

# Impact of DST-FIST Funding on Research Publications in India (2000-2020): A Bibliometric Investigation

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## ABSTRACT

The Department of Science and Technology-Funding for Improvement of Science and Technology (DST-FIST), the Government of India, is incessantly supporting the academic and research institutions to promote the research culture. The Government and specific funding agencies would like to know the impact of such research funding across various states, fields, disciplines, institutions, and researchers. The present study investigates the impact of DST-FIST funding on research publications in India through bibliometric analysis using the R programming and VOS viewer. Among the various other research outcomes, only research papers published during 2000-2020 by acknowledging the DST-FIST funding from the Web of Science database were considered for the present study. Regarding the impact of DST-FIST funding on research publications, we can draw reasonable conclusions based on bibliometric analysis. The investigation resulted in 7289 documents. The research collaboration worldwide is investigated with the help of explosion and growth patterns in scientific research outcomes. The most dominant document type is research articles, which accounted for 95.80% (6983). Research articles published under DST-FIST grants during 2000-2020 have received 76031 citations. The research publications in the field of Chemistry alone accounted for 47%, with 3437 articles. It implies that research in the chemistry domain (Crystallography, electrochemistry, polymer science, organic and inorganic, analytical, etc.) is the largest beneficiary of the DST-FIST funding scheme. The Annual Percentage Growth Rate in research publication was 25.6 %, and the compound annual growth rate for the period 2000-2020 is 45.94%. The Country Collaboration Network indicated that India collaborates with significant countries like the USA, Spain, South Korea, Saudi Arabia, etc. The maximum numbers of publication are in collaboration with the USA (227 publications), Spain (128 publications), Saudi Arabia (128 publications), and South Korea (121 publications). Overall, the study results projected a significant impact of research grants on the quality and quantity of research publications providing a wide-country collaboration network.

**Keywords:** Department of Science and Technology, Funding for Improvement of Science and Technology, India, Web of Science, Bibliometric analysis, VOS viewer.

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## INTRODUCTION

Every country worldwide is putting its efforts to improve Science and Technology capability to achieve high performance and stay competitive. In developing countries like India, there is a strong focus on enhancing Science and Technology (S&T) and advanced research to develop and improve economic growth and knowledge creations.<sup>[1]</sup> Globally, the investment in S&T has received a renewed interest, as it provides a window of opportunity. In this regard, research policy has taken an essential role in every country's broader economic scene. S&T and advanced research will decide the pace of economic growth and development<sup>[2]</sup> results in greater prosperity.<sup>[3]</sup> The S&T policy's primary focus is to increase

effectiveness and output in academic research.<sup>[4]</sup> In this regard, post-independence, the Indian government implemented many S&T policies. However, the investment concept in S&T and Research and Development (R&D) projects in India has less than a few decades of history, unlike in western countries. Globally, the investment in S&T has received a renewed interest as it provides a window of opportunities. The R&D expenditure across the world by different countries along with global share is as shown in Table 1.

## Investment in S&T and R&D activities in India

The educational institutions are the knowledge creation and innovation centers. The Government of India has taken many initiatives to promote and nurture S&T activities in educational institutions. It will foster research rigor in the educational institutions thereby, strengthen the R&D capabilities. It is a well-known fact that S&T institutions in India have the forte to produce high-quality graduates by making a critical contribution to sustainable economic growth.<sup>[5]</sup>

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**Table 1: Investment on Research and Development in various Nations along with global share (as on 2018).**

| Rank | Country             | R&D Spending (PPP) | Global Share (%) |
|------|---------------------|--------------------|------------------|
| 1    | United States       | \$476.5 billion    | 26.4%            |
| 2    | China               | \$370.6 billion    | 20.6%            |
| 3    | Japan               | \$170.5 billion    | 9.5%             |
| 4    | Germany             | \$109.8 billion    | 6.1%             |
| 5    | South Korea         | \$73.2 billion     | 4.1%             |
| 6    | France              | \$60.8 billion     | 3.4%             |
| 7    | India               | \$48.1 billion     | 2.7%             |
| 8    | United Kingdom      | \$44.2 billion     | 2.5%             |
| 9    | Brazil              | \$42.1 billion     | 2.3%             |
| 10   | Russia              | \$39.8 billion     | 2.2%             |
| 11   | Italy               | \$29.6 billion     | 1.6%             |
| 12   | Canada              | \$27.6 billion     | 1.5%             |
| 13   | Australia           | \$23.1 billion     | 1.3%             |
| 14   | Spain               | \$19.3 billion     | 1.1%             |
| 15   | Netherlands         | \$16.5 billion     | 0.9%             |
|      | All other countries | \$249.8 billion    | 13.9%            |

\*PPP:- Purchasing Power Parity (Source: <https://www.visualcapitalist.com/money-country-puts-r-d/>)

Indian Government has implemented many initiatives to increase S&T capabilities through R&D programs and funded projects. Globally, the investment and public funding on S&T development have shown an increasing trend over the years,<sup>[6]</sup> which is true even in India. However, the total investment as a percentage of GDP, as a fraction of GDP, public expenditures on R&D in India is fixed between 0.6–0.7 percent of GDP over the last two decades. It is significantly less compared to other nations such as the United States (2.8), China (2.1), Israel (4.3), and Korea (4.2). In India's the R&D expenditure is dominated by public investment, and it lacks funding from private agencies. While, in other countries, the R&D investment made by private agencies is more than the Government funding.

### DST-FIST Fund

The educational institutions have been the sources of knowledge creation and centers where a high volume of research activities are conducted. The outcome of such research activities results in innovative breakthroughs that can solve societal problems. It is necessary to strengthen the S&T infrastructure in the educational institutions to carry out quality research and innovative programs in interdisciplinary areas. Even though the Government has a strong linkage with various research centers across the country, perhaps the significant research base remains with academia. Therefore, the research contribution by educational institutions cannot be ignored, and it needs to be supported by Government agencies.

