopeshwar is a *NAAC-A* grade college and presently having total 23 departments (19 regular governments and 4 self-finance departments). Now this college has been made Sri Dev Suman Uttarakhand University Campus, Gopeshwar, which include *IGNOU* centre, *UOU* Centre and also have *NCC*, *NSS*, *Rovers Rangers* unit and *Red Cross* Unit. Out of these 23 we take only 15 departments for this study and ignore remaining 8 department due to the lack of data and some other reasons like faculties and students or both are not available for the session 2011-2012, at least two years period data are included in this study.

DEA is a non-parametric technique used to find the efficiency of the decision making units (*DMUs*). Due to non-parametric, hypothesis testing is extremely complicated to examine stability (or robustness) of the efficiency score of *DMUs* obtain by using *DEA* technique. So, sensitivity analysis (or post optimal analysis) is used to determine the stability of the efficiency score of the *DMUs*. In this research article, we proposed

4 models of Sensitivity analysis in *DEA* efficiency results. These models examine stability (robustness) of the efficiency scores by changing the reference set (input output parameters) of the *DMUs*. Models are used for ranking the efficient and inefficient *DMUs*. By omitting the Inputs (*I/Ps*) and Outputs (*O/Ps*) from its reference set excellent efficiency score of *DMUs* also evaluated. In this research paper, applying the sensitivity analysis, we examine the stability (robustness) of the research efficiency score of 15 acad. depts. of Higher Educational Institute (*HEI*) of Uttarakhand (India) obtained by *BCC* output oriented *DEA* model.

The main objective of this research problem is to examine activity-wise research performance assessment of the departments using *DEA* by taking different combinations of the used inputs and outputs parameters. This research aims to contribute substantively to the enhancement and optimization of research performance of academics departments in higher educational institutions

2 Literature Survey

There are many more well known techniques to find the efficiency of the decision making units (*DMU*), but *DEA* is a very powerful methods to find the efficiency of the *DMUs*. Some studies related to efficiency evaluation of *HEI* with the help of *DEA* approach are reviewed below. In U.S., Ahn [1] gave comparatively efficiency study of the universities by using *CCR* fractional form of *DEA*. John [16], applied the production theory approach for to estimate the performance of the Univ. in UK. Sarrico [26] asses the performance of institute in the perspective of *HE* sector in UK. To evaluate the research assessment of university and institute Korhonen *et al.* [20] recommended methodical approach. To examine the performance of 36 *AU* Avikiran [2] used *DEA* approach. To examine the technical efficiency evaluation of *AU*, Abbott and Doucouliagos [3] used *DEA* approach. By taking *I/Ps* and *O/Ps* of the some institutions in India, Debnath *et al.* [14] used the *DEA* approach to examine efficiency. With the help of *I/Ps* and *O/Ps* parameters Besent *et al.* [8] assessed 22 occupational-technical programs of Texas college in U.S. For the session nineteen eighty six to nineteen eighty seven Beasley [10] measured the performance of the Univ. Dept. in U.K. For the time period nineteen eighty four to eighty eight Johns and Johns [17], assessed research performance of departments of U.K. University. Kao and Hung [21] considered 41 Depts. out of 67 to estimate efficiency at *NCKU* in Taiwan. Tyagi *et al.* [28] estimated performance of nineteen Acad. Depts. for session two thousands three to two thousands four of IITR (India) through *DEA*.

Jauhar *et al.* [18] measured the efficiency of Acad. Dept. of *HEI* through *DEA* technique. Ali *et al.* [4, 5, 6, 7] assessed the technical efficiency (*OTE, PTE, SE*), teaching and research performance, overall teaching performance (*OTP*) with sensitivity analysis, stream-wise teaching performance of Science and Art streams Departments separately of a Government Post Graduate College, (India) by taking different set of *O/Ps* and *I/Ps* parameters for the academic year 2012-13, 2011-12. Panwar *et al.* [23] assessed the performance of Mathematics and Science of basic education system of Myanmar using *DEA*. Due to the lack of real and exact data of some real world application Arya *et al.* [8], used the rough data to find the efficiency of Indian fertilizers units by combining *DEA* model and rough set theory. Some other related research articles Jauhar *et al.* [19], Charne's *et al.* [13] and Panwar *et al.* [24], Sindhwani *et al.* [27], Kumar and Pant [22] are very helpful in this study.

