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Re-evaluating India's Third Mission through Top Ranked Universities & Technological Institutes

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ABSTRACT

The present study explores the patenting activities of the faculty staff of the top 20 Indian academic and engineering institutes during 2011-2020 by excavating the Indian patent office database. Of the total 963 granted patents, the highest patents were published in 2016, and the academician of IIT Madras invented 167 patents followed by IIT Mumbai with 156 patents during this period. Most of the innovation takes place in the macro-field like chemical engineering, and micro-fields like nano-technology, nano-materials, and nano-complex. Collaboration with inventors of the same academic institution is found as the best choice of the inventors, only a meagre portion of patents was published in collaboration with of industries and organisations around the globe. The tag 'highest number of patents inventor' goes to Padma Shri Prof. Thalappil Pradeep of IIT Madras who has contributed 19 Indian patents in the last 10 years.

Keywords: Indian patents; inPASS; University-industry collaboration patents; Patents-India; Academic patents; Patenting activities-University

1. INTRODUCTION

There is a changing demand in academia to expand their research activities on economic and social development tangibly, not just by contributing publications in reputed journals to get citations. Over the past few decades, universities have undergone a fundamental change from their traditional mission of teaching and research to incorporating the 'Third mission', by generating knowledge outside academia for the benefit of society and resolving diverse societal challenges. Universities have been increasing their entrepreneurial activities in many areas, including patenting[1]. Patents are vital for technological innovation, either as a product or a process, essentially patents are important not only for the protection of intellectual rights but also as an indicator to understand the involvement of any academic institution in outreach activities for the benefit of society. Globally, universities' mission is now expanding to include economic development by translating the research activities into innovations or by developing commercially viable processes and technologies for others. And to what extent this "time-to-innovation" is evident for a country like India is an important question to consider. While there has been a hefty amount of research carried out on academic research activities, collaboration, or fields of interest among academician, the patent analysis using a quantitative figure of a country like India has not been the subject of in-depth study, despite having a large educational base with a considerable number of engineering institutes, research-intensive, and teaching-intensive academic institutes.

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Patents often incentivise synergic partnerships between inter-academic institutions or university-industry partnerships. Despite patents being known for generating revenue, the country's collaborative trends towards innovation could also be inferred from the patent data. The geographical region where a patent is filed or granted in, demonstrates the wide applicability of the technology for that country as perceived by the inventors, it provides a fairly reliable idea of innovation evolving in a particular geographical location over a while.

Several factors including social, environmental, political, etc. influence inventors to apply for a patent. While it is nearly impossible to consider all the factors and measure their impact on innovation, investigating output using a national database could provide a fair idea of how innovation grows and affect the knowledge flow among different stakeholder of that nation. One such database, Indian Patent Advanced Search System (inPASS) introduced in 2015, is an authoritative database maintained by the Office of the Controller General of Patents, Design & Trade Marks, Government of India (GoI). This database allows full-text search for granted patents as well as patent applications, but the whole data cannot be downloaded in one attempt. One has to download files one by one. Other known databases for searching patents include the dataset of the World Intellectual Patent Office (WIPO), US Patent & Trademark Office database (USPTO), European Patent Office database (EPO), and others, which allows complete download. However, it is challenging (explained in methodology) to get the exact output from these databases.

In this study, we restricted our analysis within the scope of inPASS. The quantitative data gathered from the national database acts as an invaluable instrument for technological planning and analysis of the country. It provides us with a technological indicator to measure technological growth, that might be useful in understanding the relation and mutual dependence of innovation and economics[2].

2. EARLIER RESEARCH

Throughout the world, a radical change in the number and share of academic patents has been observed[3] not only in the USA[4] Europe[5], or Germany[6] but also in Asian countries like Japan[7], China[8] etc. However, the academicians are now actively participating in patenting activities, not necessarily the affiliation to which they belong but the inventor's personal address. Studies have mentioned that patents produced by academics are not patented under the name of the university[9] and the institutional affiliation of the inventors is not often accurately acknowledged. As a result, 60 % - 80 % of academic patents are not owned by the universities. Thus, even patents that acknowledge only as commercial institution may have an academic origin[10].

