Demographic variations in basic science education in India: a case study of CSIR–UGC national eligibility test

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This article explores the demographic variations in basic science education across the country on the basis of the CSIR–UGC national eligibility test (NET) held during the period 2002–2006. The states, representing different demographic zones, were ranked according to the number of qualifying students and the percentage selected. A simple scatter plot of selection versus enrolment shows that Delhi and West Bengal perform better than the norm, whereas Kerala and Tamil Nadu relatively underperform. The data envelopment analysis technique has been employed to further examine the relative efficiency of basic science education, in terms of the number of students qualifying NET in five subjects, viz. chemical sciences; earth, atmospheric, ocean and planetary sciences; life sciences; mathematical sciences, and physical sciences, across different states of the country. The position of a particular state on the efficiency frontier could serve as a measure of capacity building in these disciplines.

Keywords: Basic science education, capacity building, data envelopment analysis, human resource development, national eligibility test.

INDIA has the third largest higher education system in the world, next to China and the United States. The organizational framework, consisting of more than 430 universities and over 20,000 affiliated colleges, is spread across the country in 28 states and 7 union territories. The Council of Scientific and Industrial Research–University Grants Commission (CSIR–UGC) national eligibility test (NET), a unique and ambitious scheme being implemented by the CSIR, was formulated to evaluate students from different universities on a common platform. The objective is to ensure minimum standards in research and in the teaching profession. It aims at identifying budding talent, having aptitude and aspiration to generate new knowledge, and encourages them to undertake science as a career by granting incentives through fellowships.

CSIR–UGC NET is an all-India level examination conducted twice a year across the country in five basic science areas, namely chemical sciences, earth sciences, life sciences, physical sciences and mathematical sciences, for science students having a Master of Science (M Sc) or equivalent as the minimum qualification. Over the years, student enrolment in NET has increased from 71,000 in 1998 to 157,000 in 2008 – at a compounded annual growth rate (CAGR) of 7.5%. NET qualification has virtually become a benchmark for selecting candidates for research and teaching. The scheme has played a pivotal role in creating, maintaining and replenishing the pool of trained human resource, which is being tapped by research institutions, academia and industry to meet their needs of trained S&T manpower.

During the period 1950–2008, the number of universities has increased from 20 to 431 (CAGR = 5.4%), colleges from 500 to 20,677 (CAGR = 6.6%) and teachers from 15,000 to 5.05 lakhs (CAGR = 6.2%)[1,2]. The growth in various sectors of education varied from 4.5% to 8.5% in different states of India. The present study makes an assessment of the demographical variations in basic science education based on NET, conducted during the period 2002–2006. The position of a particular state on the efficiency frontier, as determined by the data envelopment analysis (DEA), in the five basic science areas included in NET could serve as a measure of the tertiary-level capacity building in these disciplines.

Data and methodology

During the period 2002–2006, around 4 lakh students enrolled to write NET for junior research fellowship (JRF) from the 28 states and 7 union territories of India

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Table 1. State-wise cumulative enrolment and selection in CSIR–UGC NET for JRF during 2002–2006

State/UT	Number of students enrolled	Rank	State/UT	Number of students selected
Uttar Pradesh	71,243	1	West Bengal	1,948
Andhra Pradesh	42,071	2	Delhi	1,764
Kerala	37,233	3	Uttar Pradesh	1,712
Tamil Nadu	32,945	4	Andhra Pradesh	1,013
West Bengal	29,508	5	Rajasthan	677
Maharashtra	25,410	6	Kerala	639
Rajasthan	23,047	7	Maharashtra	595
Delhi	19,202	8	Tamil Nadu	455
Karnataka	15,513	9	Haryana	383
Haryana	12,291	10	Karnataka	382
Madhya Pradesh	10,526	11	Uttarakhand	303
Punjab	9,185	12	Orissa	217
Orissa	9,091	13	Himachal Pradesh	204
Uttarakhand	9,004	14	Punjab	201
Jammu and Kashmir	6,124	15	Assam	161
Himachal Pradesh	5,850	16	Jammu and Kashmir	127
Assam	5,457	17	Madhya Pradesh	120
Gujarat	4,105	18	Gujarat	116
Bihar	3,815	19	Chandigarh	110
Jharkhand	3,787	20	Jharkhand	105
Chhattisgarh	3,385	21	Bihar	101
Manipur	3,146	22	Meghalaya	57
Chandigarh	2,732	23	Tripura	55
Puducherry	1,725	24	Puducherry	49
Meghalaya	1,592	25	Manipur	47
Tripura	1,302	26	Chhattisgarh	34
Goa	908	27	Goa	28
Andaman and Nicobar	649	28	Andaman and Nicobar	24
Nagaland	475	29	Nagaland	16
Mizoram	407	30	Mizoram	10
Arunachal Pradesh	342	31	Arunachal Pradesh	7
Daman and Diu	320	32	Daman and Diu	5
Lakshadweep	271	33	Sikkim	4
Sikkim	265	34	Lakshadweep	1
Dadra and Nagar Haveli	139	35	Dadra and Nagar Haveli	0