This research article is organized as follows: In section 3, Mathematical form of *DEA* Model has been given which is used in this study. Selection of institute, *DMUs*, inputs and outputs selections for the research performance assessments with sensitivity analysis of the Acad. Dept. for this research are given in section 4. Data and computation, choice of *DEA* model has been given in section 5. Assessment of research performance for PG acad. depts. with sensitivity analysis are given in section 6 and lastly conclusions are given.

This research endeavors to bridge this notable gap in the literature, aspiring to provide a thorough examination and valuable insights into the research performance of academic departments of higher educational institutes in Uttarakhand (India), with a specific emphasis on data science related indicators/parameters. By adopting a holistic approach, encompassing *DEA BCC* output oriented models, along with the application of sensitivity analysis of Optimization theory, this research aims to contribute substantively to the enhancement and optimization of research performance of academics departments in higher educational institutions.

3 Methodology

Mathematical form of *O/P* oriented *BCC DEA* model used in this study is being given as below (Banker *et al.* [11])

$$\text{Max } e_0 = \sum_{r=1}^s v_{ro}\beta_{ro} + u_{0o}$$

$$\begin{aligned} \text{subject to } & \sum_{i=1}^m u_{io} \alpha_{io} = 1, \\ & \sum_{r=1}^s v_{ro} \beta_{rn} - \sum_{i=1}^m u_{io} \alpha_{in} + u_{0o} \leq 0, \quad \forall n \\ & u_{io}, v_{ro} \geq \varepsilon; \quad \forall i, r \text{ and } u_{0o} \text{ is unrestricted in sign.} \end{aligned}$$

(Ramanathan [25]).

3.1 Software used

All types of calculations for this study are done by using software *DEAP* 2.1 version. To find the correlation coefficients (r, ρ) among research performance models and inputs outputs parameters *SPSS* 20 Software used in this study.

3.2 Sample size

This study focuses on the research performance of the 15 PG academic departments out of 23 departments of government post graduate college, Gopeshwar, Chamoli, Uttarakhand (India) of the academic year 2011-2012. These 15 departments are selected based on the availability of research performance inputs and outputs. Its worth noting that the total sample size is 20 (15 academic departments and 5 inputs outputs parameters) in this study.

4 Research Design

4.1 Selection of *DMUs*

Fifteen PG departments of *HEI GPGC*, Gopeshwar (Chamoli), UK (India) has been taken as *DMUs*.

4.2 Outputs and Inputs Selections

4.2.1 Inputs

Three inputs variables (No. of Acad. Staff, No. of Non-Acad. Staff and Dept. Operating Cost (*DOC*)) have been taken in this study. These are essential input parameters for to run any academic departments of any educational institute/organization.

For to estimated performance assessment of any *DMU* of *HEI*, No. of acad. staff, No. of non-academic staff and *DOC* are the essential inputs parameters.

4.2.2 Outputs

Research work, student's placements and pass % all these are considered key factors for the progress of any academic institute. If any institution want to bring itself to the top position in the world, then it is very important for it to have all these. But it is a bit difficult to have all these in all the institutions because if we talk about degree colleges then there is lack of research work and other research activities, like organized Sem./Conf. by the Dept., Research Project taken by faculty of the depts., also the lack of Research scholar in the degree college depts. etc. In general in colleges the main reason for this has been found to be the lack of research labs (all science subject laboratory and computer labs etc) and all other facilities related to research.

