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# Scientometric Study of Nuclear Science and Technology Research in India and China based on Web of Science (2000-2019)

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## Abstract

The present study attempt to compare the research output in terms of publications between two Asian giants India and china in nuclear science and technology for the period 2000 to 2019 as indexed in web of Science database under different parameters like publications size, mode of communication, research wise distribution, authorship pattern and collaboration pattern, citation pattern. The study reveals that India published 8637 research papers while China published 16879 papers which is almost twice of India's publication. India leads China in terms of average citation per paper. China shows tremendous growth after 2012. In terms of collaboration, Germany is at the top with India and USA is at the top with China. Researchers have tendency to publish their papers in group rather than individual. Contributors from both the countries have tendency to publish their paper in journal. Bhabha Atomic Research Centre share 37% of the total output of India's publication where Chinese Academy of Science shares 33% of the total output of China in nuclear science and technology.

**Keywords:** Nuclear Science and Technology, India, China, Comparative study, Scientometrics, Authorship pattern, Degree of Collaboration, Bibliometrics, Growth rate

## Introduction

As many countries in the world tries to develop and utilize the nuclear science and technology in many field likes as alternative source of energy, engineering, medical applications, industrial applications and many different commercial aspect. In this aspect India and China as one of the nuclear power country also utilize the nuclear science in diverse field. Due to the effort of Homi Jehangir Bhabha who is also known as “father of Indian nuclear programme” started the Tata Institute of Fundamental Research in the year 1945 with the help of Sir Dorabji Jamsetji, Tata Trust. Homi Jehangir Bhabha also proposed the government to set up lab specially on the area atomic energy programme. Due to his effort Atomic Energy Establishment Trombay (AEET) and Department of Atomic energy was established in the year 1954. After than many institutions or specialist laboratory for nuclear science research had been established.

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In case of China, many pioneer in the field of nuclear science like Qien Sanqiang also known as Tsien San- Tsiang refer to as “China’s father of the atom bomb” founded Chinese Academy of Science (CAS) which present name is China Institute of atomic Energy. Hoff Lu who is known as the “father of Nuclear energy in China”. Hoff Lu also made remarkable contribution in nuclear physics, theoretical physics and neutron physics.

## **Literature review**

Some previous studies have done to examine the research activity of particular subject between two or more countries.

**Bid S (2016)** analysed the quantitative research output between four countries India, Pakistan, France and Germany for the period 1988-2008 as reflected in Web of Science. The paper reveal that India shows steady growth in different sub domain of physics. Nanoscience and nanotechnology, remote sensing, geochemistry and geophysics emerge as strong research fields in physics for all the four countries. It also reveal that authors from France and Germany prefer to publish their research paper in their native language where as India and Pakistan researchers prefer to publish in English language only.

**Dhawan (1998)** examined the research output of physics between India and China during 1990-1995 as reflected in INSPEC- Physics and revealed that China was ahead of India in terms of research output and also suggested a strategy for identifying leading research in physics.

**Gupta (2009)** evaluated the contribution of India, China and Brazil in social science. The study found that India lags behind China in terms of publication and publication growth rate. Brazil leads India and China in terms of average citation per paper. The USA and UK are at the top collaborating partners with the three countries.

**Garg (2002)** has examined the research output in laser between India and China and found that China output was twice to that of India. The study also reveal that Chinese preferred to publish in their domestic journal where Indian researcher published in foreign journal and also found that India research papers got more citation per paper than Chinese paper. Both the countries authors preferred to publish their paper in team.

**Suresh Kumar (2002)** the paper evaluated the research output between India and China in Computer Science during 1971-2000. In this study, to identify channels and pattern of communication, relative research effort and pattern of co-authorship of the two countries.

**Kademani (2006)** this study analyse research output of nuclear science and technology in India during 1970-2002 as reflected in International Nuclear Information System (INIS). In this study to identify year wise growth of publication, domain wise distribution, authorship pattern, collaboration pattern, channels of communication have been find out.

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It is also seen that no studies have been carried out to compare the research activities in nuclear science and technology for the two Asian giants India and China for the period of two decades. The present study is useful to understand and compare the research activities between India and china in the concerned subject.

## **Objectives**

The main objectives of the paper are

- To analyse year wise distribution of publication between India and China;
- To find out the top funding agency for India and China;
- To identify citation patterns and highly cited papers;
- To determine the authorship pattern and degree of collaboration of two universities;
- To find out the geographical distribution;
- To identify the top collaborating institutions with India and China ; and
- To study the top subject wise distribution of publications of India and China
- To find out the top journals which are preferred by the researchers of two countries

## **Methodology**

The aim of the study to find out the contribution of two Asian giants India and China in the field of nuclear science and technology for the 20 years period on the basis of data retrieved from Web of Science database (WoS), Clarivate Analytics company. In the address field of the general search option the word India were used and in the publication year field, every year from 2000 to 2019 was used individually, rather than in a group i.e., 2000-2019, to search total literature in every individual year after than refined by nuclear science and technology. In order to study the publication growth, documentary forms, funding agency, country, subjects and source title from India and China during 2000-2019, the quantitative data relating to these seven fields had been searched separately for individual year. For the analysis purposes the data, saved in text files and then imported into Micro Soft- Excel for analysis. The collected data would be evaluated and analyzed.