(Table 1). The relative efficiency of basic science education in terms of the number of students qualifying NET was measured across different states using a simple scatter plot and DEA. Based on exhaustive searches from the management information system of NET 2002–2006, only the 17 states with student enrolment more than 5000 and accounting for 93% of the students enrolled for NET were compared and assessed in the present study.

Charnes *et al.*[3] formulated the Charnes, Cooper and Rhodes (CCR) model of DEA to evaluate the relative efficiency of the decision-making units (DMUs) that could be countries, provinces, institutions, industries or individual firms. It is a novel approach to measure relative efficiency when there are multiple disproportionate inputs and outputs. If a suitable set of measures can be defined, DEA provides an efficiency measure without relying on the application of common weighting of inputs and outputs, and identifies peer DMUs and targets for inefficient units.

Numerous studies have been conducted to assess the R&D efficiency and performance of universities using DEA[4,5]. Rousseau and Rousseau[6,7] have used countries as objects of study; GDP, population and R&D expenditure as inputs; and publications and patents as outputs. For our study, we used the number of students who enrolled for NET from 17 states as input and total selections from each state as output. As the number of students who enroll for M Sc in each state significantly affects NET enrolment, the input variables also included the total M Sc enrolment, number of colleges/universities, population (rural and urban), area, and expenditure on education and training.

Four modes have been tested to assess the impact of inputs on the efficiency score. The input–output combinations used in each of the modes are shown in Table 2. These have also been tested discipline-wise (chemical sciences, earth sciences, life sciences, mathematical sciences and physical sciences) to determine the relative efficiency score of a state in a particular discipline (Table 3).

Results and discussions

India is the second most populous country in the world with considerable regional disparity. The majority of its

Table 2. Input–output combinations

	Output	Input
Mode 1	Selections (SE)	Enrolment (EN) M Sc (MS), Rural Population (RP), Area (A), Expenditure (EX)
Mode 2	Selections (SE)	Enrolment (EN) M Sc (MS), Urban Population (UP), Area (A), Expenditure (EX)
Mode 3	Selections (SE)	Enrolment (EN) M Sc (MS), Rural Population (RP), Area (A), Expenditure (EX), Universities (UN)
Mode 4	Selections (SE)	Enrolment (EN) M Sc (MS), Urban Population (UP), Area (A), Expenditure (EX), Universities (UN)

EN and SE are the total number of students enrolled and selected (per year) in CSIR–UGC NET (2002–2006).
MS is the M Sc enrolment. Source: Selected education statistics 2004–2005, Ministry of Human Resource Development. Government of India, p. 9.
RP and UP are the rural and urban population of India as per Census of India 2001; Government of India, 2001; http://www.censusindia.gov.in.
EX is the expenditure on education and training by education and other departments (revised estimates). Source: Selected education statistics 2004–2005, Ministry of Human Resource Development, Govt of India, p. 106.
UN is the total number of universities, Source: Higher education in India: issues related to expansion, inclusiveness, quality and finance, UGC, November 2008.

Table 3. Discipline-wise input–output combinations

	Output	Input
Chemical sciences (CS)	Selections (SCS)	Enrolment (ECS) Universities (UN)
Earth sciences (ES)	Selections (SES)	Enrolment (EES) Universities (UN)
Life sciences (LS)	Selections (SLS)	Enrolment (ELS) Universities (UN)
Mathematical sciences (MS)	Selections (SMS)	Enrolment (EMS) Universities (UN)
Physical sciences (PS)	Selections (SPS)	Enrolment (EPS) Universities (UN)

ECS, EES, ELS, EMS and EPS are the total number of students enrolled in chemical, earth, life, mathematical and physical sciences (per year) in CSIR–UGC NET (2002–2006).
SCS, SES, SLS, SMS and SPS are the total number of students selected in chemical, earth, life, mathematical and physical sciences (per year) in CSIR–UGC NET (2002–2006).
UN is the total number of universities. Source: Higher education in India: issues related to expansion, inclusiveness, quality and finance, UGC, November 2008.

people, i.e. about 70%, live in villages and the remaining 30% live in over 5000 towns/cities. Though the rural–urban ratio varies from state to state, the enrolment and selection of students in NET largely depend upon the level of educational infrastructure available in that state and the proportion of government expenditure towards university education.

