SILVER LININGS IN INDIAN RESEARCH FUNDING SCENARIO: A STUDY OF SCIENTOMETRICS DIMENSIONS OF RESEARCH FUNDED BY DEPARTMENT OF ATOMIC ENERGY DURING 2003-2017

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The aim of the present study is to conduct quantitative and qualitative analysis of research performed in institutes supported by the Department of Atomic Energy (DAE), Government of India. Articles from the Scopus database were searched and identified where funding source was acknowledged as DAE. Around 8240 articles were retrieved. The study revealed the exponential growth in immediacy index in the research, funded by DAE, indicating the trendiness in research with cited to uncited articles ratio of 12.55:1. Leimkuhlar model of Bradford's distribution yielded 26 core journals where 25.13% of the published articles were distributed. India has a strong collaboration with USA, China, Germany and Russia in the research activity funded by DAE. The analysis also found that DAE is providing ample funding for research under the areas of Biochemistry, Biology, Medicine, Spectroscopy and particle property studies in the selected time period i.e. 2003-2017. DAE being a premier government research funding organization in India, the outcome of the study may helpful to the government and policy makers of DAE for deciding their future course of action in providing budgets for research.

Keywords: Scientometrics, Research Funding, Keyword Analysis, Bradford's Law, Science Mapping, Leimkuhlar model

INTRODUCTION

Economic development of a country is always correlated to the Research and Development (R&D) spending of the country (Smith, 1776). Tuna, Kayacan & Bektaş (2015) have found positive relationship of high R&D expenditure with high economic growth figures for the developed and mid income countries. The signatory countries of the SDG of UN have made a pledge to increase the number of researchers & their percent share of R&D spending based on their respective Gross Domestic Product (GDP). Institute of Statistics (2019) reveals that amongst the current total global R&D spending of $1.7 Trillion, 10 countries almost account for 80% of it. The data is not that encouraging, as regions like Central Asia,

Sub-Saharan Africa, Arab states still have R&D spending share below 0.5% of their GDP, while regions like North America and Western Europe, East Asia & Pacific region have R&D spending near and above 2% of their GDP. The lack of equality in this Gross Expenditure on R&D (GERD) across countries is a challenge for SDG-2030 goals and UN is giving much emphasis to reduce this GAP.

Major share of funding in India is led by Govt. sources only & Private funding is mostly by the large Indian pharmaceutical companies. Ministry of Science and Technology is the main agency to distribute research grants in India, which further releases funds to DST, DBT, DAE, ICSSR, UGC, Earth Sciences etc. According to Economic Survey (Ministry of Finance, 2018) of 2017-18, three fifths of India's public research funding is spread among Atomic Energy, Space, Earth Sciences, Science & Technology and Biotechnology departments. These organizations then spend those fund in different mission oriented research supporting various Govt. policies and also provides fund to different organizations like universities, colleges and specific public research institutions.

REVIEW OF LITERATURE

From the literature review it is noticed that Scientometrics tools are generally been used by R & D funding institutions to evaluate their allocation of funds used for research and policy making and managing scope for future research. The domain of scientometrics had actually got major push during the peace time after World War II as governments wanted (Bellis, 2009) to have "efficiently organized scientific and technological information system for better economic growth" and for that, precise R&D funding was necessity that gives good return on investment. Evaluative bibliometric and the multidimensional works (Kalita, Deka & Hazarika, 2019; Sudarsana and Sai Baba, 2019) under it helps policy makers to track different facets of research like what is the research output, the trend of research over time, compare the local findings with the global trend, institutional performance of funded research and many more. Such key inputs are much needed in policy making and planning for better finish of coordinated mission oriented plans. Private funded research is mostly market driven, but for public funded research competitive grant proposals, quality rating of scientific results and regular progressive assessment of organizations are very much important (Kalachikhin, 2019). Kalachikhin (2018) has proposed a state of art architecture based some specific key scientometrics points that can be used for evaluation by R&D funding institutions. Wang, He & Peng (2014) reported about such endeavors by different nations of the world. Since the addition of "funded publication search" feature by Web of science in 2009, there have been studies at various levels that evaluate research funded by specific institutions and organizations. Yang *et al.* (2013) studied for the presence of any racial biasness in US National Institute of Health funded research, concluding it to be a fair and equal process for all, contra-dictating with the study of Ginther *et al.* (2011). Yu *et al*. (2017) made analysis of NSFC-Guangdong Joint Fund, finding it useful for regional co-operation building among the

research community. Ebadi and Schiffauerova (2015) studied 15 years' data of NSERC (Natural Sciences and Engineering Research Council of Canada) funded researchers, and concluded that the funding is actually helping scientists to build collaboration. Hwang *et al.* (2019) emphasized on the probability of return on investment for funded research projects in South Korea through the prism of a National Open Repository. Zhu *et al* (2020) made an empirical approach towards funded studies of global nursing research, looking for productive countries, sources of publication and key areas of research.

Expecting the enormous importance of scientometrics assessment of public funded research, the current study is undertaken to evaluate the research output of one of India's largest public research funding organization- Department of Atomic Energy (DAE). The study is planned with an aim to measure the DAE funded research on some key scientometrics scale points *viz.* performance, impact, publication channels, collaboration & research trends.

Research Funding through DAE

Department of Atomic Energy (DAE) was formed in 1954 and it comes under direct purview of Prime Minister of India. Besides its prime objective of research under Nuclear Power technology, DAE is one of India's largest enterprises that does research in basic sciences, radiation technology, agriculture and medicine. DAE have five dedicated research centers and a deemed university under it. Besides its own institutions, DAE have provisions for research funding to outside DAE institutions like other universities & academic institutions. Board of Research in Nuclear Sciences (BRNS) is the advisory body under DAE that recommends such financial assistance. BRNS have different schemes like Regular Research Grants, Young Scientist's research Award, DAE- Scientific Research Council Award via which funds are released. DAE also provides funding in forms of scholarships to young graduates for PhDs.

