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Published research documents in nuclear and high energy physics from 1996-2019: A bibliometric analysis of leading countries in comparison with India

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ABSTRACT

Abstract. A bibliometric analysis of scientific research production of top five most productive countries in comparison with India in nuclear and high energy physics is presented during the period 1996-2019 using Scopus-linked SCImago electronic database. To validate the present study, some selected bibliometric indicators such as published documents, their citations and citations per document has been studied. In total, 769180 research documents were published worldwide in journal, conference proceedings and in book series. United States (16.47%), Germany(8.64%), Japan (6.65%), China (6.41%) and Russian Federation (5.89%) were the top most productive countries rankwise, whereas India ranked 10th with 21157 research documents accounting for 2.75% of world share. The average normalized external citations magnitude varies between 7.4 (United States) and 1.2 (China), whereas, average normalized external citations per document magnitude varies only between 1.9 (United States) and 1.0 (India) indicating slightly improved performance of India. The overall scientific production output diminished year after year at world level except China (in document production) pointing towards shrink in research facilities along with more focus on applied rather than basic science research. India performed slightly better even after its least investment of % GDP (less than 1% from year 1996-2018) in research as compared to other leading counties. More research facilities along with enhancement in % GDP expenditure in basic research should be prioritize by Indian policy makers so as to increase publication count along with quality publications to improve its rank.

Keywords : Bibliometric, Nuclear physics research, High energy physics research, GDP, Scimago.

INTRODUCTION:

Nuclear and high energy physics research is mainly concerned with the structure of nuclei and understanding of their properties in detail (Alekseev et al. 2017; Bertulani and Hussein 2015). While high energy physics, also known as elementary particle physics deals with the interaction among nucleons and try to address the most fundamental question about the building blocks of the universe (Shipsey 2016). Further, these fields provide valuable information about the synthesis/ discovery of new isotopes/particles (Thoennessen 2013), formation of superheavy elements (Zhu et al. 2014) and quark-gluon plasma (Chen 2014). Due to extensive experimental and theoretical efforts at global level, a rich knowledge has been gathered over the above stated fields in the form of published research article either in journals, conference proceedings or books (SCImago 2020). As both fields are active since 1950, therefore it is difficult to compile the data in a single attempt. Therefore, lots of efforts have been made by many researchers to present and compile the scientific information related to these fields from time to time using different electronic databases. Example of bibliometric studies done in nuclear physics research are; the growth of the key words taken from the abstract, article as well as research title (Singh et al. 2019), analysis about organizations' publication (STFC 2017; Upadhye et al. 2010), research output performance at global level (Kumar 2016), authorship pattern (Jeyamala and Balasubramainan 2016), multi-institutional groups or collaborations of scientists (Pritychenko 2016) and increase in authorship of nuclear physics publications (Pritychenko 2015) during one or two decade.

Similar bibliometric studies were also carried out in high energy physics including the study on heavy flavour physics (Karaulova et al. 2020), theoretical high energy physics (Urrutia Sánchez et al. 2018), specific country output (Gonzalo et al. 2017; STFC 2017), the effect of high energy physics large collaboration at the country and institutional levels (Manganote et al 2016), pattern of Higgs boson literature (Teli and Maity 2015), the analysis of the origins or historical roots of the Higgs boson research (Barth et al, 2014), alternative communication strategies used in high energy physics research (Gentil-Beccot et al. 2010), geographical distribution areas of authors (Jan et al. 2007; Mele et al. 2006), impact on fields other than physics, and particularly on application-oriented Research and Development (R&D) (Davidse and Van Raan 1997) and experimental (Six and Bustamante 1996) high energy physics research.

The study of scientific literature is one of the important ways to track the activities in the field of science and technology which further helps the policy makers in designing new schemes to promote specific field of National/International interest. Scientific literature can be analysed by qualitative, quantitative and structural techniques (Durieux and Gevenois 2010; Mukherjee 2010a; Mukherjee 2010b). In quantitative technique (Mukherjee 2010a;), researcher focuses on number of publications or productivity of a particular researcher, group or journal. On the other hand, qualitative technique (Mukherjee 2010b) measures the impact or performance of a researcher, group or journal. The relationship among publications, authors and peer research groups can be studied through structural analysis.

Bibliometric is one of such technique used worldwide to analyse and measure the records of scientific production in particular field of interest. The use of bibliometric analysis increase the objectivity of, and confidence in evaluation of an individual, a research group/ an organization or country. These studies provides comprehensive information about the research productivity of any specific topic (Teli and Maity 2015; Six and Bustamante 1996), subject (Singh et al. 2019; Srivastav et al. 2019: STFC 2017; Jeyamala and Balasubramainan 2016; Kumar 2016) and research institute (Upadhye et al. 2010) at national as well as global level. Moreover, bibliometric is the tool to compare the scientific production of two or more countries in a particular field and this information is invaluable for the policy makers of any nation to bridge the gap of a particular subject (Srivastav et al. 2019; STFC 2017; Meo and Usmani 2014; Meo, et al. 2013; Junying et al. 2013, Reddy 2016). Meo et al.(Meo and Usmani 2014; Meo, et al. 2013) extensively studied the impact of R&D expenditure among European and Asian countries. They found a positive correlation between R&D expenditure and the number of published documents in various science disciplines in European countries (Meo and Usmani 2014). On contrary, Asian countries are not good in research due to low gross domestic product

(GDP) and less expenditure on the R&D activities (Watal and Raghavan 2019; Makkar 2015; Meo, et al. 2013) except China **(**Arana-Barbier 2020).

In the present work, we used total published data particularly in nuclear and high energy physics research since two decades, to improve the understanding on scientific impact and financial aspects underlying the basic research in leading countries in comparison with India. Further, a more deeper analysis were carried out on the basis of yearwise qualitative and quantitative publication output to check their current status.

MATERIALS AND METHODS

In the present study, data is compiled on the basis of information available on the official website of SCIMago through the link https://www.scimagojr.com (SCImago 2020). This database covers a wide variety of Journals in different subject areas at world level and is freely available for analysis.
In order to download the data, Physics and Astronomy was selected out of 27 different main fields. Further, nuclear and high energy physics was selected as sub-field out of 10 different sub-fields. For this purpose, top leading countries along with India is selected with publications in journals, book series, conferences & proceedings and trade journals from year 1996 to 2019. The top five most productive countries included are; United States, Germany, Japan, China and Russian Federation (SCImago 2020).
The downloaded data is mainly analysed on the bases of some important parameters like documents, their citations and citations per document in the normalized form. Some mathematical calculations were performed using MS Excel and graphs were plotted with the help of origin software version 6.0. The information about % age of GDP spent on R&D sector in India along with leading countries in this field were collected from world bank data (SCImago 2020; World Bank Data 2017-18; UNESCO 2019).