Why collaboration between academic-industry is needed for innovation? Montobbio[11] gave economic justification for university patenting as a way to facilitate the exploitation of scientific discoveries by industry through the provision of proprietary rights over invention. Colyvas, *et al.*,[12] argued that inventions developed by universities are often unhatched and need further investment for development. In the Indian context, Nandagopal[13] commented on the need for national policies and stratified models to bring the research output of a university to market for public benefit. Ravi and Janodia[14] proposed conceptual models for technology transfer based on empirical evidence concerning various policies available in the USA, Japan, and Israel.

In the Indian context, only a few studies have been conducted so far. Singh and Chakraborty[15] analysed the patenting activities of 64 companies in India which were published on the website of IPO during 2012 and 2013. They found that Qualcomm topped the list with 113 granted patents followed by the Council of Scientific and Industrial Research (CSIR) with 1085 patents. Ray & Saha[16] conducted a study to identify driving factors of patenting in premier technical and research institutes of India. Similarly, Sharma & Jain[17] analysed the publication and patent data of 347 universities and technical institutions from 1970 to 2010. They found 642 patent applications in IITs in the last 42 years while only 182 patent applications were filled by all state and central universities in IPINDIA patent service. The present study is different from these earlier studies because we have analysed data on granted patents instead of applied patents. To the best of our knowledge, no study has yet been conducted on patenting activities among academicians by analyzing the granted patents.

3. RESEARCH QUESTIONS

Patents are metrics to measure the success of innovation of a country in the global marketplace. The figure provided by the WIPO indicates how India's GDP (Gross Domestic Product) has been directly affected by the patent filling [see: https://www.wipo.int/ipstats/en/statistics/country_profile/profile.jsp?code=IN]. Although, the history of patent law in India dates back to 1856 [see: https://ipindia.gov.in/history-of-indian-patent-system.htm], in the last few years, the government has been taking regular initiatives to ensure the patent system to be conducive to the national interest. In 2018, the University Grants Commission (UGC) asked all universities in India to set-up intellectual property centers. Following that, most institutions set up such centers with limited resources they had. As we all know change don't happen over-night, it is necessary to explore how with time various initiatives by the government institutions are being translated into real achievement? Therefore, an attempt has been made through this study to search for the answers to the following research questions by analyzing the patenting activities of the top 20 NIRF-ranked institutes of India for the last 10 years.

- To what extent India's top-ranked academic institutions are participating in the accomplishment of the third mission by developing patents?
- At what macro- and micro-subject levels Indian innovation is predominant and who are the top players in the Indian innovation system?
- Whether their attempt is cross-institutional, cross-national, or simply restricted to organisational level and how much collaboration they are doing with industrial organisations?

4. METHODOLOGY

The sample for the study was taken from the National Institutional Ranking Framework (NIRF). The top twenty institutes in the 'Overall' category of NIRF-2021 were chosen. Due to computational and time limitations, we took only a fraction from the list instead of all. Our sample consists of central government-funded universities, state-funded universities, engineering institutions, deemed universities, and private universities.

The patent data of these universities has been collected from the InPASS database (national filling). The search was made during December 2021. Despite InPASS facilitating search for published applications and granted patents, we put a search query for 'Granted patents' using the name of the institutes as 'Inventor address' along with 'Year of the publication' (2010 TO 2020), separated by Boolean logical operator AND. All alternative names (like IIT-M or IITM or IIT Madras for Indian Institutes of Technology, Madras) were also used to include all possible results. The search result consisted a list of all patents along with their title and hyperlinked application number. As of now, the inPASS database does not allow to download all search results in any format, the data collection process follows a semi-automatic workflow to obtain results. At the outset, a set of keywords, name elements, etc. related to different Indian institutes is finalised and entered into a spreadsheet program. The CSV formatted data for a single column containing the application number are then imported into OpenRefine (an open-source data wrangling software) to fetch results from the designated database through a carefully crafted API syntax. For our experiment, we performed a similar search in the WIPO database too for cross-verification. A search string consists of ALL: ("Indian Institute of Technology Madras") AND DP:([01.01.2010 TO 31.12.2020]) (for all applications by Indian Institute of Technology Madras during 2010 to 2020) and PAA:("Indian Institute of Science") AND DG:([01.01.2010 TO 31.12.2020]) (for all granted patents of Indian Institute of Science during 2010 to 2020). However, our observation had erratic results for the academic institution like Jawaharlal Nehru University, Banaras Hindu University, or Calcutta University and satisfactory results for the Indian Institute of Technologies. Although the number of granted patents searched through WIPO for IITs were 0.25 per cent to 0.50 per cent higher than InPASS, but overall results of inPASS were stable. Because of that, we restricted our search only to inPASS.