OBJECTIVES OF THE STUDY

The study aims to do a quantitative and qualitative analysis of researches where funding source have been acknowledged as DAE or institutions under it (details in the search query under 5.1). For this aim, the study is divided into the following objectives to fulfill-

i. To measure the scientific output and research impact of DAE funded research and find out the most influential articles of the studied period in terms of citation received.

ii. To identify the major sources of publications where the DAE funded research have been published and making a comparative analysis of the sources based on Impact Factor and Schimago Journal Rank indicator.

iii. To understand the trend of inter-country collaboration in the DAE funded research.

iv. To identify the subject areas of the DAE funded research using author assigned keyword analysis.

METHODOLOGY

Data Collection and Preparation

A fifteen-year period was chosen for the study from 2003 to 2017. The reason being choosing this time period is because DAE launched numerous rigorous multifunctional

projects since 2000 and the current study wished to have a check on how the various funded projects reflected under the scientometrics banner. The upper limit year was chosen as 2017 to have more completeness in the citation record which was counted till 2020. Only those articles were considered for the study where funding source was dully acknowledged to be DAE or any institution under it. An advanced search was made in the Scopus database with the following formulation,

"(FUND-ALL ("Department of atomic energy") OR FUND-ALL ("DAE") OR FUND-ALL ("DAE-BRNS") OR FUND-ALL ("Board of research in nuclear sciences") OR FUND-ALL ("Young Scientist's Research Award") OR FUND-ALL ("ysra") OR FUND-ALL ("DAE-Scientific Research Council") OR FUND-ALL ("DAE-SRC")) AND PUBYEAR > 2002 AND PUBYEAR < 2018"

The search query retrieved 8240 documents as on 18-06-2020. Further analysis using the Bibexcel (Pearson, R Danell J & Wiborg, 2009) software. The total 8240 documents were broken down to individual year set from 2003 to 2017, i.e. total 15 sets for fifteen years.

5.2 Analysis process:

The fifteen scopus .ris formatted data set for each year from 2003 to 2017 were later merged using Bibexcel software. The merging yielded a single file with all the information intact in it where further analysis based on the selected objectives of the study were carried out. MS-Excel was used to run different statistical operations on the data set.

DATA ANALYSIS, FINDINGS AND DISCUSSION

Findings against objective 1

Research output or research productivity is measured in terms of total number of publications, while research impact is measured in terms of citation. For research output raw count of publications were taken irrespective of type of publication like journal article, conference paper etc. The output was listed as year wise, institution wise, country wise. Table 1 gives an overview of the data set of research where DAE or any organization was mentioned as a funding source from 2003 to 2017. Over the selected study period, the total 8240 articles have received 156367 citations, out of which 7632 articles have received minimum of one citations, while other 608 articles were yet to receive their first citation. Only 12.33 % articles were published as open access. **Cited to non-cited article ratio of 12.55:1 reflects that out of every 13 (H"12.55) article of DAE funded research, one article gets uncited.**

Table 1: DAE Funded Research Output During 2003-2017

Total articles	Total citations	Articles with minimum one citation	Articles without any citation	Cited to non- cited articles ratio	Open access articles
8240	156367	7632	608	12.55:1	1016

Table 2: Year Wise Contributions in Publications of DAE funded Research (2003-2017)

Year (A)	No of Publications (B)	Citation in published year (C)	Citation in two-year citation window (D)	Immediacy Index (E=C/B)	Impact in two-year period (F=D/B)
2003	140	63	602	0.45	4.3
2004	191	120	1524	0.628	7.98
2005	189	75	1180	0.397	6.243
2006	291	129	1434	0.443	4.937
2007	300	130	1564	0.433	5.213
2008	308	128	1364	0.416	4.429
2009	404	182	2170	0.45	5.371
2010	366	173	1882	0.473	5.142
2011	548	520	3798	0.949	6.93
2012	649	803	5150	1.24	7.935
2013	750	648	6138	0.864	8.184
2014	821	844	6211	1.028	7.565
2015	766	628	5552	0.82	7.248
2016	1101	1243	4429	1.129	4.023
2017	1416	1133	*	0.8	*
Total/ Average	8240	6819	42998	0.701	6.107

*three year citation data not available for the year 2017 as 2020 is still not finished till the preparation of the article

For impact, citation count was considered at two levels, first based on the immediacy index and second using two-year citation window after the publication year (i.e. for the published articles in 2003, citation data of 2003, 2004 & 2005 were counted). In this two stage citation criterion, the first process shows the trendiness of research and the second two-year citation period shows about the citation impact after the articles get a time exposure to get cited. Table 2 represents the detailed findings. Table 3 does an institution and country wise share of publications. Punjab University, IIT Bombay, IISc Bangalore, University of Delhi & Banaras Hindu University were non DAE institutions that have been featured in the top 10 institutions list along with DAE's own institutions in the selected period of study. Impact of research over two years' period is comparatively more than the same year.

