

Chemistry in India is progressing, although at a slower pace than expected.

Ms.Samiya Tanveer,

Abstract

We conducted a scientometric study of contributions from India to top interdisciplinary chemistry journals throughout the 25-year period 1991–2015 in light of remarks on Indian chemistry research made in three recent publications issued by Nature Index, Elsevier, and Thomson Reuters. We've used China as a comparison to measure India's performance. Between 2007 and 2014, the number of chemical publications published in India rose considerably. Number of articles increased at an annual compound growth rate (CAGR) of 8.9% over the three-year moving average during this time, with a rise of major journals that was above proportional. *Angewandte Chemie International Edition* (*Angew. Chem. International Ed.*) and *Accounts of Chemical Research* obtained more citations for works with at least one Indian author than the global average. However, despite the country's significant population (17 percent), India is underrepresented in the world's top journals, with a share (0.7 percent) of papers in the *Journal of the American Chemical Society*, compared to 58% for the United States, 7.6% for Germany, and 5.1% for China, and a share (1.2 percent) of papers in the *Angew.* This might be because Indian colleges have just lately begun to promote cross-disciplinary mobility. That just a few Indian scholars and institutions get published in the most prestigious publications is also a subject of concern. In the top one percentile of the most frequently referenced chemical publications, just a few papers from India can be found, but China dominates the field. More than three times as many top-tier articles from China as from India were published in 2014, yet just 2.3% were published in India.

Keywords: In the field of chemistry, there is a growing emphasis on international cooperation, interdisciplinary publications, and scientometric analysis.

Arunan et al.'s short but insightful essay on chemistry in India is the inspiration for this study. Even while research production has increased and international cooperation has increased, Indian chemistry research is still not on par with the best in the world, as we demonstrate quantitatively in this paper. Natureindex.com, SCImago, and the Web of Science–Science Citation Index Expanded (WoS–SCIE) have all recently produced studies on the state of science in India, and we pre-sent some data from these databases. Then, we look at six general chemistry publications, as well as *Nature*, *Science*, and the *Proceedings of the National Academy of Sciences, USA*, to identify major institutions and people from Indian labs that have made significant contributions. Several other nations are compared to India's performance.

Prior research

A study by the Nature Index on India

Nature Index² reports that chemistry is doing well in India, and it's really the best-performing field. There has been a substantial increase in research production despite stagnant financing for R&D as a proportion of GDP, red tape, government apathy, and unjust appointments', according to the report's examination of 68 top-quality journals. There are 14 chemical journals and four multi-disciplinary journals where Indian researchers have published their work, according to a study (<http://www.natureindex.com/faq#subjects>). The top 10 journals cited by Indian scientists out of the 68 monitored by Nature Index are all in

disciplines such as chemistry and physics. To illustrate India's overwhelming preference for chemistry, the discipline accounts for half of the whole Nature Index production in India. With a weighted fractional count (WFC) of 516.8 publications in 2015–2016

(<http://www.natureindex.com/>), India now ranks eighth internationally in chemistry (as opposed to 13th overall in science). India's chemistry research has been recognised as an emerging star³ by the Nature Index. In terms of chemistry-specific WFC, South Korea is ahead of India for the same period with a WFC of 590.40 (despite having a population that is only 3.8% that of India (www.worldmeters.info) and a nominal GDP that is less than 60% of India's (Statistics Times; IMF World Economic Outlook, April 2016)) and China is far ahead. South Korea and China are both ahead in terms of chemistry-specific performance (WFC 4194.16). As soon as Nature Index began issuing rankings, China and South Korea were always in the lead. In terms of the total quantity of papers, India is catching up to South Korea. There was an annual growth rate of 12.65 percent for the chemistry-specific WFC in India between 1 January 2012 and 31 May 2016, whereas China's was 15.5 percent and South Korea's 1.33 percent (as seen from Nature Index on 24 July 2016). Among the 68 Nature Index journals, chemistry is responsible for more than a third of co-authored publications. Since Nature Index began tracking Indian publications in 2012, the percentage of papers with at least one author from India has increased from 35.5 percent to 36.2 percent (ref. 5). In 2012, South Korea had a 40.5 percent share, while China had a 47.7 percent share in 2012 and a 53 percent share in 2015.

