How collaborative is Indian academia? A case study of top three ranked institutions

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The present study employs bibliometric methods to examine the pattern of existing collaboration in India’s top three ranked academic institutes using publications indexed in the Web of Science for the period 2000 to 2020. The results show although the number of collaborations and the degree of collaboration have increased over time, however, the collaboration coefficient remains almost the same in the three institutes. The lesser negative Pearson correlation between authors and articles with a higher positive Pearson correlation between articles and citations for JNU publications suggests that collaboration with a smaller group is more successful than a larger group for gaining citations. Collaborative publications of Banaras Hindu University (36%) and Indian Institute of Science (33%) are more inclined towards authors of the same department, while for Jawaharlal Nehru University, it is with other authors from different universities (41%). The foreign collaboration for all three institutes is almost the same. The network visualization of collaboration in three institutes suggests that the collaborative research in IISc is more diverse than JNU or BHU and in national collaboration, distance between two national organizations also play an important role for strong collaboration. Overall, theoretical aspects of physics lead in collaborative publications followed by chemical sciences. Agricultural biotechnology, clinical medicine, polymer sciences and nanoscience are some emerging disciplines where organizations are increasing their participation through collaborative research.

Keywords: Collaborative research; Collaboration; Bibliometrics

Introduction

Individual scientific research is evolving into collaborative research owing to the many inherent complexities in scientific research. Many scientific problems can be solved by working together with a team of scientists from different countries, institutions, or backgrounds. It is believed that useful and effective sharing of viewpoints, specialized knowledge of scientific disciplines, multi-disciplinary studies, increasing research costs and political factors all have played important role in increasing the level of collaboration between researchers.1

Collaborations also open opportunities to work with industries, the private sectors as well as governments through effective communication and partnership. The USA had enacted the Bayh-Dole Patent Reform Act in the 1980s for promoting cooperative ventures between and among research communities. (https://www.govinfo.gov/content/pkg/CHRG-110hhrg36592/pdf/CHRG-110hhrg36592.pdf). Many other countries have also introduced various acts based on the Bayh-Dole act. India, however, is yet to have any such act in force.

Indian Institute of Science (IISc), Jawaharlal Nehru University (JNU), and Banaras Hindu University (BHU) are the top three leading universities of India under the University category as per NIRF 2021 (https://www.nirfindia.org/2021/UniversityRanking.html). National Institutional Ranking Framework (NIRF) ranks institutes every year based on five parameters. Of these five, one parameter is “Research and Professional Practice” (30% weightage) in which publications (PU, total score 35), quality in publication (QP, total score 35), intellectual property rights (IPR, total score 15) and projects & professional practices (FPPP, total score 15) have been considered. In 2021 ranking IISc, Bangalore got 35 in PU and 35 in QP. JNU got 20.15 in PU & 20.56 in QP and BHU, 18.18 in PU and 23.64 in QP.

To promote collaboration with national and international partners, the three institutions have established linkages with universities as well as industries. While IISc has a Centre for Scientific and Industrial Consultancy, JNU has linkages with institutes in 48 countries. The International Centre, BHU was established to promote collaboration with
various nations and has adopted National Innovation & Start-up Policy. All these three centrally funded institutes have more than 50 years of existence. Comparing the research productivity of such reputed institutions is a significant and positive predictor of understanding both fiscal performance and trends in research.

Review of literature

Bibliometric analyses are relevant to the identification and characterization of the scientific profile of institutions and research fields to identify future research priorities, funding sources, and interdisciplinary collaboration. Such analysis enables institutions to judge how their policies translate into reality, to assess their strengths and weaknesses on research fronts, and accordingly modify and implement research policies. Bibliometric studies on collaboration have two preferred themes of inquiry viz., explanatory factors of collaboration and effect of collaboration on publications.

It is widely believed that collaboration correlates with research productivity and especially international collaboration with impact in research, however, Larivière et al. asserted that the impact of an article in terms of citation is particularly related to the number of participant authors, number of address and number of countries represented in the byline of an article. Narin et al., in addition, also observed that articles are more cited when collaborators are foreign as compared with those that are signed by local and national collaborators. But the number of collaborations is a predictor of publishing productivity in normal count method. It is not so in the fractional count of papers of the collaboration.

