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MEASURING STREAM-WISE TEACHING PERFORMANCE OF THE DEPARTMENTS OF HIGHER EDUCATIONAL INSTITUTE USING DEA WITH SENSITIVITY ANALYSIS

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Abstract This study focuses on assessing the teaching performance of fifteen academic departments of a government post graduate college(GPGC), Gopeshwar, Chamoli, Uttarakhand (India) for the academic year 2011-2012 using data envelopment analysis (DEA). Sensitivity analysis has also been done in order to interpret the results more accurately. The study has been done to assess the stream wise teaching performance for Science and Art departments separately using DEA with sensitivity analysis. Total six models are defined in this study, models (1-3) are defined for to assess the teaching performance of science stream departments and models (4-6) are defined for to assess the teaching performance for art stream departments. Total out of fifteen, five departments are science stream departments and ten departments are art stream departments. The input variables academic staffs and non-academic staffs are same but output variables total enrolled students (number of UG students, number of PG students) and Progress (UG first division, PG first division and both UG and PG first division students) are different in all six models define in this study. From the results of models (1-3) no science department is well performer at UG, PG and both levels and from the results of models (4–6) only one Art Hindi department is well performer at UG, PG and both levels and also the role model at all levels and leads at UG, PG and both level. Thus our study gives information about the activity of teaching of the departments and strategy creators can utilize recommended improvements and deductions to improve the performance in various zones.

1 Introduction

Education is an essential key not only for the complete growth of one's personality, but for nonstop extension of the country also. The future of nation is safe in the hands of educated individuals. Thus, In the present world, the part of instruction has gotten more basic. Presently, it is an outright need for monetary and social advancement for any country. In this study, our target area is a Government post graduate college (GPGC), Gopeshwar Chamoli Uttarakhand an A-grade PG college of Uttarakhand state, India. A-grade has been conferred by National Assessment and Accreditation Council (NAAC)-Bangalore in the year 2014 (NAAC-reports 2014, GPGC-Gopeshwar) [25]. The college was established in July nineteen sixty six and Presently college is affiliated to SDSUV (A State University) Tehri Garhwal Uttarakhand (UK), India. Here we assess the stream-wise teaching performance using DEA with sensitivity analysis of 15 academic departments of GPGC, Gopeshwar for the academic year 2011-12. Thus, in this study we assess the relative teaching performance of 5 Science and 10 Art PG departments separately through DEA with sensitivity analysis for the academic year 2011-12.

1.1 Institutions level assessment

DEA technique is a powerful tool used to evaluate the efficiency in upper education sector. The DEA technique has been used in different fields based on their scope and applications. There are a number of application areas in this sector like University, Colleges etc. Some of the studies are

reviewed as follows:

Ahn et al. [1] use CCR fractional form of DEA to find the efficiencies of public and private Ph.D.-granting institutes in the U.S. The sample size of this study contains one hundred sixty one Ph.D. institutes in the U.S. for academic year 1884-1985. Breu and Rab [2] measured the relative efficiency of top twenty five Universities and liberal Arts Colleges in U.S. chosen from 204 University and 140 Colleges. Kao [3] evaluate the junior colleges of technology in Taiwan using a simpler version of DEA. He took 11 junior colleges out of 39 to measure the efficiency. Johns [4] measure the performance of UK Universities. He talks about the production theory approach for assessing the performance in higher education. Sarrico [5], study is focused to assess the performance of UK of the upper educational institutes. Korhonen et al. [6] suggested a methodical evolution to study scholarly performance of the research institutes. Avkiran [7] examined the relative performance of thirty six Australian Universities. Abbott and Doucouliagos [8] focused on the technical efficiency assessment of the Australian University system. Debnath et al. [9] employ the DEA technique to compare the efficiency of 40 graduate level technical institutions in India, on the basis of three I/Ps and two O/Ps. Singh et al. [29] study the school level data for various states in India. Efficiency evaluated by using DEA and DE by taking I/Ps and O/Ps variable are data basic needs of schools and enrollment of students.