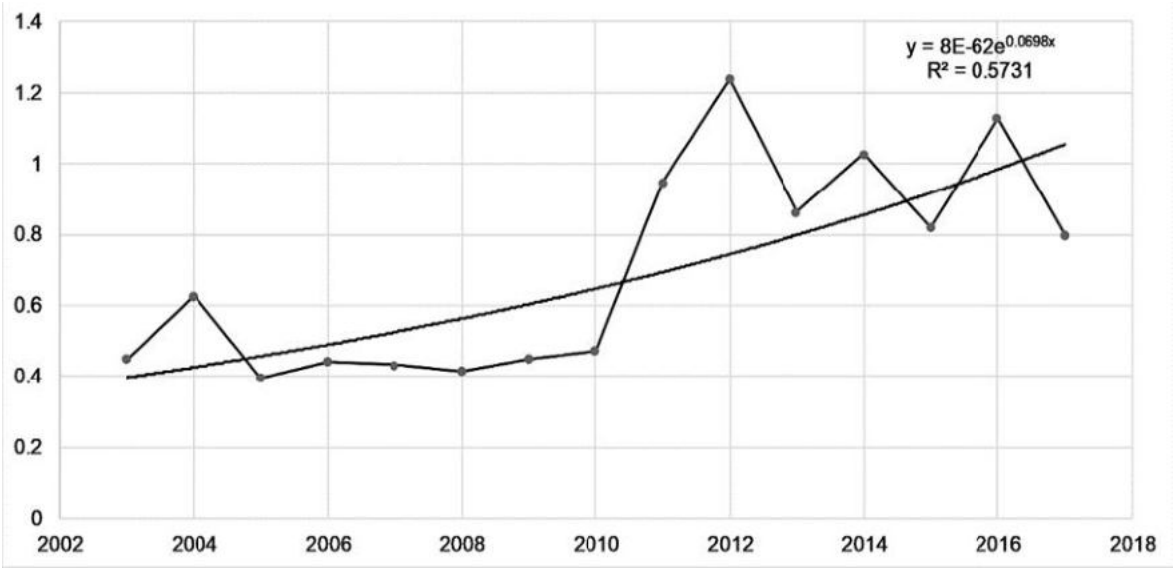


Fig. 1 Trend line of immediacy index growth of DAE funded research from 2003 to 2017

Fig. 1 and Fig. 2 represents the plot line of variations of immediacy index and two-year citation impact of DAE funded research over the selected period of study respectively. In the immediacy index plot, an exponential growth in the immediacy index line is observed from 2010. An exponential trend line is drawn over the data points, yielding R^2 value of 0.572, proving the visible moderate growth of immediacy index for the DAE funded research from 2010 onwards. For the two-year citation window, the plot line observed was of uniform type and therefore when a logarithmic trend line was drawn to check the variations, yielding R^2 value of 0.0721. The R^2 value of less than 0.5 from Fig 2, proves DAE funded research does receive a uniform amount of citation when the publications get sufficient time exposure after being published. Table 4 represents the top 15 most highly cited papers till 2020 funded by DAE during the studied fifteen years' period. The highest cited paper was published in the year 2012, and has 5139 citations to its name. This paper is a large scale collaborative paper among the world's scientific community led by the CMS group of CERN that discusses the Higgs Boson particle where India also had participation. The second highest cited paper has 2284 citations to its name and it was published in 2005. This paper discussed the results of STAR experiment and also a large scale collaborative research project among world's physicists where India also had participation. This highly cited papers and their collaboration study reveals India DAE's participation in some path breaking discovery of the world.

Cumulative Annual Growth Rate (CAGR) of DAE funded articles = $[V(t_n)/V(t_0)]^{1/n}-1$

$= [1416/140]^{1/15}-1$

$= (10.11)^{0.06}-1$

$=1.148-1$

$=0.148$

So, % CAGR $=0.148 * 100 = 14.8\%$

Where, $V(t_0)$ = value at the beginning period, $V(t_n)$ = value at the end period, n= no of years

Table 3: Institution and Country wise publication record or DAE funded research (2003 – 2017)

Indian Institutions			Institutions from outside India			Countries		
Name	Total Pubs	% share	Name	Total Pubs	% share	Name	Total Pubs	% share
Bhabha Atomic Research Centre, Mumbai	1517	18.41	Institut fiziki vysokikh energii, Ukraine	368	4.47	India	7066	85.75
Saha Institute of Nuclear Physics	534	6.48	Joint Institute for Nuclear Research, Dubna	363	4.4	United States	888	10.77
Panjab University	406	4.93	Petersburg Nuclear Physics Institute PNPI	328	3.98	South Korea	867	10.52
Tata Institute of Fundamental Research, Mumbai	405	4.91	Institut National de Physique Nucleaire et de Physique des Particules, France	326	3.95	Germany	560	6.79
Indian Institute of Technology, Bombay	385	4.67	Alikhanov Institute for Theoretical and Experimental Physics, Moscow, Russia	321	3.89	China	539	6.54
University of Delhi	309	3.75	Korea University, South Korea	312	3.78	France	468	5.67
Indian Institute of Science, Bengaluru	299	3.63	Purdue University, Indiana, U.S.	304	3.68	United Kingdom	442	5.36
Indira Gandhi Centre for Atomic Research	242	2.94	Wayne State University, Michigan, U.S.	302	3.66	Russian Federation	419	5.08
Banaras Hindu University	213	2.58	Ohio State University, U.S.	299	3.62	Brazil	395	4.79
Institute of Physics Bhubaneswar	206	2.5	Université de Strasbourg, France	295	3.58	Japan	395	4.79

Table 4: Top 15 Most influential articles with highest no of citations (2003-2017)

Sl. No	Article title	Published Year	Source Title	Total citation	Article type
1	Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC	2012	Physics Letters, Section B: Nuclear, Elementary Particle and High-Energy Physics	5139	Article
2	Experimental and theoretical challenges in the search for the quark-gluon plasma: The STAR Collaboration's critical assessment of the evidence from RHIC collisions	2005	Nuclear Physics A	2284	Article
3	Chemical modification of silica surface by immobilization of functional groups for extractive concentration of metal ions	2004	Talanta	754	Article
4	The muon g - 2	2009	Physics Reports	649	Review
5	The upgraded DØ detector	2006	Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment	624	Article
6	Mechanism of carrier accumulation in perovskite thin-absorber solar cells	2013	Nature Communications	582	Article
7	High-pT charged hadron suppression in Au+Au collisions at $\sqrt{S_{NN}}$ =200 GeV	2004	Physical Review C - Nuclear Physics	571	Article
8	A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: A green expertise	2016	Journal of Advanced Research	538	Review
9	Combined results of searches for the standard model Higgs boson in pp collisions at s=7 TeV	2012	Physics Letters, Section B: Nuclear, Elementary Particle and High-Energy Physics	461	Article
10	Multistrange baryon production in au-au collisions at $\sqrt{s_{NN}}$= 130 GeV	2004	Physical Review Letters	461	Article
11	PHENIX detector overview	2003	Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment	455	Article
12	Observation of long-range, near-side angular correlations in pPb collisions at the LHC	2013	Physics Letters, Section B: Nuclear, Elementary Particle and High-Energy Physics	431	Article
13	Long-range angular correlations on the near and away side in p-Pb collisions at $\sqrt{s_{NN}}$=5.02 TeV	2013	Physics Letters, Section B: Nuclear, Elementary Particle and High-Energy Physics	428	Article
14	Smart home energy management system using IEEE 802.15.4 and zigbee	2010	IEEE Transactions on Consumer Electronics	372	Article
15	Human health risk assessment for aluminium, aluminium oxide, and aluminium hydroxide	2007	Journal of Toxicology and Environmental Health - Part B: Critical Reviews	364	Review