SCImago

SCImago (<http://www.scimagojr.com>) reports that the number of chemical articles published in Asia surpassed that in the United States in 1996 and Western Europe in 2004. It has expanded by the year 2014. One hundred and sixty-six thousand six hundred and seventy-three of the world's 228,428 chemical publications were published in Asia, as opposed to 56,404 in Western Europe and 40,379 in North America. Singapore and Taiwan, in addition to China, Japan, South Korea, and India, have contributed to the Asian rise in chemistry. There were 4,035 citable papers in 1996; by 2004, that number had grown to 6,664; and by 2014, that number had risen to 16,576. In 1996, India had a 3.88 percent proportion of the world's literature in chemistry; in

2004, it had a 4.59 percent part; and in 2014, it had a 7.37 percent share. After a drop from 16.12 percent to 14.35 percent between 1996 and 2004, India's share rebounded to 15.76 percent in 2014. Because of China's tremendous growth, India's portion in the Asiatic region stayed nearly unchanged. As of the 17th of June, 2016, SCImago has indexed 232,304 publications from 857 journals in the category "Chemistry" in 2015. With a score of 16,159, India came in third place.

more than China (63,193 papers) or the United States combined (35,610 papers). It was determined that 1,635 of the papers from India were in analytical chemistry, 8,166 in chemistry – other (including spectroscopy), 491 were in electrochemistry, 1,432 were in inorganic and 3,402 papers were in physical and theoretical spectroscopy (1,376). As the field classification is based on journals, the overall number of numbers allocated to subfields is more than the total number of numbers given to chemistry as a whole.

Elsevier submits a Daily System Time (DST) report.

There were 64,492 active chemistry researchers connected with Indian institutions over the period of 2009–2013 according to a study issued by Elsevier for the Department of Science and Technology, New Delhi⁶ (see p. 93 of the report). There were 8,367 active chemical researchers out of a total of 82,501 in the previous edition of the report⁷, which is from December 2015. (10.1 percent). A estimated estimate of 10,000 chemists was provided by Arunan et al.¹] Indian chemistry articles accounted for 6.9% of all published chemistry papers between 2009 and 2014, which is greater than the percentage of Indian publications in all other fields. Between 2009 and 2013, the number of chemical articles published in India increased at a CAGR of 7.9%, compared to 9.9% in China and 4.4% globally.

Bengaluru's Indian Institute of Science published 2,562 chemistry papers; the Indian Institute of Technology, Kharagpur had 1,677; Indian Association for Scientific Research, Kolkata had 1,598; Indian Institutes of Technology Bombay had 1,496, and Jadavpur University had a total of 1,462

papers published in chemistry. (1,429). During this time span, 2,895 scientific articles from India were included in the top one percent of the most highly referenced papers. 394 of these (or 13.6 percent) were in chemistry. Only 0.49 percent of the 81,080 chemistry publications were in the top 1% of highly referenced papers, according to the citation data. 3,667 of the 16,999 highly cited articles published in China were in chemistry, accounting for 21.6 percent of the total number. A total of 1,333 of China's 276,000 chemical publications were among the most widely referenced, or one percent. In the years 2009–2013, Indian papers made about 10% of the most highly referenced publications. Some 7,211 (or 13.2%) of these were from the field of chemistry.

More specifically, 8.9% of all chemistry articles published in India during the time were highly referenced. 37,937 of the 282,498 Chinese publications in the top 10% most highly referenced papers were chemistry studies (13.4%). For context, 13.71 percent of all Chinese chemistry articles were in the top 10 percent in terms of number of citations, according to Google Scholar. Chemists may be surprised to see that other areas have more highly-cited publications among India's top one percent and top 10 percent of papers. For example, 949 of the 2,895 Indian papers in the top 1% of the most highly cited papers during this period were in engineering, 542 in computer science, 538 in medicine, and 527 in physics and astronomy, which is a 32.8 percent share of the 108,348 Indian papers in the top 1% of the most highly cited papers. Engineering (19,532; 35.3%), computer science (17,535; 31.7%), physics and astronomy (8343; 15.1%), and materials science (8172; 14.8%) accounted for the majority of the 55,402 publications from India in the top 10 percent of highly cited papers.

DST received a report from Thomson Reuters.

According to a Thomson Reuters study for DST8, Indian chemistry research is fast expanding. Indian chemistry publications published between 2005 and 2014 more than doubled in number. Since 2005 to 2014, Indian scientists have produced 89,598 chemistry-related research articles. To put this in

perspective, in 2014, India had a 4.05 percent share of all scientific publications, compared to China's 18.09 percent share, and in 2005, India had a 5.34 percent and an 8.07 percent share of the chemistry literature, respectively, whereas China had 15.64 percent and a 28.67 percent share. However, despite an increase in the number of research, just 0.49 percent of Indian chemistry publications (the same as in the El sevier report) made it into the top one percentile of highly-cited papers in 2013 and 2014, compared to China's 1.19 percent. While China's share is somewhat higher at 9.73 percent, India's portion is little lower at 6.95 percent. InCites shows that in 2014, India accounted for 3.4 percent of the world's Science and Technology research output indexed in Web of Science (WoS). This is a pittance in light of the fact that India is home to 17% of the global population. However, the nominal GDP of the nation is approximately 3%. (as projected by IMF World Economic Outlook in April 2016). In 2014, India contributed 6.8% of all chemical articles, more than double the global average. In fact, India's chemistry research production is the greatest among the 22 disciplines classified by Essential Science Indicators, a Thomson Reuters database, which classifies research output. The three-year moving average of the number of Indian chemistry articles published between 2007 and 2014 climbed at an annual CAGR of 8.9 percent, according to data from WoS–SCIE (gathered on August 1, 2016). Biochemistry and molecular biology and atomic, molecular and chemical physics were the fastest-growing subcategories, with CAGRs of 12.7 percent and 13.4 percent, respectively.