## Data analysis and discussion

### Publication growth

Table 1 : Year-wise Distribution of Publication with Citation (India and China)

Sl. No.	Years	Records		% of Records		Sum of the Times Cited		Average Citations per Item		h-index	
		India	China	% of 8637	% of 16879	India	China	India	China	India	China
1	2000	199	250	2.304	1.481	2937	2829	14.76	11.32	29	27
2	2001	219	239	2.536	1.416	3321	2858	15.16	11.96	29	27
3	2002	226	351	2.617	2.08	4818	8428	21.32	24.01	30	38
4	2003	336	268	3.89	1.588	17128	4870	50.98	18.17	30	29
5	2004	251	289	2.906	1.712	4163	4614	16.59	15.97	32	30
6	2005	227	318	2.628	1.884	3589	4817	15.81	15.15	31	33
7	2006	407	364	4.712	2.157	6417	6304	15.77	17.32	34	36
8	2007	315	534	3.647	3.164	4515	7303	14.33	13.68	31	39
9	2008	444	497	5.141	2.944	6239	6573	14.05	13.23	38	38
10	2009	368	557	4.261	3.3	4462	8119	12.13	14.58	30	41
11	2010	407	637	4.712	3.774	5452	8173	13.4	12.83	35	37
12	2011	568	753	6.576	4.461	5828	8621	10.26	11.45	33	38
13	2012	557	774	6.449	4.586	5182	8222	9.3	10.62	29	33
14	2013	608	1140	7.039	6.754	5270	10976	8.67	9.63	28	36
15	2014	658	1243	7.618	7.364	4968	11302	7.55	9.09	27	35
16	2015	517	1456	5.986	8.626	2999	11023	5.8	7.57	18	32
17	2016	583	1435	6.75	8.502	2722	9354	4.67	6.52	18	29
18	2017	657	1667	7.607	9.876	2938	8753	4.47	5.25	18	27

19	2018	510	1858	5.905	11.008	1656	7277	3.25	3.92	14	25
20	2019	580	2249	6.715	13.324	786	3766	1.36	1.67	10	16
	Total	8637	16879								

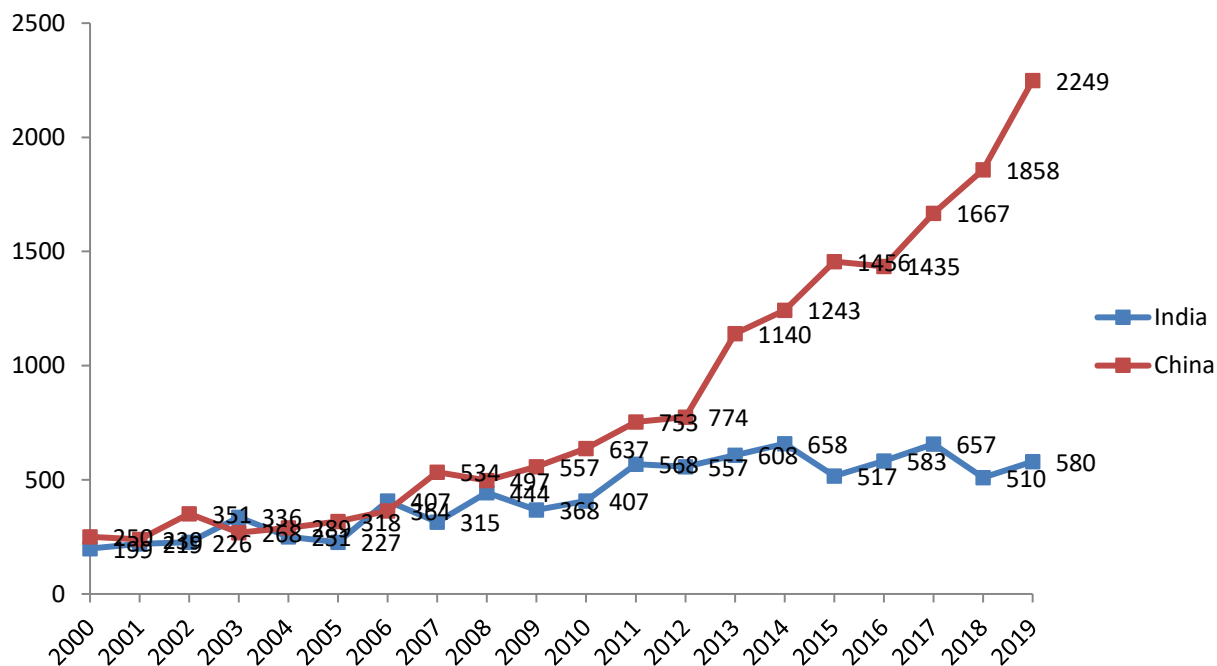


Figure 1: Year-wise Distribution of Publication from India and China

The contribution of India during the year 2000-19 in nuclear science technology is 8637 papers and the average number of papers per year is 432 whereas China has published 16879 papers during the year 2000-19 and the average number of papers per year is 844. From table 1 it is clear that for India, in 2000 which is the initial period of the study, 199 papers published while in 2019, 580 papers have been found. From the table it has been found that the highest number of papers published from India in 2014 with 658 papers followed by 2017 with 657 papers, 2013 with 608 papers, 2016 with 283 papers and so on. In the case of China, 250 papers published in 2000 while in 2019, 2249 papers have been found. The highest number of papers published from China in 2019 with 2249 papers followed by 2018 with 1858 papers, 2017 with 1667 papers, 2015 with 1456 papers and so on. It can be seen that publication from India shows fluctuating in nature while China during 2000-2008 varies but after 2009 it shows continuous exponential growth.