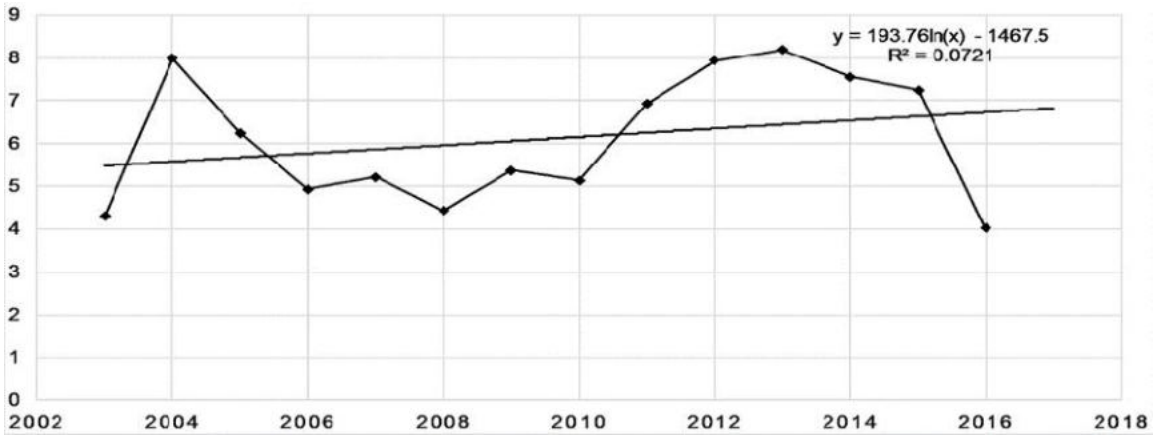


Fig. 2 Trend line of research impact growth (3 year citation window) of DAE funded research

Findings against Objective 2

To find the core sources where the DAE funded research is published most, Bradford's law (Bradford, 1948) of scattering was thought suitable. For the current evaluation, the publications were considered as a measure of productivity. The list of published sources name was retrieved using Bibexcel. By this process, details of 8012 journal articles which were distributed among 1764 journals were able to be retrieved successfully. Distribution of 8012 articles in three equivalent zones requires 2670 articles in each zone. Proceeding in such a way, three zones of journals were obtained sharing equivalent number of articles in each zone as shown in Fig 3.

The ratio of journal distribution in resultant zones were-

45:209:1510=1:4.64:33.55

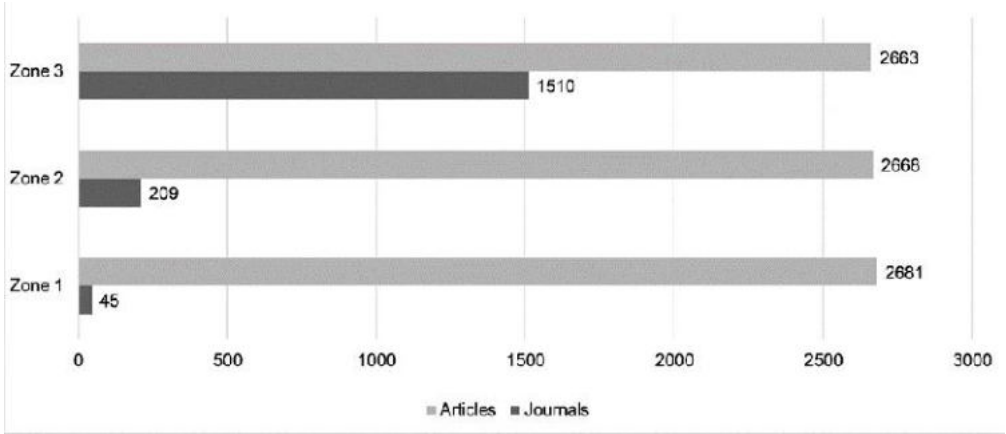
‘‘‘ 1: 4.64: $(4.64)^2$

The distribution zones were not in the form of 1: n: n^2.

Percentage error with the expected value in zone 3= {(33.55-21.59)/21.59}X 100

= 55.39%

Fig. 3 Bradford's distribution of articles in 3 zones



The percentage error for the resulted distribution was very high and the distribution was not fitting to Bradford's criteria. Therefore, in order to test the fitness of Bradford's criteria, Leimkuhlar model (Leimkuhlar, 1967) of distribution was evaluated for three zones of journals. Several studies (Qiu, 1990; Kalita, 2016; Gayan & Singh, 2019) have proved the suitability of Leimkuhlar model for non-cumulative rank frequency calculation.