RESULTS & DISCUSSION

Trends of R&D expenditure in top twenty leading countries:

Investing in R&D is a driving force for maintaining growth momentum by increasing stock of knowledge in basic research (Watal and Raghavan 2019). Further, it plays critical role in economic development of every country (Greenstone 2011) and hence in achieving Sustainable Development Goals (SDGs) (UNESCO 2019). The expenditure in R&D is also defined by Organization for Economic Cooperation and Development (OECD) as "the money spent on creative work undertaken on a systematic basis to increase the stock of knowledge and the use of this knowledge to devise new applications" (OECD 2019). Globally R&D expenditure has been rising over the last decade (UNESCO 2019). In India, gross expenditure on R&D has shown a consistently increasing trend over the years, whereas, % of GDP expenditures on R&D remains between 0.6-0.7 % of GDP over the past two decades which is far below the expenditure of that in the US (2.84%), Germany (3.09%), Japan (3.26%), China (2.19%) in year 2018 (Watal and Raghavan 2019; World Bank Data 2017-18; UNESCO 2019).
The research productivity of any particular country can be influenced by available research facilities, research environment and most importantly financial assistance. It is clear from table 1 that GDP of top 20 countries is increasing year after year (except Brazil) and accordingly the %

of GDP expenditure in R&D is also increasing except, Russian Federation, France, India, Canada and Sweden. The South Korea topped with 4.81% and Ukraine invested lowest of 0.47%, whereas, India invested only 0.65% irrespective of its 2.713 GDP achieved in Year 2018 (World Bank Data 2017-18). The percentage change was reported maximum in case of China (291.07%) and least in case of Ukraine (-60.50%), whereas in case of India it is just 1.56%.

Table 1. Comparison of top twenty countries in nuclear and particle physics research in terms of GDP and % of GDP expenditure in R & D in the year 1996 and 2018 only.

Countries	GDP (US$) (Trillions) (1996)[1]	GDP (US$) (Trillions) (2018)[1]	R& D Expenditure (% of GDP) (1996) [1]	R& D Expenditure (% of GDP) (2018) [1]	% increase/ decrease in R&D Expenditure
United State	8.073	20.580	2.45	2.84	15.92
Germany	2.50	3.949	2.14	3.09	44.39
Japan	4.83	4.975	2.69	3.26	21.19
China	0.864	13.894	0.56	2.19	291.07
Russian Federation	0.392	1.669	0.97	0.99	2.06
Italy	1.31	2.085	0.95	1.40	47.37
France	1.61	2.788	2.22	2.20	-0.90
United Kingdom	1.42	2.860	1.59	1.72	8.18
Switzerland	0.33	0.705	2.45	3.37 (2017)	37.55
India	0.393	2.713	0.64	0.65	1.56
Spain	0.643	1.419	0.79	1.24	56.96
Canada	0.629	1.716	1.61	1.57	-2.48
South Korea	0.61	1.72	2.26	4.81	112.83
Poland	0.16	0.587	0.64	1.21	89.06
Brazil	0.85	1.885	1.05 (2000)	1.26 (2017)	20.00
Netherland	0.45	0.914	1.84	2.16	17.39
Sweden	0.292	0.555	3.31 (1997)	3.34	0.91
Belgium	0.279	0.543	1.73	2.82	63.01
Ukraine	0.045	0.131	1.19 (1997)	0.47	-60.50
Australia	0.40	1.43	1.67	1.87 (2017)	11.98

[1]Source:World Bank Data (World Bank Data 2017-18; UNESCO 2019).

Several researchers have established a direct linkage between R&D investment and national innovation (Meo and Usmani 2014: Meo, et al. 2013; Brian and Lefgren 2011). More investment on R&D results in increased number as well as quality of research publications which further gives boost to high technology exports and ultimately increases in GDP of any nation. In India, expenditure on R&D is undertaken primarily by government funded institutes or universities ($ 3,255.4M) (UNESCO 2019), whereas the private and nonprofit institutions have no share and hence are lack in research facilities to carry forward research work for addressing problems of national/international importance (Watal and Raghavan 2019). The reverse is the story in advanced countries. Also the number of researchers per million inhabitants are maximum in Japan (5328) followed by Germany(4320), United States (4205), Russian Federation (3075), China (1081) and India have only 156 irrespective of approximate 138M population (UNESCO 2019).

Research output of top twenty countries of the world :

As per SCIMago Journal and country Ranking (SCImago 2020), United States ranked first followed by Germany, Japan, China, Russian Federation and India ranked 10th in global nuclear and high energy physics research publication output out of 156 countries contributed in this field since 1996.

Out of them, only top 20 countries are tabulated in table 1 along with their total scientific production output in nuclear and high energy physics research from 1996-2019. The important bibliometric analysis parameter listed in table are published documents, their external/self-citations and external/self-citations per document along with H-index. The normalized value calculated in reference to India are also listed in parenthesis to make comparison more significant one.

Table 2. The rankwise research output of first top twenty countries of the world in the field of nuclear and high energy physics from 1996-2019 (SCImago 2020).

Country	Region	Documents	External citations	Self-citations	External citations/ doc	Self-citations /doc	H-index
United States	Northern America	126702 (6.0)*	1711085 (6.4)*	1338390 (12.3)*	13.50 (1.1)*	10.56 (2.0)*	425 (2.5)*
Germany	Western Europe	66483 (3.1)	954649 (3.6)	544967 (5.0)	14.36 (1.1)	8.20 (1.6)	304 (1.8)
Japan	Asiatic Region	51183 (2.4)	589695 (2.2)	297510 (2.7)	11.52 (0.9)	5.81 (1.1)	238 (1.4)
China	Asiatic Region	49342 (2.3)	307272 (1.1)	249246 (2.3)	6.23 (0.5)	5.05 (1.0)	188 (1.1)
Russian Federation	Eastern Europe	45335 (2.1)	552290 (2.1)	248921 (2.3)	12.18 (1.0)	5.49 (1.1)	246 (1.5)
Italy	Western Europe	43251 (2.0)	628495 (2.4)	283991 (2.6)	14.53 (1.1)	6.57 (1.3)	256 (1.5)
France	Western Europe	39786 (1.9)	689453 (2.6)	248513 (2.3)	17.33 (1.4)	6.25 (1.2)	257 (1.5)
United Kingdom	Western Europe	36347 (1.7)	677877 (2.5)	242589 (2.2)	18.65 (1.5)	6.67 (1.3)	266 (1.6)
Switzerland	Western Europe	26354 (1.2)	547214 (2.0)	162610 (1.5)	20.76 (1.6)	6.17 (1.2)	264 (1.6)
India	Asiatic Region	21157 (1.0)	267333 (1.0)	109107 (1.0)	12.64 (1.0)	5.16 (1.0)	167 (1.0)
Spain	Western	20519	411456	131642	20.1	6.4	214

