Assessment of Chemical Engineering research output using Scientometric Indicators: A comparative study of India and South Korea during 2011-2015

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Abstract

This study adopts a scientometric approach to quantitatively assess current research trends in Indian and South Korean research performance in chemical engineering,it analyses scientific papers published during 2011 to 2015.Its focuses on countries global publication share, growth rate,citation quality, international collaborative publications share, using 5 years data from the web of science database. The study suggests the need to increase the pace of Indian scientific research and also improve itsquality compared with other developed and developing countries.

Keywords

Scientometrics, Chemical Engineering, Web of Science, Relative Growth Rate and Doubling Time.

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INTRODUCTION

Chemical engineering is the study and practice of transforming substances at large scales for the tangible improvement of the human condition. Such transformations are executed to produce other useful substances or energy, and lie at the heart of vast segments of the chemical, petroleum, pharmaceutical and electronic industries.Chemical engineering differs from chemistry mainly in the focus on large scales. The definition of "large" is a bit arbitrary, of course, but is set mainly by the scale of useful commercial production. Typically, this scale ranges from barrels to tank cars, whereas the chemist tends to be concerned about sizes ranging from vials to beakers.Chemical engineering has been practiced in rudimentary form since at least the great Roman road-building projects that began about 300 B.C. The cement used for pavement was based on the contemporary Hellenistic formula employing lime, a calcined (heated) form of calcium carbonate. However, academic programs in the U.S. formally called "chemical engineering" — or something similar — originated only near the start of the 20th Century.

Recognizing the importance of science and technology in economic and industrial development, the Government of India reemphasized the need to view them together in its “Science and Technology Policy –2003” following the “Science Policy Resolution of 1958” and the “Technology Policy Resolution of 1983”.The policy has recognized the central role of the S&T system in the economic and industrial development of the country, in raising the quality of life of its people, in creating national wealth, in utilizing natural resources, in protecting environment and in ensuring national security. Over the years, the country has invested heavily in developing infrastructure for R&D in different fields of S&T, including frontier areas, such as atomic energy, space sciences, electronics and telecommunications and more recently in biotechnology and information technology (Gupta & Gupta, 2011).Today, there is an increasing interest in using scientometric information for assessing or monitoring research activities. The discipline devoted to the quantitative study and evaluation of the scientific literature is called scientometric or bibliometrics. Bibliometrics has been applied to the evaluation of scientific disciplines, national scientific production, and bibliographic databases, and it provides valuable tools to describe the scientific activity in the past and to orient future research

(Schoepflin&Glänzel, 2001). The aim of scientometrics is to provide quantitative characterizations of scientific activity. Because of the particular importance of publication in scientific communities, it largely overlaps with bibliometrics, which is quantitative analysis of media in any written form. Scientometrics indicators can be classified to the number of scientometrics sets they represent and the application of reference standards (Vinkler, 1988). Scientometrics indicators referring to the measure of a single Scientometrics aspect of Scientometrics system represented by a single Scientometrics set with a single hierarchical level are termed gross indicators. Those indicators which consist of several gross or complex indicators, preferably with weighting factors and each representing a special aspect of a Scientometrics system are composite or compound indexes.

NEED FOR THE STUDY

Research is a prolonged process, aiming at discovering the truth and is a means for acquiring knowledge about any natural or human phenomena. Research in all fields is growing at a faster rate and particularly the field like library and information science is advancing. This is due to the change in the trends of research followed but the change is gradual and not all of a sudden. In the process of identifying the research trends in a field it is essential to analyze the various patterns that evident in the literature of the field.The analysis of the research output of any discipline will provide a great effects on the subject and its research. Therefore an attempt is made in the present study to investigate the research output of India and South Korea during the year 2011 to 2015 using scientometric indicators. This study certainly helps to ascertain the trends of research in developing countries in the field of chemical engineering.

SCOPE OF THE STUDY

The present study includes the chemical engineering research output of India and South Korea. However the data covered in the study includes only the data retrieved from the web of science during the period 2011-2015.