Arunan et al. conducted a study. According to Arunan et al.1 the mid-1990s were a turning point for Indian scientific research, and by 2013 the nation accounted for 3.5 percent of global research production and was ranked fifth in the world for chemistry publications in terms of the number of papers published. They looked into why India did so poorly and came up with a number of solutions. Approximately one-half of India's chemical research output is produced by just a handful of high-performing universities, according to these researchers1. Since 2007, they've provided data on the percentage of papers with authors from Indian

institutions published in several prominent chemistry journals: *Angew Chem Int Ed* (1.1 percent), *Phys Chem Chem Phys* (2.2 percent), *Org Lett* (2.5 percent), *Langmuir* (2.9 percent), *J. Phys. Chem C* (3.8 percent), and *Dalton Trans* (5.4 percent) (7.0 percent). They were of the opinion that, although these numbers seem encouraging, they fall short of the expectations they had for India's progress in chemical research throughout the 1970s and early 1980s. Notably absent from the discussion is *JACS*. Neither that journal nor other interdisciplinary chemistry publications like *Angew. Chem. Int. Ed* have published many articles by Indian scholars in the last several years. According to Arunan et al., in the four years between 2012 and 2015, India's share in the same collection of journals (WoS–SCIE included publications authored in partnership with authors working in abroad labs) grew significantly over the statistics reported by Arunan et al. *Inorganic Chemistry* (6,162; 413; 6.7 percent), *J. Phys. Chem. A* (5,526; 258; 4.7 percent), *Inorganic Chemistry* (6,162; 413; 6.7 percent), *J. Org. Chem.* (5,490; 447; 8.14 percent), *Dalton Trans.* (7914, 844, 10.66 %), *J. Phys. Chem. B* (6,588; 5 percent), *Phys. Chem. C* (10,541; 624; 5.92 percent), *Org. Lett.* (6,535; 371; 5.68 percent), *Langmuir* (7,528; 277; 3.68 percent) (2,949; 334; 11.32 percent). It's no surprise that India's participation in several of these reputable journals is higher than India's overall chemistry share of 6.8 percent. According to chemists, greater spending, the creation of Indian Institutes of Science Education and Research and new Indian Institutes of Technology, and a rise in Ph.D. student enrolment have all contributed to the country's better performance in the field. Several scientists believe that the Science and Engineering Research Council's transformation into the Science and Engineering Research Board has had an impact. However, there has been no assessment thus yet.

Among the world's major scientific publications, Indian researchers have made significant contributions. *RSC Advances* (2,174 articles), *J. Alloys Compounds* (306), and *Tetrahedron Lett.* were the journals most often cited by Indian chemists in 2015, according to WoS–SCIE.

(2), *Dalton Trans.* (2), *Phys. Chem. Chem. Phys.* (2), *New J. Chem.* (2), *J. Mol. Struct.* (2), *Eur J. Med*

Chem (2), *Chem. Commun.* (2), *J. Indian Chem Soc* (2), *Dalton Trans* (168). We looked at the highly recognised multidisciplinary chemistry journals for our assessment of India's contribution to chemistry literature. In addition, we looked at publications published in high-quality journals from India that covered a wide range of chemical subfields (Box 1). Despite the fact that *JACS* and *Ange wandte Chemie* were first published in 1879 and 1887, respectively, no papers from India were published in any of these journals for a long time. A work by Dhar¹⁰, also from India, was published in *JACS* 24 years after Ray⁹ had planted the roots of modern chemistry in India with his first publication from Indian soil. Ray and his colleagues produced 70 publications over this time span. Until the end of 2015, 696 articles from India have been published in *JACS*. For articles from India in *JACS*, the journal site does not provide an option to search by country. Full-text keyword search was performed using "India" as the search phrase, and the results were examined one by one to locate publications with the byline "India" We conducted this in order to locate all of the articles published before to 1972 that had an Indian author, and we identified 147 of them. Searching WoS–SCIE led us to more recent studies.

Box 1. Quality journals across all branches of chemistry considered to assess the rise in contributions from India

Accounts of Chemical Research
Angewandte Chemie International Edition
Biochemistry
Chemical Communications
Chemical Science
Crystal Growth & Design
Dalton Transactions
Electrochemical Communications
Electrochimica Acta
Inorganic Chemistry
Journal of Biological Chemistry
Journal of Catalysis
Journal of Chemical Physics
Journal of Organic Chemistry
Journal of Physical Chemistry A
Journal of Physical Chemistry B
Journal of Physical Chemistry Letters
Journal of the American Chemical Society
Journal of the American Society of Mass Spectrometry
Journal of the Electrochemical Society
Langmuir
Macromolecules
Nature
Nature Chemistry
Organic Letters
Polymer
Proceedings of the National Academy of Sciences of the United States of America
Science

Srikantan and Rengachari¹¹ of Andhra University were the only Indian authors to publish in *Angew. Chem.* before it began publishing in English in 1937. Palit¹² was the second Indian piece to appear in this journal after the International Edition began publishing in 1962, as was the situation for the majority of nations. Only in 1972 did the second Indian paper¹³ emerge in *Angew. Chem. Int. Ed.*, and since then, 425 publications have been published.