From each patent document, we extracted the relevant meta-information relating to the application date, title, applicant's institutions, inventor(s), broad subject category as devised in InPASS, IPC classification codes, etc. Indian patents registered in Indian Patent Office follow the International Patent Classification (IPC) system [https://www.wipo.int/classifications/ipc/ipcpub/] under which each patent can be classified under one (or more) of the eight classes bearing notation A to H. As A: Human Necessities; B: Performing Operations; Transporting; C: Chemistry; Metallurgy; D: Textiles; Paper; E: Fixed Constructions; F: Mechanical Engineering; Lighting; Heating; Weapons; Blasting; G: Physics; and H: Electricity. Each of these sectors are further classified into four levels of sub-classes. Note here, that in this study when we counted the number of patents belonging to a particular sub-class, we gave weightage of one to each class for those patents that belonged to more than one IPC sub-class. A variety of software tools for social network analysis are been used now a days. For displaying the major inventors in the domain of granted patents in India, the freeware Gephi Visualisation tool has been used. The reason behind using Gephi over other tools is its compatibility to handle extracted data in different forms. The International Patent Classification (IPC) scheme has been used to display the major domain in Indian patents and up-to four levels of IPC number have been used to show the domain in patent research.

Table 1. Distribution of patents in top academic institutions of India

Rank	Name of the Institute	Year of Establishment	IPR score	Teaching Strength*	Expenditure (in Crore)	No. of Faculty involved in patenting	No. of Granted Patents
Central Funded Engineering Institutes							
1	Indian Institute of Technology Madras (IIT M)	1959	15	642	604	349	167
3	Indian Institute of Technology Bombay (IIT B)	1958	15	682	416	296	156
4	Indian Institute of Technology Delhi (IIT D)	1961	11	706	532	209	87
5	Indian Institute of Technology Kanpur (IIT Kn)	1959	13	499	509	251	123
6	Indian Institute of Technology Kharagpur (IIT Kg)	1951	6	809	440	149	72
7	Indian Institute of Technology Roorkee (IIT R)	2002	5	574	166	39	20
8	Indian Institute of Technology Guwahati (IIT G)	1994	7	436	201	68	30
16	Indian Institute of Technology Hyderabad (IIT H)	2008	5	242	139	8	9
Central Funded Deemed Research University							
2	Indian Institute of Science, Bangalore (IISC)*	1909	13	464	214	287	136
Central Funded Universities							
9	Jawaharlal Nehru University, New Delhi (JNU)	1969	3	647	148	29	14
10	Banaras Hindu University, Varanasi (BHU)	1916	1	1535	467	49	32
13	Jamia Millia Islamia, New Delhi (JMI)	1920	3	742	105	26	11
17	University of Hyderabad (UH)	1974	1	442	17	33	18
18	Aligarh Muslim University, Aligarh (AMU)	1920	2	1674	118	29	21
19	University of Delhi, New Delhi (DU)	1922	3	1060	163	75	31
State Funded Universities							
11	Calcutta University, Calcutta (CU)	1857	6	1275	265	16	10
14	Jadavpur University, Calcutta (JU)	1955	1.50	639	99	23	11
20	Savitribai Phule Pune University (SPP)	1949	2	712	367	1	1
Private Funded Deemed Research University							
12	Amrita Vishwa Vidyapeetham, Coimbatore (AVV)	1994	11	1624	411	14	6
15	Manipal Academy of Higher Edn, Karnataka (MU)	1953	3	2661	933	11	8

Rank, Teaching Strength, Expenditure & IPR Score (out of 15) is Based on NIRF 2021; Expenditure of is in round-off value of total expenditure in Library, New Equipment for laboratories, and Maintenance of Academic Infrastructure or consumable and running expenditure (2019-20). Edn=Education

5. ANALYSIS AND DISCUSSION

5.1 Growth in Patenting Activities

Before going into details, it is important to understand that this analysis is based on the granted patents (national filling) identified in the inPASS database. So patents that were applied/filled/granted by USPTO or European patent office or others were not included. To get comprehensive results, efforts have been made to search the database by creating an alternative query for the institution's name including earlier name, abbreviated name, etc. Table 1 shows that out of the total 8 IITs, 5 earlier established IITs produced almost 63 per cent of the total patents granted compared to the newly established IITs that contributed only 6 per cent of the total patents during the taken time period for this study. The IISc, unique in its category, produced the third-highest number of patents (27 %) with an average of 0.47 patents per academician.