Concerning this, in the year 2000, the Department of Science and Technology (DST), Government of India, announced a new initiative titled "Fund for Improvement of S&T (FIST) to strengthen the infrastructure facilities in universities and higher educational institutions. Since 2000, the DST-FIST is funding institutions and research centers to produce and disseminate scientific knowledge. The funding support extends for five years for primary equipment purchase, networking, computational facilities, research infrastructure, new facilities, and equipment maintenance. Till 2012, the department has funded 96194.8 lakhs in INR. The financial assistance in the form of funds/grants will help educational institutions to develop adequate infrastructural facilities such as laboratory space, equipment, etc., crucial for S&T research in the institutions.<sup>[7]</sup> Many researchers have claimed that the funding will result in producing high-quality research outcomes.<sup>[8]</sup> Generally, the outcome of funding is a measure of the scientist's research activity in a specific time frame, including research publications in refereed, peer-reviewed journals, conference proceedings, book chapters, patents, the article in review, and essay letters, etc. Despite the magnitude of investment in S&T across the country, the value for money, i.e., the best possible results from investment in research, need to be estimated.<sup>[9]</sup> Every funding agency will have its operational framework to support the research policies.<sup>[10]</sup> These policies generally focus on promoting multiple research activities,<sup>[11]</sup> supporting collaboration for maintaining and improving its position in strategic/upcoming research areas.<sup>[12]</sup> Accordingly, researchers try to publish the outcome of scientific research to secure their precedence in discoveries<sup>[13]</sup> in return for the research funding. Apart from this, they also present their work in conferences, seminars and also patent them. The advancement of Information and Communication Tools has helped researchers collaborate and work on different interdisciplinary research themes. The thorough literature search using databases such as Google Scholar, Scopus, and Web of Science revealed no bibliometric research studies published on the impact of DST-FIST funds on research publications in the Indian context. Therefore, the present study will establish first-hand data on this topic for future comparisons and for policymakers to allocate funds for S&T research with an emphasis on increasing the research rigor across the country.

### Objectives of the study

Across the globe, researchers have analyzed and evaluated the impact of funding by government and other funding agencies. The present study aims to assess the impact of DST-FIST funding on research outcomes. The research objectives are as follows:

- To examine the research output of India due to the DST-FIST scheme.

- To measure the publication trend in various research subject categories.
- To identify the top performed institutions.
- To classify the top authors based on citations and research quality.

## METHODOLOGY AND DATA COLLECTION

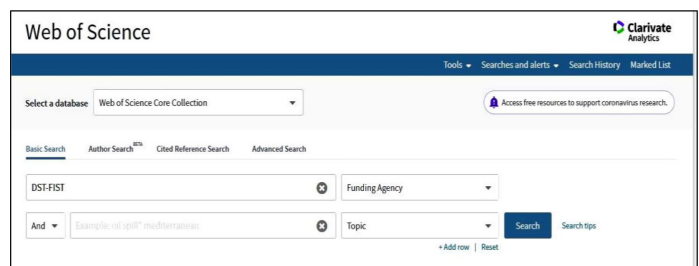
Evaluating and estimating the impact of funding on research publications and other results is a complex issue.<sup>[14]</sup> Due to an assortment in research output, one may consider multiple indicators of research activities.<sup>[15]</sup> Many scholars have used different quantitative and qualitative approaches to evaluate the impact of funding, stimulating the research outcomes in specific fields through publication analysis. A Bibliometric study is a more objective and reliable analysis<sup>[16]</sup> used extensively by many researchers in different disciplines, as it involves numerous and diversified studies.<sup>[17]</sup> The bibliometric analysis provides insights on publication trends over time, research themes, the shift in research domain/discipline, the most dominant authors and institutions, and presents the bigger picture of extant research.<sup>[18]</sup> Such information is necessary to track and explore the research publication trends and their quality and quantity. For this purpose, the present study uses bibliometric and structured network analysis. The data is analyzed in two stages, namely, descriptive analysis and network extraction. Various approaches are used to develop and generate bibliometric networks using different units shown in Table 2.

In the bibliometric study, the first step is to select the database from which the relevant documents need to be collected. In the present study, Web of Science was used to achieve the stated research objectives. The present study covers the research publications published from 2000 to 2020, acknowledging the DST-FIST funding agency. Using the “DST-FIST,” DST\_FIST, DST-FIST as keywords in the title and affiliation section of the Web of Science (WOS) Core Collection database, the research articles are retrieved. According to the regulations of funding organizations, the grant number and name of the funding organization are mandatory to acknowledge in the research article.<sup>[19-21]</sup> This helped us retrieve the data by selecting the “Department of Science and Technology-Fund for Improvement in Science and Technology” in the funding agency category. The snapshot of the WOS database indicating the DST-FIST as a funding agency, as shown in the Figure 1.

The data were retrieved from the WOS database on February 8, 2020. The search yielded 7289 research articles/documents and was downloaded in “Tab-delimited” and “Bibtex” format, and it was imported to the “Bibliometrics” package in R programming. Further, the VOS viewer is used for network

**Table 2: Classification of Bibliometric Analysis.**

| Type of analysis       | Units considered | Relationship  |
|------------------------|------------------|---|
| Bibliographic Coupling | Document         | Documents with common references                          |
|                        | Sources          | Sources with common references                            |
|                        | Author           | Authors with common references                            |
|                        | Organizations    | Organizations with common references                      |
|                        | Country          | Countries with common references                          |
| Co-citation            | Sources/Journals | Co-cited journals   |
|                        | Authors          | Co-cited authors  |
|                        | Cited References | Co-cited references                                       |
| Co-author              | Organization     | Co-occurrence of organizations in research articles/books |
|                        | Country          | Co-occurrence of countries in research articles/books     |
|                        | Authors          | Co-occurrence of authors in research articles/books       |
| Co-word                | All Keyword      | Co-occurrence of terms in research articles/books.        |
|                        | Author Keyword   |   |
|                        | Keyword Plus     |   |



**Figure 1:** Snapshot of DST-FIST as Funding Agency.

**Table 3: Retrieved records from the WOS database.**

| Search Query   | Records obtained | Duplicates identified | Unique | NA |
|--|------------------|-----------------------|--------|----|
| “DST-FIST” DST_FIST, DST-FIST as keywords in the title and affiliation and “Department of Science and Technology- Funds for Improvement in Science and Technology” in the funding agency section | 7289             | 0                     | 7289   | 0  |

visualization of journals, publications, keywords, and authors. The retrieved data was checked for duplications using R programming and validated for accuracy. To validate the accuracy of the extracted database, a data frame “FX- Funding text and FU- funding agency along with project code” retrieved from R programming was examined using a sampling test and obtained accurate results, as shown in Table 3.