The total number of citations per article for the last 20 years of India & China is also shown in the table 1, which varies from 1.36 to 50.98 for India and 1.67 to 24.01 for China. For 8637 papers of India received **95390** citations i.e. 11.04 average citation per paper and for 16879 paper of China received **144182** citations i.e. 8.54 average citation per paper. This shows that average citation per papers of India is better than China. Data also reveals that for India, in 2003 got the highest average citation per papers i.e. 50.98 followed by 2002 with 21.32, 2004 with 16.59, 2005 with 15.81, 2006 with 15.77 and so on. For China, it got the highest average citation per paper in the year 2002 with 24.01 followed by 2003 with 18.17, 2006 with 17.32, 2004 with 15.97 and so on. It shows that for both the countries have got highest number of citation per paper in the year 2002.

**Table 2** Quadruple Publication Output (2000-2019) of India and China

Year	Paper		Quadruple Growth Rate, %	
	India	China	India	China
2000-03	980	1108		
2004-07	1200	1505	22.44	35.83
2008-11	1787	2444	48.91	62.39
2012-15	2340	4613	30.94	88.74
2016-19	2330	7209	-0.42	56.27

From table 2, quadruple publications output by Indian authors published 980 papers in 2000-03, 1200 papers in 2004-07, 1787 papers in 2008-11, 2340 in 2012-15 and 2330 papers in 2016-19. Thus the publications growth has been 22.44 for the quadruple period 2000-03 to 2004-07. Growth rate shows sudden increasing trend with 48.91 again it gradually decreased to 30.94 for the period 2008-11 to 2012-15 and it shows a negative trend for the period 2012-15 to 2016-19.

From the above table, quadruple publications output by Chinese authors published 1108 papers in 2000-03, 1505 papers in 2004-07, 2444 papers in 2008-11, 4613 in 2012-15 and 7209 papers in 2016-19. Thus the publications growth has been 35.83 for the quadruple period 2000-03 to 2004-07. Which increased to 62.39 for the period 2004-07 to 2008-11 again it shows positive increasing trend with 88.74 and it suddenly shows a decreasing trend with 56.27 for the period

2012-15 to 2016-19. It has been noticed that in terms of publication for both the countries, only in the year 2003 and 2006 the publication output of India is more than China and the total publication output of China is near about twice of India's publication output. After 2012 China's research output in terms of publication has shown tremendous growth while India contribution shows almost steady growth in terms of publication throughout the study period.

## Document type

Table 3: Types of publication preferred by the authors of India and China

Document Type	Records of India	Records of China
Article	8426(97.55)	16554(98.07)
Correction	31(0.35)	56(0.33)
Editorial material	31(0.35)	66(0.39)
Letter	32(0.37)	20(0.11)
Proceeding papers	1496(17.32)	2841(16.83)
Review	112(1.29)	182(1.07)

The papers published by the authors of India and China publish in different types of documents. Both the countries have almost similar trend of publishing and authors preferred to publish papers in journal, proceeding papers, review as shown in the table 3

## Funding agencies for India and China

Table 4: Top 10 funding agencies for India and China

Funding Agencies for India	Sponsored papers	Funding Agencies For China	Sponsored papers
Department of Atomic Energy DAE	402 (4.65)	National Natural Science Foundation of China	6986(41.38)
University Grants Commission India	248(2.87)	Fundamental Research Funds for The Central Universities	810(4.79)
Board of Research in Nuclear Sciences BRNS	237(2.74)	National Basic Research Program of	698(4.13)



		China	
Department of Science Technology India	226(2.61)	Chinese Academy of Sciences	634(3.75)
Council of Scientific Industrial Research CSIR India	180(2.08)	China Postdoctoral Science Foundation	376(2.22)
Euratom Research and Training Programme	72(0.83)	National Magnetic Confinement Fusion Science Program of China	319(1.89)
United States Department of Energy DOE	42(0.48)	United States Department of Energy DOE	272(1.61)
Engineering Physical Sciences Research Council EPSRC	30(0.34)	China Scholarship Council	245(1.45)
IUAC New Delhi	30(0.34)	National Key Research and Development Program of China	194(1.14)
Science Technology Facilities Council STFC	26(0.30)	Ministry Of Science and Technology China	186(1.10)
Federal Ministry of Education Research BMBF	23(0.26)	National High Technology Research and Development Program of China	178(1.05)
Ministry of Education Culture Sports Science And Technology Japan MEXT	22(0.25)	National Key R D Program of China	175(1.03)
National Science Foundation NSF	21(0.24)	Ministry of Education China	170(1.00)
Defence Research Development Organisation DRDO	19(0.22)	National Magnetic Confinement Fusion Science Program	164(0.97)
European Union EU	18(0.20)	National Magnetic Confinement Fusion Program	150(0.88)