On the other hand, centrally funded and state-funded traditional universities (excluding IISC) contributed only 15 per cent (13 % & 2 %, respectively) of the total patents. While a greater percentage of academicians from IISc (29 %) & IITs (30 %) are involved in patenting activities, such percentage in traditional universities never exceeded 5 per cent. Among IITs, IIT Madras topped the list followed by IIT Bombay and among centrally funded deemed universities, IISC, Bangalore topped the list followed by Banaras Hindu University. Among the state-funded institutes JU and CU (both from West Bengal) are on the top in their group. Our results differ considerably from the results obtained by Sharma and Jain[16]. Their study was undertaken using 42 years of data on patents applied by the inventors of IITs and Centrally-funded institutes. Interesting to note here is that as per the NIRF-2021, the IPR score for AVV is 11 for 6 granted patents while, it is 1.5 for JU with 11 patents.

Figure 1 shows the growth of granted patents in these academic institutes for the last 10 years and it is clearly evident that the scenario has changed completely for the present contemporary time (119 patents in 2019) from that in 2010 (36 patents).

However, a sudden decline from 2016 (163 patents) to 2017 (89 patents), and finally in 2020 (72 patents) for all engineering and academic institutes was observed. These decline are almost same as mentioned in the Economic Survey Report by Government of India. In the year 2016, the Government of India amended the rule by withdrawing some imposed restrictions. Such flexibilities hiked the patent filling up to 108 % in 2017-18 than the previous year in 2016-17.

The initiative towards the establishment of intellectual property office at the university level might also give advantages to the inventors towards patent filling. However, a fall in patent filling in the earlier years like 2015-16 and a dip of 3.2 per cent in patent filling in 2016-17 may be the reason for such decline[18,19]. Moreover, the average pendency for getting the final decision on a patent application in India was three and half years in 2020 compared to the more than 4 years in 2019 and more than 5 years in 2017[20].

Recently in 2020, the government amended Form 27 (changing from Calendar year to Financial year to make collation of information for filling easier; one form for multiple patents, etc.) and Rules 131(2) and Rule 21 and in 2021, the Indian government again amended patent rules by reducing the patent filing fee and prosecution of education institutes by 80 per cent[20]. It is expected that such an initiative will strengthen innovation and creativity in the knowledge economy in the coming days.

5.2 Fields of Invention

Every patent information in inPASS contains two fields: Field of Invention (Unique) and IPC (more than one). Table 2 provides information on the fields of the invention of the patenting activities. To visualise the major fields and their interconnection with other fields, a visualisation graph was prepared using IPC classification using Gephi software. The graph and their corresponding table are shown in Fig. 2 and Table 3, respectively.

From the IPC classes, it is clear that most academicians developed their patents in the IPC classes H, A, G & C. While considering co-occurring classes, it was further seen that the fields like medial apparatus, wireless communication, & conversion of electrical apparatus show convergent-field while rest shows diversified co-occurring classes. Individually, Chemical Science/Engineering is the most productive field where almost all institutes generated patents. This suggests the propensity of academic inventors is higher in the field. Almost 35 per cent of the total patents belong to this field. When these