The data pertaining to NET indicate that there is a large variation in the enrolment as well as selection patterns of students across different states. Amongst the states in the northern region, Uttar Pradesh (UP) with the highest rural population (131,658,339 according to the 2001 Census) accounts for the largest number of student enrolment in M Sc (34,683) and NET (14,249 per year) and is among the top three states in the country after West Bengal (WB; 390 per year) and Delhi (353 per year) in terms of selection in NET (342 per year). Though Maharashtra has the highest urban population (41,100,980 according to the 2001 Census) and the highest number of universities/deemed universities (42 in 2004–2005), it lags behind UP, both in terms of student enrolment (5082 per year) and selection (119 per year) in NET. Both UP and Maharashtra have the highest expenditure on education in the country, accounting for 7.5% and 10.4% respectively of government spending[8,9].

Amongst the southern states, Andhra Pradesh (AP; 8414 per year) followed by Kerala (7447 per year) and Tamil Nadu (TN; 6589 per year) showed the highest enrolment in NET and stand at the fourth (203 per year), sixth (128 per year) and eighth positions (91 per year) respectively, in terms of selection. Madhya Pradesh (MP), the central regional state, in spite of having the

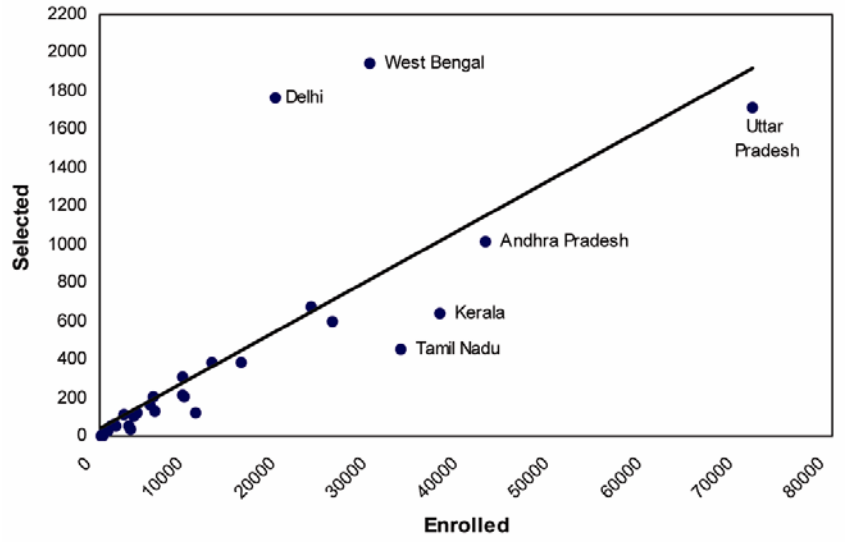

Figure 1. Selection versus enrolment scatter plot for CSIR–UGC NET (2002–2006).

second highest geographical area (308,245 sq. km) showed lower enrolment (2105 per year) and lowest selection (24 per year) of students in NET.

WB and Delhi (having the highest NET enrolment per lakh of population, at 138.64) are ranked the top two promising states in terms of selection of students in NET (Table 1). The performance of Delhi (9.19%) is, however, fairly above WB (6.60%) in terms of the percentage selected. A scatter plot of selection versus enrolment revealed that Delhi and WB perform at levels, which are 3× and 2.5× the norm, whereas Kerala and TN relatively underperform (Figure 1). It is interesting to note that Kerala and TN are placed at the sixth (128 per year) and eighth positions (91 per year) respectively, in terms of the total number of students selected; underperformance is essentially due to the relatively lower percentage selected and higher enrolment. Surprisingly, Himachal Pradesh (HP), which has the second lowest NET enrolment (1170 per year) amongst the 17 promising states, showed the third highest selection percentage of 3.49, after Delhi and WB.