Table 4 shows the top 15 funding agencies for India and China. Maximum numbers of funding for India has come from DAE, UGC, BRNS, DST, CSIR and China came from National Natural Science Foundation of China, Fundamental Research Funds for The Central Universities, National Basic Research Program of China, Chinese Academy of Sciences and China Postdoctoral Science Foundation. It is also noticed that out of top15 funding agencies for India, 2 funding agencies each from United States, European countries, United Kingdom and one from Japan and Germany while in case of China only one funding agency came from United States i.e United States Department of Energy DOE and rest 14 funding agencies are from China. Above

table also shows that the top 15 funding agency covers only 18.47% of the total publication of India while top 15 funding agency covers 68.47% of the total publication of China. It shows that China funded more on research and development self financed where India has been funded by the other countries also.

### Citation Profile & highly Cited papers

Table 5 Citation distribution of India and China

Times Cited	Number of papers		% of India 8637	% of China 16879
	India	China		
Zero Citation	1046	2657	12.11068658	15.74145388
1	950	2170	10.99918953	12.85621186
2	804	1883	9.308787774	11.15587416
3	727	1428	8.417274517	8.460216837
4	605	1137	7.004747019	6.736181053
5	545	955	6.310061364	5.657918123
6--10	1728	2968	20.00694686	17.58398009
11--50	2046	3365	23.68878083	19.93601517
51-100	141	228	1.632511289	1.350790924
100-150	28	44	0.324186639	0.26067895
151-200	9	18	0.104202848	0.106641389
201-250	2	6	0.023156188	0.03554713
251-300	0	10	0	0.059245216
>300	6	10	0.069468565	0.059245216
Total	8637	16879	100	100

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In case of India, table 5 shows that 1046 papers received zero citation, 950 papers received one citation, 804 papers received two citations, 727 papers received 3 citations, 605 papers received 4 citations, 545 papers received 5 citation, 1728 papers in citation range 6-10, 2046 papers in citation range 11-50, 141 papers in citation range 51-100, for more than 100 citations are received by 37 papers, more than 200 citations are received by 2 papers and more than 300 citations are received by 6 papers. Top 5 highly cited papers of India in the nuclear science technology.

Agostinelli S, Allison J, Amako, K. et. al. GEANT4-a simulation toolkit. *Nuclear Instruments & Methods in Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment*. 2003; 506 (3) : 250-303p. (Times cited : 12557)

Abashian A, Abe K, Abe R. et. al. The Belle detector. *Nuclear Instruments & Methods in Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment*. 2002; 479 (1): 117-232p. (Times cited: 1153)

Abazov V. M., Abbott B, Abolins M. et.al. The upgraded DO detector. *Nuclear Instruments & Methods in Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment*. 2006 ; 565 (2) : 463-537p. (Times cited : 513)

Adcox K, Adler SS, Aizama M. et. al. PHENIX detector overview. *Nuclear Instruments & Methods in Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment*. 2003 ; 499 (2-3) : 469-479p. (Times cited : 427)

Abbon P, Albrecht E, Alexakhin V. Yu.. et. al. The COMPASS experiment at CERN. *Nuclear Instruments & Methods in Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment*. 2007 ; 577(3) : 455-518p. (Times cited : 384)

In case of China, table 5 shows that 2657 papers received zero citation, 2170 papers received one citation, 1883 papers received two citations, 1428 papers received 3 citations, 1137 papers received 4 citations, 955 papers received 5 citation, 2968 papers in citation range 6-10, 3365 papers in citation range 11-50, 228 papers in citation range 51-100, for more than 100 citations are received by 62 papers, more than 200 citations are received by 16 papers and more than 300 citations are received by 10 papers. Top 5 highly cited papers of China.

Aubert B, BazanA, Boucham A. et. al. The BABAR detector. *Nuclear Instruments & Methods in Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment*. 2002; 479 (1): 1-116p. (Times cited: 1182)

Abashian A, Abe K, Abe R. et. al. The Belle detector. *Nuclear Instruments & Methods in Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment*. 2002; 479 (1): 117-232p. (Times cited: 1153)

Abraham J, Aglietta M, Aguirre IC. et.al. Properties and performance of the prototype instrument for the Pierre Auger Observatory. *Nuclear Instruments & Methods in Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment*. 2004; 523 (1-2): 50-95p. (Times cited: 654)

Abazov, V. M., Abbott B, Abolins M. et. al. The upgraded DO detector. *Nuclear Instruments & Methods In Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment*. 2006; 565(2): 463-537p. (Times cited: 513)

Ackermann KH, Adams N, Adler C. et.al. STAR detector overview. *Nuclear Instruments & Methods in Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment*. 2003; 499(2-3): 624-632p. (Times cited: 501)

From the above it can be seen that the title “The Belle detector” received 1153 citation and has common to both the countries. Nuclear Instruments & Methods in Physics Research Section A-Accelerators Spectrometers Detectors and Associated Equipment is the most common source where both countries authors publish their research papers and all the top 5 cited papers from both the countries are coming from this journal.