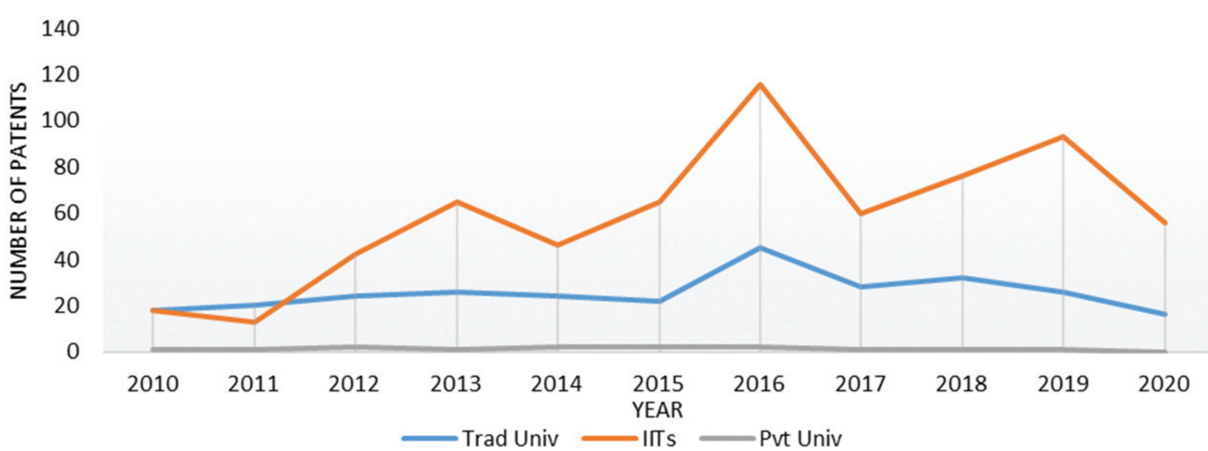

Figure 1. Comparative growth of patent contribution in academia.

Table 2. Distribution of patents according to the fields of invention

Domain	IITs	Trad Univ.	Pvt Univ.	Total	Top 10% contributing institutes
Chemical Technology	249	88	3	340	IIT-Ma, IIT-B, IIT- IIT-K
Mechanical Engineering	80	36	1	117	IIT-Ma, IISc, IIT-K
Electrical Engineering	64	35	0	99	IISc, IIT-B, IIT-Ma
Physics	43	21	0	64	IISc, IIT-K, IIT-B
Pharmaceuticals	39	19	4	62	IIT-M, IIT-Kn
Polymer Science	51	9	1	61	IIT-Kn, IIT-Ma, IIT-M
Communication	33	5	0	38	IIT-B, IIT-Ma, IIT-Kn
Biotechnology	20	15	3	38	IISc, IIT-M, IIT-D
Electronics	24	10	0	34	IISC, IIT-K, IIT-B
Computer Science	11	8	1	20	IISc, IIT-Ma
Biochemistry	7	10	0	17	IISc
General Engineering	9	3	0	12	IIT-K
Bio-medical Engineering	12	6	0	18	IIT-Ma
Agrochemical	5	4	0	9	IISc
Metallurgy	4	5	0	9	IISc
Microbiology	3	4	1	8	-
TK Biotechnology	0	6	0	6	UH
Textile	4	0	0	4	IIT-D
Agriculture Engineering	2	1	0	3	-
Civil	3	0	0	3	-
Food	1	0	0	1	-
Total	664	285	14	963	-

TK=Traditional Knowledge, Trad Univ.=Traditional Universities, Pvt Univ.=Private Universities

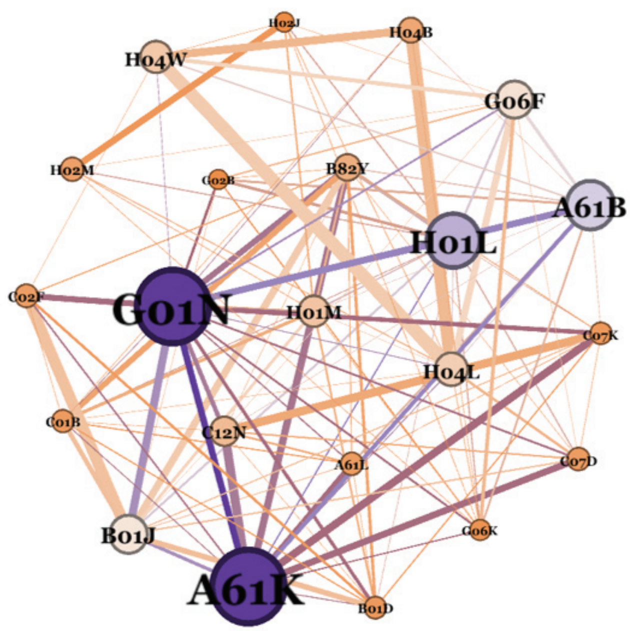

Figure 2. Network of co-occurrence of major four digit IPC class of inventions.

figures in Table 2 are adjusted with the IPC class, as visible in Table 3, it was further observed that chemical analysis materials towards the development of better sustainable materials, preparation of medical apparatus; development of semiconductor devices, etc. are a few major areas where Indian academics are driving their attention. From these top 15 highly productive patent classes, it is quite clear that Indian academia is mostly interested in developing utility patents than design or plant patents. Schmoch[21] pointed out that one of the reasons for seeking patent protection is to show an interest in the commercial exploration of new technology and accordingly, most of the patents assigned are for industrial enterprises. In our study, the considerable number of patents by these academic institutions in the fields like chemical technology or chemical engineering especially the application of nontechnology for the production of nano-products might be the reason. Academic inventors are also developing patents in the fields like polymer science and pharmaceutical science which is a positive sign. However, more attention is expected from the inventors in the fields like agricultural engineering, bio-medical engineering, textile, food, etc. to develop indigenous patents that are necessary for the country's overall growth.