Frenken et al. showed that the diffusion of scientific knowledge as measured by citation is dependent on both intra- and inter-organizational characteristics. Citation impact can be related to the geographical scale of collaboration. Therefore, it is not fair to say that collaboration always leads to citations as there are other factors like number of collaborators, type of institutions involved and country of affiliation which also act as a catalyst for getting more citations.

Researchers who wish to add something new to their field may find that the reward is greater in doing so through remote collaboration than with others of the same laboratory. International collaborations are preferable as they seem to produce higher impact. It has also been believed that trade-off between academic publication and industry-oriented research and collaboration with industry lead to an initial increase in productivity.

To understand the diversity of collaborations, social network analysis becomes an important tool to study the partner’s position embedded in collaboration network. The configuration of linkage between partners, including the center and periphery in the organizational network, helps in determining the process of creation and flow of knowledge among partners. It also helps to answer the question of how partners should change their interactions to acquire a more desirable and advantageous position within a network. The degree of centralities like closeness and betweenness helps to understand the number of collaborators each node has, and also the distance between nodes and partners, and further the number of times a node lies ‘between’ other pairs of nodes.

Research collaboration is common in research, including natural and medical sciences as well as social sciences. It is also observed that across all disciplines, science in contemporary time has globalized at steady rate and the average collaboration distance per publication has increased from 334km in 1980 to 1553km in 2009. Despite significant difference in globalization rates across nations, a pervasive process in motion has been observed in the context of collaboration in science.

De Sola Price pointed out that collaboration plays a pivotal role, alongside competition in the innovation process of the country and has suggested that most productive researchers are those who collaborate most. The existing literature on collaboration pattern in India mostly discusses the authorship pattern or explains the pattern of collaboration in specific discipline like chemistry, biotechnology, solar cell research, economics, psychology. However, irrespective of discipline, how academic authors of a large-scale institutes participate in knowledge-focus collaboration with national and international partners, or property-focused collaboration with industries, or how collaboration effects in getting citation, and overall, how collaboration exhibit holistic knowledge output in different disciplines of an institution is yet to be explained.

This study is an attempt to assess the current situation of collaboration by considering India’s top three academic institutes in terms of quantity, citation,
extend of national & foreign participation in collaboration, and prominent areas of collaboration. To handle the data to a manageable extent, the present paper analyse all these parameters by restricting only top three NIRF ranked academic institutes of India.

Objectives of the study

- To identify the scientific activity (publications, collaboration, citations) of top three institutions; and form of collaboration (domestic or international, partnering countries);
- To assess the extent of collaboration between top national and international partners by using social network analysis; and
- To compare the collaborative dimensions (sectors, disciplines, and publication outlets) by establishing a subject framework.

Methodology

We identified top three ranked universities from the National Institutional Ranking Framework (NIRF) 2021. In the mid of June 2021, we retrieved publications of the three institutions from Web of Science for the period 2000 to 2020. We used the following parameters: Affiliation [name of each institution as mentioned in A-Z list] and Year Published [2000-2020]. Full bibliographic records of ‘articles’, ‘reviews’, ‘proceedings’, were considered from total download for analysis and however, publication types like ‘Letters’, ‘Corrections’, ‘Editorial materials’, and ‘News Items’ were excluded from the total downloaded data.

MS-Excel software was used for data analysis. Simple descriptive statistics like collaborative index (CI), degree of collaboration (DC), and collaboration coefficient (CC) have been calculated using formula given below. While CI is counted by the formula suggested by the Lawani\textsuperscript{26}; the DC is counted by the formula suggested by the Subramanyam\textsuperscript{27}; and the CC is counted by the formula suggested by the Ajiferuke et al.\textsuperscript{28}, which are as follows:

\[ CI = \frac{\sum_{j=1}^{n} j \times f_j}{N} \]
\[ DC = 1 - \frac{f_1}{N} \]
\[ CC = 1 - \left\{ \frac{\sum_{j=1}^{n} (1/j) f_j}{N} \right\} \]

Where,

- \( j \) = the number authors in an article i.e. 1, 2, 3 ……
- \( f_j \) = the number of \( j \) authored articles during the period
- \( f_1 \) = the number of single-authored articles

N = the total number of articles published during the same period, and
k = the number of authors per article

To analyze and visualize the collaborative network of these three institutions, the social network analysis tool VOS viewer and Pejak have been used. VOS viewer is a freely available tool based on Clauset, Newman, and Moore’s\textsuperscript{23} algorithm developed by Waltman, van Eck, and Noyons\textsuperscript{30}.