1.2 Department and programs level assessment

A few studies associated to efficiency evaluation of academic departments and based on programs level of higher educational institutes (HEI) through DEA technique are review below as follows:

Besent et al. [10] examined 22 work-related industrial program in San Antonio College in Texas, U.S. by taking 3 outputs and 4 inputs. Beasley [12] assess the efficiency of Physics and Chemistry departments of the University in U.K. for the Academic year 1986-1987. Johns and Johns [12] examined the performance of 36 DMUs of economics' in the U.K. for the period 1984-88. Basely [11] measured the teaching and research efficiency of University departments. They considered 3 O/P and 3I/P for the above study. In this study data was collected for the year 2003-2004, taking 3 O/P and 3 I/P. Rayeni and Saljooghi [15] studied the efficiency of the departments taking 3 O/P and 2I/P. Aziz et al. [16] studied the comparative departmental analysis within university using 3 O/P, 3 I/P. Jauhar et al. [17] calculated the efficiency of 19 academic departments of a HEI, India using DEA. They used in this study 9 O/p and 8 I/P variables. Ali et al. [18] assess the efficiency of 15 academic departments of a GPGC, Gopeshwar India by using 6 O/P and 8 I/P. Ali et al. [19] assess the relative performance of fifteen academic departments of a GPGC, Gopeshwar, India by using 3 O/P and 3 I/P. The O/P variables are total enrolled students in UG, PG courses, Progress, Research award index. The I/P variables are no. of academic staffs, number of non-academic staffs and DOC. Ali et al. [20] assess the Technical efficiency of 20 scholarly departments of a GPGC, Gopeshwar for the year 2012-13, by utilizing 3 O/P and 4 I/P. Kaur et al. [30] evaluate the efficiency of 35 academic department of a university for the academic year 2016-17, by taking the combination of inputs and outputs.

This research article is prepared as follows: In Section 2, brief description of DEA has been given. Institution selected, DMUs, and explanation of chosen I/P and O/P for performance assessments of the DMUs for this article are explain in Section 3. In Section 4 data and computation, choice of DEA model has been given. Teaching performance assessments for Science and Art PG departments separately with sensitivity analysis are given in Section 5 and finally in Section 6, conclusions are given.

2 Methodology

Charnes, Cooper and Rhodes (CCR) developed DEA technique in 1978. Banker, Charnes and Cooper (BCC) extended this in 1984. Data efficiency analysis technique is well known and is used in various fields like as Schools, Colleges, University, Technical Institute, Banking, Railways, Hospitals, Transportation, Petrol pumps, and in all those fields where we want to find and calculate the efficiency. DEA technique has been used by various researchers (Charnes et al. [21]; Banker et al. [22]; Ramanathan [23]; Tyagi et al. [14]; Moga et al. [24], Jauhar et al. [17], Ali et al. [18, 19, 20] and Dyanne et al. [28] etc. respectively). It has been used for measuring

the relative performance of the DMU's. The basic concept of efficiency assessment used in DEA characterized by "the proportion of overall outputs to overall inputs".

If we have single input and single output, then the performance is obtained by graphical method, but if we have two inputs and one output than performance evaluation become more complicated compared to single input-output case. However, we cannot use the graphical methods if we consider several inputs and outputs. Hence a general mathematical formulation is required to tackle the case of several inputs and several outputs. In DEA approach the efficiency variation of all DMUs lies between zero and one. The efficient DMU have one efficiency score otherwise it is inefficient (or less efficient).

The general form of BCC (Banker et al. [22]) DEA Model used in this study is being given as below:

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

$$\text{subject to } \sum_{i=1}^{m} u_{io}\alpha_{io} = 1,$$

$$\sum_{r=1}^{s} v_{ro}\beta_{rn} - \sum_{i=1}^{m} u_{io}\alpha_{in} + u_{0o} \leq 0, \ \forall\, n$$

$$u_{io}v_{ro} \geq \varepsilon; \ \forall\, i, r \text{ and } u_{0o} \text{ is unrestricted in sign.}$$

(R. Ramanathan, [23, p. 40]).

3 Research Plan

3.1 Choice of DMUs

15 academic departments of HEI of GPGC, Gopeshwar, Uttarakhand (India) has been taken as DMUs. Academic departments have been taken as DMUs in a few past studies by the following researchers: Ali et al. [18, 19, 20]; Jauhar et al. [17]; Tyagi et al. [14].