5.3 Micro-level Significant Inventions

Next, a micro-level subject distribution has been identified by analyzing the title and the abstract of the patents. In Table 4, column 4, significant micro-areas are mentioned where inventors of these institutions developed patents. For this purpose, every title has been tracked manually and terms were identified from the title. The three major macro-areas where

Table 3. Top 15 patenting Macro-areas according to IPC

IPC class	No. of patents	Description of domain	Top three co-occurring class
G01N	196	Physics-->Investigating or analysing materials by determining their chemical or physical properties	C12Q, B01J, B01L
A61K	166	Medical-->Preparations for medical, dental apparatus	A61B, A23L, A61p
A61B	161	Medical-->Diagnosis; Surgery; Identification	H01L, G06F, A41D
H01L	107	Electricity-->Elements-->Semiconductors	B82Y, G01N, G02B
H01M	99	Electricity-->elements-->Processing of making Chemical to Electric energy	G03G, B65D, G11B
B01J	93	Performing Operation-->Apparatus for physical chemical process	C02F, G01N, B82Y
H04W	92	Electricity-->Wireless Communication Network	H04L, H04B, G06F
H02M	77	Electricity-->Conversion of electricity apparatus	H02J, H03K, H04L
G06F	76	Physics-->Computers-->Electric digital Data processing	H04L, A61B, G06T
H04L	76	Electricity-->Transmission of digital information	H04W, H04B, G06F
B82Y	75	Performing Operation-->Nanostructures	A61K, B01J, G01N
C02F	69	Chemistry--> Water treatment	B01J, G01N, B63C
C07D	69	Chemistry--> Heterocyclic Compounds	A61K, A61P, H04L
C12N	60	Chemistry-->Biochemistry-->Microorganism, Genetic engineering	A61K, C07K, C12P
H02J	58	Electricity-> Circuit-Electrical power, Storing Electrical Energy.	H02M, G05F, G01R

Table 4. Significant inventions

IPC class	No. of patents	IPC description	Major micro-areas
B82Y30/00	52	Nanotechnology for materials or surface science	Preparation of Free Nano-Particles, Iron Oxide, Encapsulated Core-Shell Nanoparticles, Carbon Non-Tube, Graphene Oxide Thin Films, Polyaniline-Graphite Nanoplatelet Materials
A61B5/00	41	Measuring for diagnostic purposes; Identification of persons	Detection Of Latent Fingerprints, Portable Sensor To Measure Food Quality, Non-Invasive Glucose Monitoring System, Spatiotemporal Parameters for Gait And Movement Analysis
A61K9/00	35	Medicinal preparations characterised by special physical form	Core-Shell Nanomedicine, Anti-Cancer Agent, Biodegradable Polymeric Nanoparticles, Liposome-In-Gel Composition, Zein-Gold Nanoshells, Copper Catalyzed Carbon-Heteroatom
G06K9/00	35	Methods or arrangements for graph-reading or for converting the pattern of mechanical parameters	Diffractive Interference Sensor, Recognition Of Handwritten Telugu Characters, Analyzing Cytological Specimens, Recovering 3d Structure, E-Learning System, Methods for Yaw Estimation
G01N33/00	28	Investigating or analysing materials by specific methods	Colorimetric Biosensor For Pathogen Detection, Nanocomposite Sensor For Detection of Natural Gas, Enzymatic Sensors, Nanosensor For Single and Multidrug Resistance In Acute Coronary Syndrome
G01N21/00	27	Investigating or analysing materials by the use of optical means, i.e. using sub-millimetre waves, infrared, visible or ultraviolet light	Laser Beam Scanning Techniques, Non-Invasive Method For Estimation Of Strain Profile Of Soft Material, Multi-Color Fluorescent Liponions, Nano Sensing Temperature Device, Magnetic Enrichment Of Magnetically Marked Analytes

the patents are quite large are nanoscience, medical science, and polymer science.