OBJECTIVES OF THE STUDY

The purpose of this study is to explore the main scientific output in order to measure the extent of scientific research in chemical engineering. The specific objectives of this study are as follows:

- To identify the year wise distribution of research articles of India and South Korea in the field;
- To find out the relative growth rate and doubling time ofchemical engineering during the five year (2011 to 2015);
- To identify the distribution of articles in different document formats;
- To know the highly productive research institutions in the field;
- To know the subject-wise (sub fields) distribution of the research publications;
- To know the international collaborations.

METHODOLOGY

The data for this study were collected by searching the Science Citation Index- Expanded (SCI-E) of Web of Science Database which is a very comprehensive and exhaustive database enveloping almost all subjects of Science and Technology, via the subject of concerned countries for the period from 2011 to 2015. The Web of Science Affiliation search was used to gather the raw data required to study the scientific productivity of each university (for example, SU=Chemistry, Refined by: Web of Science Categories: (engineering chemical) ANDCU=India,Timespan: 2011-2015. Indexes: SCI-Expanded) search aid is used to retrieve the most comprehensive and accurate results.

Relative Growth Rate (RGR) The Relative Growth Rate (RGR) is the increase in number of articles per unit of time. This definition is derived from the definition of relative growth rates in the study of growth analysis of individual plants and effectively applied in the field of Botany (Hunt (1978and 1982); Poorter and Garnier, 1996; Hoffmann and Poorter, 2002). There exists a direct equivalence between Relative Growth Rate and Doubling Time (Bradford, 1934). If the number of articles of a subject get doubled during a given period then the difference between the logarithms of numbers at the beginning and end of the period must be logarithms of number 2. If natural logarithm is used this difference has a value of 0.693. The mean RGR of articles over the specific period of interval is represented as

$$R = W_2 - W_1/T_2 - T_1$$

Where

R = mean relative growth rate over the specific period of intervals;

W_1 = Log W_1 (natural log of initial number of publication);

W_2 = Log W_2 (natural log of final number of publication);

$T_2 - T_1$ = the unit difference between the initial and final time

This formula even holds good for the calculation of RGR Subject wise

Doubling Time (D_t) Doubling Time (Dt): The doubling time is the given period required for quantity to double in size or value. This can be calculated by using the formula.

Doubling time $D_t = 0.693/R$

Here, Dt (P) = average doubling time of publications

RESULTS AND DISCUSSION

Growth of Publications of India and South Korea in Chemical Engineering

Table 1 depicts the chemical engineering research output of India and South Korea, India has produced 2,324publications, and received 11,299 citations during the period 2011 to 2015, average citations per publication is 4.86. South Korea has produced more than India i.e. 2,607publications, and received 20,509 citations during the period, average citations per publication is 7.87. Both countries publications are gradually increased year by year. In terms of publications, citations received, average citations per paper and h-index South Korea achieved more than India. In terms of growth rate publications, the largest (26.07) was achieved by South Korea than India (23.24) during 2011-2015. In terms of citation impact per paper comparatively higher impact (7.87) was registered by South Korea than India (4.87) during the study period.

Table 1: Growth of Publications and Citations India VS South Korea

	India					South Korea				
Years	**TP**	**%**	**TC**	**ACP**	**H-Index**	**TP**	**%**	**TC**	**ACP**	**H-Index**
2011	387	16.65	3353	8.66	26	506	19.41	7123	14.08	36
2012	419	18.03	2809	6.7	22	563	21.60	6233	11.07	37
2013	494	21.26	2826	5.72	19	456	17.49	3893	8.54	30
2014	485	20.87	1933	3.99	17	499	19.14	2551	5.11	20
2015	539	23.19	378	0.7	7	583	22.36	709	1.22	10
	2324	**100**				**2607**	**100**			

Note: TP=Total publications, TC= Total Citations, ACP=Average Citations per Paper

Relative Growth Rate (RGR) and Doubling Time (Dt.)