3.2 Choice of Inputs and Outputs

3.2.1 Inputs

3.2.1.1 Number of academic staff. To run the department and for progress of wide range of activities related to education of the students no. of academic staff is essential. Allocations of academic staffs to the departments are depends on the basis of the total number of enrolled students and on the basis of the programmed run by the departments like UG, PG etc. So, in this study academic staff has been taken as an input variable. Also to measure the teaching performance assessment of any DMU of the HEI, number of academic staff has been the essential key used by various researchers: Jauhar et al. [17], Tyagi et al. [14], Ali et al. [18, 19, 20], Kuo and Wang [26] etc. as an input variable.

3.2.1.2 Number of non-academic staff. Each higher educational Institute (HEI) is divided in different blocks like Academic block and non-academic block. In case of Degree College mostly, Academic block generally has three types of academic departments: (i) Science department (like Physics, Chemistry, Geology, Zoology, Botany etc.) (ii) Art departments (like Geography, Education and Home Science etc.) (iii) Commerce department are the type of departments in which practical subject are run and they have laboratory for practical and in each laboratory Lab assistant, Lab technician, helpers etc., also work. All such type of employees is counted as non-academic staff, which helps to the students and academic staff. Administrative block has administrative officers, accountants and all others employees. All such type of employees is counted as a non-academic staff and they works for Scholastic staffs and understudies. This administrative block is counted as a non-academic block. It is clear that all the employees of library and administrative block are commonly work for faculty and students of all departments. So to evaluate the performance of the academic departments, non-academic staff is also required

to be taken in this study; non-academic staff has been counted as I/P variable. This I/P has also been utilized as a variable by the researchers Ali et al. [18, 19]; Jouhar et al. [17] and Tyagi et al. [14].

3.2.2 Outputs

3.2.2.1 Total enrolled students. This output variable with same data has been used by Ali et al. [19] and also taken in this study for to assess the stream-wise teaching performance of the DMUs with sensitivity analysis defined as:
Total enrolled students = Number of UG students + 1.125(Number of PG students) + Ph.D. scholar index.
The above output variable has been taken by the following researchers Kuo and Wang [26]; Tyagi et al. [14]; Ali et al. [18, 19]. Ph.D. Scholar index is included in the above output variable has been used by Ali et al. [18, 19].

3.2.2.2 Progress. Three kind of total 15 academic departments namely sciences, arts and commerce have been taken in this study. Here we assumed commerce department as an art discipline. All the above 15 departments have UG, PG and researchers types students.
For stream-wise teaching performance assessment we get a parameter for each department number of UG and PG students obtaining first division (i.e. obtaining marks greater than or equal to sixty percent) by taking this parameters we form an O/P variable known as "Progress". This was utilized by Tyagi et al. [14]; Ali et al. [19]; as an output variable.

4 Data and Computations

Data utilized for this study has been gathered from the GPGC, Gopeshwar, NAAC-2014 [25] and SSR of the college for the scholastic year 2011-12. DEAP version 2.1 (Coelli 1996) [26] is utilized for all calculation related to DEA method. SPSS 20 was used for calculation of the correlation coefficients between I/P and O/P variables. I/P, O/P data and correlation coefficient between I/P and O/P variables are given below in Table 1 and Table 2.

Table 1. Explanatory information I/P and O/P data

Charactristics	Inputs		Outputs	
	Number of academics staff	Number of non-academics staff	Total enrolled students	Progress
Max	5	20	395.75	107.75
Min	1	17	24.05	2.30
Average	2.867	17.6	182.963	31.177
S.D.	2.121	0.707	139.247	9.122

Table 2. Correlation coefficients between I/P and O/P

	Academic staff	Non-academic staff	Total enrolled student	Progress
Academic staff	1			
Non-academic staff	0.649**	1		
Total enrolled student	0.039	0.071	1	
Progress	0.431	0.471	0.339	1

**: Correlation is significant at 0.01(1%) levels (2-tailed)

4.1 Choice of Model

For this study BCC O/P oriented DEA model has been used (i.e. variable return to scale (VRS) DEA model used)

5 Performance Assessments of Departments with Sensitivity Analysis

The stability of DEA results are testing by omitting the I/P and O/P variables and then studying the results. The DEA is an extraordinary point and non-parametric procedure can't utilize theoretical tests of statistics for to assess the certainty with which DEA efficiencies are calculated (R. Ramanathan [23, p. 176, p. 154]). Therefore, In this way, to test the robustness of DEA results and to assess the performance of the departments from various criteria (like which department is better for at least first division students and so on), we use sensitivity analysis.