5.4 Nature of Collaboration in Patenting

A patent application includes the name and affiliation of all those contributors as co-inventors who contribute to its invention. Table 5, gives information on the collaborative partners from industries, academia, government, private and R&D institutes to analyse the extent of collaboration made by an academician in patenting activities. This table also reveals that 6 per cent of the total patents came from the single inventor. The data indicate that academicians prefer to collaborate more with faculty members of their institution (70 %) followed by the scientists in industries, private sector, and R&D sectors. INMAS, DRDO, CSMCRI, RRI, IARI, CSIR, Tata Steel, TVS Motors are some of the government, R&D, and private sectors with whom these universities collaborate more for inventing patents. Patents are also invented in collaboration with the inventors of Germany (4), the USA (4), Nepal (3), China (2), Pakistan (2), New Zealand (1), the Republic of Korea (1), Singapore (1), Ethiopia(1), Israel(1), UK (1), Brazil (1), Australia (1).

In Fig. 3, a considerable number of links are established between Individuals and other institutes. Here 'Individual' means those inventors who have not disclosed their affiliation in the patent document and have filled the application with a residential or other address. Almost all IITs and IISc have such links, where at least one of the inventors did not disclose his/her affiliation. This network is based on inventors having 10 or more patents. Private organisations like Tata Steel, Tata Consultancy, Jaylakshmi Estate, and CEAT Limited, in collaboration with academicians, developed patents. IIT-Kharagpur, IIT-Madras, and IISc have more such links but IIT-Bombay does not have such public-private partnership inventions.

5.5 Prolific Inventors

Of the top inventors, having more than 5 patents in their capacity as shown in Table 6, inventors of IIT Bombay dominate in this ranking with four authors in the prolific list, followed by three from IIT Madras and two from IIT Kanpur – all three top enlisted IITs of India. The most renowned inventor Prof. Thalappil Pradeep is from IIT Madras in the field of chemistry. He is the recipient of India's one of the most prestigious awards Padma Shri in 2020. He conceptualised and

Table 5. Extent of collaboration in patenting

Inst name	Indv.	Collaborative patents					
		Total Institutions involved	Within University	University-University	University–Industry	University-Industry-Others	International
IIT, Madras	8	510	119	8	7	25	0
IISC, Bangalore	5	463	87	8	14	17	4
IIT, Bombay	9	483	114	3	14	11	4
IIT, Delhi	3	258	73	3	7	1	0
IIT, Kanpur	3	365	104	3	5	3	4
IIT, Kharagpur	3	240	51	2	13	1	2
IIT, Roorkee	0	61	15	1	3	0	1
IIT, Guwahati	0	96	24	2	1	3	0
JNU, New Delhi	0	49	6	4	4	0	0
BHU, Varanasi	6	137	13	9	3	2	2
CU, Calcutta	1	43	3	2	2	2	0
AVV, Coimbatore	0	14	3	0	0	0	1
JMI, New Delhi	0	34	6	3	1	0	1
JU, Calcutta	2	38	2	4	2	1	0
MAHE, Karnataka	0	0	0	0	0	0	0
IIT, Hyderabad	6	15	2	1	0	0	0
UH, Hyderabad	1	59	11	2	1	3	0
AMU, Aligarh	7	47	9	2	0	2	1
DU, New Delhi	1	112	22	0	7	0	1
SPPU, Pune	0	7	0	0	0	0	1
MU, Karnataka	0	13	2	0	0	0	1
	55	3045	666	57	84	71	23

Indv=Solo inventor

built the International Centre for Clean Water at IIT Madras on which he also has a patent. The most common field of invention is Chemical science followed by polymer technology and the most preferred domains are nontechnology or nanoscale materials.

Figure 4 presents the cooperation network between the most active inventors (having 5 or more patents) in Indian academia. Inventors collaborate with different other inventors for many reasons including easier access to knowledge from both groups. Applicants not connected with the other applicant