The year-wise total output of India and South Korea has been shown in Table 2 (five years) along with the growth rate and doubling time. The table shows that the relative growth rate of Indian output decreases gradually from 0.73 to 0.26 in five year's period (2011-2015). The doubling time (Dt) correspondingly increases from 0.94 to 2.63 in this period. With regard to South Korea the relative growth rate decreases gradually from 0.75 to 0.25, the doubling time (Dt) correspondingly increases from 0.93 to 2.74 during 2011 to 2015. But the year-wise analysis of growth rate and doubling time for India and South Korea indicates a different finding. The average growth rate of India and South Korea is 26.07 and 23.24.

Table 2: Relative Growth Rate (RGR) and Doubling Time (Dt.)

	India				South Korea			
Year	**TP**	**Cumulative Publications**	**RGR**	**Dt.**	**TP**	**Cumulative Publications**	**RGR**	**Dt.**
2011	387	387			506	506		
2012	419	806	0.73	0.94	563	1069	0.75	0.93
2013	494	1300	0.48	1.45	456	1525	0.36	1.95
2014	485	1785	0.32	2.19	499	2024	0.28	2.45
2015	539	2324	0.26	2.63	583	2607	0.25	2.74

Source wise Distribution of Research output of India and South Korea in the field of Chemical Engineering

The sources of Chemical Engineering research include articles published in the journals, reviews, conference and seminars proceedings, editorial materials, corrections and book chapters. This study has observed a total of 4931 publications in chemical engineering from India and South Korea over a period of six years from 2011 to 2015. Out of them, articles appeared in the journals have shown a predominant contribution (94.77%) from both countries. The comparative analysis indicates that the total output of articles in the years India (96.60) achieved the highest than the South Korea (93.13) was 21 whereas in the succeeding years contribution has increased considerably. However the whole study period 4673publications are appeared in journals articles from India and South Korea. The chemical engineering research output appeared with reviews rank as second in order (2.68%) in an overall output. The output from the conference and seminars proceedings publications records a third place in an overall chemical engineering literature output.

Table 3: Publication patterns of India and South Korea in the field of Chemical Engineering

INDIA				SOUTH KOREA		
Sl. No.	**Document Types**	**Publications**	**%**	**Document Types**	**Publications**	**%**
1	Article	2245	96.60	Article	2428	93.13
2	Review	53	2.28	Review	80	3.07
3	Proceedings Paper	9	0.39	Proceedings Paper	80	3.07
4	Editorial Material	8	0.34	Correction	11	0.42
5	Correction	5	0.22	Editorial Material	6	0.23
6	Book Chapter	4	0.17	Book Chapter	2	0.08
	Total	**2324**		**Total**	**2607**	

National collaboration links of India and South Korea

The Table 3 displays results of top selected institutions and comparison between India and South Korea based on their highest publications according to the web of science database. Indian Institute of Technology (IIT), Delhi contributed the highest publications to the field of chemical engineering, i.e. 183 publications with 8.61%, followed by Institute Chemical Technology (ICT), Mumbai with 99 publications (4.26%), Council of Scientific Industrial Research (CSIR), Delhi, with 98 publications (4.22%), Bhabha Atomic Research Centre (BARC), Mumbai with 98 publications (4.22%),National Institute of Technology, Goawith 82publications (3.53%), Aligarh Muslim University, Aligarh, with 69 publications (2.97%), and Institute Chemical Technology (ICT), Hyderabad with 54publications (2.32%). With regard to South Korea the Seoul National University, Seoul, has published the highest publications i.e. 213 (8.17%), followed by Korea University, Seoul with 152 publications (5.83%), Korea Advanced Institute Science Technology, Daejeon, with 138 publications 5.29%, Korea Institute of Science and Technology, Seoul with 128 publications (4.91%), Hanyang University, Seoul with 126 publications4.83%, Inha University, Incheon with 125 publications (4.80%), Chonnam National University, Yeosuwith 111 publications (4.26%) and Kyungpook National University, South Korea with 109 publications (4.18%).