American Chemical Society Journal

Over the course of 25 years, scientists from a variety of Asian nations published a significant number of articles in top interdisciplinary chemistry journals. Table 1 shows the number of publications published by scientists from these countries. More articles from China and Singapore are being published in JACS than in any other country. Indian academics produced 495 publications in JACS throughout this time span from 82 universities (Table 1). There are a number of

Indian institutions from which papers in JACS have frequently come over the past 25 years (as seen from their bylines), including the Indian Institute of Science (IISc), the National Institute of Interdisciplinary Science and Technology (NIIST, 46), National Chemical Laboratory (NCL, 44), the Indian Institute of Technology, Kanpur (IITK, 43), and the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR, 32). (IITM, 13). Many articles now include authors from more than one university since cooperation has become more commonplace. JACS has published several works by Indian scientists, including E. D. Jemmis (IISc, 25 papers), P. Balaram (IISc, 21 papers), G. R. Desiraju (IISc, 16 papers), A. Ajaya ghosh (14). If we just look at writers who have written in the last few years, we'll find some new Indian voices who were active between 2011 and 2015. There were 144 publications with 691 authors listed, many of them were from other countries. Rahul Banerjee (NCL, 6) and Abhishek Dey (IACS, 5), Partha Sarathy Mukherjee (IISc, 4) and Sharath Kandambeth (IISc, 4) are among the rising Indian researchers (4). The connections of an author's institutions may not be the ones from where he or she has authored all of his or her publications. Before moving to IISc, both Jemmis and Desiraju worked at the University of Hyderabad, and UoH was the source of 18 of Jemmis' 25 JACS publications and 12 of Desiraju's 16. The true author and affiliation of a work are not always obvious; for example, S. Roy might be either Subendhu Roy (IISc, two papers published in JACS between 2011 and 2015) or Sudipta Roy (IISER, Kolkata, three papers in JACS). We're now at the starting point.

Table 1. Number of papers published by selected Asian countries in three general chemistry journals during 1991-2015 (as seen from Science Citation Index Expanded)

Country	1991-2000		2001-2010		2011-2015		Total	
	No. of papers	Sum of citations	No. of papers	Sum of citations	No. of papers	Sum of citations	No. of papers	Sum of citations
JACS								
Japan	2,111	181,678	3,820	293,250	1,589	44,657	7,440	519,585
China	85	8,549	1,513	169,758	1,857	83,257	3,455	261,564
South Korea	135	13,640	649	65,910	485	19,198	1,269	98,748
Australia	269	16,726	363	26,545	225	7,558	857	50,821
India	138	9,029	213	14,948	144	4,206	495	28,183
Taiwan	97	7,158	263	18,622	126	3,928	486	29,708
Singapore	7	739	184	26,593	226	9,496	419	32,805
Total	2,852	239,579	7,065	609,626	4,576	172,202	14,433	1,023,134
World	22,229	1,697,637	38,981	2,364,429	14,428	442,825	67,638	4,504,891
Angew. Chem.								
Japan	479	37,814	1,771	129,574	1,292	28,646	3,542	195,356
China	48	5,246	1,049	113,757	2,210	75,134	3,307	193,556
South Korea	33	3,221	494	36,841	495	11,246	942	51,124
Australia	53	7,765	177	16,809	240	6,751	470	30,391
India	39	4,784	155	16,501	202	4,791	396	25,991
Singapore	9	735	109	16,298	249	9,819	387	20,000
Taiwan	19	867	109	7,251	135	3,529	263	11,612
Total	680	60,432	3,774	338,251	4,753	139,096	9,287	528,818
World	6,515	488,126	14,848	1,198,169	12,284	316,858	35,567	1,954,945
Chem. Commun.								
China	331	12,657	2,219	118,910	6,084	117,218	8,634	248,905
Japan	2,161	82,712	2,313	82,088	1,850	25,857	6,324	168,918
South Korea	137	5,895	662	33,236	946	15,517	1,745	54,688
India	377	11,653	482	17,678	794	11,347	1,653	40,678
Australia	352	10,931	361	16,416	470	7,809	1,183	35,156
Taiwan	164	4,210	252	9,653	312	5,151	708	18,994
Singapore	78	1,987	183	8,316	410	8,948	671	19,243
Total	5,560	109,645	6,432	206,397	10,866	191,114	20,858	586,542
World	11,887	376,785	15,851	652,149	17,520	276,443	45,238	1,317,377

Citations per paper in JACS average 66.6 worldwide, with India coming in at 56.93 and China at 75.49%. Globally, citations per manuscript in Angew. Chem. are 56.4, with India (65.63), and China (58.52). C.H.C, average number of citations per paper: 28.9 for the whole globe, 24.9 for Indian researchers, and 28.82 for Chinese researchers.

