

Scientometric analysis of research publications of six Indian Institutes of Technology

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The paper presents the analysis of bibliographic data of 72,940 research papers published by six Indian Institutes of Technology (IIT Delhi, IIT Kharagpur, IIT Madras, IIT Bombay, IIT Kanpur and IIT Roorkee) and indexed in Scopus database during the period 2006-2015. The analysis indicates that the relative citation impact of IIT Roorkee and IIT Bombay are more than other IITs. Works by authors from IIT Kharagpur are cited more than that of other IITs. *Physics of Plasma, Journal of Applied Polymer Science, Journal of Applied Physics, Journal of Applied Polymer Science, and RSC Advances* are the journals most used by the researchers of the six IITs.

Keywords: Scientometrics; Citation analysis; Research papers; Indian Institutes of Technology

Introduction

Given the importance of science and technology in economic development of a nation, India has invested heavily in R&D infrastructure in the frontier areas like space sciences, electronics, telecommunication, atomic energy and more recently in biotechnology. Science and technology are complementary wherein science exemplifies discovery and knowledge creation, and technology exemplifies innovations using knowledge. The benefits of science are delivered to the people and society through technology development.

The Indian Institutes of Technology (IITs) have been recognized as the peninsula of perfection in the orbit of higher education in the country. The numbers of IITs have increased from five to 23 by 2016. Initially, with the assistance of international organizations or foreign governments, four of the five IITs were established. The first IIT was established in May 1950 at Kharagpur (West Bengal), followed by IIT Bombay in 1958, Madras in 1959, and Kanpur in 1959. By an act of 1961 known as Institutes of Technology Act, these institutes were named as "institutions of national importance." By an amendment to the 1961 act, the College of

Engineering, established in New Delhi in 1961 was named as IIT Delhi in 1963. IIT Guwahati was established in 1994 and IIT Roorkee was assimilated into the IIT system in 2001, becoming the seventh IIT. As a result, in 2001, there were seven institutes under the IIT system. Currently, there are 23 IITs in India. Among the technological institutes in the country, the IITs produce a number of PhDs in science, engineering and social sciences and also contribute a large number of research articles every year.

In this study, an attempt has been made to analyze all the 72,940 research papers published by six Indian Institutes of Technology (IIT Delhi, IIT Kharagpur, IIT Madras, IIT Bombay, IIT Kanpur and IIT Roorkee) published by them during the period 2006-2015. Other IITs are newly established and contributed less number of papers to the total output of India. Therefore, the contributions of other IITs are not taken for this study.

Review of literature

Several studies in the past have been published in literature dealing with the research performance of countries, different subjects and institutions. For

instance, Siddaiah et al¹ analyzed the contribution and citation impact of eight new IITs during 2010-14 which indicate significant differences in publication pattern of new IITs. Prathap and Gupta² analyzed the research performances of Indian engineering and technological institutes for the period 1999-2008, which showed how these institute acts as generators of new knowledge in the higher education sectors of India. Saxena, Gupta and Jauhari³ evaluated and compared the application of h-index, g-index, and p-index on 40 Indian engineering and technological institutes and accordingly ranked them. Singh, Gupta & Kumar⁴ used various quantitative and qualitative indicators and suggested a methodology for getting an idea about the relative performance of various subject fields of IIT Roorkee from 1993 to 2001. Singh⁵ analyzed the research performance of Indian Institute of Technology, Delhi in terms of publications, collaboration and international participation and major research areas of study. Physics, mathematics and material science are the top research areas of IIT Delhi. Arif⁶ analyzed the research productivity of four IITs based on data collected from websites for the period 2011-2015 and showed that there were huge differences in number of publications, growth of literature, authorship pattern and trends, etc. though these institutes are established with same mandate and have similar objectives and characteristics. Singh⁷ mapped the research performance of Indian Institute of Technology Kharagpur during 1990 to 2014, which showed that three-author papers have been increasing over the years, indicating increasing collaborative research among the scientists of the institute. For Indian Institute of Technology Bhubaneswar (IITB) papers published during 2009 to 2014, the average citation received by per paper (ACPP) and HiCP is highest for the year 2010 and increasing trends towards multi-authorship publications could be seen⁸.