It was required to group subjects from a number of diversified author keywords in a framework from which the country’s research performance and emerging research fronts could be properly gauged. For this, we followed two steps. In the first step, all the subfields of the publications were identified; in the second, all these subfields were categorized into a framework of major domains of research.

WoS proves a tag, ‘SC’ (Research Area). One thousand three hundred and twenty-eight (1328) unique ‘SCs’ were identified. For effectiveness, we developed a framework and grouped all these subfields into a cluster of broad fields.

To develop the framework, we consulted the Essential Science Indicator (ESI) maintained by Clarivate Analytics and the Revised Fields of Science & Technology (FOS) classification in the Frascati Manual of OECD (2007) to understand how the subjects of science can be grouped in the best possible manner. Both the classification schemas organize related subjects under a broad subject category. By consulting both the schemas, we have developed a new schema consisting of 10 broad fields and 25 subfields.

In case the ‘SC’ field of any publication contained more than one subfield of our scheme, we kept it as multidisciplinary. The reason behind developing a new schema was that the existing two frameworks are not fully compatible to show the emerging and important research areas of Indian science and technology. For grouping subjects, two principals were kept in mind, viz. 1) Specific research fields are preceded by General research fields and 2) if any publication has ‘practice’ emphasis, the publication has been kept in practice sub-fields.

Results

Table 1 summarizes the publication, fractional publications, authors, and authors in contrast with citations for the three academic institutions. IISc authors received more citations than BHU and JNU authors. However, the dataset in our analysis suffers
from dispersion as the standard deviation of publication (56.93, 89.60, & 65.86 for IIS, JNU, and BHU respectively) of all three organizations significantly exceed its means (22.39, 20.82, & 20.52 for IISc, JNU, and BHU respectively). This skewed distribution suggests that a small number of publications received many citations while many publications receive a small number of citations.

The collaboration index shows that on average, each article from BHU was the result of collaboration between more authors than JNU or IISC. This is because there are 51 articles from BHU and 18 articles from JNU where the number of authors per article is more than 500, whereas no article of IISc has such large author group.

Figure 1 shows the number of collaborative publications for BHU has increased steadily as compared to JNU or IISC. Overall, a degree of collaboration of 0.85 to 0.96 showed a relatively similar tendency towards collaborative works. The collaboration coefficient nears to 1 for all three institutions which indicates that the trend of collaboration is more towards the multi-authored paper. However, at the same time, a negative Pearson correlation between author and article means although ‘number of collaborative articles per year’ has increased from 2000 to 2020, the other variable that is ‘number of authors per article’ has not increased with the same magnitude, or the two datasets move in a non-linear way.

A higher degree of collaboration is found only because of a limited number of articles where the number of authors is quite high. Negative moderate degree correlation has been observed in IISc whereas a negative weak degree correlation has been observed in BHU and JNU. In contrast, a positive correlation between author and citation indicates that the number of authors in an article is deciding factor in getting more citations.

If we relate the quality of publication with the number of citations received, it may be concluded that quality could generally be dependent on collaboration activities but collaboration with a smaller group is more effective than in a larger group, as the Pearson correlation is much higher for JNU than BHU or IISc.

In Table 1, we have summarized that collaboration has a relation with citation. In the next steps, we try to understand which form of collaboration leads to more citation.