The Bradford's multiplier K for the Leimkuhlar distribution is get from,

$$K = (e^y\ Ym)^{1/P}$$

where, e^y = 1.781 (Eular No)
Ym = no of citation in the top productive source
P = no of zones of distribution

For 3 core groups, the Bradford's multiplier from Leimkuhlar model,

$K = (1.781 \times 263)^{1/3} = (408.463)^{1/3} = 7.766$

Number of journals in the Nucleus Zone as given by Leimkuhlar model is,

$R_0 = T(K-1)/(K^p-1)$, *where T = Total no of journals*
$= 1764\ (7.766-1)/(7.766^3-1)$
$= 11935.224/\ 467.373$
$= 25.53$ H" 26

Using Leimkuhlar model, modified Bradford's distribution can be written as,

$26 : 26 * 7.766 : 26 * (7.766)^2 = 1 : n : n^2$
$\Rightarrow$ 26: 201.916 : 1568.079

Total no of journal accommodated in the modified distribution = (26+201.916+1568.079)
= 1795.99

$$\text{Percentage of error} = \frac{Observed\ value - Expected\ Vlue}{Expected\ Value} * 100$$
$$= \frac{1795.99-1764}{1764} * 100$$
$= 1.81\ \%$

With the resultant error percentage of 1.81%, the modified Bradford's distribution can be accepted. Bradford's multiplier is not a constant entity and its value varies depending on the no of distribution zone. The log normal distribution curve for the total journals is shown in Fig 4. In the distribution curve, the observed step rise from point A to B is the core group of 26 journals, following which an exponential rise is visible with a longer tail. The core group of 26 journals shared 25.13% of total 8012 articles tested for Bradford's distribution (Table 5). The longer tail only yields that the articles are sparsely distributed among a larger share of journals in the lower end of the Bradford's distribution.

Further analysis of the 26 core journals was made finding out their Impact Factor (Garfield, 2006) based on Journal Citation Reports (JCR) and Schimago Journal Rank (2019) for the year 2018. The best quartile distribution of journals based on SJR were also checked. The highest impact factor journal amongst the 26 core is *Sensors and Actuators, B: Chemical* (IF= 6.393 as on JCR 2018), 88 articles were published in it. The best journals based on SJR value is *Physics Letters, Section B: Nuclear, Elementary Particle and High-Energy Physics* (SJR value= 1.806), with 263 articles published in it. The average value of IF for the 26 core journals is 2.99 and average SJR is 0.850.

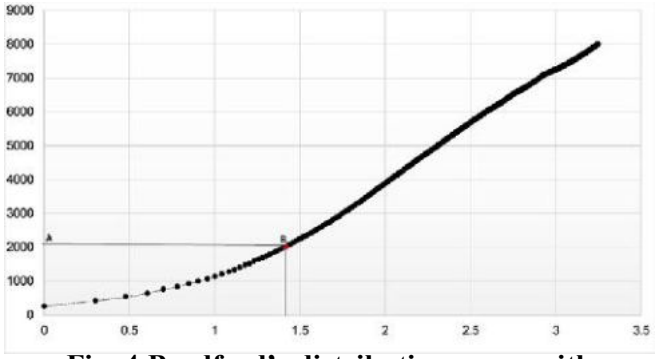


Fig. 4 Bradford's distribution curve with cumulative no of journals in Y axis and Log of cumulative no of journals in X axis

Table 5: Core group of journals for DAE funded research (2003-2017)

Sl. No	Source Title	Impact Factor[A]	SJR Value[B]	Quartile Distribution[C]	No of articles
1	Physics Letters, Section B: Nuclear, Elementary Particle and High-Energy Physics	4.162	1.806	Q1	263
2	Journal of Alloys and Compounds	4.175	1.065	Q1	168
3	Applied Physics Letters	3.521	1.331	Q1	110
4	Journal of Radioanalytical and Nuclear Chemistry	1.186	0.408		104
5	Journal of Magnetism and Magnetic Materials	3.046	0.680	Q2	103
6	Sensors and Actuators, B: Chemical	6.393	1.389	Q1	88
7	Journal of Applied Physics	2.328	0.746	Q2	88
8	RSC Advances	3.049	0.807	Q1	74
9	Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy	2.931	0.574	Q2	70
10	Ceramics International	3.450	0.888	Q1	69
11	Journal of Luminescence	2.961	0.645	Q2	69
12	Applied Surface Science	5.155	1.115	Q1	66
13	Nuclear Instruments and Methods in Physics Research, Section B: Beam Interactions with Materials and Atoms	1.210	0.518	Q2	65
14	Pramana - Journal of Physics	1.185	0.318	Q3	64
15	Chemical Physics Letters	1.901	0.577	Q2	63
16	Materials Research Bulletin	3.355	0.744	Q1	63
17	Journal of Materials Science: Materials in Electronics	2.195	0.487	Q2	58
18	Physica B: Condensed Matter	1.874	1.503	Q1	54
19	Radiation Physics and Chemistry	1.984	0.487	Q2	51
20	Materials Chemistry and Physics	2.781	0.650	Q2	49
21	Biochemical and Biophysical Research Communications	2.705	0.973	Q2	49
22	Tetrahedron Letters	2.259	0.621	Q2	47
23	Scientific Reports	4.525	1.414	Q1	46
24	Journal of High Energy Physics	5.833	1.016	Q1	45
25	Nuclear Physics A	1.463	0.926	Q2	44
26	Journal of Molecular Structure	2.120	0.434	Q3	44
Total/Average		2.99	0.850	--	2014 (25.13% of total articles tested for Bradford's law)

A= Impact Factor based on Journal Citation Reports-2018
B= Schimago Journal Rank (SJR) value of 2018
C= Best Quartile distribution rank of journals in a particular subject as on SJR 2018.

Findings against Objective 3

Inter country collaboration trend is shown in Fig 5. For the inter country collaboration study, the top 20 countries with highest number of articles were chosen. The collaboration map was prepared using the Bibexcel program and was later analyzed using the VOSviewer tool. In the collaboration map, among the top 20 countries, two different visible clusters were found. The green colored cluster having strongest collaboration and the red colored cluster having less strong collaboration than the others. India is found to have a strong collaboration with USA, Russia, France, Germany and China in the DAE funded research of the selected study period (map in Fig 6). Japan is found to be an outlier in the collaboration map, having moderate collaboration with other countries.