	Europe	(1.0)	(1.5)	(1.2)	(1.6)	(1.2)	(1.3)
Canada	Northern America	16175 (0.8)	362398 (1.4)	73119 (0.7)	22.4 (1.8)	4.5 (0.9)	199 (1.2)
South Korea	Asiatic Region	15101 (0.7)	240511 (0.9)	61502 (0.6)	15.9 (1.3)	4.1 (0.8)	157 (0.9)
Poland	Eastern Europe	14863 (0.7)	259024 (1.0)	81320 (0.7)	17.4 (1.4)	5.5 (1.1)	198 (1.2)
Brazil	Latin America	12628 (0.6)	175114 (0.7)	69294 (0.6)	13.9 (1.1)	5.5 (1.1)	146 (0.9)
Netherlands	Western Europe	10598 (0.5)	269195 (1.0)	46594 (0.4)	25.4 (2.0)	4.4 (0.8)	184 (1.1)
Sweden	Western Europe	9793 (0.5)	214193 (0.8)	40769 (0.4)	21.9 (1.7)	4.2 (0.8)	159 (1.0)
Belgium	Western Europe	9593 (0.5)	195180 (0.7)	41652 (0.4)	20.3 (1.6)	4.3 (0.8)	149 (0.9)
Ukraine	Eastern Europe	8415 (0.4)	75459 (0.3)	23396 (0.2)	9.0 (0.7)	2.8 (0.5)	109 (0.7)
Australia	Pacific Region	7069 (0.3)	142259 (0.5)	30763 (0.3)	20.1 (1.6)	4.4 (0.8)	124 (0.7)
Rest of World		138486	2889628	576323			
Total		769180	12159780	4902218			

*****(Normalized to the India)

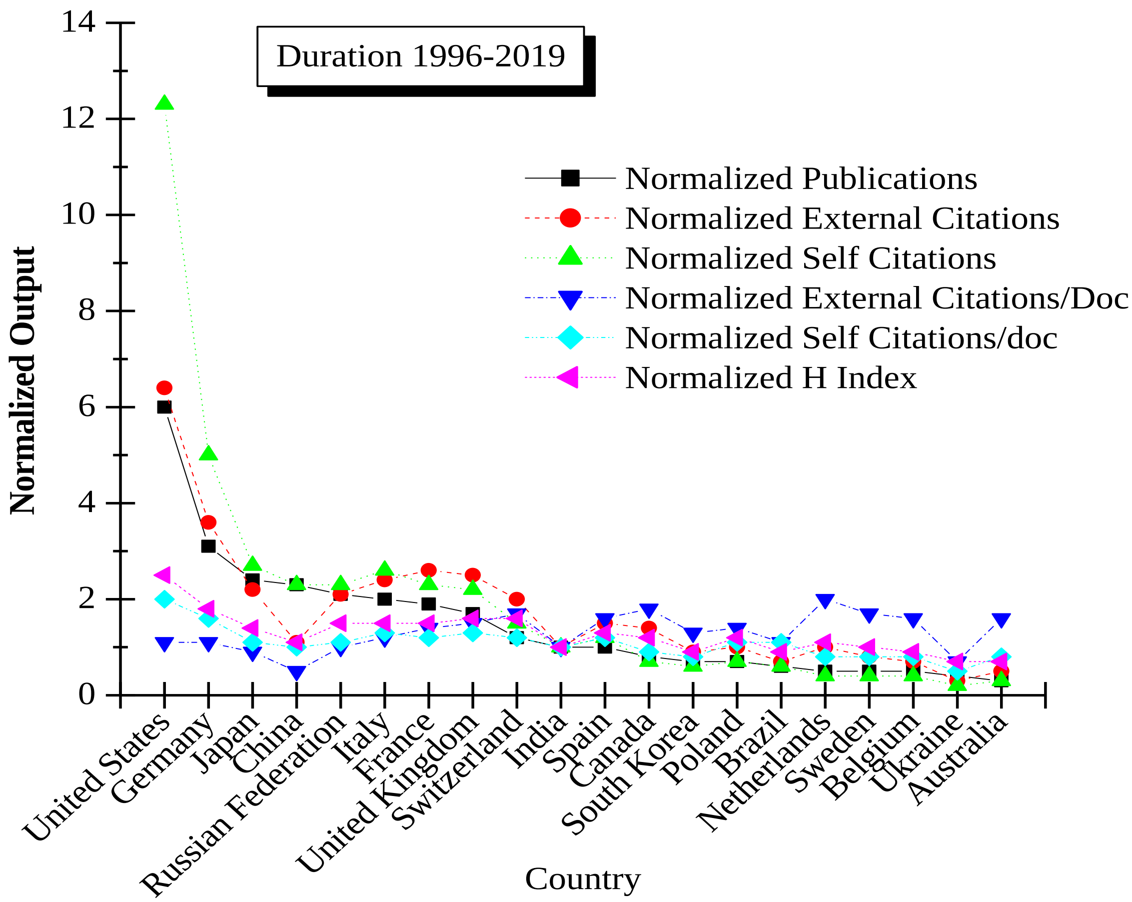

Figure.1 Normalized publication output of top twenty countries in nuclear and high energy physics research from 1996-2019.

The rankwise total normalized research production output in comparison with India of first top twenty countries of the world in the field of nuclear and high energy physics from 1996-2019 is presented in figure 1. The United States occupies the first position with maximum publications of 126702 and share of 16.47% followed by Germany (8.64%), Japan (6.65%), China (6.41%), Russian Federation (5.89%), Italy (5.62%), France (5.17%), United Kingdom (4.73%), Switzerland (3.43%), India (2.75%), Spain (2.67%), Canada (2.10%), South Korea (1.96%), Poland (1.93%), Brazil (1.64%), Netherland (1.38%), Sweden (1.27%), Belgium (1.25%), Ukraine (1.09%), Australia (0.92%) and remaining countries accounting for about 18% of published output during this study period. Based on the above facts, the percentage change in document production of India is very far from major players like the United States (498.9%), Germany (214.2%), Japan (142%), China (133.2%), Russian Federation (114.3%) and Italy (104.4%). One of the reason of better research publications from countries like, the United States Germany, Japan, Russian Federation and Italy is that they have English as native language and hence a research paper have greater chance of acceptance in Scopus indexed Journal (Sweileh et al. 2018). Apart from this reason, the sum of publications count in nuclear and high energy physics research may depend on the availability of research facilities. According to Nature Index

(NI 2019), the top institutions for theoretical and experimental research related to this field that are justifiable to the scientific community and research journal belongs to leading countries such as, United States (S-U, FermiLab, Caltech, MIT, LBNL, UC Berkeley, NASA, BNL, UW-Madison), Germany (HAGRC,MPS), Japan (U-T, HEARO), China (CAS), Russia (NRCKI, RAS, JINR), Italy (INFN, INAF), France (CEA, LAL, CPPM, LPNHE, LAPP, LPC)**,** United Kingdom **(**UoO, ICL, UoC, UoM, UoG, STFC),Switzerland (CERN, PSI, UZH) with sophisticated research facilities, whereas, very few belongs to India (HBNI, TIFR, IITs) (NI 2019).