Objectives of the study

- To examine the pattern of growth of the output of the six IITs;
- To delve into the dissemination pattern of the six institutes in terms of journals originating country and the impact factor of these journals;
- To investigate the distribution of citation pattern and to identify highly cited authors;

- To identify the disciplines of research in which the results are published; and
- To identify the journals most preferred for publishing the research results.

Methodology

The study was undertaken based on the data downloaded from Scopus database for the period 2006-2015 using the following search strategy under "Affiliation search"(AF-ID ("Indian Institute of Technology Delhi"60032730)ORAF-ID (Indian Institute of Technology Kharagpur"60004750) ORAF-ID ("Indian Institute of Technology Madras"60025757) ORAF-ID ("Indian Institute of Technology Bombay"60014153) ORAF-ID ("Indian Institute of Technology Kanpur"60021988) ORAF-ID ("Indian Institute of Technology Roorkee"60031818)) AND (LIMIT-TO (PUBYEAR, 2015) ORLIMIT-TO (PUBYEAR, 2014) ORLIMIT-TO (PUBYEAR, 2013) ORLIMIT-TO (PUBYEAR, 2012) ORLIMIT-TO (PUBYEAR, 2011) ORLIMIT-TO (PUBYEAR, 2010) ORLIMIT-TO (PUBYEAR, 2009) ORLIMIT-TO (PUBYEAR, 2008) ORLIMIT-TO (PUBYEAR, 2007) ORLIMIT-TO (PUBYEAR, 2006)) AND (LIMIT-TO (DOCTYPE, "ar") ORLIMIT-TO (DOCTYPE, "cp") ORLIMIT-TO (DOCTYPE, "re") ORLIMIT-TO (DOCTYPE, "ch") ORLIMIT-TO (DOCTYPE, "le") ORLIMIT-TO (DOCTYPE, "no"))

Bibliographic details downloaded consisted of name of author(s), document title, year, source title, volume, issue, pages, citation count, source and document type, DOI and Bibliographical information included affiliations, serial identifiers (e.g. ISSN), DOI, publisher, editor(s), language of original document, correspondence address, abbreviated source title.

The data downloaded was analyzed using M S-Excel as per the objectives of the study. Whole counting is followed to analyze the data. Each author is credited with one count for every publication that bears his/her name regardless of whether it is a single-authored or multiple-authored publication.

Bibliometric indicators used

The bibliometric indicators used in this study are - Total Number of Publications (TNP); Total Number

of Citations (TNC); Citations per Paper (CPP); and Relative Citation Impact (RCI) as measures of output and impact. TNP and TNC are absolute indicators, while CPP and RCI are relative indicators. The values of TNP and TNC were directly obtained from the downloaded data. CPP is the average number of citations per paper (C/P). It has been widely used in bibliometric studies to normalize a large disparity in volumes of published output among disciplines, countries and institutions for a meaningful comparison of research impact. RCI is a measure of both the influence and visibility of a nation's research in global perspective. It is defined as "a country's share of world citations in the subspecialty/country's share of world publications in the subspecialty". $RCI = 1$ denotes a country's citation rate equal to world citation rate; $RCI < 1$ indicates a country's citation rate less than world citation rate and also implies that the research efforts are higher than its impact; and $RCI > 1$ indicates a country's higher citation rate than world's citation rate and also imply high impact research in that country. These indicators have been used by Dwivedi et al⁹ and Pradhan & Ramesh¹⁰ for assessment of organic chemistry research in India.