In spite of all this, if we want to get the research efficiency of the depts. of degree college, then we have to define the output variables by including all the research activities (major/minor) running in the departments. In this research article, to measure the research performance assessment of depts. (*DMUs*) of the degree college (a *HEI*), we have define two output variables, namely, *Research scholar index*, *research index* which are defined as follows:

Research scholar index (Total enrolled research students index) = $5 * 10^{-3}$ (No. of UG students who is appear in I-year) + $5 * 10^{-2}$ (No. of PG students who is appear in I-year) + $15 * 10^{-1}$ (No. of teachers or students in the dept. of degree college doing the major (or minor) research projects funded by U/some other agency) + 2 (No. of research scholar guided by research staff of the dept. of degree college but not a research centre) + $25 * 10^{-1}$ (No. of research scholars whose research guide and research centre is the research staff of the dept. of the degree college).

Research scholar index is as an output parameter is taken in this study. In regarding quality of research work there are various conflicting opinions between peoples. According to common view of the academic staffs of the college depts. and available research parameters at PG level we form an output variable "Research Index" as:

Research index = No. of papers of the depts. in journals + $5 * 10^{-1}$ (No. of papers of the depts. in Conf.

/seminar) +6 * 10⁻¹ (No. of dissertation taken by the faculties the dept.) +3 * 10⁻¹ (No. of Conf./seminar attended by the faculties of the dept.)

5 Data and Computations

Data collection done for this study from the NAAC Report-2014 [15], SSR and exam section of the college for session 2011-12. All types of calculations for this study are done by using DEAP version 2.1 (Coelli, 1996) [12]. *I/Ps* and *O/Ps* static data and the correlations coefficient between *I/Ps* and *O/Ps* variables (calculated by “SPSS-20” Software) are given below in Table 5.1 and 5.2 respectively.

Table 5.1: *I/Ps and O/Ps statistic data*

Charact-eristics	Inputs			Outputs	
	No. of acade-mics Staff	No. of non-acade-mics staff	Dept. operating Cost (<i>DOC</i>)	Research scholar index	Research Index
Max	5	20	15000	7.45	31.8
Min	1	17	150	0.3	3.2
Average	2.867	17.6	2270	2.793	15.46
S.D.	2.121	0.707	3323.402	0.332	1.626

Table 5.2: *Correlation coefficients among I/Ps and O/Ps*

	Acad. Staff	Non-cad. Staff	<i>DOC</i>	Research Scholar Index		Research index
Acad. staff	1					
Non-acad. staff	0.649**	1				
<i>DOC</i>	0.450	0.891	1			
Research Scholar index	0.039	0.071	0.013	1		
Research index	0.229	0.148	0.067	0.223	0.686**	1

** At 10⁻² (one percent) levels (two-tailed) correlation is significant

5.1 Selection of DEA Model

BCC O/P oriented DEA model has been used for this study.

6 Research performance assessments of acad. depts. with sensitivity analysis

DEA is a linear programming non-parametric technique used to find the efficiency of the decision making units (*DMUs*). Due to non-parametric technique hypothesis testing is very complicated to examine the stability (robustness) of the efficiency score of *DMUs* obtained by using DEA technique. So, sensitivity analysis (Post optimal analysis) used to determine the stability of the research efficiency score of the *DMUs*. Sensitivity analysis (Post optimal analysis) is used to know how sensitive the solution values and efficiency scores of the *DMUs* are to the numerical observations. In this research article, we proposed some models in DEA research efficiency results. These models examine the stability (robustness) of the research efficiency scores *DMUs* by changing the reference set (input output parameters) of the *DMUs*. Models are used for ranking the efficient and inefficient *DMUs*. By omitting the *I/Ps* and *O/Ps* parameters from its reference set excellent research efficiency department also evaluated Ramanathan [25]. In this research paper, applying the sensitivity analysis, we examine the stability (robustness) of the DEA results (like efficiencies of *DMUs*, peers among others etc) of the academic departments in terms of the research activity and to assess the

performance of the departments from different criteria (like which department is better for at least for “Ph.D. award index” or Dissertation etc.), we use sensitivity analysis. We use these testing approach in this study. Efficiency score of 15 academic departments of *HEI* of Uttarakhand (India) obtained by *BCC* output oriented *DEA* model.