In case of normalized citations (external/self) i.e., another bibliometric indicator, the United States again topped with normalized magnitude (6.4/12.3) followed by Germany (3.6/5.0), Japan (2.2/2.7), China (1.1/2.3), Russian Federation (2.1/2.3), Italy (2.4/2.6), France (2.6/2.3), United Kingdom (2.5/2.2), Switzerland (2.0/1.5), and least for Ukriane (0.3/02). Surprisingly, the normalized magnitude of self citations comes out to be more than external citations for many countries like the United States, Germany, Japan, China, Russian Federation, Italy which are already leading in document production. This clearly indicates that researchers from these nations cite more of their own work which is quite obvious because origin of most of research problems first start from research laboratories available there. This could be the one of the possible reason of large publications, their citations and hence H-index (Bartneck and Kokkelmans 2011) whereas Indian researchers cite more of foreign work resulting in its low rank and H-index. Out of top twenty countries, Spain (1.5/1.2) and Canada (1.4/0.7) have also higher normalized external citations index irrespective of their lower rank as compared with India. This further indicate that the quality of research article cannot be judged simply based on the high citation count presumably because of huge amount of self-citations declines the effectiveness of research work.

Lastly the citation impact was analyzed with the help of important bibliometric indictor; citations (external only) per document. In this case the maximum calculated normalized external citations per document magnitude cones out to 2.0 corresponding to Netherlands followed by 1.8 (Canada), 1.7 (Switzerland & Sweden), 1.6 (Spain, Belgium & Australia), 1.5 (United Kingdom), 1.4 (France & Poland), 1.3 (South Korea), 1.2 (Italy), 1.1 (United States, Germany, Brazil), 1.0 (Russian Federation) and below one for Japan (0.9), Ukraine (0.7) and China (0.5). Surprisingly, the lower impact of research work from many leading countries clearly indicates the decline in quality of their published work irrespective of quantitative document production and hence higher rank. Therefore, researchers from counties like Netherland, Canada, Sweden, Spain, Belgium, Australia and Poland published qualitative work irrespective of their lower rank in quantitative research aspects.

Research output of top five most productive countries of the world:

Now, it is interesting to analyze year wise research output trend of countries to see more in-depth view in comparison with India. To analyze year wise scientific production output, only top five most productive countries were selected and compared. In figure 2, the normalized published documents calculated using the Σ document (country/year selected)/ Σ document (India) for top five countries year wise in nuclear and high energy physics from 1996-2019 in comparison with India are plotted. If we see the normalized publications year wise then the Unites States is at top throughout the period of study as compared to other countries irrespective of fluctuations in the field at global level. From 1996 to 2007, the performance of the Unites States is remarkable in comparison with other countries. During 2008-2019, the document performance is continually decreasing due to the fact that India's performance improved. To check annual corresponding growth (ACG%) of each country, the following equation (Singh & Pandita 2018) is used.

$$\text{ACG}\left(\%\right)=\frac{\text{end value}-\text{first value}}{\text{first value}}\times 100 \quad (1)$$

Where 'end value' represents the entries in the year for which ACG (%) calculated and 'first value' correspond to entries in the preceding year. During 1996-2019, the average ACG (%) comes out to be 0.52% (Unites States), 1.01% (Germany), 1.27% (Japan), 10.41% (China), 0.91% (Russian Federation) and 5.79% (India). It is surprising to see the performance of China (inverted triangle symbol); in the year 1996, it published only 499 documents and it was at ninth position, whereas; in year 2014, it published 3499 (approx seven time or 601.2% increase) and reached second position and continued with same, following the United States. It is due to the fact that China is investing more to upgrade Chinese science education and in improving Chinese scientific capability with an intention to narrow the gap between itself and United States (Fu et al. 2013). In order to understand China's publications activities further, some special programmes such as the Changjiang Scholar Programme and the Thousand Talent Programme to attract particularly China born scientist working in United States so as to come back to work in China on temporary or permanent basis were also started (Xie 2014). At the same time, they boost their % of GDP expenditure on R&D from 0.56% in 1996 to 2.18% in 2018 with a projection of 2.5% by 2020 (Du 2018). On to the other hand, India showed slight improvement from rank 12 in year 1996 to rank seven in year 2016 in document publication and in 2018 at 9th position in this field (SCImago 2020), irrespective of its stagnant investment between 0.6-0.7% of GDP in R&D (Watal and Raghavan 2019). This indicates that developing countries are performing better in publication output as compare to developed countries (White et al. 2017).

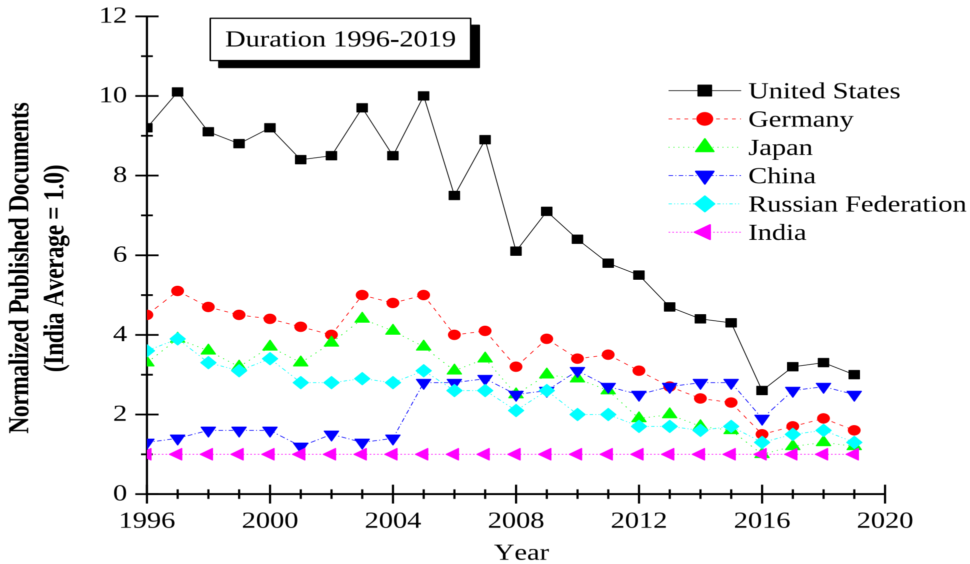

Figure.2 Normalized published documents of top five most productive countries in comparison to India in nuclear and high energy physics research from 1996-2019.