Table 4: National collaboration links of India and South Korea

INDIA				SOUTH KOREA		
Sl. No.	**ResearchInstitution**	**TP**	**%**	**ResearchInstitution**	**TP**	**%**
1	Indian Institute of Technology (IIT), Delhi	183	7.87	Seoul National University, Seoul,	213	8.17
2	Institute Chemical Technology (ICT),Mumbai	99	4.26	Korea University, Seoul	152	5.83

3	Council of Scientific and Industrial Research (CSIR), New Delhi	98	4.22	Korea Advanced Institute Science Technology, Daejeon	138	5.29
4	Bhabha Atomic Research Centre (BARC), Mumbai	98	4.22	Korea Institute of Science and Technology, Seoul	128	4.91
5	National Institute of Technology, Goa	82	3.53	Hanyang University, Seoul	126	4.83
6	Aligarh Muslim University, Aligarh, Uttar Pradesh	69	2.97	Inha University, Incheon	125	4.80
7	Institute Chemical Technology (ICT),Hyderabad	54	2.32	Chonnam National University, Yeosu	111	4.26
8	Anna University, Chennai	49	2.11	Kyungpook National University, South Korea	109	4.18
9	Indian Institute of Science, Bangalore	41	1.76	Korea Institute Energy Research, Daejeon	105	4.03
10	National Chemical Laboratory, Pune	37	1.59	Pusan National University, Miryang	104	3.99
11	High Energy Materials Research Laboratory, Pune	33	1.42	Yonsei University, Seoul	97	3.72
12	Guru Nanak Dev University, Punjab	33	1.42	Sungkyunkwan University, Suwon and Seoul	93	3.57
13	Indian Institute of Technology (IIT), Guwahati	32	1.38	Yeungnam University,Gyeongsan	92	3.53
14	Jadavapur University, Kolkata	29	1.25	Chungnam National University, Daejeon	91	3.49
15	University of Delhi, Delhi	28	1.21	Chonbuk National University ,Jeonju	89	3.41
16	Banaras Hindu University, Varanasi	28	1.21	Kyung Hee University, Seoul	86	3.30
17	University of Calcutta, Kolkata	27	1.16	Dankook University, Gyeonggi	77	2.95
18	Indira Gandhi Centre for Atomic Research, Tamil Nadu	27	1.16	Kangwon National University , Gangwon	67	2.57
19	Tezpur University, Assam	25	1.08	Konkuk University, Seoul	64	2.46
20	Indian Institute of TechnologyRoorkee , Uttarakhand	24	1.03	Kwangwoon University, Seoul	63	2.42

Top sub-fields research priority in Chemical Engineering of India and South Korea

Table 6 indicates that the sub-fields research priority in chemical engineering research of India and South Korea. Thermodynamics, Materials Science, Energy Fuels, Biotechnology Applied Microbiology, Pharmacology Pharmacy, Environmental Sciences Ecology, Polymer Science, were considered on the basis of the highest number of publications. In India during the period 2011 to 2015Thermodynamicshas got the first position with 301(12.95%) publications, followed by Materials Science with 177(7.62%)publications, Energy Fuels with 120 (5.16%) publications, Biotechnology Applied Microbiology with 91 (3.92%) publications, Pharmacology Pharmacy with 61 (2.63%) publications, Environmental Sciences Ecology with 30 (1.29%) publications, and Polymer Science with 28 (1.21%) publications. Similarly with regard to South Korea Energy Fuels has got the first position with 258 (9.90%) publications, followed by Environmental Sciences Ecology with 191 (7.33%)publications, Material Science with

177(6.79%) publications, Thermodynamics with 124 (4.76%) publications, Biotechnology Applied Microbiology with 40 (1.53%) publications, Pharmacology Pharmacy with 34 (1.30%) publications, and Polymer Science with 29 (1.11%) publications.