Here performance of all depts. based on research *O/Ps* (as “Research index”, “Ph.D. degree award index”, “No. of dissertation”). To describe the more specific performance of depts. related to research, we make division in the *O/P* variable “Research Index”, as shown in Table 6.1. In the section 7, four models are developed.

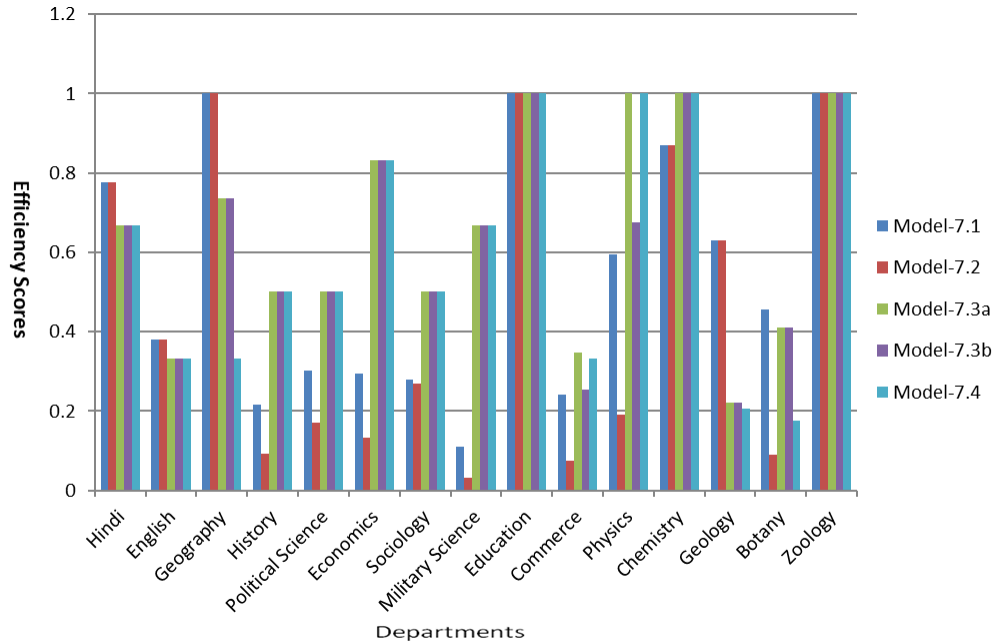


Figure 6.1: Comparison of VRS efficiency scores for research performance models (Model 7.1-7.4)