Once the document gets published, citation count starts accumulating when they are referred by more recent publications. The citation count reflects the value placed on a research work by later researchers. Some of the research papers get cited quite frequently and other remain uncited even after long time of their publication. Highly cited research work is recognized worldwide and have a greater impact in qualitative evaluation of the performance of an individual/group or organization (Nederhof et al. 1993). Indeed, the number of citations of a research paper in a journal is influenced by factors such as; journal outlook, journal subscription, open access, speed in publishing, progress and level of interest in research field (Bernius,2010).
A more in-depth view of scientific impact can be judged by calculating that how many times a research document is cited by another researcher. Figure 3 shows a comparative view of normalized external citations calculated using the Σ external citation (country selected)/ Σ external citation (India) in the selected year from 1996-2019 in the field nuclear and high energy physics research for the top five most productive counties.

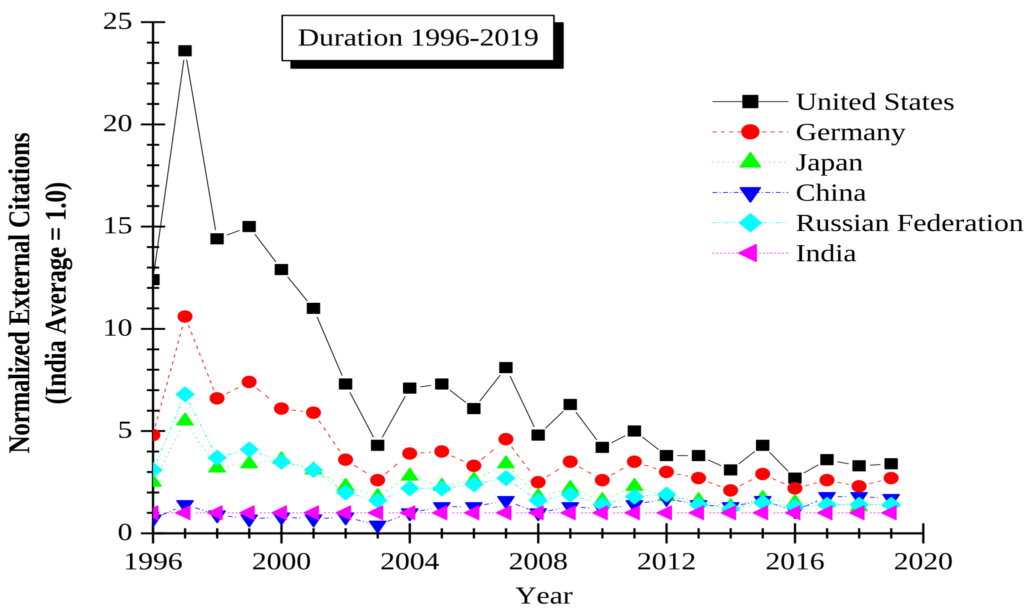

Figure.3 Normalized external citations of top five most productive countries in comparison to India in nuclear and high energy physics research from 1996-2019.

From the figure, it is clear that out of top five countries, the external citations of United States is relatively at top throughout the study period irrespective of continuous fluctuations or change. This change in average citations of any research document over the year may be termed as ‘citation dynamics’ (Durieux and Gevenois 2010; Mori and Nakayama 2013). Almost all countries have the highest normalized external citation value in 1997. Surprisingly, China is either on line with India or below irrespective of its higher rank in document production. During the study period, the average normalized external citations values are 7.4 (United States), 4.0 (Germany), 2.4 (Japan), 2.3 (Russia Federation) and 1.2 (China) with maximum magnitude 23.6 corresponding to United States in Year 1997 and minimum 0.4 corresponding to China in Year 2003. It is interested to note that initially, the magnitude of external citations is more than five, for the United States and Germany, whereas in the recent time 2017 onwards, it reduced to below 4 even for United States and other leading countries indicating improvement in India's performance at world level. It is important to note that it takes time for a research paper to accrue citations. For example papers published in year 2019, for instance with citation count to the end of year 2019, they only have less than a year to accrue any citations; half the papers will have less than six months. This is not usually a problem with papers published over longer time period but make difficult to analyze recent papers because citation count naturally grow over time. Citation count also depends on the 'citation window' which refer the number of years after publication during which citations were counted (Durieux and Gevenois 2010). Therefore, Wang introduced the concept of three-year citation window means the number of citations received during the first three year after publication date are counted along with the year of publication (Wang 2013).

Sometime in a research work, a continuation of previous studies is required then author cites his own research papers and this is quite obvious. It is known as self-referencing. On the other hand, self-citations demonstrate the impact of work upon the scientific community" (Szomszor et al. 2020; Sugimoto & Larivière 2018). However, in fact, there is a limit of self-citation. Although self-citation is a trend prevalent among authors across disciplines, the practice is still more prevalent amongst researchers from pure and applied sciences than social and humanistic sciences. It is a proven fact that self-citations help to increase h-index and Impact factor of Journals and authors (Rad 2012).