Results and discussion

Document types

The selection of an appropriate outlet often has an influence on the visibility and impact of the published research. Hence, analyses of the types of document used for communicating research results are very important. The results of the analysis on the type of

documents used by six IITs for publishing research results are given in Table 1 which indicates that about 70% of the output was published as journal articles. The proportion of journal papers was almost equal for IITR and IITKGP closely followed by IITK. Among all the six IITs, IITB published highest (29.89%) papers as conference papers followed by IITD (27.59%).

Publication pattern of six IITs

During 2006-2015, the six IITs published 72,940 papers. Among these IITKGP published highest (20.8%) of the papers closely followed by IITD with 19.3% of the papers. The lowest number of papers was published by IITR with 12.6% of the output. The share of IITB and IITM were almost the same. Data presented in Table 2 indicates that the output of the six IITs has grown continuously during the period of study. Data were examined for change in output during 2006-2010 (block 1) and 2011-2015 (block 2). Data presented in Table 2 indicates that in block 2 the output for IITD, IITKGP and IITK has declined as compared to block 1. The highest decline in output was for IITKGP, while for IITM, IITB and IITR the output in block 2 has increased. The highest increase was for IITB followed by IITR and IITM. We also examined Compound Annual Growth Rate (CAGR) of six IITs during 2006 to 2015. The values of CAGR for different IITs are IITD (2.77%), IITKGP (3.95%), IITM (5.23%), IITB (6.36%), IITK (2.93%) and IITR (7.24%), which has been calculated by using the formula available at www.investopedia.com/

Table 1—Type of documents

Document Type	IITD	IITKGP	IITM	IITB	IITK	IITR	Total
Articles	9472 (67.2%)	11267 (74.3%)	8548 (69.9%)	8008 (66.8%)	7401 (72.3%)	6845 (74.5%)	51541 (70.7)
Conference papers	3892 (27.6%)	3399 (22.5%)	3351 (27.4%)	3587 (29.9%)	2503 (24.5%)	1976 (21.5%)	18708 (25.7)
Reviews	386 (2.8%)	273 (1.8%)	183 (1.5%)	241 (2.6%)	182 (1.8%)	237 (2.6%)	1502 (2.1)
Book Chapters	274 (1.9%)	164 (1.1%)	113 (0.9%)	124 (1.03%)	98 (0.9%)	85 (0.9%)	858 (1.2)
Letters	57 (0.5%)	36 (0.3%)	18 (0.2%)	12 (0.2%)	13 (0.2%)	15 (0.2%)	151 (0.3)
Notes	23 (0.2%)	34 (0.3%)	19 (0.2%)	26 (0.3%)	42 (0.5%)	36 (0.4%)	180 (0.3)
Total	14104	15173	12232	11998	10239	9194	72940 (100)