Findings against objective 4

Author assigned keywords is an essential element to identify the broad topics covered in an article. Analysis of these keywords definitely helps to identify the trend of research areas. Author keywords are stored in the "KW" field of .ris format, and these were pulled out using Bibexcel. As single individual keywords might not mean anything, therefore a co-occurrence study was made for the keywords to identify the broader domain of subjects and a map was prepared which was later analyzed using the VOSviewer tool. Table 6 represents the top 50 keywords that have appeared in highest no of articles during the study period. The keyword co-occurrence map with minimum edge strength of 20 is presented in fig 7. Distinct cluster of keywords was visible in the keywords co-occurrence map. The longest connection in each clusters is separately highlighted in Fig 8, Fig 9 and Fig 10. It is observed in the green cluster (Fig. 8) that with the keyword "Controlled Study" words like "Genetics", "unclassified drugs", "Human", "drug effects", "Mouse", "Rats", "Gene expression regulation", "animal tissue", "in vitro study" etc. appeared most indicating researches from the field of biology, bio-chemistry and medical

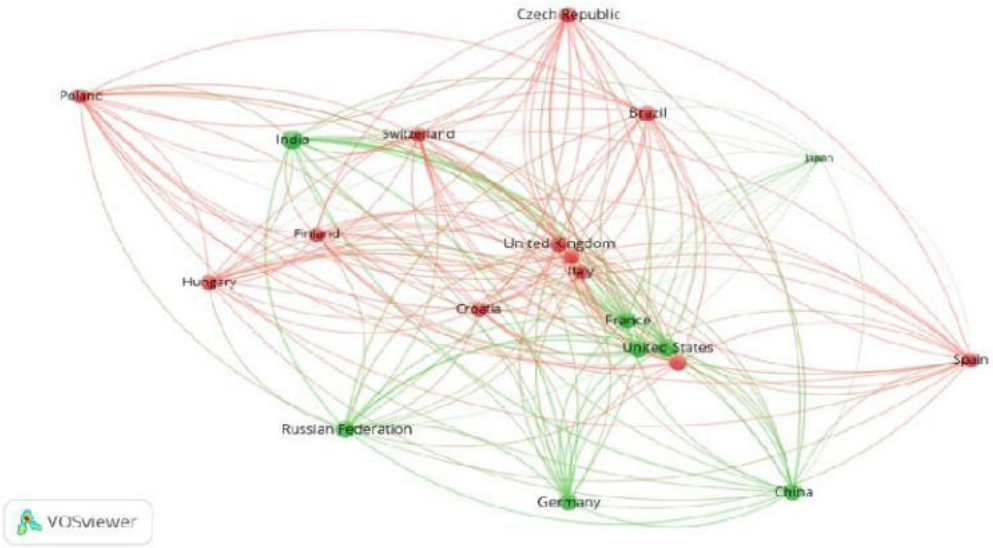


Fig. 5 Overhaul Country collaboration in DAE funded research (2003 to 2017)

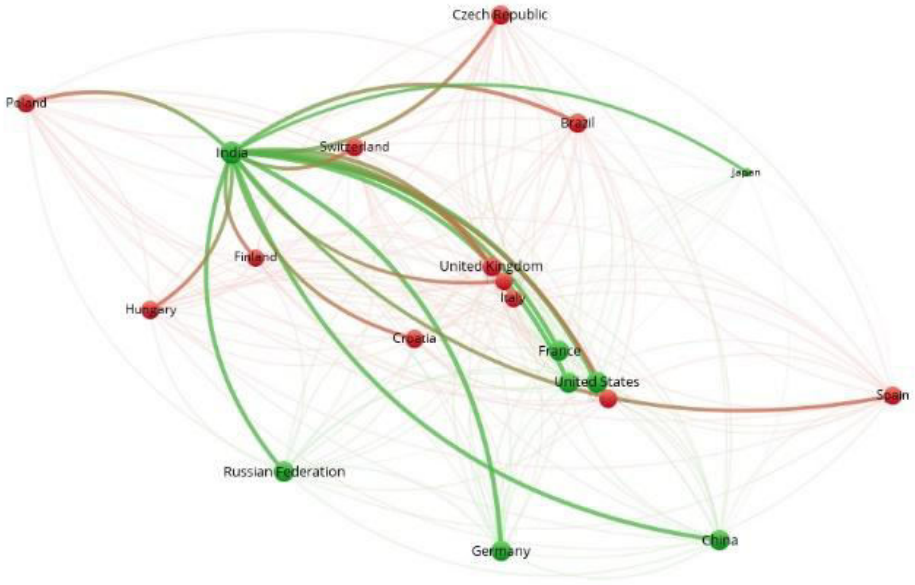


Fig. 6 India's collaboration with other countries in DAE funded research

sciences that primarily included application of drugs and animal experiments. In the red cluster (Fig. 9, Fig. 10) with keywords "Scanning electron microscopy" words like "X ray diffraction", "crystal structure", "synthesis(chemical)", "Nano particles", "optical properties", "magnetic properties", "transmission electron microscopy" etc. appeared most, indicating research related to spectroscopy & particle property studies and research about thin films.