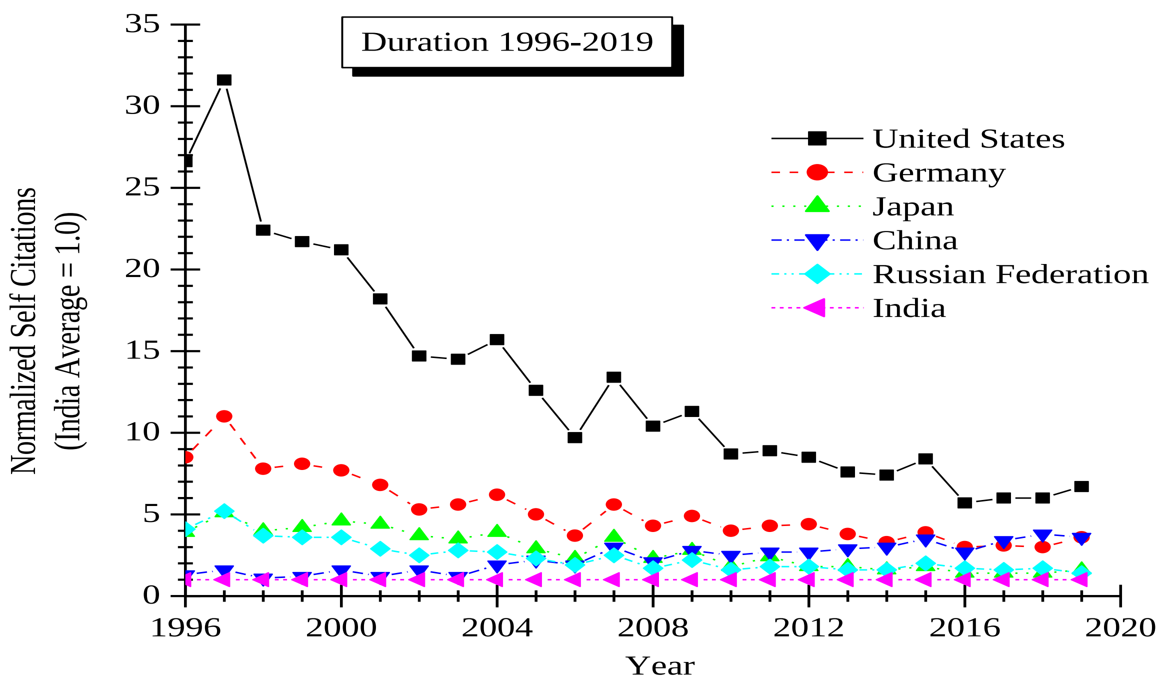

Figure 4. Normalized self citations of top five most productive countries in comparison to India in nuclear and high energy physics research from 1996-2019.

In figure 4, comparative view of normalized self-citations calculated using the Σ self-citation (country selected)/ Σ self-citation (India) versus year is presented for the top five most productive countries from 1996-2019 in the field nuclear and high energy physics research in comparison with India. From the figure, it can be seen that United States toped in self-citations and magnitude even more than external-citations (see figure 3) and is decreasing year wise (except China). It is a proven fact that self-citations rises with number of authors on a publication, as is also seen for citation impact and over time an author's self-citation rates tends to decline (Szomszor et al. 2020). The average normalized self-citations magnitude respectively for United States, Germany, Japan, Russia Federation and China, are 13.3, 5.3, 2.8, 2.4 and 2.3. This indicates that the Indian researchers generally cites more research papers of foreign researchers rather than Indian researcher, whereas, researchers from the United States, Germany, China and Russia Federation are citing more of their own research work hence have greater magnitude.

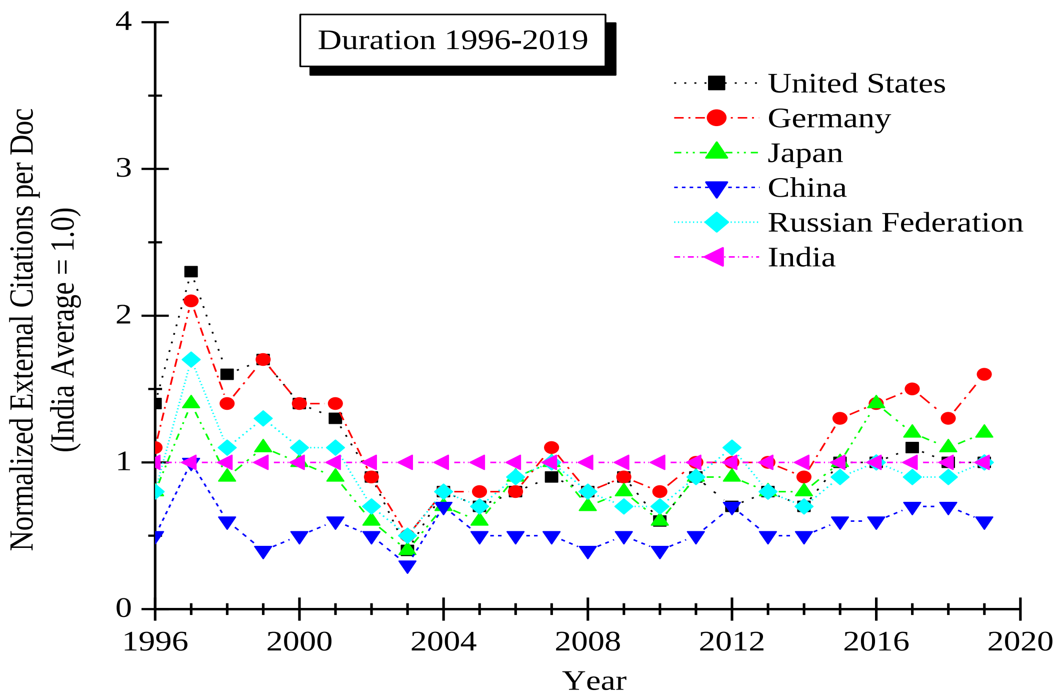

Figure 5. Normalized external citations per document of top five most productive countries in comparison to India in nuclear and high energy physics research from 1996-2019.

To access the scientific impact, it is important to study the citations count per document of published documents. Further it is important since it denotes impact factor (Cobo et al 2015).

Figure 5 shows a comparative view of normalized external citations per document for the above mentioned top five most productive counties of the world during the period 1996-2019 in the field of nuclear and high energy physics research in comparison with India. It can be observed from the figure, the average magnitude of normalized external citations per document is around at 1.0 for countries like Germany, United States and Japan, whereas in case of China and Russia Federation its value is below 1.0 indicating good impact of Indian research at world level. Furthermore, China never led the external citation per paper magnitude for nuclear and high energy physics research among the 24 years time frame studied regardless it becomes the main scientific paper publisher in Asia nowadays.

Similarly, normalized self-citations per document for the above mentioned top five most productive counties of the world during the period 1996-2019 in the field nuclear and high energy physics research in comparison with India is also presented in figure 6. The average magnitude of normalized self-citations per document is maximum for USA (1.9) followed by Germany (1.5) whereas China, Japan and Russia Federation are closer to that of India (1.0).