Table 5: Top Sub-fields research priority in Chemical Engineering of India and South Korea

INDIA				SOUTH KOREA		
Sl. No.	**Subject**	**Publications**	**% of 2324**	**Subject**	**Publications**	**% of 2607**
1	Thermodynamics	301	12.95	Energy Fuels	258	9.90
2	Materials Science	177	7.62	Environmental Sciences Ecology	191	7.33
3	Energy Fuels	120	5.16	Materials Science	177	6.79
4	Biotechnology Applied Microbiology	91	3.92	Thermodynamics	124	4.76
5	Pharmacology Pharmacy	61	2.63	Biotechnology Applied Microbiology	40	1.53
6	Environmental Sciences Ecology	30	1.29	Pharmacology Pharmacy	34	1.30
7	Polymer Science	28	1.21	Polymer Science	29	1.11

Most preferred Indian and South Korean Journals in the field of Chemical Engineering

Periodicals play a very vital role in scientific communication and serve as a repository of information, knowledge and media for communication from mind to mind.The list of top 15 source journals shown in Table 6. The share of the top 20 most productive journals in Indian output 86.53% share of the total countries output, with regard to South Korea the share of the most productive journals to the total countries output is 98.39%. Out of the 40 journals from countries, 15 are basically from Netherlands, 07 from USA,05 from England (U. K.), 02 from China and South Korea, 1 from India, and Serbia.

Most preferred journals of Indian authors are *Separation Science and Technology* has published 283 articles, followed by *Journal of Chemical and Engineering Data* with 206 articles, *Journal of Industrial and Engineering Chemistry* with 201 articles, *Indian Journal of Chemical Technology* with 196 articles, *Acs Sustainable Chemistry Engineering* with 118 articles and *Korean Journal of Chemical Engineering* with 117 articles. With regard to South Korea *Journal of Industrial and Engineering Chemistry* has got highest publications i. e. 752 (28.85%) articles followed by *Korean Journal of Chemical Engineering* with 723 articles, *Energy Environmental Science* with 191 articles, *Dyes and Pigments* with 142 articles, *Applied Catalysis B Environmental* with 126 articles and *Catalysis Today* published 120 articles

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Table 6: Most preferred Indian and South Korean Journals in the field of Chemical Engineering

INDIA				SOUTH KOREA		
Sl. No.	**Source /Journal**	**TP**	**% of 2324**	**Source /Journal**	**TP**	**% of 2607**
1	Separation Science And Technology United Kingdom	283	12.177	Journal of Industrial and Engineering Chemistry, Netherlands	752	28.85
2	Journal Of Chemical And Engineering Data, USA	206	8.864	Korean Journal of Chemical Engineering South Korea	723	27.73
3	Journal Of Industrial And Engineering Chemistry, Netherlands	201	8.649	Energy Environmental Science, United Kingdom	191	7.33
4	Indian Journal of Chemical Technology, India	196	8.434	Dyes and Pigments, Netherlands	142	5.45