ORCID (www.orcid.org) should be used universally by scientists and scholars¹⁴. A whopping 44% of the Indian articles published in JACS were co-authored by academics from other countries. There were a large number of foreign participants from the United States, Germany, Japan, Britain, and France. Researchers at Naval Research Laboratory, the Department of Defense, the United States Navy, and the French National Center for Scientific Research (CNRS) and the US Department of Energy have worked together on the majority of articles published by the institution (9). The University of Gottingen,

the University of California System, and the Universities of Oxford, Osaka, and Stuttgart have all provided eight each (six each). In 1992, fewer than 20% of publications were co-authored by authors from outside of the United States (ref. 15). We should have predicted the 44 percent share of Indian publications during the 25-year period. More than half of the research from China, Australia, Singapore, South Korea, Taiwan, and Japan was done in conjunction with researchers in other Asian nations, according to the journal JACS, which publishes research from the journal's other Asian members (20.7 percent). In JACS, papers from India have gotten an average of 57 citations per paper, whereas the global average is 66.6 and China's average is 75.5. 39,477 of the 67,638 articles published by JACS in the last 25 years came from the United States, with 5156 (7.5%) from Germany, 3465 (5.1%) from China, and 495 (0.7%) from India making up the rest. More than 4.5 million times, four of these articles have been quoted over 5000 times, seven of these papers have been cited over 4500 times, and 71 have been cited over 1000 times (till 12 May 2016). Int'l Edition of Angewandte Chemie There is data in Table 1 showing the number of publications from various Asian nations that have been published in the Angew. It demonstrates that Asia's contribution to the journal is fast expanding, with China and Singapore contributing the majority of the growth. Wiley-VCH, the publisher of Angew. Chem. Int. Ed., was inspired by the rapid growth of chemical research in the region and partnered with chemical societies in Asia (including the Chemical Research Society of India) to start two new journals, Chemistry – An Asian Journal and Asian Journal of Organic Chemistry¹⁶. Table 1 lists the 84 institutions where the 396 Indian-authored publications in Angew. Chem. Int. Ed. between 1991 and 2015 (Table 1) were published. At the top of the list of Indian contributions are Ajayaghosh (NIIST, 18), G. R. Desiraju (IISc), C. NARRA, S. J. George, and C. N. R. Rao (JNCASR) (JNCASR, 11). As of 2015, there were 202 papers with 729 authors' names in the byline (2011–2015), with majority of them from outside the United States. There are a number of Indian researchers who have published frequently over the past five years, including De babrata Maiti (IITB 6), Kana M. Sureshan (NIIST 5), Ashwini K. Phukan (University of Tezpur 4), Suhrit Ghosh,

Narayan Pradhan, Talappil Pradeep, Govindasamy Mugesh, and Venkataramanarao G. Anand (IISc, 4), as well as other researchers (IISER Pune, 4). About 38% of the publications were co-authored by writers from other countries.

Participants from Germany, the United States, the United Kingdom (UK), Japan, and France made up the majority of the international team. Many studies have been authored in collaboration with researchers from many institutions, including the Universities of Gottingen (11), France's CNRS (10) and the University of Stuttgart (7), as well as the Universities of Wurzburg, Duisburg Essen, and the Max Planck Society (6 each) (5). Overseas cooperation is a significant part of the research published in Angew. Chem. International Edition from various Asian nations, including Australia (58.7%), Singapore (46.3%), South Korea (40.3%), China (34.3%), Taiwan (33.1%), and Japan (33.1%) (18.7 percent). During this period, Angew. Chem. Int. Ed. published 33,567 articles; 9,395 (28 percent) were from Germany, 8,489 (25.3 percent) from the United States, 3,307 (9.9 percent) from China, and 396 (1.2 percent) from India. The global average citation rate was 57.6 and China's average citation rate was 58.5. At least 1,161 thousand times, with 4 citations over 5000, 9 exceeding 3000, 89 exceeding 1000 and 4687 above 100 as of May 12, 2016, these works were referenced collectively in 1,161 million other citations.

Chemical exchanges

The number of articles published in Chem. Commun. has increased little in India, but China, South Korea, and Singapore have seen a huge rise in their contributions (Table 1). The number of publications published by Indian chemists from 178 universities has increased from 15 in 1985 to 197 in 2015. Since 2008, there has been a dramatic increase in publications from India in JACS and Angew. Chem (Figure 1). What makes you think this is so? Many users are pleased with the timely and high-quality communications; the messages are brief, concise, and to the point; they are often updated. As a long-time journal user puts it, 'it enables me express precisely what I want to say, particularly when one is working on a highly interpretative issue and wants to sell a