## ANALYSIS AND RESULTS

Bibliometric offers explicit awareness regarding core research themes with the highest productivity in a domain

by identifying influential and leading researchers, publication sources, and author affiliation along with citation index.<sup>[18]</sup> Further, the co-citation-based network analysis will help determine various research domains, and bibliographic coupling helps to analyze the latest trends and variations in the knowledge network over the period.<sup>[22]</sup> The results derived from the R programming using bibliometric package indicate the features of the DST-FIST data obtained from the WOS database. This information is critical to understand the impact of DST-FIST funding on various research outcomes.

### Visualization of data

In this method, knowledge from data is extracted to represent the same using intuitive visualization or maps such as social networks, dendrogram, or bi-dimensional maps. Visualization techniques represent different analyses and an overall science map to understand the relationship between the various knowledge domains. Using network analysis, statistical analyses are performed on the maps to measure the network's different statistical parameters and the relationships or the other clusters' overlapping. In this current study, a software visualization tool called "VOS viewer" is used to construct and visualize bibliometric networks. The network generation input is the raw data extracted from the Web of Science Database in the "Tab-delimited" format. The VOS-Viewer software provides insights on co-citations, bibliographic coupling, and co-occurrences of the most often cited authors, papers, keywords co-occurrence, etc.

### R Package for Bibliometrics

The R Package 'bibliometrix' was streamed on the raw data to gain insights about the FIST publications and their correlation, and the results extracted, accordingly. The extracted documents are indicated in Table 4.

A total of 7289 documents were extracted, which met the study criteria. The extracted database had ten different types

**Table 4: Summary of Exported Data.**

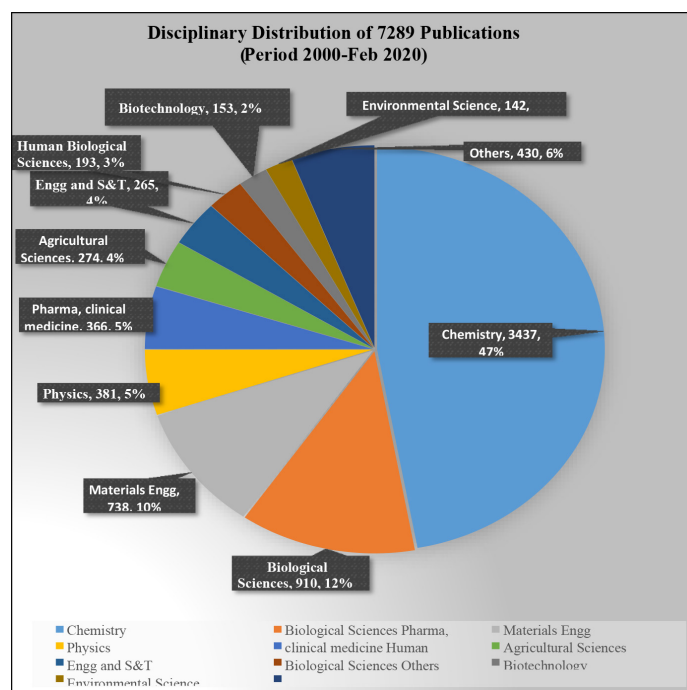
| Document types                 | Numbers | Percentage |
|--------------------------------|---------|------------|
| Article                        | 6983    | 95.80      |
| The article, early access      | 65      | 0.89       |
| The article, proceedings paper | 79      | 1.08       |
| Article, retracted publication | 1       | 0.01       |
| Editorial material             | 6       | 0.08       |
| Letter                         | 5       | 0.07       |
| The letter, early access       | 1       | 0.01       |
| Meeting abstract               | 2       | 0.03       |
| Review                         | 145     | 1.99       |
| Review, early access           | 2       | 0.03       |
| Total                          | 7289    | 100        |

of documents and their corresponding frequencies. The most dominant document type is research articles, which accounted for 95.80% (6983), 145 review articles accounting for 1.99%, 79 proceedings accounting for 1.08%, 65 early access articles accounting for 0.89%, etc.

### Disciplinary distribution of publications across the academic subjects

The disciplinary distribution of various publications across the academic subjects tabulated and presented below. The research areas coded from 1-55 numbers based on academic matters. The proportion of each discipline is shown in Figure 2.

The technological breakthroughs witnessed in the last century in various sectors like healthcare, agro, manufacturing, life sciences, energy, environment, and food are mainly reliant on progress in the chemical sciences domain.<sup>[23]</sup> The research in the chemistry domain contributes to several other multidisciplinary research areas. It helps to solve the socio-economic challenges faced by society and to improve the quality of life. It is evident from Figure 2 the research area "Chemistry" tops the Table with 3437 publications accounting for 47% of the total FIST acknowledged publications. It implies that research in the multiple areas (Crystallography, electrochemistry, polymer science, organic and inorganic, analytical, and other) of chemistry is the largest beneficiary of the DST-FIST funding scheme. Next was Biological Sciences with 910 publications (accounting for 12% of the total



**Figure 2: Disciplinary distribution of DST-FIST Publications (WOS database).** (Ref:[http://www.shanghairanking.com/shanghairanking-subject-rankings/attachment/Mapping\\_between\\_Web\\_of\\_Science\\_categories\\_and\\_54\\_academic\\_sub\\_jects.pdf](http://www.shanghairanking.com/shanghairanking-subject-rankings/attachment/Mapping_between_Web_of_Science_categories_and_54_academic_sub_jects.pdf)).



publications) and Materials engineering with 738 publications (accounting for 10% of the overall publications). Further, from the midterm review report of DST, it was evident that the chemical sciences domain has topped the list (<http://www.fist-dst.org/html-flies/majordepartmentprofile.html>).

### Impact of DST-FIST funding scheme on Volume and Quality of Research

The impact of research funding is generally measured using research publications, international collaborations, number of citations, patents, technology commercialization, and others. [24] To obtain detailed information on the impact of DST-FIST funding in the chemistry domain, we collected data on the different research outcomes, national and international collaboration, citation data, and others before and after FIST from the 364 DST-FIST funded institutions over twenty years (2000–2020). Table 5 presents the status of research work in the chemistry domain before and after DST-FIST funding.

From Table 5, it is evident that the impact of DST-FIST funding has significantly improved all the different subsets of research outcomes. The percentage change in publications of Original articles, Paper Presentation in Conference, Articles in Conference Proceeding, Books Chapter, Books, Case reports/ Editorial Notes and monograph as reported by DST-FIST funded institutions was more than 100% except for review articles which were 97.5%. Similarly, for collaboration with the outside world, substantial change was witnessed among the DST-FIST funding institutions.