5.1 Performance Assessment of Teaching for Science and Arts Departments

The Government PG College has a high level reputation in the field of Science and Arts and Commerce. Since It is a NAAC-A grade well established college, the education environment specially teaching in this college is very high. So, our aim is to assess the progress (I-Division students) of UG & PG both in the teaching prospective for the science departments and Arts departments separately.

Performance Assessment of teaching for Science Departments

First we assess the progress in teaching of the science departments. Here we developed the three models and the outcomes are looked in Table 3.

Table 3. VRS efficiency scores comparison of models (1-3) for the Science Departments at UG and PG level

Dept. Code	Dept. Name	Model-1		Model-2		Model-3	
		VRS score	Peer count	VRS score	Peer count	VRS score	Peer count
D16	Physics	0.775	0	1	1	0.809	0
D17	Chemistry	1	0	0.941	0	1	0
D18	Geology	1	1	1	0	1	1
D19	Botany	1	2	0.842	0	1	0
D20	Zoology	1	0	1	1	1	1
Average		**0.955**		**0.957**		**0.962**	
S.D.		0.159		0.0		0.135	

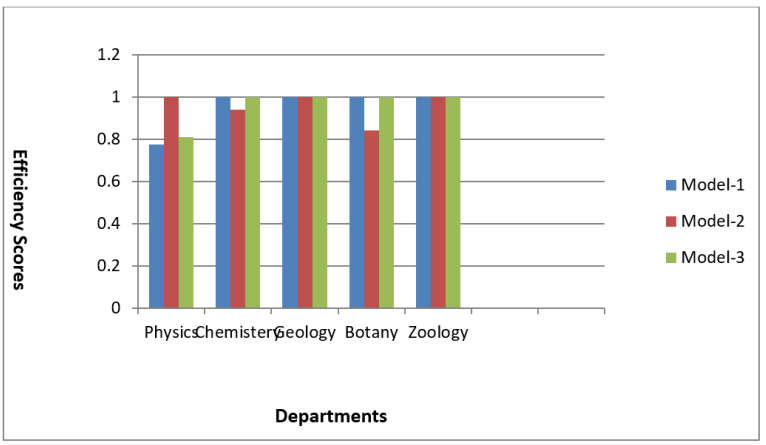

Figure 1. Efficiency scores Comparison for teaching performance models (Model 1-3)

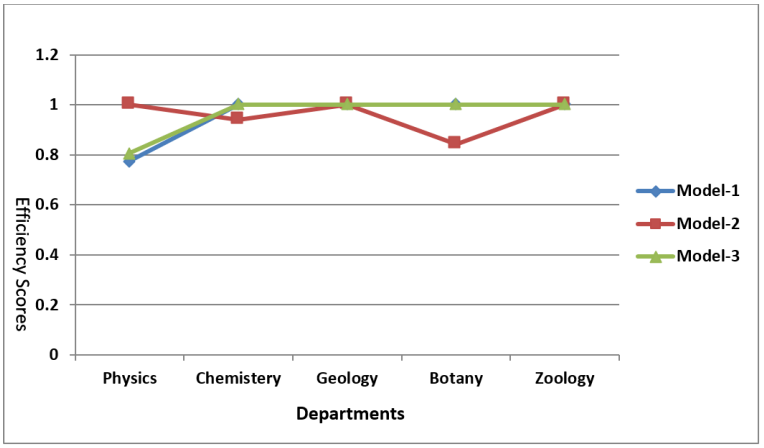

Figure 2. VRS efficiency scores pattern for Model (1-3) of the Science departments