DEA-based evaluation

The results of DEA, under four different modes with different inputs, indicate that the thrust of basic science education across states varies significantly from one mode to another (Tables 2 and 4).

From the mode 1 results, only Delhi (with the lowest rural population: 944,727 according to the 2001 Census) is found to be the most efficient (efficiency score 100) in terms of the number of students selected in NET. WB exhibits an efficiency score of 72 and the remaining states score below 50. When urban population was taken as input (mode 2) instead of the rural population (mode 1), Delhi and HP were found to be most efficient (efficiency score 100), and only three states, viz. Uttarakhand, WB and Kerala exhibited efficiency scores more than 50. When the number of universities was taken as an additional input in modes 1 and 2, there was an improvement in efficiency score in two southern states, viz. Kerala (19 to 68 in mode 3; 53 to 68 in mode 4) and AP (26 to 39 in mode 3; 33 to 39 in mode 4), and two northern states, viz. Haryana (34 to 41 in mode 3; 42 to 45 in mode 4) and UP (26 to 40 in mode 3; 33 to 40 in mode 4). The efficiency of the other states, viz. Assam, Rajasthan, Karnataka, Orissa, Maharashtra, Punjab, and Jammu and Kashmir, however, has remained more or less the same. TN and MP exhibited the lowest efficiency scores (less than 16).

It is widely acknowledged that India is among the few nations that have demographic advantage, with a large number of young citizens. Thus, it is vital that our youth are provided the necessary training to enable them to compete globally. It may be seen from the results of DEA that out of the 17 states showing promise in NET enrolment, only Delhi (with 93% urban population and literacy rate of 81.82%) remains efficient with a perfect score of 100, irrespective of rural or urban population. Surprisingly, HP (with 9.8% urban population and literacy rate of 76.5%) showed the same efficiency as Delhi, when only urban population was taken as input. In terms of the total number of students enrolled and those selected in NET, HP ranks 16 and 13 compared to Delhi with ranks 8 and 2 respectively; whereas in terms of the percentage selected, HP ranks 3 in comparison to Delhi with the rank 1.

Our recent study on the CSIR–UGC NET has identified the University of Delhi and Jawaharlal Nehru University, Delhi as the top-ranking institutions amongst the top 32 universities in terms of selection and selection percentage respectively[10]. Data on research papers published from

Table 4. Overall efficiency score (in parenthesis) for all modes across states/union territories

Mode 1	Mode 2	Mode 3	Mode 4
Delhi (100)	Delhi (100)	Delhi (100)	Delhi (100)
West Bengal (72)	Himachal Pradesh (100)	West Bengal (72)	Himachal Pradesh (100)
Himachal Pradesh (43)	Uttarakhand (73)	Kerala (68)	Uttarakhand (73)
Uttarakhand (37)	West Bengal (72)	Himachal Pradesh (43)	West Bengal (72)
Haryana (34)	Kerala (53)	Haryana (41)	Kerala (68)
Assam (32)	Haryana (42)	Uttar Pradesh (40)	Haryana (45)
Rajasthan (32)	Rajasthan (36)	Andhra Pradesh (39)	Uttar Pradesh (40)
Karnataka (27)	Assam (34)	Uttarakhand (37)	Andhra Pradesh (39)
Uttar Pradesh (26)	Uttar Pradesh (33)	Assam (32)	Rajasthan (36)
Andhra Pradesh (26)	Andhra Pradesh (33)	Rajasthan (32)	Assam (33)
Orissa (26)	Jammu and Kashmir (31)	Karnataka (27)	Jammu and Kashmir (31)
Maharashtra (25)	Orissa (28)	Orissa (26)	Orissa (28)
Punjab (24)	Karnataka (27)	Maharashtra (25)	Karnataka (27)
Jammu and Kashmir (23)	Maharashtra (25)	Punjab (24)	Maharashtra (25)
Kerala (19)	Punjab (24)	Jammu and Kashmir (23)	Punjab (24)
Tamil Nadu (15)	Tamil Nadu (15)	Tamil Nadu (15)	Tamil Nadu (15)
Madhya Pradesh (12)	Madhya Pradesh (12)	Madhya Pradesh (12)	Madhya Pradesh (12)

Table 5. Efficiency score (in parenthesis) for five disciplines across states/union territories