Table 6: Top 50 Author Assigned Keywords and their respective frequency (2003-2017)

Sl. No	Frequency	Word	Sl. No	Frequency	Word	Sl. No	Frequency	Word	Sl. No	Frequency	Word	Sl. No	Frequency	Word
1	1916	Article	11	561	Scanning Electron Microscopy	21	313	Synthesis (Chemical)	31	244	DNA	41	215	Ions
2	976	Controlled Study	12	560	Female	22	310	Fluorescence	32	243	Synthesis	42	213	In Vitro Study
3	961	Priority Journal	13	480	Metabolism	23	310	Temperature	33	243	Fourier Transform Infrared Spectroscopy	43	213	Enzyme Activity
4	857	X Ray Diffraction	14	470	Chemistry	24	305	Adult	34	243	Zinc	44	208	Magnetism
5	785	Nonhuman	15	395	Nanoparticles	25	291	Animal Experiment	35	237	Oxidative Stress	45	208	Silver
6	731	Male	16	377	Thin Films	26	281	Optical Properties	36	233	Animal Tissue	46	207	Protein Expression
7	688	Human	17	344	Transmission Electron Microscopy	27	276	Crystal Structure	37	232	Human Cell	47	206	Irradiation
8	673	Unclassified Drug	18	334	India	28	263	Genetics	38	220	Animal Cell	48	206	Adsorption
9	647	Humans	19	322	Apoptosis	29	260	Copper	39	219	Mice	49	205	Glass
10	596	Animals	20	317	Animal	30	244	Mouse	40	217	Particle Size	50	203	Kinetics