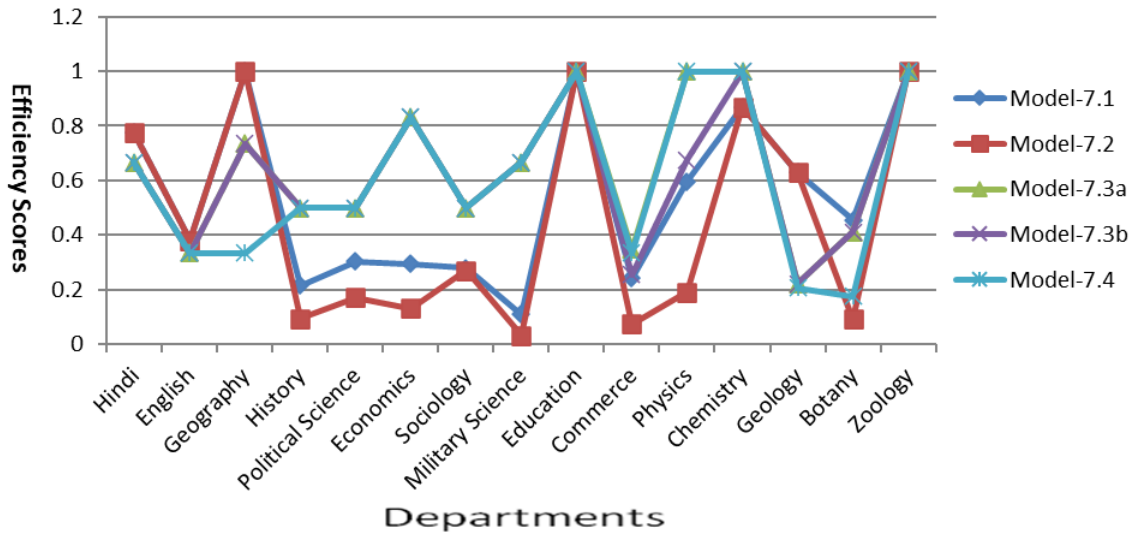


Figure 6.2: VRS efficiency scores pattern for research performance models (Model 7.1-7.4)

Table 6.1: VRS Efficiency Scores Comparison of Research Performance Models

Sr. number	Depts. name	Model-7.1	Peer count	Model-7.2	Peer count	Model-7.3a	Peer count	Model-7.3b	Peer Count	Model-7.4	Peer Count
1	Hindi	0.776	0	0.776	0	0.667	0	0.667	0	0.667	0
2	English	0.380	0	0.380	0	0.333	0	0.333	0	0.333	0
3	Geography	1	0	1	2	0.735	0	0.735	0	0.333	0
4	History	0.215	0	0.093	0	0.5	0	0.5	0	0.5	0
5	Political Science	0.303	0	0.171	0	0.5	0	0.5	0	0.5	0
6	Economics	0.295	0	0.132	0	0.833	0	0.833	0	0.833	0
7	Sociology	0.278	0	0.269	0	0.5	0	0.5	0	0.5	0
8	Military Science	0.11	0	0.031	0	0.667	0	0.667	0	0.667	0
9	Education	1	12	1	9	1	11	1	12	1	8
10	Commerce	0.241	0	0.074	0	0.347	0	0.255	0	0.333	0
11	Physics	0.595	0	0.191	0	1	1	0.676	0	1	2
12	Chemistry	0.870	0	0.870	0	1	1	1	0	1	1
13	Geology	0.630	0	0.630	0	0.222	0	0.222	0	0.207	0
14	Botany	0.456	0	0.091	0	0.411	0	0.411	0	0.176	0
15	Zoology	1	2	1	3	1	3	1	4	1	2
Average		0.543		0.447		0.648		0.619		0.603	
S.D.		0.158		0.158		0.235		0.235		0.235	

7 Research Performance Models

Model-7.1

In this model, we take 3 inputs, namely, “Acad. staff, Non-academic staff”, “DOC” and 2 O/Ps, “PhD” and “Research Index” have been considered. “PhD” output variable contain “PhD scholar index” and “PhD award index” in a particular year. “Research Index” explains in the O/P variable section 4.2.2, of this article. DEA has been carried out using VRS output oriented model. From Table 6.1, we examine that out of these 15 depts. 3 depts. are only efficient due to their VRS efficiency score is 1. From the above 3 VRS efficient depts. only 2 depts. form the peer group. These peers and their peer counts to the other depts. are Education (12) and Zoology (2). One dept., namely, Geography, which is the VRS efficient but, not has a peer count for any inefficient depts. The higher peer count of a dept. represents the scope of its robustness compared to the other efficient depts. Here Education department with peer count (12) is the maximum peer count department, followed by Zoology departments with peer count (2). Therefore these depts. are high-quality examples for inefficient depts. to follow their work practice to get better their performance for the O/Ps “PhD” and “Research Index”.