concept rather than facts'. They might be invasive in that the reviewers could be too careful to the point of interfering with an author's proposal in the other prominent publications. Because of the rapid increase in the quantity of articles being published, some older chemists believe that a few may not meet the criteria that were in place only a few years ago. The 1,633 Indian studies were referenced 25 times on average, compared to the 29 citations per paper for China and the whole globe combined. At least one author with an overseas address appears in the byline of around 350 Indian articles (21%). In addition to the United States (76), Germany (48), the United Kingdom (46), Japan (34) and France (34), these writers collaborated (30). NCL (204), IISc (202), IACS (139), UoH (127), IICT (109) and IITB (109) comprise more than half of all contributions from India in this journal (76). A state university, Guru Nanak Dev University, has contributed 19 publications to this journal, which is not included in the list of leading chemical research institutions. CNRS, France (20), the National Institute of Materials Science, Japan (10), the University of California System (8), the Japan Science and Technology Agency (8), and Howard University are among the institutions working with us on this project from outside (8). According to Table 2, Indian involvement in JACS, Angew. Chem. and Chem. Commun has been shown in all three journals. Only 35 Indian academic institutions have published work in all three venues. A total of only nine academic institutions have published at least 100 articles across all three journals during the last quarter century. IISc

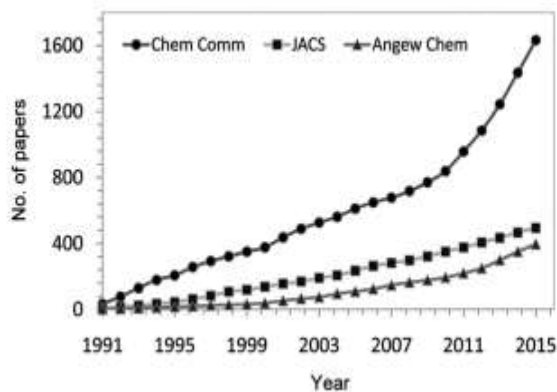


Figure 1. Number of papers published from India in three major general chemistry journals

Table 2. Distribution of papers published in all three general chemistry journals during 1991–2015 by institution

Institution	JHCS		Angew. Chem.		Chem. Commun.		Total
	No. of papers	Sum of citations	No. of papers	Sum of citations	No. of papers	Sum of citations	
IISc, Bengaluru	107	5,779	64	4,603	202	6,280	373
CSIR-NCL, Pune	44	2,398	37	1,660	204	4,615	285
University of Hyderabad, Hyderabad	39	3,180	28	5,283	127	5,679	194
IACS, Kolkata	25	819	28	793	139	3,548	192
CSIR-IIT, Hyderabad	32	2,676	25	1,557	109	2,510	166
IIT Kanpur	43	2,571	25	1,433	73	1,507	141
JNCASR, Bengaluru	31	1,930	31	3,349	66	3,597	128
IIT Bombay, Mumbai	24	1,234	24	1,855	76	1,350	124
CSIR-NIIST, Thiruvananthapuram	46	3,997	24	2,687	44	992	114
IIT Madras, Chennai	13	382	12	471	56	918	81
IIT Kharagpur	11	730	6	95	57	1,887	74
IISER, Pune	5	98	9	407	53	683	67
CSIR-CSMCR, Bhubanagar	7	545	5	236	40	986	52
Bhabha Atomic Research Centre, Mumbai	17	1,016	8	765	23	421	48
IISER, Kolkata	7	52	5	196	33	543	45
Guru Nanak Dev University, Amritsar	2	51	1	11	38	736	41
IIT Guwahati	3	51	9	425	28	688	40
IISER, Thiruvananthapuram	12	216	11	169	9	89	32
University of Delhi, Delhi	2	255	3	244	23	564	28
CSIR-CDR, Lucknow	5	247	8	162	13	214	26
Jadavpur University, Kolkata	3	348	4	228	19	537	26
IISER, Bhopal	1	12	3	50	17	295	21
TIFR, Mumbai	5	103	5	157	11	80	21
University of Pune, Pune	7	214	2	47	12	157	21
Punjab University, Chandigarh	4	151	2	285	10	83	16
University of Calcutta, Kolkata	2	41	2	10	12	133	16
CSIR-IICB, Kolkata	1	28	2	14	10	75	13
NIPER, Mohali	2	137	1	27	10	365	13
CSIR-CCMB, Hyderabad	5	215	1	37	5	124	11
CSIR-IGIB, New Delhi	3	76	3	107	4	28	10
Tezpur University, Tezpur	1	28	7	77	2	35	10
CSIR-CLRI, Chennai	4	123	4	117	1	37	9
CSIR-NPL, New Delhi	4	457	1	4	2	31	7
BB Ambedkar University, Lucknow	1	14	2	40	3	80	6
S.N. Bose National Centre for Basic Sciences, Kolkata	1	16	3	110	1	5	5

UoH (194); IICT (166), IITK (141), JNCASR (128); NIIST (124) and NCL (373). (114). The connections shown below are taken directly from the author's byline. The year 1991 wasn't the start of every institution's existence. IISERs, Tezpur University, and B. R. Ambedkar University, for example, all came into existence after the year 1991. According to Arunan et al.1, only a small number of universities publish high-quality publications, and even then, only a few papers1. It's encouraging to see several lesser-known institutions on this list.