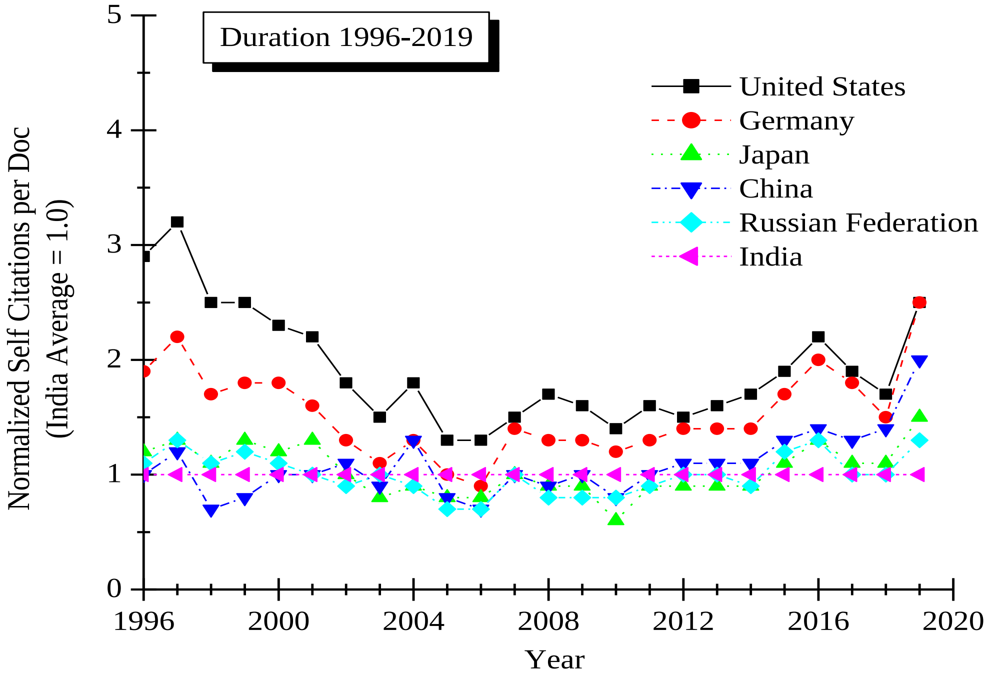

Figure 6. Normalized self citations per document of top five most productive countries in comparison to India in nuclear and high energy physics research from 1996-2019.

From the above discussion it has been observed that the United States topped in document production, their external citations and self citations also, whereas, in case of citation impact i.e. citations per document its performance is closer to India (1.0). Other countries like Germany, Japan and Russian Federation follow more or less similar trend with relatively lesser magnitude. Whereas, the performance of China in document production and self citations is increased abruptly since last decade. The best performance of United States in document production may be due to the fact that most of the journals, conference proceedings and book series available on SCImago website belongs to it (see table 3). In recent time, both the volume and the quality of papers published by the top five most productive countries have been decreased year after year (except China) in this field. On the other hand, the performance of India in research publication is improving year after year irrespective of very few journals belongs to India are either SCI or Scopus indexed (see table 3).

Table 3. Number of journals, conference and proceedings and book series published by top five most productive countries of the world in comparison with India in the field of nuclear and high energy physics from 1996-2019 (SCImago 2020).

Year	United States	Germany	Japan	China	Russian Federation	India

2019	36(15+18+3)*	2(2+0+0)	0(0+0+0)	5(5+0+0)	7(7+0+0)	0
2018	43(16+24+3)	2(2+0+0)	1(0+1+0)	6(5+1+0)	7(7+0+0)	0
2017	50(16+32+2)	2(2+0+0)	3(0+3+0)	6(5+1+0)	7(7+0+0)	0
2016	50(16+32+2)	2(2+0+0)	3(0+3+0)	6(5+1+0)	7(7+0+0)	0
2015	43(15+26+2)	2(2+0+0)	3(0+3+0)	7(5+2+0)	6(6+0+0)	0
2014	47(15+30+2)	3(2+1+0)	2(0+2+0)	7(5+2+0)	5(5+0+0)	0
2013	43(14+27+2)	6(4+2+0)	1(0+1+0)	7(5+2+0)	5(5+0+0)	0
2012	47(14+31+2)	7(5+2+0)	1(0+1+0)	7(5+2+0)	6(5+1+0)	0
2011	50(14+34+2)	11(2+9+0)	2(1+1+0)	6(5+1+0)	6(4+2+0)	0
2010	50(13+35+2)	13(2+10+1)	2(1+1+0)	6(6+0+0)	6(4+2+0)	0
2009	50(13+35+2)	13(2+10+1)	1(1+0+0)	6(6+0+0)	6(4+2+0)	0
2008	50(13+35+2)	13(2+10+1)	2(1+1+0)	6(6+0+0)	6(5+1+0)	1(0+1+0)
2007	42(13+27+2)	10(2+6+2)	2(1+1+0)	6(6+0+0)	5(5+0+0)	1(0+1+0)
2006	30(13+15+2)	7(2+4+1)	2(1+1+0)	6(6+0+0)	5(5+0+0)	1(0+1+0)
2005	29(13+14+2)	3(2+1+0)	2(1+1+0)	6(6+0+0)	3(3+0+0)	1(0+1+0)
2004	21(13+6+2)	2(2+0+0)	1(1+0+0)	6(6+0+0)	2(2+0+0)	0
2003	22(13+7+2)	2(2+0+0)	1(1+0+0)	6(6+0+0)	2(2+0+0)	0
2002	22(13+7+2)	2(2+0+0)	1(1+0+0)	6(6+0+0)	2(2+0+0)	0
2001	19(13+4+2)	2(2+0+0)	1(1+0+0)	6(6+0+0)	2(2+0+0)	0
2000	18(12+4+2)	3(3+0+0)	1(1+0+0)	5(5+0+0)	2(2+0+0)	0
1999	16(12+1+3)	3(3+0+0)	0(0+0+0)	5(5+0+0)	2(2+0+0)	0

* Total (Including journal + conference and proceedings + book series)

Reddy et al. (Reddy 2016) highlighted several factors that influence the performance of high impact research viz. individual, university and country-specific factors. One of the reasons of recent decline in research in the field of nuclear and high energy physics may be due to the fact that some of the countries have reduced the research grant in basic research (Kwon 2017; Mervis 2017; Kumar 2017) and they focus more on applied research (NSF 2018). Also many research facilities are either shut down or converted for different needs (Pritychenko 2015).

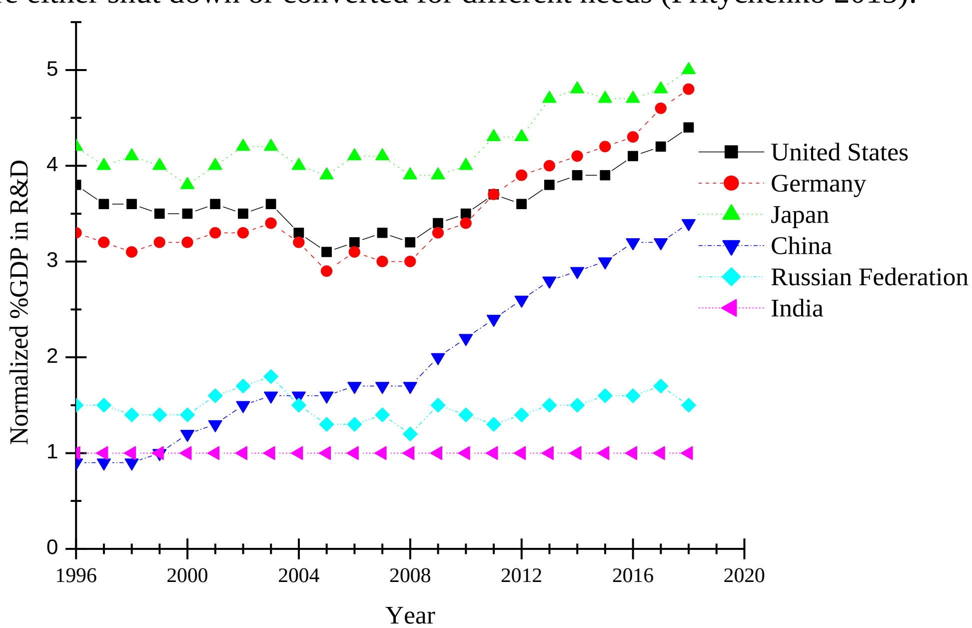

Figure 7.: Normalized % GDP expenditure in R&D by top five most productive countries in comparison to India from 1996-2019.