### Authorship Pattern

Table 6 Authorship Pattern of Papers Published India

Year	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Ten>	Total	%
2000	11	39	41	46	25	13	11	3	3	2	5	199	2.30
2001	15	32	47	42	27	21	13	8	1	2	11	219	2.53
2002	12	33	36	62	35	19	7	6	4	3	9	226	2.61
2003	16	46	57	57	63	42	25	9	7	3	11	336	3.89
2004	10	54	47	45	33	27	17	6	1		11	251	2.90
2005	10	32	43	50	32	22	11	8	2	2	15	227	2.62
2006	11	66	59	85	67	54	30	7	8	7	13	407	4.71
2007	13	58	54	66	47	28	10	14	5	6	14	315	3.64
2008	12	68	84	73	87	47	32	16	6	10	9	444	5.14

2009	17	57	71	66	55	38	21	15	8	4	16	368	4.26
2010	12	67	72	94	56	42	23	11	7	5	18	407	4.71
2011	25	74	99	114	80	60	44	19	11	10	32	568	6.57
2012	10	73	115	91	74	73	45	26	15	8	27	557	6.44
2013	16	82	110	114	93	65	35	20	14	22	37	608	7.03
2014	32	87	112	119	101	69	47	21	16	18	36	658	7.61
2015	9	57	96	95	74	55	40	31	15	17	28	517	5.98
2016	22	55	91	110	90	67	43	20	30	11	44	583	6.75
2017	25	64	126	101	87	82	49	18	20	10	75	657	7.60
2018	13	66	87	91	73	61	20	26	12	9	52	510	5.90
2019	15	87	100	93	87	58	35	31	11	8	55	580	6.71
Total	306	1197	1547	1614	1286	943	558	315	196	157	518	8637	100
%	3.543	13.859	17.911	18.69	14.89	10.9	6.4606	3.647	2.269	1.82	5.997	100	

From the table 6 shows the authorship pattern of India. The authors of India, published 8637 papers which is indexed in WoS database shows that they preferred to publish contributed by four authors (18.69%) followed by three authors (17.91%), five authors (14.89%), two authors (13.85%), six authors (10.9%) and seven author (6.46%) and so on. This pattern shows that authors of India published their paper with the group of authors rather than single. There are 152 no. of titles where the single paper is contributed by more than 100 authors out of which 115 no. of titles having more than 1000 contributors. The title “A locked mode indicator for disruption prediction on JET and ASDEX upgrade” has been contributed by 2133 authors published in Fusion Engineering and Design in the year 2019.

**Table 7** Authorship Pattern of Papers Published China

year	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Ten>	Total	%
2000	12	21	48	47	37	23	20	12	6	7	17	250	1.48
2001	16	19	41	54	29	26	15	8	9	1	21	239	1.41

2002	13	33	61	69	54	36	26	13	13	5	28	351	2.07
2003	8	26	37	51	45	31	20	11	2	8	29	268	1.58
2004	9	29	53	39	42	39	25	13	10	5	25	289	1.71
2005	10	26	57	61	42	22	28	17	8	7	40	318	1.88
2006	19	42	46	78	57	38	24	15	15	8	22	364	2.15
2007	14	44	84	96	73	69	46	35	22	17	34	534	3.16
2008	14	59	66	94	81	57	47	21	18	8	32	497	2.94
2009	9	42	113	103	84	70	49	26	10	10	41	557	3.29
2010	9	36	79	122	107	88	61	47	20	19	49	637	3.77
2011	11	48	97	147	148	89	60	40	30	10	73	753	4.46
2012	8	50	132	117	149	101	80	39	32	11	55	774	4.58
2013	24	55	128	178	228	149	119	83	55	30	91	1140	6.75
2014	16	72	129	217	244	186	126	91	53	32	77	1243	7.36
2015	18	56	174	226	273	226	172	96	53	38	124	1456	8.62
2016	16	78	172	202	255	229	161	90	66	38	128	1435	8.50
2017	14	60	143	257	266	287	182	126	80	64	188	1667	9.87
2018	17	68	169	271	328	299	204	153	104	56	189	1858	11.00
2019	25	85	198	313	401	332	253	204	117	107	214	2249	13.32
Total	282	949	2027	2742	2943	2397	1718	1140	723	481	1477	16879	100
%	1.67	5.62	12.009	16.25	17.4	14.2	10.18	6.75	4.283	2.85	8.75	100	

Table 7 shows the authorship pattern of China. China authors also preferred to publish their papers contributed by five authors (17.4%), four authors (16.24%), six authors (14.20%), three authors (12 %), seven authors (10.17 %), more than ten authors (8.75%). The paper published by a single author is only 1.67%. There are 189 no. of titles where the single paper is contributed by more than 100 authors out of which 115 no. of titles having more than 1000 contributors. The

title “A locked mode indicator for disruption prediction on JET and ASDEX upgrade” has been contributed by 2133 authors published in Fusion Engineering and Design in the year 2019.

From the above it is seen that authorship patterns show almost the same nature for both the countries India and China, and have a tendency to publish their research paper in multi-authored rather than the single-authored. It is also found that for both the countries have 115 numbers of research papers where contribution by more than 1000 authors.