Model-7.2

Here omit the O/P “Research Index” and take 1 output “PhD” and inputs are taken same as in Model-7.1. By doing this, we want to see that what effect will be made on the efficiencies of the departments and also want to assess the ability of the depts. in the field of concerning to PhD programs. From Model-7.2 results, we observe that only three departments viz. Geography, Education and Zoology are efficient and well performing department for doctoral programs, since their efficiency score is unit. The three efficient departments are the peer for inefficient departments, so they are relatively efficient for doctoral programs. Remaining 12 depts. are not efficient due to their efficiency score is less than 1. Out of these 12, 3 inefficient departments, namely, Hindi (0.776), Chemistry (0.870) and Geology (0.630) have score above the average efficiency score ($447 * 10^{-3}$). So the performance of these depts. are may be assumed satisfactory but not good and not consider in the group of well performing depts. Nine inefficient depts. have the efficiency score less than average efficiency score ($447 * 10^{-3}$). In all 12 inefficient departments, one department, namely, Military science has the least efficiency score 0.031. So, this department has very low performance for doctoral program.

For Model-7.2, we examine that each inefficient dept. has the lower efficiency score than for Model-7.1. Four depts., Hindi ($776 * 10^{-3}$), English ($38 * 10^{-2}$), Chemistry ($87 * 10^{-2}$) and Geology ($63 * 10^{-3}$) have only the same efficiency score in both the models. This indicates that these four departments has performing consistently for all research activities, but no other depts. are as good for doctoral programs as they are for other activities.

Model-7.3a

“Publications” and “Dissertations” are taken by us in this model as a output parameters from the “Research Index” output variable. Output parameter “Publications” contains research papers published in journals, conferences and seminars proceedings. Output parameter “Dissertation” is the research activity of each department at Degree College levels which is taken by all the final year PG students of the department under the supervision of the faculty member of the concern departments. By doing this, our purpose to find which activity (Ph.D., Publications and Dissertation) of research is required to sufficient changes for a dept. to become efficient. The results of this model represents, four depts., namely, Education, Physics, Chemistry and Zoology are efficient as they have efficiency score is one. The Peer counts for these peer departments are Education (11), Physics (1), Chemistry (1) and Zoology (3). Education department has highest peer count (11), it is the most performer department for this model.

Here in this Model-7.3a, Botany department have efficiency score less than Model-7.1 but greater than Model-7.2. This indicates that only Botany is a well performing department for the activities “Publications” and “Dissertations” in contrast the doctoral programs. Here we can also discuss the suggested, reduction in I/P and improvements in O/Ps and for inefficient dept.

Model-7.3b

In this model, we take the output parameters same as in Model-7.3a and omit one input variable DOC form Model-7.3a. Our purpose, by this change is just examining the robustness of the results. Comparing the results of Model-7.3a and Model-7.3b, it is clear that, among the efficient depts. only Physics dept. has lost its efficiency from one to $676 * 10^{-3}$. Only one inefficient dept. of Model-7.3b, namely, Commerce has also scored less than Model-7.3a.

Model-7.4

In Model-7.4, we take only “Publications” O/P parameter and omit the “Dissertation” from Model-7.3a the inputs are same as in Model-7.3a. Here we want to examine which depts. are sensitive to this o/p . Model-7.4 results indicate, Four departments, namely, Education, Physics, Chemistry and Zoology are fully efficient due to their efficiency score is equal to 1. Here Education department has Maximum no. of peer count (8), so it is the mainly fully well performing efficient department. From Model-7.3a and Model-7.4 results analysis, it is also clear that there is no effect on the efficiency of the some efficient and inefficient departments, in both the models after omitting the output “Dissertation” from Model-7.3a, for Model-7.4. The name of these efficient depts. is Education, Physics, Chemistry and Zoology. Some of the inefficient depts. are Geography, Commerce, Geology and Botany have also score less than Model-3a and only these departments are sensitive for this output.