<table>
<thead>
<tr>
<th>Particulars</th>
<th>IISc</th>
<th>JNU</th>
<th>BHU*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Output: Output in collaboration (%)</td>
<td>31946: 29925 (93.67)</td>
<td>7884: 6748 (85.59)</td>
<td>17872: 17235 (96.44)</td>
</tr>
<tr>
<td>Average authors/ collaborative articles</td>
<td>3.98</td>
<td>2.76</td>
<td>11.82</td>
</tr>
<tr>
<td>Collaborative Index</td>
<td>3.83</td>
<td>7.44</td>
<td>11.43</td>
</tr>
<tr>
<td>Degree of Collaboration</td>
<td>0.9500</td>
<td>0.8559</td>
<td>0.9643</td>
</tr>
<tr>
<td>Collaboration Coefficient</td>
<td>0.6806</td>
<td>0.6107</td>
<td>0.6842</td>
</tr>
<tr>
<td>Cit./Art (Solo): Cit./Art (Collaborative)</td>
<td>12.31: 22.39</td>
<td>3.98: 20.82</td>
<td>10.94: 20.52</td>
</tr>
<tr>
<td>Fractional Cit. /Collaborative article</td>
<td>6.90</td>
<td>4.73</td>
<td>5.10</td>
</tr>
<tr>
<td>Pearson Correlation [article &amp; author] (y)</td>
<td>-0.46756</td>
<td>-0.23108</td>
<td>-0.20662</td>
</tr>
<tr>
<td>Pearson Correlation [author &amp; citation] (y)</td>
<td>0.059493</td>
<td>0.466553</td>
<td>0.288156</td>
</tr>
</tbody>
</table>

Art. = Article, Cit.=Citation, * = Excluding IIT-BHU

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**Fig. 1** — Collaborative research trends
While collaborative publications of BHU (36%) and IISc (33%) are more inclined towards authors of the same department (ID), authors of JNU collaborate more with authors from different universities (41%) Table 2. The foreign collaboration publications for all three institutes are almost equal, which never exceed 20%. However, authors of almost 160 countries out of 195 countries of the world have participated in collaborative activities. Articles published in collaboration with foreign authors received 37% of the total citations for JNU, 33% for BHU but only 22% for IISc.

Collaborative Publications & Citations

<table>
<thead>
<tr>
<th>Collaborative Publications &amp; Citations</th>
<th>IISc</th>
<th>JNU</th>
<th>BHU</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Global: % Citations</td>
<td>20.77:22.95</td>
<td>20.04:37.02</td>
<td>19.52:33.70</td>
</tr>
<tr>
<td>% Local: % Citations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University-Industry (UI)</td>
<td>6.51:7.25</td>
<td>7.34:7.07</td>
<td>8.89:7.63</td>
</tr>
<tr>
<td>University-University (UU)</td>
<td>29.47:29.71</td>
<td>41.06:33.24</td>
<td>25.02:19.65</td>
</tr>
<tr>
<td>Intra-Department (ID)</td>
<td>33.52:31.46</td>
<td>26.90:13.93</td>
<td>36.34:30.24</td>
</tr>
<tr>
<td>Intra-University (IU)</td>
<td>9.29:8.62</td>
<td>3.42:2.43</td>
<td>9.90:8.78</td>
</tr>
<tr>
<td>Active MoUs (# Countries)</td>
<td>110 (27)</td>
<td>91 (36)</td>
<td>57 (22)</td>
</tr>
</tbody>
</table>

Table 2 — Extent of collaboration in academic institutes

Collaborative Publications & Citations

<table>
<thead>
<tr>
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<th>IISc</th>
<th>JNU</th>
<th>BHU</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Global: % Citations</td>
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<tr>
<td>% Local: % Citations</td>
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<td>57 (22)</td>
</tr>
</tbody>
</table>

Collaboration as visualized in network analysis

Table 3 indicates the number of links, closeness centrality, and betweenness centrality of the top 5 national and international institutions of each of these organizations based on total collaborative publications. The disparity in total publications and total links indicates that real social connections are difficult to establish. The larger number of clusters for IISc suggests that the dimension of collaborative research in IISc is more diverse than JNU or BHU. JNU and BHU have more generic characteristics and thus yield fewer clusters. In national collaboration,
location also play an important role as two nearby institutions collaborate more than institutions located at distance.