Chemical sciences	Earth sciences	Life sciences	Mathematical sciences	Physical sciences
West Bengal (100)	Delhi (100)	Delhi (100)	West Bengal (100)	Delhi (100)
Andhra Pradesh (64)	Kerala (95)	Kerala (46)	Delhi (97)	West Bengal (96)
Kerala (57)	West Bengal (66)	Himachal Pradesh (42)	Haryana (71)	Kerala (58)
Delhi (50)	Uttarakhand (44)	Haryana (39)	Kerala (68)	Uttar Pradesh (50)
Assam (38)	Rajasthan (34)	Uttarakhand (36)	Maharashtra (68)	Rajasthan (48)
Rajasthan (32)	Uttar Pradesh (32)	West Bengal (33)	Karnataka (54)	Karnataka (43)
Himachal Pradesh (29)	Karnataka (27)	Uttar Pradesh (31)	Uttar Pradesh (53)	Uttarakhand (43)
Uttar Pradesh (26)	Assam (27)	Jammu and Kashmir (26)	Uttarakhand (45)	Haryana (39)
Orissa (25)	Maharashtra (25)	Punjab (21)	Rajasthan (40)	Orissa (35)
Haryana (24)	Orissa (23)	Karnataka (21)	Punjab (39)	Himachal Pradesh (33)
Karnataka (20)	Haryana (19)	Rajasthan (20)	Andhra Pradesh (39)	Assam (31)
Maharashtra (19)	Madhya Pradesh (18)	Andhra Pradesh (20)	Assam (35)	Punjab (27)
Uttarakhand (19)	Punjab (17)	Maharashtra (19)	Himachal Pradesh (27)	Andhra Pradesh (23)
Punjab (17)	Himachal Pradesh (16)	Orissa (19)	Jammu and Kashmir (25)	Maharashtra (22)
Tamil Nadu (14)	Jammu and Kashmir (16)	Assam (17)	Madhya Pradesh (22)	Madhya Pradesh (8)
Jammu and Kashmir (7)	Andhra Pradesh (9)	Tamil Nadu (13)	Tamil Nadu (20)	Tamil Nadu (8)
Madhya Pradesh (3)	Tamil Nadu (2)	Madhya Pradesh (13)	Orissa (20)	Jammu and Kashmir (7)

India during 1996–2006, as reflected in the Scopus international database, further indicated that out of the top 35 productive S&T institutions in India, six are located in Delhi[11]. Though universities are as good a choice for doing Ph D as R&D institutions, our study has shown that barring a few universities, students move from universities to R&D institutions to pursue their Ph D[12]. It seems that the substantially lower number of R&D institutions in HP probably makes the bright students from the state to move to R&D institutions/universities in other states. The initiative by the Ministry of Human Resource Development, Government of India to establish an Indian Institute of Technology at HP (Mandi) and in the adjoining state of Punjab (Ropar), and an Indian Institute of Science Education and Research at Mohali, Punjab, would not only prevent the forced migration of students from these states, but also produce professionals capable of creating new knowledge, and designing and developing products and processes for the benefit of our society.

Discipline-wise DEA-based evaluation

The enrolment data indicate that the majority of the students appearing for NET across the states are from life sciences (46%), followed by chemical sciences (24%), physical sciences (15%), mathematical sciences (12%) and the least (3%) from earth sciences[10]. The impact of different disciplines of basic science in the 17 states has been assessed using DEA. The number of universities/deemed universities/institutes of national importance in each state was used as an additional input. The results

of DEA (Tables 3 and 5) indicate that in earth sciences, life sciences and physical sciences, Delhi has received a perfect score of 100 and narrowly missed the mark in mathematical sciences, but lags behind in chemical sciences with a score of 50. WB has the best efficiency score of 100 in chemical and mathematical sciences, and exhibits a score of 96 in physical sciences. It is noteworthy that except Kerala and Haryana, which have done particularly well in earth sciences (score 95) and mathematical sciences (score 71) respectively, all the other states have efficiency scores below 50 in all the five basic science subjects.

These vast differences in efficiency scores (Tables 4 and 5) across different states and union territories indicate the need for directed efforts to upgrade the overall standard of basic science education in the country. A transparent, accountable, discipline-specific quality assurance system would ensure the best educational outcome. Emergence of two states, viz. Delhi and HP, with contrasting demographic profiles, on the efficiency frontier may serve as a role model for other states to imitate.

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Received 14 December 2010; revised accepted 5 July 2011