Table 2—Publication pattern of six IITs during 2006-2015

Year	Total number of papers (%)						
	IITD	IITKGP	IITM	IITB	IITK	IITR	Total
2006	1160(8.3)	1146(7.6)	867(7.1)	796(6.7)	829(8.1)	580(6.4)	5378(7.4)
2007	1238(8.8)	1246(8.3)	971(7.9)	898(7.5)	905(8.9)	625(6.8)	5883(8.7)
2008	1253(8.9)	1406(9.3)	1083(8.9)	920(7.7)	1025(10)	713(7.8)	6400(8.8)
2009	1207(8.6)	1483(9.8)	1069(8.8)	1019(8.5)	977(9.6)	775(8.5)	6530(8.9)
2010	1410(9.9)	1580(10.5)	1241(10.2)	1113(9.3)	978(9.6)	856(9.4)	7178(9.9)
Block 1 (2006-2010)	6268 (19.9)	6861(21.9)	5231(16.7)	4746(15.2)	4714(15.1)	3549(11.4)	31369 (43)
2011	1426(10.2)	1527(10.1)	1348(11.2)	1252(10.5)	1045(10.3)	1007(10.9)	7605(10.5)
2012	1520(10.8)	1638(10.8)	1333(10.9)	1303(10.9)	1067(10.5)	1161(12.7)	8022(10.9)
2013	1622(11.6)	1665(10.9)	1361(11.2)	1539(12.9)	1132(11.1)	1103(11.9)	8422(11.6)
2014	1744(12.4)	1793(11.9)	1515(12.4)	1684(14.1)	1174(11.5)	1207(13.2)	9117(12.5)
2015	1524(10.9)	1689(11.2)	1444(11.9)	1474(10.9)	1107(10.9)	1167(12.7)	8405(11.6)
Block 2 (2011-2015)	7836(18.84)	8312(19.99)	7001(16.84)	7252(17.44)	5525(13.29)	5645(13.57)	41571(56.99)
% (Block 1 and 2)	1.13%	1.87%	-0.16%	-2.31%	1.73%	-2.26%	13.98%
Total	14104(19.34)	15173(20.81)	12232(16.76)	11998(16.45)	10239(14.03)	9194(12.61)	72940(100)
CAGR	2.77%	3.95%	5.23%	6.36%	2.93%	7.24%	

Table 3—Citation pattern of journal articles of six IITs

Institutions	Total no. of articles	TNC	CPP	Papers uncited	% of uncited papers	Papers cited	% of papers cited
IITD	9472	88374	9.33	1314	13.87	8158	86.13
IITKGP	11267	97967	8.69	1320	11.72	9947	88.28
IITM	8548	82356	9.63	1163	13.61	7385	86.39
IITB	8008	80427	10.04	918	11.46	7090	88.54
IITK	7401	72574	9.81	906	12.24	6495	87.76
IITR	6845	67306	9.83	1007	14.71	5838	85.29

calculator/cagr.aspx. It indicates that highest CAGR for IITR followed by IITB.

Citation analysis of articles

Research impact of individual researchers is measured in terms of citations received, journal's rank or journal impact factor wherein an author's works appeared in, and collaboration matrix of collaborating authors. Citation analysis measures the eminence of research productivity, which presumes that the greater the eminence, command, or priority of a particular publication, the more intermittently it will be cited in the scientific literary works. By counting citations, one can judge the domination or perceptibility of individuals or groups or institutions. Scientific supremacy and visibility of a scientific publication have been observed by noteworthy citations it received. An author's perceptibility can be deliberated through a calculation of how frequently it has been cited in subsequent publications.

Table 3 gives the distribution of citations received by journal articles during 2006-2015. Out of the total articles published by scientists of six IITs, 14.71 % of the IITR articles did not get any citation followed by IITD (13.87%), IITM (13.61%), IITK (12.24%), IITKGP (11.72%) and IITB (11.46%). Out of the cited articles highest 88.54% articles of IITB were cited one or more times, IITKGP (88.28%), IITK (87.76%), IITD (86.13%), IITM (86.39%) and IITR (85.29%). Considering the motif of citations also, one can conclude that the scientific impact of the six IITs is strongly connected to the mainstream science as more than four-fifth of the papers were cited in the international literature.

Highly cited Papers

Table 4 exhibits 17 highly cited papers which received more than 500 citations. Out of the 17 highly cited papers, highest 4 papers are from IITKGP, followed by 3 papers each from IITR, IITD and IITB, 2 papers each from, IITM and IITK. The 17 papers