In organization co-authorship network of IISc, institutions like BHU, BARC, University of Hyderabad, IITs, University Tokyo, National University of Singapore are more likely to collaborate on similar subjects. Therefore, they are in the same cluster (Cluster 1). Foreign organizations like Stanford University, MIT, Columbia University, Lund University are in another cluster (Cluster 2); CNRS, TIFR, CSIR in yet another cluster (Cluster 6).

In case of JNU, University of Delhi, BHU, ICMR, University of Illinois, IITs, AIIMS, International Centre for Genetic Engineering and Biotechnology constitute a cluster as they collaborate on the same subjects while University of Colorado, University of Cambridge, University of Hyderabad are in other clusters but have very weak relation between them. In the third cluster, University of Washington, University of Tokyo, Karolinska Institute have a greater role in collaboration. University of Oxford and Harvard University play an important role in connecting Clusters 2 and 3. For BHU, there are three clear clusters visible whereas University of Tokyo, University of Tennessee, BARC, etc. constitute a strong cluster while IITs, University Delhi, CSIR, etc. constitute another cluster. University of Cambridge, Punjab University, etc., are in the third cluster but have no relation between these organizations.

The co-authorship network of organizations shows that group of organizations with more closer relationships and greater productivity are in the centre, while the organizations which have relatively less connectivity, are situated on the periphery. Closeness centrality (CC) considers how close the node is to any other node in the network. The CC (measured through Pejak) of a node is calculated considering the total distance between one node and all other related nodes, where a larger distance yields a lower closeness centrality score.

As it is inverse to the mean distance, a smaller index value indicates a higher distance between the nodes and a higher closeness score demonstrates a shorter distance between the nodes. On the other hand, the betweenness indicates, how important a node is in terms of connection with other nodes and how it serves as a gatekeeper. An institution with higher betweenness means the institutions has more control over the flow of information and has more capacity to keep groups of co-authors separate.

In this study, we observed that only a small group of organizations exercised minimal control over the knowledge flow. The mean of these indices is close to zero and even organizations those appeared highlighted have low scores. The shortage of nodes that serve the function of gatekeeper could be considered as a determining factor for the low connectivity of the network and for contributing to narrowing of the knowledge into small communities.

The collaboration network maps of IISc, BHU and JNU with institutions that they have each collaborated or 10 or more article is shown in Figures 2, 3 and 4.

Subject distribution

The collaboration pattern in different research areas and its effect on citations are indicated in Table 4. It is seen that the overall, theoretical aspects of physics lead to collaborative publications followed by chemical sciences. However, an increasing collaboration is observed in the fields like biochemistry and
Table 4 — Subject pattern in collaborative articles