Research in the field of chemistry

Acc. Chem. Res. published 3,497 publications between 1991 and 2015 (CPP 127.15), with India contributing 72 papers (CPP 157.39) and China contributing 299 papers (CPP 157.39). (CPP 107.14). Among the 72 publications from India, 25 have

earned more than 100 citations and 3 of them more than 1000. The institutes and researchers who are responsible for such high average citations include UoH, JNCASR, NIIST and IISc, and Desiraju, Rao, Nair and Ajayaghosh. We also looked at publications from India in two journals which begun publishing in the preceding decade.

Chemistry in Nature

As of the end of 2015, Nature Chem. has published 1621 articles at a CPP of 45.26 since its inception in 2009. There are 57 papers in all, with 11 from India (CPP 23.45) and 57 from China (CPP 66.82).

Chemical Science

It wasn't until 2014 that more than ten manuscripts from India were published in this magazine, which began publishing in 2010. Scientists in India published 28 publications (CPP 13.89) by the end of 2015, compared to 591 papers published by Chinese scientists during the same period (CPP 22.69). NCL, JNCASR, NIIST, and IISER Kolkata are a some of the institutions that contributed to this body of work. A wide range of periodicals are published in these fields. Chemistry publications are not the only source of information for chemists.

Multidisciplinary journals

in addition to distributing it. Nature, Science, and PNAS stand out. Between 2010 and 2015, a WoS–SCIE search turned up 80 entries detailing India's contribution to nature. There are just two unique research contributions in chemistry if we exclude general news pieces, policy-related observations, book reviews, and so forth. Six original chemistry research publications – four articles, one editorial, and one review – were found in a search of Science throughout the six years from 2010–2015. PNAS' chemistry division has 12 publications with Indian authors, according to a search. In these prestigious publications, Indian chemists are significantly underrepresented.

Papers with a lot of citations

Many chemists want to have their work published in peer-reviewed journals with a high impact factor. 1.29 percent of the world's more than 1.18 million chemical publications published between 2009 and 2014 have been referenced at least 100 times, according to a search of WoS–SCIE. In China, 1.65 percent of the more than 240,000 publications analysed met this criterion. By the end of September 2016, little under 0.5 percent of the 68,300 articles published in India had received 100 or more citations. J. Phys. Chem. C (15 articles from India between 2009 and 2014) and Colloids and Surfaces B (15 papers) are just a few of the 103 publications that have published these 388 works, which have appeared in a variety of fields (12 papers). Young Indian chemists who consistently and often publish in high-quality specialty journals may be able to emerge as leaders in their field.

International

collaboration An rise in India's percentage of foreign co-authored articles from 15.4% in 2005 to 20.7 percent in 2014, according to data from journals classed under the WoS–SCIE categories "Chemistry" and "Electro chemistry." In 2005, India partnered with 56 nations; in 2008, 65; in 2011; and in 2014, 75 countries; with 95 countries. Since 1997, there have been 979 (one percent) citations of at least 100 citations in Indian chemistry publications published throughout this period (as on 2 August 2016). Two hundred and seventy-six of these were authored by Indian scientists working with at least one coauthor from one of forty other nations. International co-authorship was therefore represented by somewhat more than 28% of the publications with high citation counts. If you look at the citation patterns of works that have been developed via international cooperation, you will see that they are more often referenced.

Discussion

Nature Index aims to eliminate the myth that Indian scientists aren't generating anything of value by presenting a favourable picture of science in India today. Indian science and technology minister Harsh Vardhan praised the country's advancements in chemistry and nanoscience¹⁷ while discussing the

country's research development. Only 18 chemistry journals are tracked by the Nature Index. Indian researchers utilised 468 of the 600 chemistry-related journals tracked by WoS–SCIE in 2014, compared to SCImago, powered by Scopus, which monitors 857 journals. After China and the United States, SCImago and Elsevier both use Scopus data in their reports to DST, whereas Thomson Reuters relies on WoS–SCIE data for their report to DST. These reports put India third in chemical research, contrasted to eighth on Nature Index. If only publications in high-quality journals are taken into account, India's ranking diminishes, leading to the question "are we publishing poor stuff?" when the number of journals analysed climbs by an order of magnitude. Does excellence in science follow from a greater scope for the scientific enterprise? "Quality is a product of quantity, and without quantity there can be no quality," Chairman Mao famously said in one of his many speeches. If you have a lot of people, "quantum fluctuation" will enable a few to break out of the system and be noticed by the rest of us. Many researchers in India have underlined the need of expanding the base^{19,20}, which is more difficult than it seems. According to Vale and Dell²¹, "India's biggest challenge will be in teaching, recruiting, and supporting its next generation of scientists," yet "the smartest students in India simply are not coming to graduate school.". There is a strong correlation between a substantial rise in the number of researchers and the quantity of high-quality research articles, thus we estimated the CAGR of papers published in high-quality journals from India over the course of six years. Our study shows that the number of Indian articles published in the chosen journals increased from 1064 to 1742 between 2010 and 2015. (CAGR of 10.4 percent). The total number of publications published in chemistry increased by 7.1% during the same time period. Despite the fact that Indian chemical research is doing better than