Table 4. Karl Pearson's (r) and Spearmen's rank (ρ) correlation coefficients (r, ρ) between teaching performance models for Science stream departments at UG and PG level

	Model-1 (r, ρ)	Model-2 (r, ρ)	Model-3 (r, ρ)
Model-1	1, 1		
Model-2	0.395, 0.352	1,1	
Model-3	1^{**}, 1^{**}	0.395, 0.352	1,1

**: Correlation is significant at one percent levels (2-tailed)

Model-1: Here simply we complete the measurement for the UG program. The inputs "Academic Staff" and "Non-Academic Staff" and outputs "ESTUG" and "FSTUG" are taken. "ESTUG and "FSTUG" incorporate number of understudies took on UG and graduate understudies with at least first division in UG.

The analysis explains that Chemistry, Geology, Botany and Zoology departments have scored one. Therefore these departments are efficient to produce the graduates with first division. But Chemistry and Zoology department do not have peer count for any other inefficient department. Therefore, only Botany (peer count= 2) and Geology (peer count= 1) are the role models at UG level to produce the science graduates with at least first division. The Physics department is the inefficient department due to VRS scores less than one. The VRS score of the Physics department is 0.775 which is not exactly the average efficiency scores 0.955. Therefore, it is very poor department to create the I-division science graduates at UG level.

Model-2: Here we measure the performance for Post graduates program only in the science-stream department. "ESTPG" and "FSTPG" have been taken as output variable, and input variables are same as used in Model-1. "ESTPG" and "FSTPG" indicate students enrolled in PG program in the department and completed PG degree with at least first division, respectively.

The result shows that Physics, Geology and Zoology have scored one. However Geology is not a peer for any inefficient department. Therefore, Physics and Zoology departments are the good examples at PG level. From the results of Model-1 and Model-2, unmistakably all the science departments (except Physics) in model-1 have greater VRS efficiency score with respect to the Model-2. This indicates that all the science departments are performing superior at UG level than for PG level program. Just exception is the Physics department that performs superior for PG over UG level programs.

Model-3: Here we look at both UG and PG programs together "ESTUGPG" and "FSTUGPG" have been taken as O/P and I/P factors are same as in Model-1 and Model-2. The O/P factors are characterized as:
ESTUGPG = Total number of understudies in UG programs + 1.125 (Total number of understudies in PG programs)

FSTUGPG = Total number of science graduates with at least first division + 1.125 (Total number of Post graduate with at least first division in the department for PG Programs).

The results clarify that Chemistry, Geology, Botany and Zoology departments have VRS score one. Chemistry and Botany do not have peer for any wasteful department. Comparing the results for Model-1 and Model-3, unmistakably the efficiency score in model-1 and model-3 are equivalent (not including physical science). Therefore for Physical Science (Physics), incorporation of the PG program results in the improvement of efficiency scores. This give surety that the Physics department should focus on its UG program.

Comparing the results of Model-2 and Model-3, it is clear that the efficiency score in model-2, for Chemistry and Botany are less than for Model-3. So, after inclusion of UG program in both departments the efficiency scores are increased. Therefore, these two departments should pay attention for their PG program. Geology and Botany both have equal efficiency; there is no effect of inclusion of UG program. From the results of all models in Table 3, it is clear no science department is well performer at UG, PG and both levels.

Performance Assessment of Teaching for Art Departments

We assess the progress in teaching of the Art stream departments. Three Models (Model4-6) are created and the results are analyzed below in Table 5.

Table 5. VRS efficiency scores comparison of models (4-6) for the Art Departments at UG and PG level

Dept. Code	Dept. Name	Model-4		Model-5		Model-6	
		VRS score	Peer counts	VRS score	Peer count	VRS score	Peer count
D1	Hindi	1	6	1	7	1	6
D3	English	0.712	0	0.796	0	0.725	0
D4	Geography	1	0	0.685	0	1	0
D5	History	1	0	1	0	1	0
D6	Political Science	0.855	0	0.320	0	0.762	0
D7	Economics	0.661	0	0.240	0	0.497	0
D8	Sociology	0.497	0	0.280	0	0.457	0
D9	Military Science	0.254	0	0.056	0	0.227	0
D10	Education	1	2	1	0	1	0
D12	Commerce	0.052	0	0.111	0	0.061	0
Mean		**0.703**		**0.549**		**0.673**	
S.D.		0.670		0.629		0.664	