<table>
<thead>
<tr>
<th>Main Division</th>
<th>Subdivisions</th>
<th>BHU</th>
<th>JNU</th>
<th>IISc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural Sciences &amp;</td>
<td>Agricultural Sciences including Dairy and Veterinary sciences (AG-A)</td>
<td>479</td>
<td>12.76</td>
<td>74</td>
</tr>
<tr>
<td>Applications (AG)</td>
<td>Agricultural Biotechnology (AG-B)</td>
<td>296</td>
<td>33.86</td>
<td>81</td>
</tr>
<tr>
<td>Biological Sciences &amp;</td>
<td>Animal Sciences (BS-A)</td>
<td>256</td>
<td>19.41</td>
<td>47</td>
</tr>
<tr>
<td>Applications (BS)</td>
<td>Biochemistry &amp; Molecular Biology (BS-B)</td>
<td>856</td>
<td>17.32</td>
<td>970</td>
</tr>
<tr>
<td></td>
<td>Plant Sciences (BS-C)</td>
<td>623</td>
<td>22.37</td>
<td>226</td>
</tr>
<tr>
<td></td>
<td>Other Biological Sciences (BS-D)</td>
<td>389</td>
<td>13.8</td>
<td>213</td>
</tr>
<tr>
<td>Chemical Sciences (CH)</td>
<td>Electrochemistry (cell, energy, and fuels etc.) (CH-A)</td>
<td>449</td>
<td>25.64</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Polymer Science including Material science (CH-B)</td>
<td>1114</td>
<td>16.16</td>
<td>169</td>
</tr>
<tr>
<td></td>
<td>Other Chemical Sciences (CH-C)</td>
<td>1839</td>
<td>18.84</td>
<td>384</td>
</tr>
<tr>
<td>Earth sciences (ES)</td>
<td>Geosciences, Meteorology &amp; Atmospheric Sciences (ES-G)</td>
<td>1088</td>
<td>16.6</td>
<td>543</td>
</tr>
<tr>
<td></td>
<td>Oceanography, Hydrology, Water Resources (ES-W)</td>
<td>75</td>
<td>14.79</td>
<td>107</td>
</tr>
<tr>
<td>Engineering and Technology (ET)</td>
<td>Civil, Mechanical &amp; Electrical Engineering (ET-A)</td>
<td>857</td>
<td>16.24</td>
<td>394</td>
</tr>
<tr>
<td></td>
<td>Chemical, Material &amp; Environmental Engineering (ET-B)</td>
<td>1060</td>
<td>26.78</td>
<td>201</td>
</tr>
<tr>
<td></td>
<td>Biotechnology &amp; nanotechnology (ET-C)</td>
<td>796</td>
<td>23.58</td>
<td>455</td>
</tr>
<tr>
<td>Medical &amp; Health Sciences (MH)</td>
<td>Basic Medicine (MH-B)</td>
<td>1334</td>
<td>23.4</td>
<td>510</td>
</tr>
<tr>
<td></td>
<td>Clinical Medicine (MH-C)</td>
<td>1558</td>
<td>25.14</td>
<td>480</td>
</tr>
<tr>
<td></td>
<td>Health science &amp; medical Biotechnology (MH-H)</td>
<td>432</td>
<td>24.37</td>
<td>189</td>
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<tr>
<td>Physical Sciences (PS)</td>
<td>Physics - Theoretical Aspects (PS-A)</td>
<td>1742</td>
<td>23.18</td>
<td>647</td>
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<tr>
<td></td>
<td>Physics - Experimental Aspects (PS-B)</td>
<td>307</td>
<td>14.98</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Space Physics (PS-C)</td>
<td>322</td>
<td>17.72</td>
<td>19</td>
</tr>
</tbody>
</table>

(Contd.)
molecular biology, polymer sciences, environmental sciences. But subjects under arts and humanities, social science received little attention for collaboration. On the other hand, articles in agricultural science tend to have more citations on average when in collaboration followed by clinical medicine. Subjects like space physics, nanotechnology, and molecular biology also received more citations while collaborating. Very less citations have been noted for collaborative articles in mathematics.

**Discussion**

Analysis of institutional collaboration by employing bibliometric methods unveils collaborative trends in the top three Indian academic institutes for the last two decades. This study shows that the frequency of collaboration in top Indian universities is growing and articles in collaboration receive more citations. Collaboration with a group consisting of a few members is more effective than collaboration with many authors and institutions. Such small-group collaboration is more predominant in IISc than BHU or JNU. Communication between universities, even foreign institutes is also noticed in this study but collaboration between industries is quite less. For improving the innovative environment that better meet the need of society, the collaboration between university and industries are expected.

The network analysis of collaboration between institutions suggests that the distance between institutions is a deciding factor of national collaboration, as we have observed that JNU remains more collaborative with Delhi University; IISc with Jawaharlal Nehru Centre for Advanced Science & research, Bangalore, and BHU with IIT, Kanpur. However, for international collaboration, these three institutions collaborate more with institutes located in advantageous countries like the USA, UK, Germany, Singapore, etc. These findings are in accordance with the findings of Sooryamoorthy.

**Conclusion**

The domains where most collaborations have been made indicate that collaboration is still more predominant in traditional fields like physics, chemistry, or its allied application-oriented disciplines. However, the citation behavior of articles in fields like agricultural biotechnology, clinical medicine, polymer science, nanotechnology suggests that there may be a wide scope to increase participation with such subjects which have industrial emphasis. Further analysis of how each existing collaboration group is formed is desirable to imply such practices in other disciplines too. As India is yet to have any act like Bayh-Dole Patent Reform Act, a holistic framework seems to be effective to address many positive aspects of university-industry collaboration.

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