Further to know the overall trend of research activities and quality, the data on intramural grants, extramural grants, patents filed, technology commercialization, product and process developments, publications, the trend in impact factor, citation trend, consultancy, and other outreach activities were collected from the DST-FIST funding institutions. The data was collected using 5 points Likert's Scale, and responses are tabulated in Table 6.

From Table 6, it is evident that across all 364 institutions, the respondents acknowledged that the DST-FIST grants have significantly improved the research activities in the chemistry domain. (<http://www.fist-dst.org/html-flies/majordepartmentprofile.htm>)

### Biblio-Analysis Function in R

The “Biblio-Analysis” function in R generates the descriptive information of bibliometric data through summary and plots. The outcome of this function on the Web of Science database is represented in the following table.

Table 7 represents the descriptive bibliographic data extracted from the Web of Science Database using a bibliometric

**Table 5: Status of Research work in Chemistry Domain before and after DST-FIST.**

| Research Outcomes                               | Number of publications N=364 |            |            |
|---|------------------------------|------------|------------|
|   | Before FIST                  | After FIST | Change (%) |
| <b>Different types of Research Publications</b> |                              |            |            |
| Books   | 908                          | 2643       | 191        |
| Books Chapter                                   | 1756                         | 2163       | 23         |
| Original articles                               | 21423                        | 45980      | 115        |
| Review articles                                 | 1623                         | 2867       | 77         |
| Case reports/ Editorial Notes                   | 437                          | 1124       | 157        |
| Articles in Conference Proceeding               | 4747                         | 10449      | 120        |
| Paper Presentation in Conference                | 9456                         | 22318      | 136        |
| Other publications                              | 254                          | 513        | 102        |
| Monograph                                       | 237                          | 752        | 217        |
| <b>Type of Collaboration</b>                    |                              |            |            |
| National Collaboration                          | 635                          | 1444       | 127        |
| International Collaboration                     | 302                          | 980        | 225        |

**Table 6: Overall trend in output and quality of research in Chemistry Domain.**

| Items                           | Status of DST-FIST Support N=364 |                 |                 |                |                     |
|---------------------------------|----------------------------------|-----------------|-----------------|----------------|---------------------|
|                                 | Decrease N (%)                   | Can't say N (%) | No change N (%) | Improved N (%) | Sig. Improved N (%) |
| Intramural Grants               | 2                                | 22              | 97              | 196            | 46                  |
| Extramural Grants               | 2                                | 15              | 53              | 214            | 79                  |
| Patents Filed                   | 0                                | 38              | 21              | 152            | 151                 |
| Commercialization of Technology | 1                                | 60              | 9               | 85             | 207                 |
| Product and Process Development | 0                                | 58              | 10              | 126            | 170                 |
| Papers Published                | 1                                | 12              | 10              | 179            | 162                 |
| Trend in Impact Factor          | 0                                | 15              | 7               | 185            | 157                 |
| Trend in Citation Index         | 0                                | 19              | 7               | 200            | 138                 |
| Consultancy                     | 0                                | 46              | 33              | 169            | 114                 |
| Outreach activities             | 0                                | 28              | 81              | 206            | 48                  |

package in the R programming. It provides an overview of the entire information in a structured way.

### Research and Development Support by DST-FIST

Over the years, there is a tremendous improvement in the quality and intensity of research supported by DST-FIST funding. It is evident in research databases such as Web of Science, as shown in the Figure below.

**Table 7: Descriptive outcomes of Biblio Analysis function.**

|  |           |
|--|-----------|
| Total number of articles   | 7289      |
| Frequency distribution (Books, Journals and others)  | 1469      |
| Keywords Plus (ID- Frequency distribution of keywords associated with the document by Web of Science database) | 18344     |
| Author's Keywords (DE- Frequency distribution of the author's keywords)  | 15428     |
| Period   | 2000-2020 |
| Average citations per documents  | 10.53     |
| Authors' frequency distribution  | 10770     |
| Number of author appearances   | 31049     |
| Single-authors   | 23        |
| Multiple-authors   | 10747     |
| Single-authored document   | 30        |
| Documents per author   | 0.677     |
| Authors /document  | 1.48      |
| Co-authors /documents  | 4.26      |
| Collaboration index  | 1.48      |
| Total number of documents  | 7005      |
| Article in Press   | 65        |
| Review   | 145       |

Source: Bibliographic information from Web of Science dated February 8, 2020

**Table 8: AGR and CAGR over the period 2000-2019.**

| Sl. No | Year | No. of articles | Total Citations | Total FIST funds sanctioned (Rs. in lakhs) | Annual Growth Rate |
|--------|------|-----------------|-----------------|--|--------------------|
| 1      | 2003 | 2               | 0               | 7864.3                                     | -                  |
| 2      | 2004 | 0               | 0               | 3832                                       | -100.0             |
| 3      | 2005 | 0               | 0               | 3716                                       | -                  |
| 4      | 2006 | 1               | 8               | 7440.6                                     | -                  |
| 5      | 2007 | 3               | 27              | 12858.3                                    | 200.0              |
| 6      | 2008 | 65              | 1299            | 9539.9                                     | 2066.7             |
| 7      | 2009 | 214             | 5739            | 7543.5                                     | 229.2              |
| 8      | 2010 | 235             | 4865            | 11888.4                                    | 9.8                |
| 9      | 2011 | 306             | 6613            | 12983                                      | 30.2               |
| 10     | 2012 | 356             | 7621            | NA   | 16.3               |
| 11     | 2013 | 467             | 9130            | NA   | 31.2               |
| 12     | 2014 | 619             | 10759           | NA   | 32.5               |
| 13     | 2015 | 701             | 8858            | NA   | 13.2               |
| 14     | 2016 | 794             | 8687            | NA   | 13.3               |
| 15     | 2017 | 968             | 7312            | NA   | 21.9               |
| 16     | 2018 | 1158            | 4493            | NA   | 19.6               |
| 17     | 2019 | 1236            | 1340            | NA   | 6.7                |

\*Note: Year 2000-2002 has witnessed zero publications acknowledging the FIST scheme

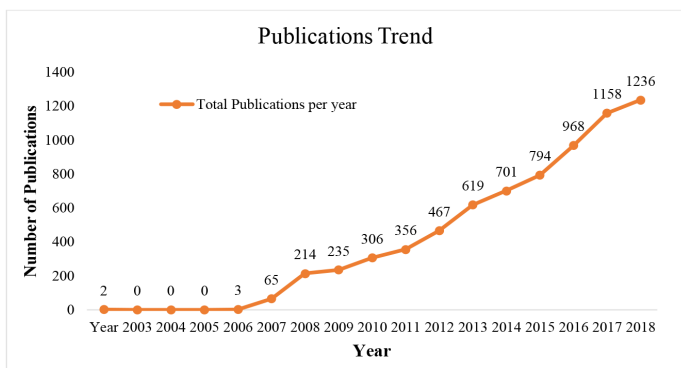
**Figure 3:** Publication Trend for the year 2000-2020.