### Degree of Collaboration (DC)

**Table 8 :** Authorship Pattern with Degree of Collaboration Measures (DC)

	Number of publication		Percentage (%) of total publication		Nm+Ns		DC	
	India	China	India	China	India	China	India	China
Total number of Single/Multi-Authored Publications	8637	16879	100	100				
Number of Co-Authored Publication (NM)	8331	16597			8637	16879	0.96	0.98
Number of Single-Authored Publication (NS)	306	282	3.5429	1.6707				
Number of two-Authored Publication	1197	949	13.859	5.6224	1503	1231	0.79	0.77
Number of three-Authored Publication	1547	2027	17.9113	12.009	1853	2309	0.83	0.87
Number of Four-Authored Publication	1614	2742	18.687	16.245	1920	3024	0.84	0.90
Number of Five-Authored Publication	1286	2943	14.8894	17.436	1592	3225	0.80	0.91
Number of Six-Authored Publication	943	2397	10.9181	14.201	1249	2679	0.75	0.89
Number of Seven-Authored Publication	558	1718	6.46058	10.178	864	2000	0.64	0.85

Number of Eight-Authored Publication	315	1140	3.6471	6.754	621	1422	0.50	0.80
Number of Nine-Authored Publication	196	723	2.26931	4.2834	502	1005	0.39	0.71
Number of Ten Authored Publication	157	481	1.81776	2.8497	463	763	0.33	0.63
Number of Eleven and above-Authored Publication	518	1477	5.99745	8.7505	824	1759	0.62	0.83

For finding the degree of collaboration (DC) of India and China, Subramanyam (1983) formula has been used i.e  $DC = \frac{Nm}{Nm+Ns}$

Where  $Nm$  = Number of multi-authored papers

$Ns$  = Number of single authored papers

Calculation: DC for two authored publications

$Nm = 1197$  &  $Ns = 306$

$DC = \frac{1197}{(1197+306)} = 0.796$

Table 8 shows that the value of DC of India is lowest among ten authored which is 0.13 and highest among four authored (0.84) followed by three authored (0.83), five authored (0.80), two authored (0.79) and so on. The same patterns show for the DC of China. The lowest value of DC is found among ten authored publications (0.63) and highest found among five authors (0.91) followed by four authored publications (0.90), six authored publications (0.89), three authored (0.87) and so on. Both the countries have shown the same trend towards multi- authorship papers.

## Collaboration with other Countries

Table 9: Geographical Distribution of Publications

Collaborating countries with India			Collaborating countries with China			Rank
Country	Records	% of 8637	Country	Records	% of 16879	
Germany	437	5.06	USA	1572	9.31	1



USA	427	4.944	Japan	876	5.19	2
France	340	3.937	Germany	694	4.11	3
Japan	317	3.67	France	567	3.35	4
South Korea	283	3.277	Italy	388	2.29	5
Italy	277	3.207	South Korea	383	2.26	6
England	231	2.675	Russia	362	2.14	7
Peoples R China	226	2.617	England	354	2.09	8
Russia	223	2.582	Switzerland	323	1.91	9
Spain	189	2.188	Sweden	231	1.36	10
Switzerland	185	2.142	India	226	1.33	11
Austria	182	2.107	Netherlands	220	1.30	12
Poland	178	2.061	Spain	215	1.27	13
Czech Republic	163	1.887	Canada	213	1.26	14
Greece	160	1.852	Poland	195	1.15	15

Table 9 shows the top 15 countries collaborate with India and China. It has been found that both the countries have collaboration with the other countries researcher of the world for publishing their research papers. It is found that 10 countries are common out of top 15 countries in both the countries. China rank 9<sup>th</sup> in terms of collaboration with India while India rank 11<sup>th</sup> with China. The Germany is at the top in collaboration with India with 437 records followed by USA with 427 records, France with 340 records, Japan with 317 records, South Korea with 283 records and so on. In case of China, USA is at top with 1572 records followed by Japan with 876 records, Germany with 694 records, France with 567 records, Italy with 388 records and so. It is also found that top 15 countries collaboration with India share 44.20 % of total publication where countries collaboration with China share 40.4% of the total output of China in nuclear science technology.

From the table it is also visible that USA, Germany, Japan, France, Italy, Russia and England are the countries where more research work have been done in the field of nuclear science technology for that reason this countries are common with both the countries India and China.

## Research area -wise Distribution of Publications

Table 10: Subject-wise Number of Papers Produced

Research Areas	Records for India	Records for China
Chemistry	2653(30.71)	2460(14.57)
Computer Science	16(0.18)	349(2.06)
Energy Fuels	280(3.24)	830(4.91)
Engineering	118(1.36)	890(5.27)
Environmental Sciences Ecology	399(4.62)	344(2.03)
Imaging Science Photographic Technology	16(0.18)	349(2.06)
Instruments Instrumentation	1737(20.11)	3426(20.29)
Life Sciences Biomedicine Other Topics	134(1.55)	144(0.85)
Materials Science	642(7.43)	1463(8.66)
Nuclear Science Technology	8621(99.81)	16528(97.92)
Physics	2776(32.14)	5384(31.89)
Public Environmental Occupational Health	399(4.62)	344(2.03)
Radiology Nuclear Medicine Medical Imaging	1013(11.72)	1250(7.40)

Contributors from both the countries have published their research paper in the above research area. From the table 10, Indian researchers published 2776 (32.14%) in physics followed by chemistry with 2653 (30.71%), instruments and instrumentation with 1737 (20.11%), radiology nuclear medicine medical imaging with 1013 (11.72%), material science with 642 (7.43%), environmental science ecology and public environmental occupational health with 399 (4.62%) each, energy fuels with 280 (3.24%) and followed by other.