Papers from India are less likely to be published in high-quality journals in recent years, as indicated by a rise in the total number of articles published and the number of papers published in high-quality journals²². The DST-commissioned Thomson Reuters report⁸ shows that India's share of highly cited papers in chemistry was lower than the global

average from 2005 to 2014 and lower than that of the majority of advanced and emerging economies. Moreover, an increase in higher-quality publications was not enough to propel India into the top four countries with the largest share of 10% of the most-cited publications in chemistry from 2003–2012.9 (ref. 23). Among the most frequently referenced publications in chemistry are those from the US, China, Germany, and Japan, respectively. The number of highly referenced articles in China has risen tremendously along with the increase in the number of published research papers²⁴. With a small advantage over India starting in 2000, China's lead grew by an order of magnitude by 2014, as seen in Figure 2. For the first time in a decade, China has overtaken the United States as the most highly-cited one percent of publications. To put it another way, China has the highest proportion of 10 percent most-cited articles in 11 different categories, according to the OECD's STI Scoreboard for 2015²³. Chemical engineering is the only area in which India has a presence. There are 35 Indian institutions with papers in JACS, Angew. Chem., and Chemical Communications over the 25-year period (1991–2015), 21 of which are higher education institutions. These include four state universities (Jadpur, Pune, Calcutta and Panjab), 10 CSIR laboratories, 2 DST laboratories, and two DAE facilities. 44 percent of JACS publications and 38 percent of Angew papers were co-authored by researchers from outside the United States. Chem.

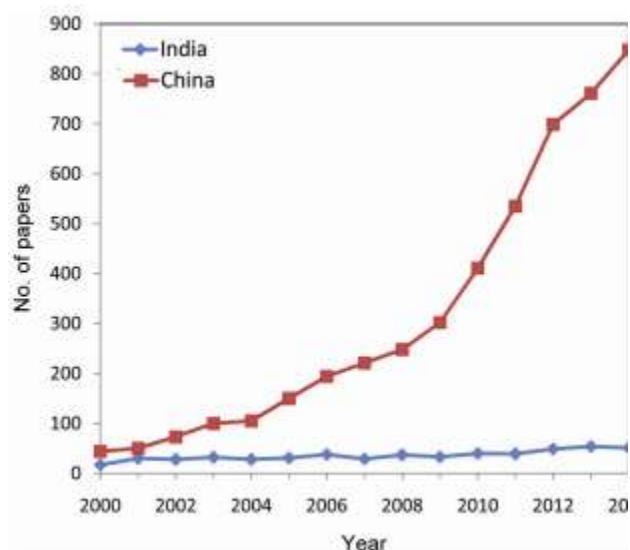


Figure 2 shows the percentage of highly referenced chemistry publications from India and China in the top 1% of the Web of Science's most highly cited papers. Nine institutes, including IISc and NCL, make up the bulk of these works. Some anxiety is warranted by the fact that there are so few higher education institutions, and even fewer public colleges and universities. Indian scholars have not published many articles in JACS for the same reasons they haven't published many papers in Nature and Science. JACS is not only interdisciplinary, but it also expects publications to cross borders across disciplines. In most academic departments, the puritanical tradition of keeping physical, organic, and inorganic chemistry distinct has not been broken, nor has it been expanded to include burgeoning fields such as chemical biology and materials science^{25,26}. The fact is that Indian labs are unable to keep up with the rapid advancements in Western chemistry research due to a lack of agility. What's more, India has failed to capitalise on its traditional strengths, such as natural products chemistry and inorganic chemistry,²⁵ Concerningly, Thomson Reuter's list of the top 100 chemists in the world during 2000–2010 did not include a single Indian (working at an Indian university), whereas three South Koreans and one each from Brazil and South Africa²⁷ made the cut. However, there are some promising people working at less well-known institutions who may benefit from a helping hand. We must expand the number of researchers and students at all levels and enhance the quality of instruction. India's science would profit much if we employ overseas academics, according to Ganesh²⁸ and Arunan et al¹. For some time now, the government has set up a number of fellowships with the goal of recapturing scientists who have fled the nation and "reversing the brain drain." This is despite the fact that comparable initiatives in China have proved successful (K. S. Jayaraman, pers. commun.). Graduates from well-known colleges and universities are increasingly opting to pursue further education in other countries. In 2008, Desiraju²⁹ estimated that more than 60 percent of IISER graduates would leave the nation to pursue doctoral courses. Some of India's most prestigious universities, on the other hand, are struggling to secure research and teaching positions for their Ph.D. students, says a concerned professor at one of the country's top schools..

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