Figure 3 represents the yearly growth in publications published with the support of the DST-FIST facility. The first article was published in 2003, though the DST FIST scheme started in the year 2000. Over the last two decades, the growth of scientific research witnessed its outcomes in the form of an increase in publications. Various meta-analytic reviews, such as book chapters, conference proceedings, doctoral dissertations, review papers, patents, etc., are also the outcomes of DST FIST funding. In the present study, only research publications are considered.

### Annual Percentage Growth Rate (APGR) and Compound Annual Growth Rate (CAGR)

From the above Table 8: the APGR of DST-FIST publications for the period 2000-2019 was 25.6 %. Typically, the growth

of publications every year accounts for a quarter of the previous year's total publications. The CAGR for the period 2000-2020 is 45.94%, and it implies that the mean growth of publications due to the DST-FIST scheme is predominantly significant over the study period.

### Explosion in research publications and citations with the support of DST FIST Grants

In the last two decades, many scientific journals are published by acknowledging DST FIST funding. Figure 4 represents publications and citations covering all areas of science and engineering.

From Figure 4a, it is evident that there is an increasing trend in research publications. There is a tremendous increase in the number of citations over the years. The highest number of citations was in the year 2014, with 10759 Citations. From 2015 onwards, there is a gradual decrease in citations. There might be several reasons for decreasing trend in publications. According to Price's Law of scientific research model, any research theme intends to follow the precursor phase, where few researchers start publishing articles on the new research area. In the exponential growth phase, the research area gains more publicity as many researchers publish articles on the new theme; this is followed by a consolidation stage during which the studies on the research theme will become stagnant or iterative over the period and from then on the research on

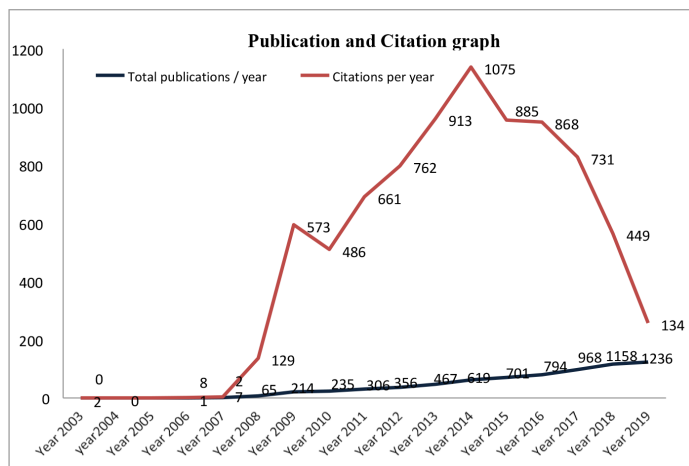


Figure 4: Publications and citations for the period 2000-2020.

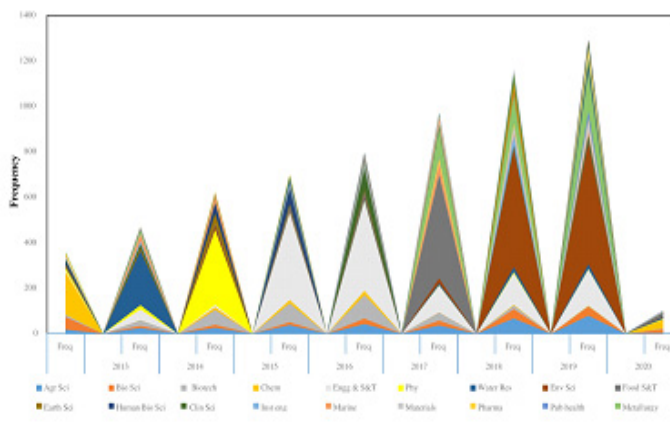


Figure 5: Domain Analysis for the Period 2012-2020.

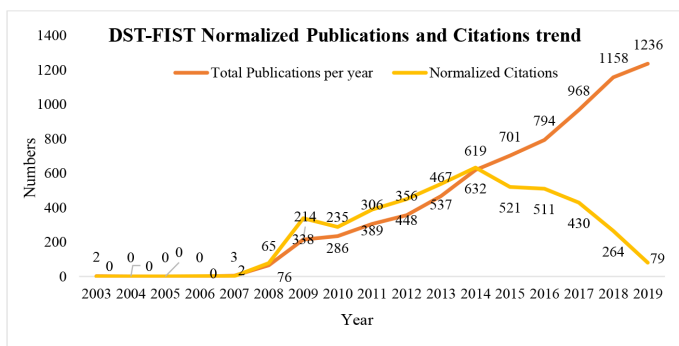


Figure 4a: Publications and citations normalized for the period 2000-2020. (Source: [http://www.shanghairanking.com/shanghairanking-subjectrankings/attachment/Mapping\\_between\\_Web\\_of\\_Science\\_categories\\_and\\_54\\_academic\\_subjects.pdf](http://www.shanghairanking.com/shanghairanking-subjectrankings/attachment/Mapping_between_Web_of_Science_categories_and_54_academic_subjects.pdf))

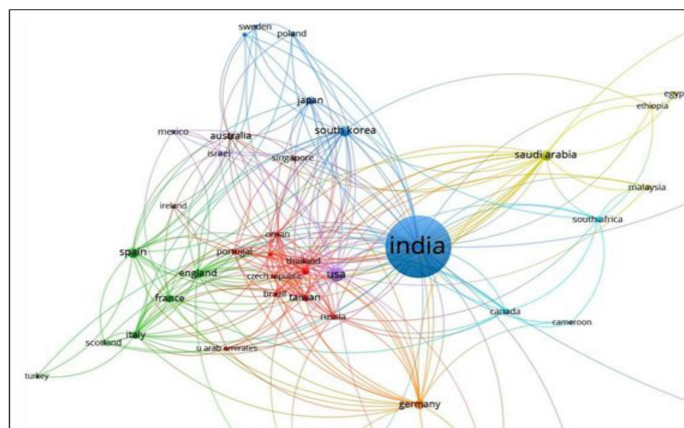


Figure 6: Country Collaboration Network.

that theme slowly decreases.<sup>[25,26]</sup> Relating the Price law for the downward trend in citations, it can be said that the research areas have reached the stage of stagnation or maturity. However, the research themes still had the potential to grow in collaboration with new research domains and gained prominence. Further, to explore the shift in citation trend, domain analysis was conducted, and the results are shown in Figure 5. The domain analysis was performed using the “Research Area-SC” category of the WOS database using the R program for 8 years (2012–2020). The WOS categories are coded from 1–55 in par with the academic subjects for the analysis purpose.