In case of China, Physics ranked top with 5384 (31.89%) followed by instrument and instrumentation with 3426 (20.29%), chemistry with 2460 (14.57%), radiology nuclear medicine medical imaging with 1250 (7.40%), engineering with 890 (5.27%), energy fuels with 830 (4.91%) and so on.

## Institution-wise Distribution of Papers

Table 11: Top 25 institutions/Universities collaborating with India & China

Affiliation with India	Records	Affiliation With China	Records
Bhabha Atomic Research Center BARC	3174(36.74)	Chinese Academy of Sciences	5604(33.20)
Indira Gandhi Centre For Atomic Research IGCAR	1006(11.64)	Tsinghua University	1571(9.30)
Indian Institute Of Technology System IIT System	847(9.80)	University of Science Technology of China CAS	1256(7.44)
Inter University Accelerator Centre	605(7.00)	Xi An Jiaotong University	1020(6.04)
Institute For Plasma Research IPR	510(5.90)	University of Chinese Academy of Sciences CAS	979(5.8)
Homi Bhabha National Institute	349(4.04)	Shanghai Institute of Applied Physics CAS	747(4.42)
Saha Institute of Nuclear Physics	311(3.60)	Institute of High Energy Physics CAS	737(4.36)
Helmholtz Association	280(3.24)	Chinese Academy of Engineering Physics	696(4.12)
Indian Institute of Technology IIT Bombay	245(2.83)	Institute of Modern Physics CAS	684(4.05)
Council of Scientific Industrial Research CSIR India	232(2.68)	Shanghai Jiao Tong University	665(3.94)
Variable Energy Cyclotron Centre	225(2.60)	Peking University	644(3.81)
United States Department of Energy DOE	209(2.42)	China Institute of Atomic Energy	637(3.77)
CEA	201(2.32)	United States Department of Energy DOE	576(3.41)
Centre National De La Recherche Scientifique CNRS	192(2.22)	Helmholtz Association	450(2.66)
ITER	175(2.02)	Lanzhou University	407(2.41)
Chinese Academy of Sciences	169(1.95)	Harbin Engineering University	396(2.34)
University of California System	159(1.84)	Sichuan University	388(2.29)
Max Planck Society	156(1.80)	Southwestern Institute of Physics China	296(1.75)
Karlsruhe Institute of Technology	153(1.77)	University of California System	292(1.73)
Guru Nanak Dev University	148(1.71)	Beijing Normal University	285(1.68)

Panjab University	148(1.71)	Fudan University	285(1.68)
Institute of Physics Bhubaneswar IOPB	145(1.67)	University of Science Technology Beijing	282(1.67)
Mangalore University	144(1.66)	Centre National De La Recherche Scientifique CNRS	274(1.62)
University Of Delhi	143(1.65)	North China Electric Power University	271(1.60)
Tata Institute Of Fundamental Research TIFR	142(1.64)	Nucl Power Inst China	269(1.59)

The contributors from India and China publish their research work from many institutions/universities. It is found from the table that Indian authors from Bhabha Atomic Research Center ranked top with 3174 records followed by IGCAR with 1006 records, IIT systems with 847 records, Inter University Accelerator Centre with 605 records, Institute for Plasma Research with 510 records, Homi Bhabha National Institute with 349 records, Saha Institute of Nuclear Physics with 311 records and so on. It is clear from the table that top 5 institutions cover 71.11% of the total output in nuclear science technology. Maharashtra contributed 45.27% of the total output, 17.58% from other countries and rest from other states of India.

In case of China, Chinese Academy of Sciences ranked top with 5604 records followed by Tsinghua University with 1571 records, University of Science Technology of China with 1256 records, Xi An Jiaotong University with 1020 records and soon. It is also found that only three institutions which are from other countries are in the list of top 25 institutions.

### Journal-wise Distribution of Papers

table 12: List of top 25 Journals where contributors of India and China published their papers

Source Titles For India	Records	IF	Source Titles For China	Records	IF
Journal of Radioanalytical and Nuclear Chemistry	1293(14.97)	1.18	Nuclear Instruments Methods in Physics Research Section B Beam Interactions with Materials and Atoms	1782(10.55)	1.21
Nuclear Instruments Methods in Physics Research Section B Beam Interactions with Materials and Atoms	1096(12.69)	1.21	Nuclear Instruments Methods in Physics Research Section A Accelerators Spectrometers Detectors and Associated Equipment	1644(9.74)	1.433
Journal of Nuclear Materials	642(7.43)	2.547	Fusion Engineering and Design	1468(8.69)	1.45