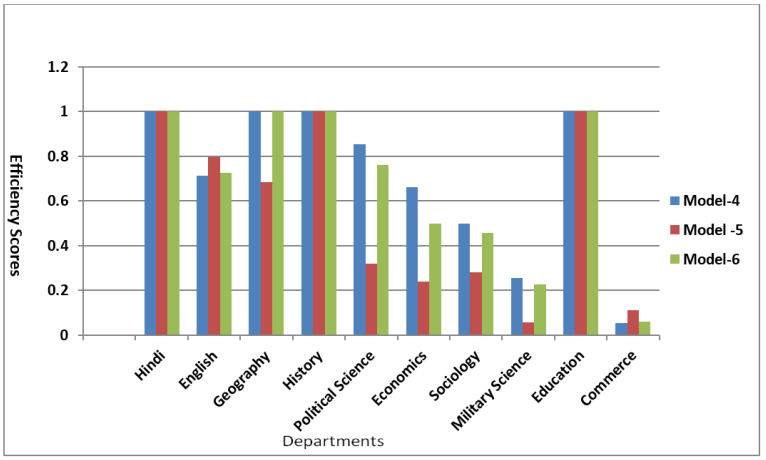

Figure 3. Efficiency scores comparison for teaching performance Models (Model 4-6)

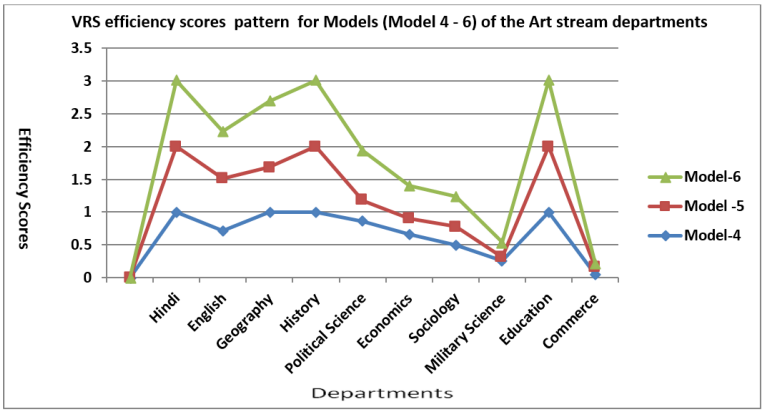

Figure 4. VRS efficiency scores pattern for Models (Model 4-6) of the Art stream departments

Table 6. Correlation coefficients (r, ρ) among teaching performance models for Art stream departments at UG and PG level

	Model-4 (r, ρ)	Model-5 (r, ρ)	Model-6 (r, ρ)
Model-4	1,1		
Model-5	0.899^{**}, 0.830^{**}	1, 1	
Model-6	1.0^{**}, 0.987^{**}	0.899^{**}, 0.892^{**}	1,1

**: Correlation is significant at one percent levels (2-tailed)

Model-4: Here simply we complete the measurement for the Art stream UG program. The I/P "Academic Staff" and "Non-Academic Staff" and O/P "ESTUG" and "FSTUG" have been taken. "ESTUG and "FSTUG" incorporate number of understudies took on UG and graduate understudies with at least first division in UG.

The analysis clarifies that four departments, viz. Hindi, Geography, History and Education have scored one. Therefore these departments are efficient to produce the graduates with first division. But Geography, History department do not have peer count for any other inefficient department. Therefore, only Hindi (Peer count $= 6$) and Geography (peer count $= 2$) are the good examples at UG level to produce the graduates in Art stream with at least first division. Hindi with peer count six is the most efficient department to produce the graduates with at least first division mark. All the remaining departments are wasteful as their VRS efficiency is under 1. English (0.712) and Political science (0.855) departments have more efficiency score than average efficiency (0.703). But Commerce department has the least efficiency (0.052) among all inefficient departments. Therefore, it is very poor performer at UG level.