Among these four models to test the robustness and stability Karle Pearson’s and Spearman’s rank correlation coefficients (Γ, ρ) are calculated and lies in the range between $314 * 10^{-3}$ to $969 * 10^{-3}$. The highest values of the coefficient represents results are robust for these models See Table 7.1 given below

Table 7.1: Correlation coefficients (τ, ρ) between research performance models

	Model-7.1	Model-7.2	Model-7.3a	Model-7.3b	Model-7.4
Model-7.1	1, 1				
Model-7.2	.946**, .909**	1, 1			
Model-7.3a	.459, .343	.352, .314	1, 1		
Model-7.3b	.488, .383	.445, .390	.956**, .969**	1, 1	
Model-7.4	.398, .286	.343, .337	.839**, .797**	.787*, 0.748**	1, 1

** Correlation is significant at 0.01 (i.e., 1%) levels (2-tailed)

8 Conclusions

The main purpose of this research is to examine activity-wise research performance assessment of the departments using *DEA* by taking different combinations of the used I/Ps and O/Ps . In this study we examine that which departments are good performers for research activity. For this, we did the research performance assessment for all 15 PG departments by using 4 models with sensitivity analysis. Sensitivity analysis is done in these models by changing the inputs and outputs.

Only two departments, namely, Education and Zoology out of fifteen are best performer in all activities of Ph.D. Programs as well as others like Publications etc., Model 7.1-7.4 results indicate that Model-7.2 has lowest mean score $447 * 10^{-3}$ than other research performance Models. Therefore, it indicates that to improve the research performance of the inefficient depts., focused on “Ph.D. scholar index” and “Ph.D. award index”.

Thus our study provides information about research activity of the depts. and policy makers can use suggested reductions and improvements to improve the research performance in different areas.

Finally, we are giving below some concluding remark for this study:

Only two departments, namely, Education and Zoology are efficient in every area of research. Remaining depts. should pay attention for research and advised to change their IPs/OPs to become efficient at these levels and some depts. not utilized effectively their staffs for some particular actions allied to research.

Funding: There is no funding from any agency for this research.

Declaration Conflict of Interest: The authors declare that there is no conflict of interest and also no funding agencies involve in this research work.

References

- [1] T. Ahn, V. Arnold, A. Charnes and W.W. Cooper, *DEA and ratio efficiency analysis for public institutions of higher learning in Texas*, *Research in Government and Non-profits Accounting*, **5** (1989), 165-185.