Nuclear Instruments Methods in Physics Research Section A Accelerators Spectrometers Detectors and Associated Equipment	641(7.42)	1.433	Journal of Nuclear Materials	1463(8.66)	2.547
Radiation Physics and Chemistry	599(6.93)	1.98	Journal of Radioanalytical and Nuclear Chemistry	1386(8.21)	
Nuclear Engineering and Design	534(6.18)	1.54	Nuclear Science and Techniques	1279(7.57)	0.96
Applied Radiation and Isotopes	464(5.37)	1.34	Annals of Nuclear Energy	1083(6.41)	1.38
Radiation Effects and Defects in Solids	416(4.81)	0.63	Nuclear Engineering and Design	989(5.85)	1.54
Fusion Engineering and Design	405(4.68)	1.45	International Journal of Energy Research	828(4.90)	3.34
Radiation Measurements	364(4.21)	1.43	IEEE Transactions on Nuclear Science	557(3.3)	1.42
Annals of Nuclear Energy	336(3.89)	1.38	Radiation Physics and Chemistry	503(2.98)	1.98
Radiation Protection Dosimetry	312(3.61)	0.83	Progress in Nuclear Energy	463(2.74)	1.56
Radiochimica Acta	297(3.43)	1.33	Applied Radiation and Isotopes	413(2.44)	1.34
International Journal of Energy Research	276(3.19)	3.34	Journal of Fusion Energy	349(2.06)	0.64
International Journal of Radiation Biology	134(1.55)	2.26	Ieee Transactions on Medical Imaging	329(1.94)	7.81
Progress in Nuclear Energy	103(1.19)	1.56	Radiation Measurements	281(1.66)	1.43
Ieee Transactions on Nuclear Science	102(1.18)	1.42	Journal of Nuclear Science and Technology	238(1.41)	1.24
Nuclear Science and Engineering	76(0.88)	1.06	Radiation Protection Dosimetry	209(1.23)	0.83
Kerntechnik	73(0.84)	0.26	Fusion Science and Technology	202(1.19)	1.4
Nuclear Technology	67(0.77)	0.95	Science and Technology of Nuclear Installations	181(1.07)	1.08
Fusion Science and Technology	63(0.72)	1.4	Radiation Effects and Defects in Solids	164(0.97)	0.63
Journal Of Fusion Energy	48(0.55)	0.64	Radiochimica Acta	156(0.92)	1.33
Nuclear Materials and Energy	47(0.54)		International Journal of Radiation Biology	144(0.85)	2.26
Nuclear Engineering and Technology	41(0.47)	1.54	Nuclear Engineering and Technology	130(0.77)	1.54
Health Physics	35(0.40)	0.99	Nuclear Science and Engineering	128(0.75)	1.06

Table 12 shows the top 25 journals where the contributors from India and China published their research papers in nuclear science technology. It is found that Journal of Radioanalytical and Nuclear Chemistry gets the highest number of publications with 1293 records followed by Nuclear Instruments Methods in Physics Research Section B Beam Interactions with Materials and Atoms with 1096 records, Journal of Nuclear Materials with 642 records and followed by other sources.

In case of China, authors preferred to publish their articles in Nuclear Instruments Methods in Physics Research Section B Beam Interactions with Materials and Atoms with 1782 titles followed by Nuclear Instruments Methods in Physics Research Section A Accelerators Spectrometers Detectors and Associated Equipment with 1644 titles, Fusion Engineering and

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Design with 1468 titles, Journal of Nuclear Materials with 1463 titles and followed by other journals.

It is found that there are 21 journals are common in both the countries and it shows that these journals are core journal in the field of nuclear science technology. Top 10 journals of India contribute 75 % of the total output while 74% contributed by top ten journal of China. It is also found that all top 25 journals are published from foreign countries where the authors from India published their research papers while only one journal from China is in the list of top 25 journals of China. Impact factor varies from 0.26 to 3.34 for top 25 journals where the authors from India prefer to publish their paper while for China impact factor varies from 0.63 to 7.81.

## **Conclusion**

The present study mainly highlights the quantitative as well qualitative analysis of two Asian countries, India and China in the field of nuclear science and technology during the period 2000-2019. The major finding of the study showed that India published 8637 papers and China published 16879 papers. The highest numbers of papers published by the researcher of India in the year 2014 with 658 papers and China in the year 2019 with 2249 papers. The studies revealed that India leads China in terms of publication only in the year 2003 and 2006. India shows almost steady growth while China shows tremendous growth after 2012. In terms of average citation per paper, India leads China. The papers published from India and China received 95390 and 144182 citations. China ranks 9<sup>th</sup> in terms of collaboration with India while India ranks 11<sup>th</sup> with China and journal articles, proceeding papers and review are the most favourite mode of communication. In terms of funding agency, India is funded by 7 foreign agencies while China is funded by only one foreign agency within the top 15 funded agencies and it shows China is more reliable on self financed research in nuclear science and technology. There were 6 Indian papers and 10 Chinese papers, which got more than 300 citations. One paper from India has received a 12557 citation while China got the highest citation on single paper with 1182. The paper also revealed that both the countries had almost the same nature of citation distribution among papers and had a tendency to publish the paper in multi-authored rather than solo publication. It was also found that there were 115 numbers of titles where contributed by more than 1000 authors for both the countries. Bhabha Atomic Research Center and Chinese Academy of Sciences were the top institutions from India and China. Maharashtra contributed 45.27% of the total output in the field of nuclear science and technology.

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