5	Acs Sustainable Chemistry Engineering, USA	118	5.077	Applied Catalysis B Environmental, Netherlands	126	4.83
6	Korean Journal of Chemical Engineering, South Korea	117	5.034	Catalysis Today, Netherlands	120	4.60
7	Dyes And Pigments, Netherlands	101	4.346	Separation Science and Technology United Kingdom	66	2.53
8	Fluid Phase Equilibria, Netherlands	95	4.088	Journal of Chemical and Engineering Data, USA	65	2.49
9	Journal Of Chemical Technology And Biotechnology, USA	91	3.916	Fuel Processing Technology, Netherlands	61	2.34
10	Journal Of Surfactants And Detergents, USA	87	3.744	Fluid Phase Equilibria, Netherlands	59	2.26
11	Catalysis Today, Netherlands	75	3.227	Journal Of Chemical Technology And Biotechnology, USA	40	1.53
12	Fuel Processing Technology, Netherlands	73	3.14	Journal of Catalysis, Netherlands	40	1.53
13	Journal Of Microencapsulation, United Kingdom	61	2.625	Journal of Supercritical Fluids, Netherlands	35	1.34
14	Applied Catalysis B Environmental, Netherlands	56	2.41	Journal of Microencapsulation, London	34	1.30
15	Tenside Surfactants Detergents, Germany	53	2.281	Reactive Functional Polymers, Netherlands	29	1.11
16	Chemical Industry Chemical Engineering Quarterly,Serbia	46	1.979	Chinese Journal of Catalysis, China	23	0.88
17	Chinese Journal Of Catalysis, China	42	1.807	Coloration Technology, USA	17	0.65
18	Polish Journal Of Chemical Technology, Germany	38	1.635	Acs Sustainable Chemistry Engineering, USA	17	0.65
19	Propellants Explosives Pyrotechnics, USA	36	1.549	Science And Technology of Energetic Materials, Japan	13	0.50
20	Pigment Resin Technology, United Kingdom	36	1.549	Adsorption Journal of the International Adsorption Society, Germany	12	0.46

International collaborating partners of India and South Korea

Table 8 depicts the international collaborative papers of India and South Korea with top with 20 countries during 2011-2015. The share of International collaborative publications in the chemical engineering research output South Korea achieved the highest publications i.e. 22.02% than India (17.86%) during the period. The largest number of collaborative publications (3356) of India in this research was with South Korea with 3.70% share, followed by United States with 1.98%share, Saudi Arabia with 1.94%share and South Africa with090%share. With regard to South Korea the highest collaborating partner is United States with 5.75% of publications, followed by Peoples R China with 3.33%, India with 3.29%, Japan with 2.45% and Australia with 1.18%. Many countries are contributed with below 1% share with India and South Korea in chemical engineering research during 2011 to 2015 (Table-8).

Table 8: International collaborating partners of India and South Korea

India				**South Korea**		
Sl. No	**Country**	**TP**	**% of 2324**	**Country**	**TP**	**% of 2607**
1	South Korea	86	3.70	USA	150	5.754
2	USA	46	1.98	Peoples R China	87	3.337
3	Saudi Arabia	45	1.94	India	86	3.299

4	South Africa	21	0.90	Japan	64	2.455
5	Malaysia	20	0.86	Australia	31	1.189
6	Australia	20	0.86	Saudi Arabia	21	0.806
7	Japan	19	0.82	England	17	0.652
8	Germany	18	0.78	Vietnam	14	0.537
9	Canada	18	0.78	Italy	13	0.499
10	France	16	0.69	Iran	13	0.499
11	Italy	15	0.65	Germany	13	0.499
12	Singapore	13	0.56	Malaysia	11	0.422
13	Iran	13	0.56	Egypt	9	0.345
14	Turkey	12	0.52	Scotland	8	0.307
15	Taiwan	12	0.52	Canada	8	0.307
16	Spain	10	0.43	Switzerland	6	0.23
17	Peoples R China	9	0.39	Singapore	6	0.23
18	England	8	0.34	Pakistan	6	0.23
19	Sweden	7	0.30	Oman	6	0.23
20	Portugal	7	0.30	Russia	5	0.192

CONCLUSION

The present study gives a scientometric description of the research performance of countries status in world. The assessment of countries productivity can be measured by the counting of research publications in the journals and proceedings, and the number of citations received in those publications. Scientometric indicators have been used as valuable indicators to quantitatively measure the output of scientific research. They merely show part of scientific enterprise, which is activity with diverse aspects. However, there is nothing on par with these indicators in terms of the abundance of information contained. This study reveals that India has produced 2,324 publications, and received 11,299 citations during the period 2011 to 2015, average citations per publication is 4.86. South Korea has produced more than India i.e. 2,607 publications, and received 20,509 citations during the period, average citations per publication is 7.87. Both countries publications are gradually increased year by year. The average growth rate of India and South Korea is 26.07 and 23.24.

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