Model-5: In this model assessment has been done for the Art stream Postgraduate (PG) program only. Inputs are same as used in Model-4 and outputs are "ESTPG" and "FSTPG" have been taken. "ESTPG and "FSTPG" include number of students enrolled in PG program and PG degree completed students with at least first division in PG Program.

The result shows that Hindi, History and Education have scored one. However History and Education Departments are not a peer for any inefficient department. Therefore, only Hindi department leads at the PG level. Comparing the results of model-4 and 5, it is seen that all the art departments (except English and Commerce) in model-4 have greater VRS efficiency score with respect to the model-5. This indicates that all the Art departments are performing superior at UG level than for PG level program. Only exceptions are the English and Commerce departments that perform better for PG than UG level programs.

Model-6: Now we investigate both UG and PG programs together for Art stream departments. In this model, inputs are same as taken in previous model 4 and 5. "ESTUGPG","FSTUGPG" have taken as O/Ps. They are defined as:
ESTUGPG = Total number of understudies in under graduate (UG) programs + 1.125 (Total number of understudies in Post Graduate programs)

FSTUGPG = Total number of science graduates with at least first division + 1.125 (Total number of Post graduates with at least first division in the departments for PG Programs).

The result clarifies that Hindi, Geography, History and Education have efficiency score one. But departments with code D4, D5, D10 are not peer for any wasteful department. Therefore just Hindi Department with code D1 leads at both UG and PG level program together. Contrasting the results for Models-4 and 6, we locate that all the departments (except English and Commerce) have scored lesser for Model-6 than for Model-4. Subsequently, consideration of the PG programs results in the reduction of efficiency scores. This confirms that all Art departments should focus on their PG programs.

Reduction in input and augmentation (i.e. improvements) in outputs for the inefficient departments can be reported given below in Table 7.

Table 7. Recommended I/P reduction and O/P improvement (or augmentation) for inefficient Art departments for Model-6

Dept. Code	Dept. Name	I/Ps Reduction		O/Ps Augmentation	
		Academic Staff	Non Academic Staff	ESTUGPG	FSTUGPG
D3	English	1.45	12.325	283.375	38.709
D6	Political Science	1.524	13.005	297.75	38
D7	Economics	0.994	8.449	194.375	21.172
D8	Sociology	0.371	7.769	178.625	28.21
D9	Military Science	−0.215	3.859	40.375	10.125
D12	Commerce	−1.756	1.098	23.75	6.357

From the results of all models in Table 5, It is clear that Hindi, History and Education departments are efficient at UG, PG and both level. But only one department, namely Hindi is the role model at all levels and leads at UG, PG and both level, since it is the peer for inefficient departments at each level.

6 Conclusions

The fundamental target of this study was we want to know that which departments are high-quality performers for teaching activity. So for this, here we did assessed stream-wise teaching performance assessment for 5 sciences, 10 Arts PG departments separately for all 15 PG departments by using 6 models (model(1-3) for Science departments and model (4-6) for Art Departments) with sensitivity analysis. Sensitivity analysis is done in these models by changing the inputs and outputs.

From the result of Model-1 to Model-3, it is clear that Geology and Botany departments is best performer at UG program, Physics and Zoology department are best performer at PG program. Geology and Zoology is best performer when both UG and PG program are taken together. There is no science department among all which is best performer at all level.

From Model-4 to Model-6 results, Hindi department is the best performer for both PG and UG programs among all Art departments. The Education department is performing admirably just for UG program.

Lastly, we are giving below a number of final remarks from this study for the departments.

- Only one Art Hindi department is doing well in producing first division students for both PG and UG programs among all Art departments. So any remaining available Art departments should take care for the First division activity.
- There is no science department among all which is best performer for UG, PG and both program among all science departments. So all the science departments are encouraged to change their inputs and outputs to become efficient at these levels.
- A number of departments are not using adequately their academic and non-academic staff for some particular activities identified with teaching.
- Policy maker can use the suggested improvements and reduction in inputs/outputs to improve the performance of teaching of college academic departments. It can be extended in future for various colleges, universities and institutions to find the teaching performance.

Conflict of Interest
Authors declare that they have no conflict of interest.

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