The domain analysis highlights the advent of new domains such as Energy Science, Mechanical Engineering, Telecommunication Engineering, Computer Science Engineering, Water Resources, Metallurgical Engineering, etc., after 2014, as shown in Figure 5.

### Country Collaboration Analysis

The country collaboration network reflects the degree of communication between countries and their active research

towards scientific development (International Comparative Performance of India’s Scientific Research, 2012). The country collaboration network is shown in Figure 6. The distribution of color in the network represents the diversity of research. The size of the node represents the influential parameter of the countries. i.e., the bigger the size of nodes, the most significant is the country. The link strength between them can visualize the relationships among institutes of different countries. The cooperation level between the countries is represented by the distance between the countries and the link strength. i.e., the lesser the distance, the more cooperative are the countries in research. Similarly, the stronger the links, the stronger is the research collaboration between the institutes.

From the above network, it is evident that India is collaborating with countries like the USA, Spain, South Korea, Saudi Arabia, etc.

Table 9 shows that the countries with which Indian researchers work in DST FIST departments collaborate and publish research articles. The maximum numbers of publications are

**Table 9: Country Collaboration.**

| S. No. | Country      | Documents | Citations |
|--------|--------------|-----------|-----------|
| 1      | India        | 7284      | 76721     |
| 2      | Spain        | 128       | 2274      |
| 3      | USA          | 227       | 2148      |
| 4      | South Korea  | 121       | 1588      |
| 5      | Saudi Arabia | 128       | 1509      |
| 6      | Germany      | 94        | 1392      |
| 7      | England      | 89        | 1035      |
| 8      | Taiwan       | 54        | 971       |
| 9      | Italy        | 63        | 870       |
| 10     | Japan        | 66        | 683       |

**Table 10: Total Citations per Country.**

| Country        | Total citations | Average citations |
|----------------|-----------------|-------------------|
| India          | 73035           | 10.32             |
| Spain          | 946             | 26.28             |
| Korea          | 414             | 20.7              |
| USA            | 397             | 17.26             |
| Germany        | 297             | 37.12             |
| Italy          | 295             | 21.07             |
| China          | 189             | 14.54             |
| Japan          | 186             | 23.25             |
| Saudi Arabia   | 171             | 15.55             |
| United Kingdom | 101             | 8.42              |

with the USA (227 publications and 1588 citations), Spain (128 publications and 2274 Citations), Saudi Arabia (128 publications and 1509 Citations), and South Korea (121 publications and 1588 Citations).

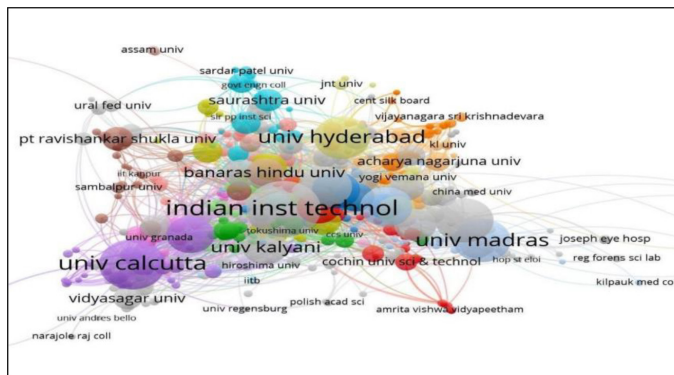
### Top Ten Cited Countries

By acknowledging the DST FIST funding, around 7289 publications (only in WOS) have received 76031 citations. Table 10 provides details on the name of the country, the number of Citations, and the average article citations.

Table 10 shows that Spain (946), South Korea (414), and the USA (397) are the top 3 countries that have cited the research publications under DST FIST support apart from researchers in India who have widely cited (73035) the references.

### Institute Co-Authorship Analysis

Many projects need collaborative strength for the accomplishment of research work. Co-authorship analysis is a measure of the level of research collaboration, and it is an index to assess the status of research in a specific field. Institute co-authorship analysis is presented to visualize the extent of author involvement from various academic institutions.

**Figure 7: Institute Co-Authorship Network.****Table 11: Institute wise research publications acknowledging the DST FIST facility.**

| S. No. | Organization                   | Documents | Citations |
|--------|--------------------------------|-----------|-----------|
| 1      | Indian Institute of Technology | 623       | 8796      |
| 2      | University of Calcutta         | 476       | 6581      |
| 3      | Bharathidasan University       | 350       | 5655      |
| 4      | University of Madras           | 333       | 4129      |
| 5      | University of Hyderabad        | 318       | 3618      |
| 6      | Pondicherry University         | 273       | 3557      |
| 7      | Indian Institute of Science    | 303       | 3167      |
| 8      | Jadavpur University            | 230       | 2741      |
| 9      | Aligarh Muslim University      | 232       | 2557      |
| 10     | Anna University                | 171       | 1983      |

Figure 7 represents visualizations of institute co-authorship networks constructed using VOS viewer. Each circle represents a university/institute. The names of the university are not presented in complete form; to prevent overlapping; it is shown only as a subset of the full name. The size of the circle reflects the number of publications of the affiliated universities/institutes. The co-authorship link between institutes/universities is generally justified considering the closeness of circles and their lines. The stronger and denser the line, the better is the institute/university link.

Considering the above graph, the Indian Institute of Technology, University of Calcutta, University of Madras, University of Hyderabad, and Bharathidasan University are the top five influential institutes actively involved in scientific research. Indian Institute of Technology (IIT) has wide networking with various researchers of diverse institutions, which can be justified based on network strength.