- [2] N.K. Avkiran, Investigating technical and scale efficiencies of Australian university, *A Data Envelopment Analysis Socio Economics Planning Sciences*, **35** (2001), 57-80.
- [3] M. Abbott and C. Doucouliago, The efficiency of Australian's universities, *A Data Envelopment Analysis Economics of Education Review*, **22** (2003), 89-97.
- [4] I. Ali, M. Pant, U.S. Rana and S.K. Jauhar, DEA for measuring the academic performance of a higher educational institute of Uttarakhand, India, *International Journal of Computer Information Systems and Industrial Management Applications*, **9** (2017), 206-217.
- [5] I. Ali, M. Pant and U.S. Rana, Relative performance assessment of academic departments of higher educational institute using DEA with sensitivity analysis, *International Journal of Hybrid Intelligent Systems*, **14** (2017), 181-191.
- [6] I. Ali, U.S. Rana, M. Pant, S.K. Jauhar and S.K. Mogha, Estimating technical efficiency of academic departments, case of government pg college, *Advanced in Intelligent System and Computing*, **584** (2018), 405-417.
- [7] I. Ali, Y. Kumar and R.L. Keshtwal, Measuring stream-wise teaching performance of the departments of higher educational institute using DEA with sensitivity analysis, *Palestine Journal of Mathematics*, **11** (Special Issue III 2022), 145-155.
- [8] A. Arya and A. Hatami-Marbini, A new efficiency evaluation approach with rough data an application to Indian fertilizer, *Journal of Industrial and Management Optimization*, **19**(7) (2023), 5183-5208.
- [9] A.M. Bessent, E.W. Bessent, A. Charnes, W.W. Cooper and N.C. Thorogood, Evaluation of educational program Proposals by means of DEA, *Educational Administration Quarterly*, **19**(2) (1983), 82-107.
- [10] J. Beasley, Determining teaching and research efficiencies. *Journal of Operation Research Society*, **46** (1995), 441-452.
- [11] R.D. Banker, A. Charnes and W.W. Cooper, Some models for the estimation of technical and scale efficiency data envelopment analysis, *Management Science*, **30**(9) (1984), 1078-1092.
- [12] T.J. Coellie, *A Guide to DEAP version 2.1: A Data Envelopment Analysis (Computer) Program*, Centre for Efficiency and Productivity Analysis (CEPA), Department of Econometrics, University of New England Armidale, NSW 2351, Australia. Working Papers No. 8/96, (1996).
- [13] A.Charnes, W.W. Cooper and E.L. Rhodes, Measuring the efficiency of decision making units, *European General of Operation Research*, **2** (1978), 429-444.
- [14] R.M. Debnath, R. Shankar and S. Kumar, Performance evaluation of technical institutions: an application of data envelopment analysis, *Education, Knowledge and Economy*, **2**(1) (2008), 51-56.
- [15] GPGC, Gopeshwar, Chamoli Uttarakhand India, NAAC (2014).
- [16] J. Johnes, Performance Assessment in higher education in Britain, *European Journal of Operation Research*, **89**(1) (1996), 18-33.
- [17] J. Johnes and G. Johnes, Research funding and performance, *U.K. University Department of Economics of Education Review*, **14**(3) (1995), 301-314.

- [18] S.K. Jauhar, M. Pant and R. Dutt, Performance measurement of an Indian higher education institute: a sustainable educational supply chain management perspective, *International Journal of System Assurance Engineering and Management*, **1** (2016), 180-193.
- [19] S.K. Jauhar, M. Pant and A. Deep, Differential evolution for supplier selection problem: a DEA based approach, *Proceeding of the third international conference on soft computing for problem solving*, Springer India, (2014b), 343-353.
- [20] P. Korhonen, R. Tainio and J. Wallenius, Value efficiency analysis of academic research, *European Journal of Operation Research*, **130** (2001), 121-132.
- [21] C. Kao and H.T. Hung, Efficiency analysis of university departments: An empirical study, *Omega*, **36**(4) (2008), 653-664.
- [22] A. Kumar and M. Pant, Role of network data envelopment analysis approach in manufacturing industry, review of last 5 years, *Reliability Engineering for Industrial Process, Springer Series in Reliability Engineering*, (2024), 51-54.
- [23] A. Panwar, M. Tin and M. Pant, Assessment of the basic education system of mayanmar through the data envelopment analysis, *Proceeding of International Conference on Scientific and Natural Computing*, (2021), 221-232.
- [24] A. Panwar, M. Olfati and M. Pant, A review on the 40 years of existence of data envelopment analysis models, historic development and current trends, *Archives of Computational Methods in Engineering*, **29** (2022), 5397-5426.
- [25] R. Ramanathan, *An Introduction to Data Envelopment Analysis*, Sage Publication India Pvt. Ltd., New Delhi (2003).
- [26] C.S. Sarrico, S.M. Hogan, R.G. Dyson and A.D. Athanassopoulos, Data envelopment analysis and university selection, *Journal of Operational Research Society*, **37** (1997), 1163-1177.
- [27] R. Sindhvani, A. Arya and J. Jayaram, Greener healthcare operations during COVID-19 pandemic: A data envelopment analysis approach, *Journal of Cleaner Production*, **452** (2024), 142043.
- [28] P. Tyagi, S.P. Yadav and S.P. Singh, Relative performance of academic departments using DEA with sensitivity analysis, *Evaluation and Program Planning*, **32** (2009), 168-177.