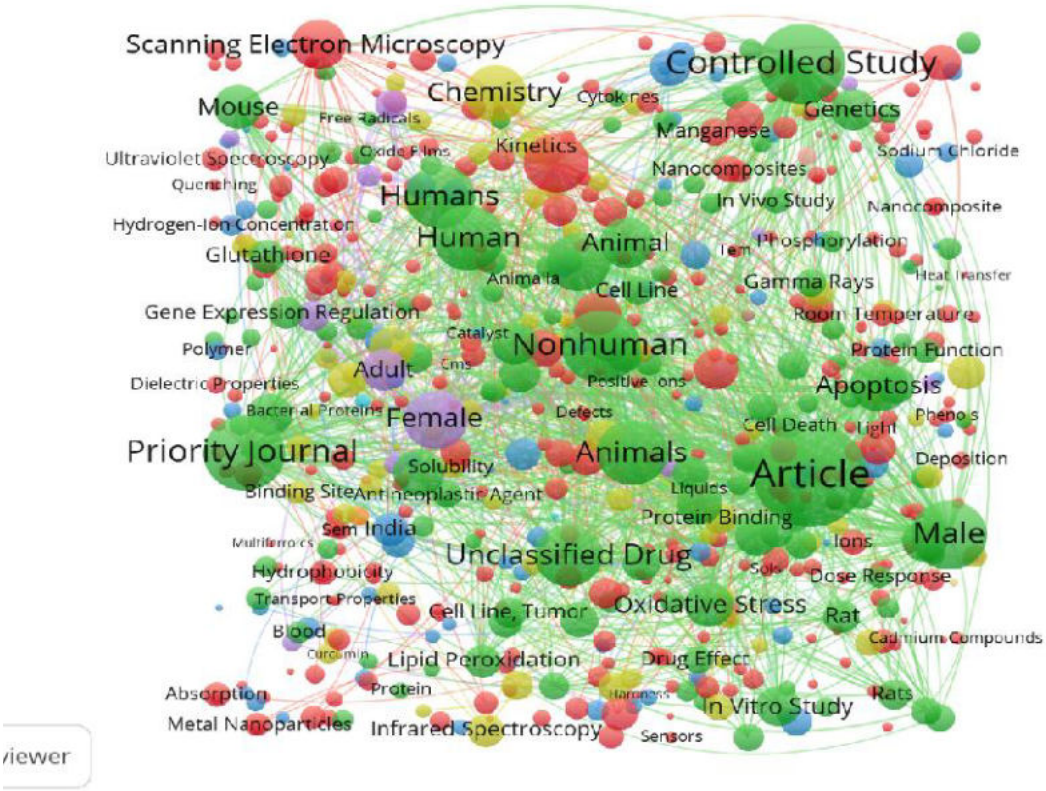


Fig. 7 Keyword's co-occurrence map with minimum edge strength of 20

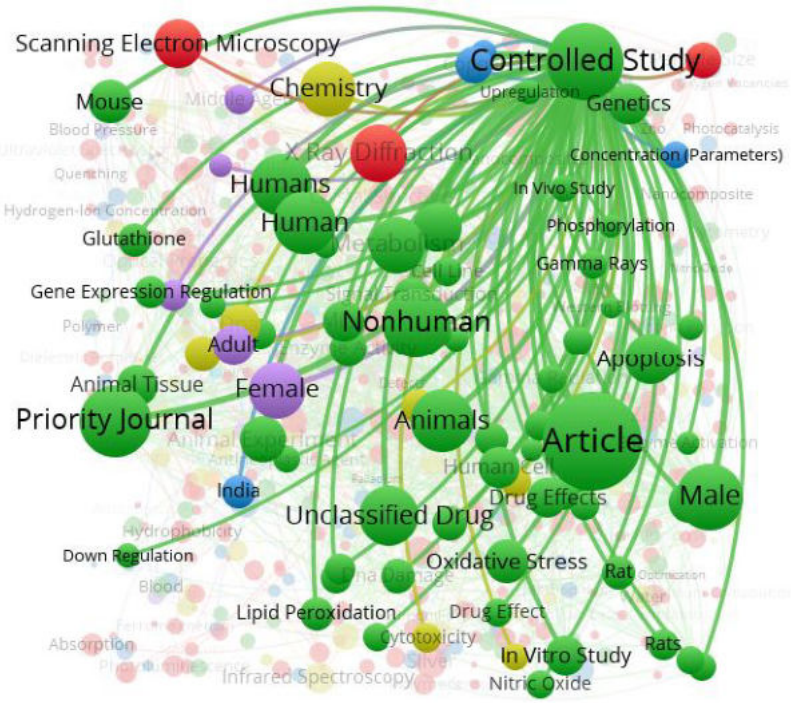


Fig. 8 Keywords co-occurrence map from Biology and medicine cluster

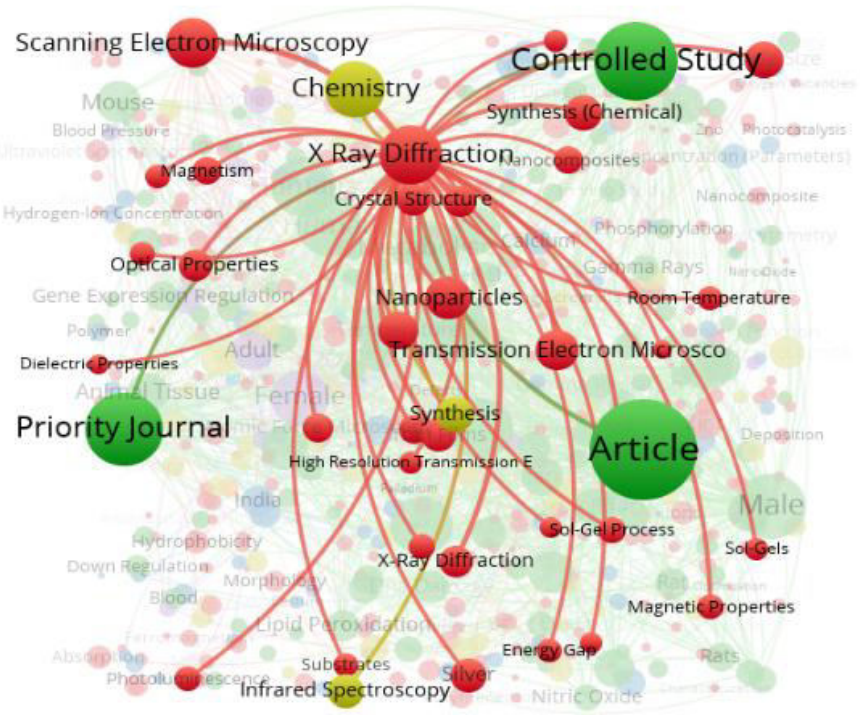


Fig. 9 Keywords co-occurrence from Chemistry & particle properties cluster

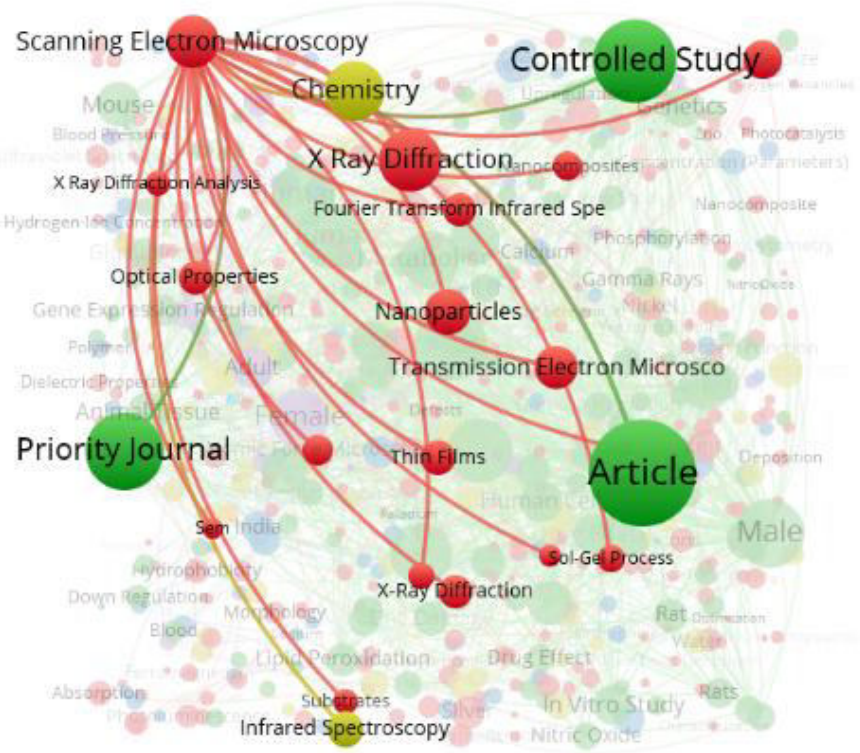


Fig. 10 Keywords co-occurrence map from Spectroscopy and particle properties cluster

CONCLUSION

The study yielded some crucial and interesting findings about the DAE funded research for the period from 2003 to 2017. During this period, 8240 articles were there where funding source was DAE, having a cumulative growth rate of 14.8%. The immediacy index of the articles has seen an exponential growth from 2010 onwards, proving increase in the immediate citation gaining capacity of the articles. Cited to non-cited article ratio of 12.55:1 reflects that out of every 13 (H"12.55) article of DAE funded research, one article gets uncited. Leimkuhlar modification of Bradford's law was applied to find out the prime sources, that yielded 26 core group of sources which have been major channels of communication for the DAE funded research with a longer tail indicating sparse distribution of articles in a large corpus of journals. Average IF for the core 26 journals were 2.99, while the SJR value for the same were 0.850. Strong international collaboration of India is found in the DAE funded research articles, having stronger bond with USA, Russia, France, Germany & China. A subject trend analysis using the author assigned keywords and their co-occurrence map was studied that helped to conclude DAE providing ample fund to the researches of biochemistry, biology, medicine, spectroscopy & particle property studies.

The current study is limited to scientific publications only and measured output is based on the empirical data of publications. The findings are thought to be useful for the government and DAE, for planning and decision making regarding their future research funding strategies. The strong international collaboration with the developed economics is a good indication, but GoI can work on plans to include the developing economics in its collaborative partners that may include ASEAN and SAARC countries. Moreover, future research funding can be more focused on towards emerging areas on electronics and semiconductor, as in the fifteen years of studied period there has been some major breakthrough research in the areas of biological sciences and in the field of chemistry and particle property studies.

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