Lastly we highlighted the normalized % GDP expenditure in R&D by top most productive countries normalized with India and is plotted in figure 7. This is again the same situation presented graphically that table 1 showed except here considered all data available ((World Bank Data 2017-18; UNESCO 2019)) to synchronize with present study. From the figure it is clear that the United States, Germany, and Japan invested huge amount in R&D right from the beginning of study period. While India was ahead of China in the initial years, China increased its R&D investment abruptly during last decade and tried to follow the trends of above nations to minimize the research gap and has raced ahead of India. On the other hand, India investment is stagnant in R&D during study period 1996 to 2019. Therefore, in order to minimize the research gap, the % GDP invested in R&D must be increased to a reasonable percent just like in leading counties. This facts can be visualized with the help of figure 8, in which % change in published documents, their citations(external/self) and citations/doc along with %GDP in R&D by top five most productive countries in comparison to India during starting year 1996 & last year 2019 was plotted. The recent decline stated above is clearly visible from this graph as % change is towards negative side in case of citations and citations/documents. Only China showed remarkable performance in document producttion just due the corresponding increase in %GDP in research, irrespective of its citation impact. Further it can be pointed out that volumetrically China produced maximum documents after the United States, but results obtained regarding external citations and external citations per document not reflect a relevant level of trust from the scientific community. The similar findings were presented in a recent study (Arana-Barbier 2020).

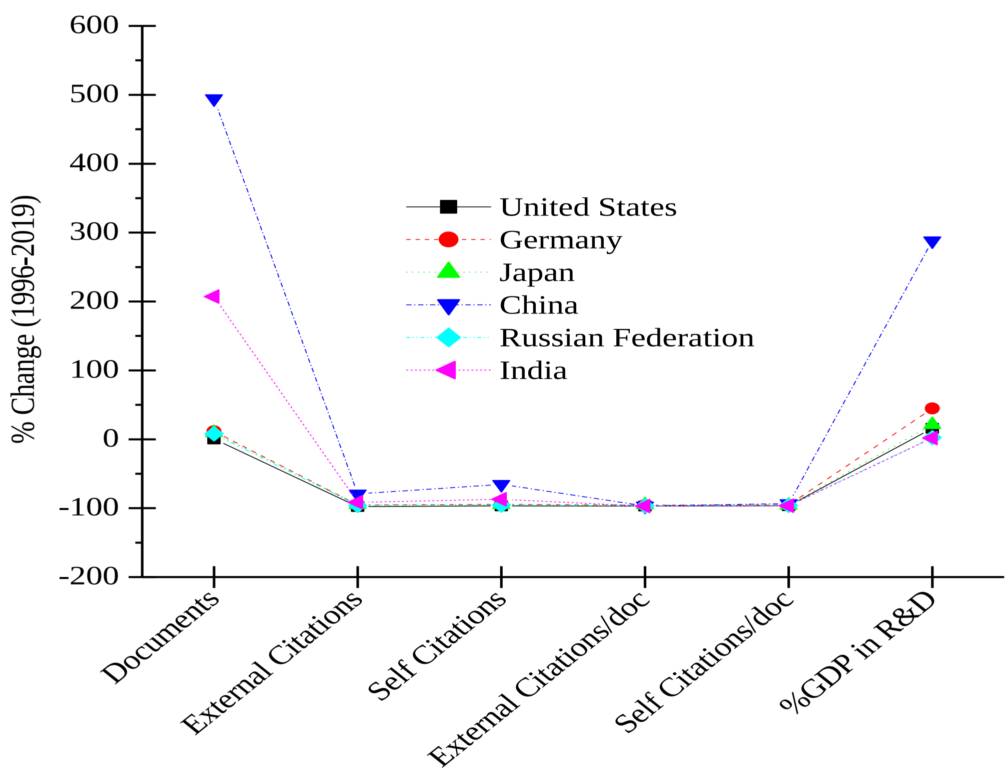

Figure 8.: The % change in published documents, their citations(external/self) and citations/doc along with %GDP in R&D by top five most productive countries in comparison to India during starting year 1996 & 2019.

Further, nuclear and high energy physics is a synergetic field and its theories and concepts find a natural application in other fields (Alekseev et al 2017; Shipsey 2016; Bertulani and Hussein 2015). Therefore, to achieve excellence in both qualitative and quantitative research at world level, India need to enhancement the percent of GDP expenditure for basic research. Also more work is required in the direction to improve its capability in terms of theory and experiments and train young researchers working in different government and private universities/institutions.

CONCLUSIONS AND LIMITATIONS

This paper presents the bibliometric analysis of research output in nuclear and high energy physics, one of the important discipline of physical science. First, an overview of top twenty most productive countries scientific production output along with their % GDP expenditure in R&D in the year 2017-18 was presented. Second, the top five most productive countries i.e., United States, Germany, Japan, China and Russian Federation along with India on the basic of bibliometric indicators; published documents, their external/self citations and external/self citations per document from 1996 to 2019 were analysed in detail. Based on the data retrieved from SCImago, in total 769180 research documents were published with an average of 32049 per year. United States topped with 16.47% share followed by Germany (8.64%), Japan (6.65%), China (6.41%), Russian Federation (5.89%) and India's is at 10th position with 2.76% of world share in document production which is relatively less as Indian higher education system is the third-largest after the United States and China. During starting study period, the magnitude of external citations is more than five, for the United States and Germany, whereas, in recent years it is below five indicating some improvement in India's performance. Citation impact of most productive countries was closer to that of India except China. Some countries reduced budget in basic science and focus more on applied research. Finally in spite of the different strategies applied among the top leading countries studied along with India, still their document publication and their citations impact have dwindling day by day and become more challenging to bring back on track. Although SCImago is a very reliable database for the published scientific literature, this could not exclude the possibility of unexpected errors arising from different referencing and citation styles in different journals through database selection which could be a limitation of this paper. Conclusively, as India emerges as one of the world's largest economies, it needs to gradually move from being a net consumer of knowledge to becoming a net producer. This could be only possible if publishing more with Indian journals and hence improving their quality at international level along with enhancement in % of GDP expenditure for basic research and number of scientists because it creates new knowledge that fuels technological advances to achieve SDGs (UNESCO 2019).

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