Table 11 reports that the Indian Institute of Technology has topped the list with 623 research publications and 8796 citations, followed by the University of Calcutta (476 research publications and 6581 Citations), Bharathidasan University (350 research publications and 5655 Citations), and the



**Table 12: Most Relevant Sources.**

| Sources   | Impact Factor (IF) | Articles |
|---|--------------------|----------|
| Royal Society of Chemistry Advances                   | 3.049              | 281      |
| Chemistry Select                                      | 1.716              | 146      |
| New Journal of Chemistry                              | 3.069              | 134      |
| Tetrahedron Letters                                   | 2.33               | 134      |
| Dalton Transactions                                   | 4.052              | 122      |
| Polyhedron  | 2.067              | 103      |
| Crystal Growth and Design                             | 4.153              | 92       |
| Inorganic Chemistry                                   | 4.850              | 81       |
| Journal of Molecular Structure                        | 2.011              | 76       |
| Journal of Materials Science-Materials In Electronics | 2.195              | 71       |

\*Note: IF as on 2018

University of Hyderabad (318 research publications and 3618 Citations).

### Top ten most frequent journals

The top journals will provide prominent recognition to the authors and their affiliated institutes or universities by giving global credit for the work published. Table 12 presents the top 10 journals in which the highest number of articles published, acknowledging DST FIST funding support.

From Table 12, it is evident that most of the research contributions acknowledged the DST FIST support is from the domain of chemistry. A total of 1240 research articles were published in the top 10 journals. About 281 research articles were published in the Royal Society of Chemistry Advances (IF-3.049), followed by 146 articles in Chemistry Select (IF-1.716) and 134 articles each in the New Journal of Chemistry (IF-3.069) and Tetrahedron Letters (IF-2.33). The research articles are scattered in different branches of chemistry, physics, and material science. The research developed using the FIST facility is significantly high, justified by publication journals and their impact factor. The quality of the research publication is assessed based on the rank and IF of the journal published.

### Top ten productive authors

The most productive author/ researcher in a field helps identify the researcher who has individually contributed to the evolution and growth of research.<sup>[27]</sup> Identifying such pioneers in a particular research domain will help other budding researchers in that domain to approach them for a higher quantum of research, conduct multidisciplinary research and collaborations to achieve fruitful results for societal development, and solve other related issues. Table 13 presents the topmost publishing authors who have significantly contributed to the evolution and growth of research in diversified areas.

**Table 13: Top Ten Productive Authors.**

| Authors     | Articles | Authors     | Articles Fractionalized |
|-------------|----------|-------------|-------------------------|
| Ghosh A     | 124      | Ghosh A     | 32.5                    |
| Das S       | 105      | Biradha K   | 30.1                    |
| Ghosh S     | 100      | Rajakumar P | 29.6                    |
| Kumar A     | 93       | Das G       | 27.4                    |
| Roy S       | 88       | Ghosh S     | 22.7                    |
| Kumar S     | 87       | Roy S       | 22.5                    |
| Rajakumar P | 81       | Kumar S     | 20.3                    |
| Biradha K   | 78       | Das S       | 20                      |
| Das G       | 70       | Khan MA     | 19.5                    |
| Mukherjee S | 67       | Kumar A     | 19.3                    |

**Table 14: *h*-index, *g*-index, and *m*-index of authors.**

| Author      | <i>h</i> _index | TC   | NP  | PY_start |
|-------------|-----------------|------|-----|----------|
| Ghosh A     | 27              | 2169 | 124 | 2010     |
| Das S       | 16              | 827  | 105 | NA       |
| Ghosh S     | 16              | 835  | 100 | NA       |
| Kumar A     | 16              | 897  | 92  | NA       |
| Roy S       | 18              | 991  | 88  | 20080    |
| Kumar S     | 15              | 711  | 85  | 2009     |
| Rajakumar P | 14              | 563  | 81  | 2008     |
| Biradha K   | 23              | 1407 | 78  | NA       |
| Das G       | 20              | 1123 | 70  | 2008     |
| Mukherjee S | 17              | 896  | 66  | 2009     |

TC: Total Citations; NP: No. of Publications PY\_start: Publication Year

It is evident from Table 13 that Gosh A of the University of Calcutta has got the highest number of articles (124) by acknowledging DST- FIST funding, followed by Das S with 105 articles; and also the articles fractionalized. The article fractionalized indicates that if there are three authors associated with a single research article, each author is assigned a credit of 0.33 articles instead of one.<sup>[28]</sup> Professor Gosh A has the highest number of publications with a fractional credit of 32.5 articles. Further, from the above Table, it is evident that high-quality publications are from the northeast region.

### Citation analysis: *h*-index

The authors' *h*-index is an author-level metric that attempts to evaluate a scientist's research publications' citation impact and their respective productivity.<sup>[29]</sup> The index is based on the most cited papers and citations received in other publications.

Table 14 shows that Ghosh A has topped the list with an *h*-index of 27 and total citations of 2169 from 124 publications. It implies Ghosh A has been productive and positively impacted other researchers for their research work.



the keywords into 11 different clusters, as shown in the below Figure 8.

The Keyword co-occurrence network using VOS viewer resulted in 11 different clusters, of which four clusters are predominantly visible from the above Figure 8. The cluster has the keyword “oxidative stress,” which has the highest frequency of 114, and it is represented by red color in Figure 8. The other clusters, like crystal structure (110), x-ray diffraction (110), and cytotoxicity (91), are represented in yellow, green, and blue clusters, respectively. The link strength between two nodes refers to the co-occurrence frequency of keywords, and it means a quantitative index relationship between two nodes. The node’s total link strength is the sum of node strength over all the other nodes. The node oxidative stress (193) has strong and thick lines with the crystal structure (188), x-ray diffraction (303), Cytotoxicity (203), Apoptosis (141), Magnetic Properties (154), Antibacterial Activity (145), Fluorescence (94), Photoluminescence (96) and Antioxidant (98). These are all the nodes whose link strength is more than 10.

From the keyword co-occurrence network, it is evident that, of all the 7289 publications, there are a total of 31159 keywords. The top 10 keywords are oxidative stress (114), crystal structure (110), X-ray diffraction (107), cytotoxicity (91), apoptosis (87), magnetic properties (73), antibacterial activity (65), fluorescence (61), photoluminescence (59), and antioxidant (56). The keyword co-occurrence network map and top ten keywords in publications acknowledging the DST- FIST fund was constructed by VOS-Viewer software.