Table 4—Highly cited papers

Sl. no.	Authors and bibliographic details	TNC	Country of origin	ACP	Institute
1	Ravi Kumar, M N V, <i>Reactive and Functional Polymers</i> , 46(1) (2000) 1-27.	2095	The Netherlands	139.66	IITR
2	Klionsky D J, Abdalla F C, Abeliovich H, (...), Zschocke J, Zuckerbraun B, <i>Autophagy</i> , 8 (4) (2012) 445-544.	1673	USA	418.25	IITK
3	*Schnable PS, Ware D, Fulton R S, (...), Wing R A, Wilson R K, <i>Science</i> , 326 (5956) (2009) 1112-1115.	1567	USA	223.85	IITB
4	***Meher L C, Vidya Sagar D, Naik S N, <i>Renewable and Sustainable Energy Reviews</i> , 10(3) (2006) 248-268.	1536	UK	153.6	IITD
5	Agarwal A K, <i>Progress in Energy and Combustion Science</i> , 33(3) (2007) 233-271.	1235	USA	137.22	IITK
6	**Ghosh S K, Pal T, <i>Chemical Reviews</i> , 107(11) (2007) 4797-4862.	1184	USA	131.55	IITKGP
7	*Gupta V K, Suhas, <i>Journal of Environmental Management</i> , 90(8) (2009) 2313-2342.	1184	USA	169.14	IITR
8	***Bhardwaj N, Kundu S C, <i>Biotechnology Advances</i> , 28(3) (2010) 325-347.	1064	USA	177.33	IITKGP
9	*Bond T C, Doherty S J, Fahey D W, (...), Warren S G, Zender C S, <i>Journal of Geophysical Research Atmospheres</i> , 118(11) (2013) 5380-5552.	856	USA	285.33	IITB
10	*Naik S N, Goud V V, Rout P K, Dalai A K, <i>Renewable and Sustainable Energy Reviews</i> , 14(2) (2010) 578-597.	727	UK	121.16	IITD
11	*Bhadra S, Khastgir D, Singha N K, Lee J H, <i>Progress in Polymer Science (Oxford)</i> 34(8) (2009) 783-810.	703	UK	100.42	IITKGP
12	***Chattaraj P K, Sarkar U, Roy D R, <i>Chemical Reviews</i> , 106(6) (2006) 2065-2091.	634	USA	63.4	IITKGP
13	***Gupta K C, Sutar A K, <i>Coordination Chemistry Reviews</i> , 252(12-14) (2008) 1420-1450.	605	The Netherlands	75.62	IITR
14	**Ruparelia J P, Chatterjee A K, Duttagupta S P, Mukherji S, <i>Acta Biomaterialia</i> , 4(3) (2009) 707-716.	572	The Netherlands	81.71	IITB
15	*Von Maltzahn G, Park J H, Agrawal A, (...), Sailor M J, Bhatia S N, <i>Cancer Research</i> , 69(9) (2009) 3892-3900.	559	USA	79.85	IITM
16	*Dhillon H S, Ganti R K, Baccelli F, Andrews J G, <i>IEEE Journal on Selected Areas in Communications</i> , 30(3) 2012, 6171996, 550-560	541	USA	135.25	IITM
17	Pandey S, <i>Analytica Chimica Acta</i> , 556(1) (2010) 38-45.	522	The Netherlands	87	IITD

*International collaborative paper; **Domestic collaborative paper, ***Institutional collaborative (Author of one institute)

received 17257 (2.66%) of the total citations, with an average of 1015.22 citations per paper. Out of 17 highly cited papers, 8 papers had international collaborations. Three papers were published by one author. Two IITD papers published in *Renewable and Sustainable Energy Reviews*, which are also high IF journals and received citations more than 1500 and 700 citations. A study by Garg and Kumar also showed that papers with international collaborations had higher citations¹¹.

Preferred journals

A higher emergence rate of periodicals in a subject field can be a measure of the growth of knowledge in

that field. It is a recognized fact that in the field of science there is ostensibly an increasing rate of emergence of new journals to meet the rapid explosion of information. The most preferred journals used to communicate research results are depicted in Table 5, which indicates that there remain differences in communicating their research results in journals. However, there are also some common journals in which six IITs publish their papers. These are *Journal of Applied Polymer Science*, *Journal of Applied Physics*, *RSC Advances*, *Materials Science and Engineering A*, *Journal of Alloys and Compounds*.