### Top 10 Local Citations

The local citation analysis [Local citation implies citation by Indian Authors] refers to the local author’s quality of research publications by the number of citations. In other words, it refers to the number of times other researchers cited the local author’s research works. It also measures how many times an

**Table 16: Top 10 Keywords of publications acknowledging DST FIST funding support.**

| S. No. | Keyword                | Occurrences | Total Link Strength |
|--------|------------------------|-------------|---------------------|
| 1      | Oxidative Stress       | 114         | 193                 |
| 2      | Crystal Structure      | 110         | 188                 |
| 3      | X-Ray Diffraction      | 107         | 303                 |
| 4      | Cytotoxicity           | 91          | 203                 |
| 5      | Apoptosis              | 87          | 141                 |
| 6      | Magnetic Properties    | 73          | 154                 |
| 7      | Antibacterial Activity | 65          | 145                 |
| 8      | Fluorescence           | 61          | 94                  |
| 9      | Photoluminescence      | 59          | 96                  |
| 10     | Antioxidant            | 56          | 98                  |

**Table 17: Top 10 Local Citations.**

| Author            | Local Citations |
|-------------------|-----------------|
| Ghosh A           | 464             |
| Das G             | 377             |
| Biradha K         | 277             |
| Rajakumar P       | 220             |
| Bakthadoss M      | 197             |
| Mohanakrishnan AK | 197             |
| Mohanta S         | 185             |
| Das Lk            | 171             |
| Drew Mgb          | 164             |
| Hajra A           | 161             |

author is included in this collection (database) has been cited by other local authors.

Table 17 shows that the research work of Ghosh A of Calcutta University has been cited 464 times by local authors or researchers. It is noteworthy to report, Ghosh A has been the most productive author (124 articles), with the highest number of citations (464), and he is the topmost local cited author in this study.

### CONCLUSION

The present bibliometric study was conducted to evaluate the DST-FIST scheme’s impact on scientific research publication growth. The data was extracted in WOS and used VOS viewer for visualization of bibliometric networks. This study consolidates bibliometric analysis and visualization of publications acknowledging the DST-FIST scheme/program. The study can identify several prominent researchers, their specific field of study, country collaboration, and publication sources in various research domains. This study also revealed interesting information regarding authors who have published the maximum number of papers, preferred sources of publication, most cited references, top ten authors, keywords, etc. Some exciting results covering DST-FIST acknowledged publications are summarized as follows:

The publication acknowledging DST-FIST was first published in 2003, although DST- FIST was established in 2000. The publications fluctuated at a low level during the initial period of 2003; after 2010, the number of publications multiplied. In 2003, the number of publications was only two, and during 2020 the number of publications is 7289. The analysis revealed a 25.6% annual percentage growth rate in publications each year. It indicates that DST-FIST acts as a facilitator to improve the research rigor across various research domains. Further, based on the findings, it is evident that higher funding rates are correlated with increased productivity in some studies but small or no increases in other research publications.

## Domain Analysis

A disciplinary distribution study revealed the focus areas of research publications acknowledging DST-FIST. It is quite evident that 47% of the total publications favoured to “Chemistry” domain, followed by “Biological Sciences (12%)”, “Materials Engineering (10%)”, “Physics (5%),” etc. The findings revealed that the publications from necessary science departments have a higher degree of research articles; incidentally, these domains’ funding is also ranked number one.

**Collaborative research work:** Concerning collaborative research work, India has a collaboration network among countries like the USA, Spain, England, Russia, France, Singapore, South Korea, etc. In terms of institutions, the Indian Institute of Technology has the highest number of publications and citations, followed by the University of Calcutta. It implies that the Indian Institute of Technology is effectively utilizing FIST funds for quality research publications.

**Citations:** The most common analysis in the bibliometric study is citation analysis. It measures the importance of publication work by counting the number of times cited by other authors. It also indicates the relevance of the research area. Concerning the number of citations, the trend graph revealed a positive growth up to 2014; it gradually took a decreasing trend after 2015 onwards. To identify the downward shift in citations, a domain analysis was carried out, which revealed that there was diversification in domain areas; for example, Materials was a part of basic science, later it emerged as a new research domain. The probable reason for the decreasing trend is assumed to be progressive changes in the research domain, the other factors like quality of the research paper, minimum time to gain the citations, obsolescence of research area, etc. The Journal Royal Society of Chemistry ranks first among top journals in which most research papers are published. It clearly shows that most of the articles published acknowledging DST-FIST support were published in Tier 1 journals, which indeed talks about the quality of scientific research across various Nation institutions.

In the analysis of keywords, we have found that more focus is on chemistry in the research area of “oxidative stress” followed by “crystal structure” and “X-ray diffraction,” etc. The keyword co-occurrence network gave insights regarding the main research themes across various institutions in India.

**Author:** It is essential to study the most influential/productive authors, and their affiliations and author-based analysis were carried out. The findings revealed that Ghosh A of the University of Calcutta, department of organic chemistry, is the most influential author with 124 articles published acknowledging DST-FIST. An article fractionalized count of 32.5 and *h*-index of 27. And also, Ghosh A has topped the local citations Table with a count of 464 citations. Co-citation

analysis refers to the citing of two publications of the same author reflected in other articles. The co-citation network analysis revealed 11 clusters of publications that are frequently cited together. An author-based bibliographic network yielded 24 clusters and revealed information about linkages and grouping various authors’ research works. Further, the analysis provides an understanding of the changes occurring over time and the trends in author-based knowledge networks.

From this, it can be concluded that DST-FIST support for science and technology infrastructure has been a boon and a motivational factor for researchers and academicians to involve them in active research and make significant contributions in diversified research areas. Such studies provide in-depth insights for policymakers on key research areas, the impact of research funding, output indicators, and recognize the potential areas for future funding. These output indicators can be further differentiated between Government and non-government institutions and study the relative strengths and weaknesses to perform better with government bodies’ assistance.

## LIMITATION AND FUTURE WORK

This study focused on the only DST-FIST funding from 2000–2019. As this infrastructural funding focused on the Indian academic higher education institutions, this may shed light only in India at the higher education level. Further research could be considered, at the discipline level, to compare the different disciplines and their outcome for various schemes, funding agencies. The present study has considered only WOS indexed publications, not other publications indexed in other databases such as Scopus, Google, etc. The present study also not focused on the patents and different research outcomes; this could be considered for further research. Lastly, an in-depth analysis of the relations between the amount spent on S&T and diverse research output from an economic perspective would be suggested.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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