Table 5—Preferred journals

Sl. no.	Journal	Journal publishing country	IF	No. of papers	Institutes
1	<i>Physics of Plasmas</i>	USA	1.93	163	IITD
2	<i>Journal of Applied Polymer Science</i>	USA	1.866	152	IITD
3	<i>Journal of Applied Physics</i>	USA	2.101	142	IITD
4	<i>Journal of Applied Polymer Science</i>	USA	1.866	140	IITKGP
5	<i>RSC Advances</i>	UK	3.289	123	IITKGP
6	<i>Journal of Applied Physics</i>	USA	2.101	119	IITM
7	<i>Indian Journal of Fibre and Textile Research</i>	India	0.42	115	IITD
8	<i>Physical Review B Condensed Matter and Materials Physics</i>	USA		114	IITK
9	<i>Materials Science and Engineering A</i>	Netherlands	2.647	111	IITKGP
10	<i>Journal of the Textile Institute</i>	England	0.94	109	IITD
11	<i>Dalton Transactions</i>	UK	4.177	109	IITB
12	<i>Journal of Applied Physics</i>	USA	2.101	107	IITK
13	<i>International Journal of Heat and Mass Transfer</i>	UK	2.857	106	IITM
14	<i>Inorganic Chemistry</i>	USA	4.82	106	IITB
15	<i>Journal of Alloys and Compounds</i>	Switzerland	3.014	104	IITKGP
16	<i>Applied Physics Letters</i>	USA	3.142	99	IITD
17	<i>Journal of Applied Physics</i>	USA	2.101	87	IITKGP
18	<i>Industrial and Engineering Chemistry Research</i>	USA		99	IITB
19	<i>Inorganic Chemistry</i>	USA	4.82	97	IITK
20	<i>Applied Physics Letters</i>	USA	3.142	91	IITB
21	<i>Tetrahedron Letters</i>	UK	2.347	90	IITK
22	<i>Materials Science and Engineering A</i>	Netherlands	2.647	88	IITM
23	<i>Industrial And Engineering Chemistry Research</i>	USA		84	IITK
24	<i>Physical Review D Particles Fields Gravitation and Cosmology</i>	USA	IF missing	84	IITM
25	<i>Physical Review Letters</i>	USA	7.645	83	IITB
26	<i>Journal of Applied Physics</i>	USA	2.101	83	IITB
27	<i>RSC Advances</i>	UK	3.289	79	IITB
28	<i>Physical Review C Nuclear Physics</i>	USA		77	IITB
29	<i>Materials Science and Engineering A</i>	Netherlands	2.647	77	IITKGP
30	<i>Journal Of Chemical Physics</i>	USA	2.894	77	IITK
31	<i>RSC Advances</i>	UK	3.289	77	IITK
32	<i>Journal of Alloys and Compounds</i>	Switzerland	3.014	75	IITKGP
33	<i>Journal of Physical Chemistry C</i>	USA	4.509	75	IITM
34	<i>Journal of Alloys and Compounds</i>	Switzerland	3.014	75	IITM
35	<i>RSC Advances</i>	UK	3.289	75	IITM
36	<i>Physical Review E Statistical Nonlinear And Soft Matter Physics</i>	USA		73	IITK
37	<i>RSC Advances</i>	UK	3.289	72	IITR
38	<i>Advanced Materials Research</i>	Switzerland		70	IITR

Conclusion

In this study, the analysis of comparative research performances in terms of publication outputs and its impact in terms of citations during the period 2006-2015 of six IITs is presented. It is observed from the study that though the research publications of six IITs has grown from 5378 in 2006 to 8405 in 2015, but in an inconsistent way. Considering the pattern of citations also, it can be concluded that the scientific

impact of the six IITs is strongly connected to the mainstream science as more than four-fifth of the papers were cited in the international literature.

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