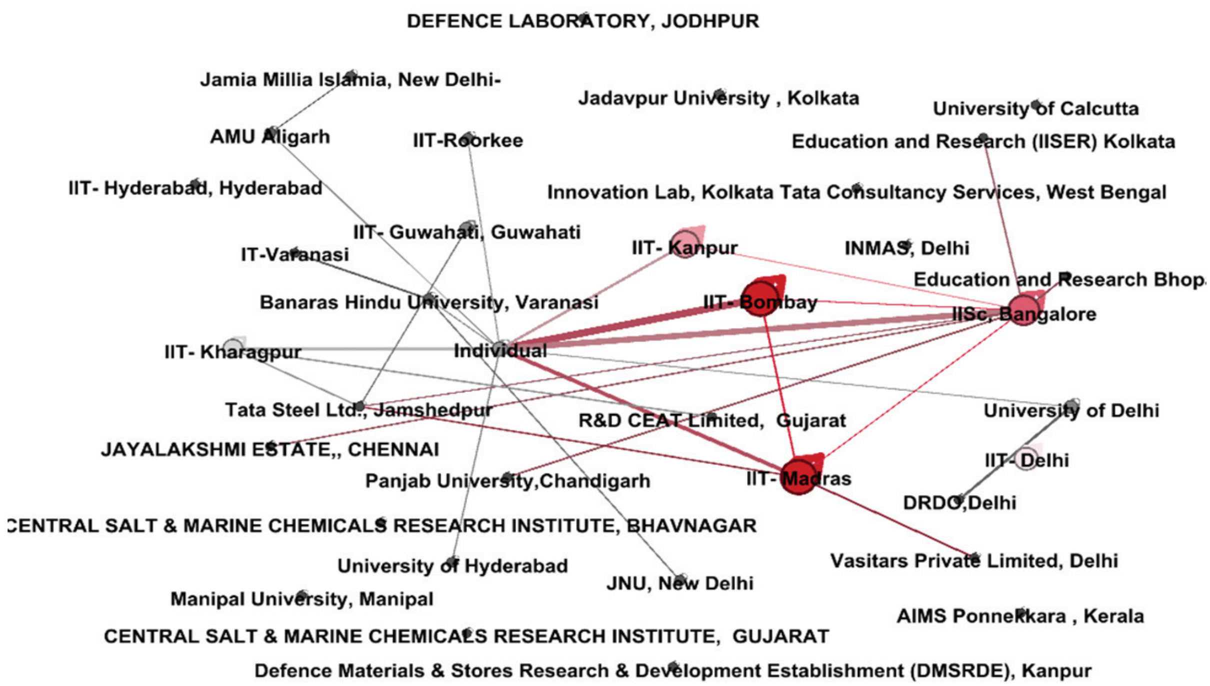

Figure 3. Network of major collaborators in patenting.

Table 6. Prolific contributors in patenting

Name & affiliation	AS	PG	CC	BC	Major Domains of Invention
Prof. Thalappil Pradeep, Chemistry, IIT Madras	31	21	0.896552	1062.483	Water filter system; nanoparticles synthesis; degradation of polymers
Prof. Rohit Srivastava, Bio-science & Bio-engineering, IIT Bombay	29	20	0.657895	618.3667	Gold-coated nano-structure, nano-particles, multi-color fluorescent, polymer for drug delivery, bone healing depot formulation.
Dr. Sri Sivakumar, Chemical Engineering, IIT Kanpur	28	12	0.745098	570.5	Nano-particles; dye-sensitized water splitting device; immobilised liquid crystal emulsion.
Prof. Chebrolu Pulla Rao, Chemistry, IIT Bombay	21	12	0.360656	594	benign glycoconjugate, calix[4]arene conjugate, copper complex
Prof. Kamal Krishna Kar, Mechanical Engineering, IIT Kanpur	18	10	0.933333	80	synthesis of graphene nanosheets, nanotubes, ORR electrocatalyst derived from feather fiber
Prof. Debabrata Maiti, Chemistry, IIT Bombay	13	8	0.331658	697	process for meta-CH cyanation of arenes, novel D-shaped template assembly, preparing pharmaceutically relevant heterocycles
Prof. Sundara Ramaprabhu, Physics, IIT Madras	14	7	0.722222	59.5	a rechargeable iron ion battery, multiwall carbon nanotubes, graphene-polyvinyl alcohol composite films
Prof. Kiran Kumar Kuchi, Electrical Engineering, IIT Hyderabad	23	7	1.0	0.0	generating a waveform in a communication network, transmitting a sequence with a low peak-to-average-power-ratio, network communication equipment
Dr. Jayesh Bellare, Chemical Engineering, IIT-Madras	40	7	1.0	23.0	antifouling and high flux polymer, polymer nanocomposite, three-dimensional hybrid scaffold, 3-D printed gel
Prof. Maryam Shojaei Baghini, Electrical Engineering, IIT-Bombay	16	7	0.323529	564.0	Graphene quantum dots based sensor, electrical converter, microstrip antenna

AS=Application Submitted, PG=Patents Granted, CC=Cloness centrality, BC= Betweenness centrality

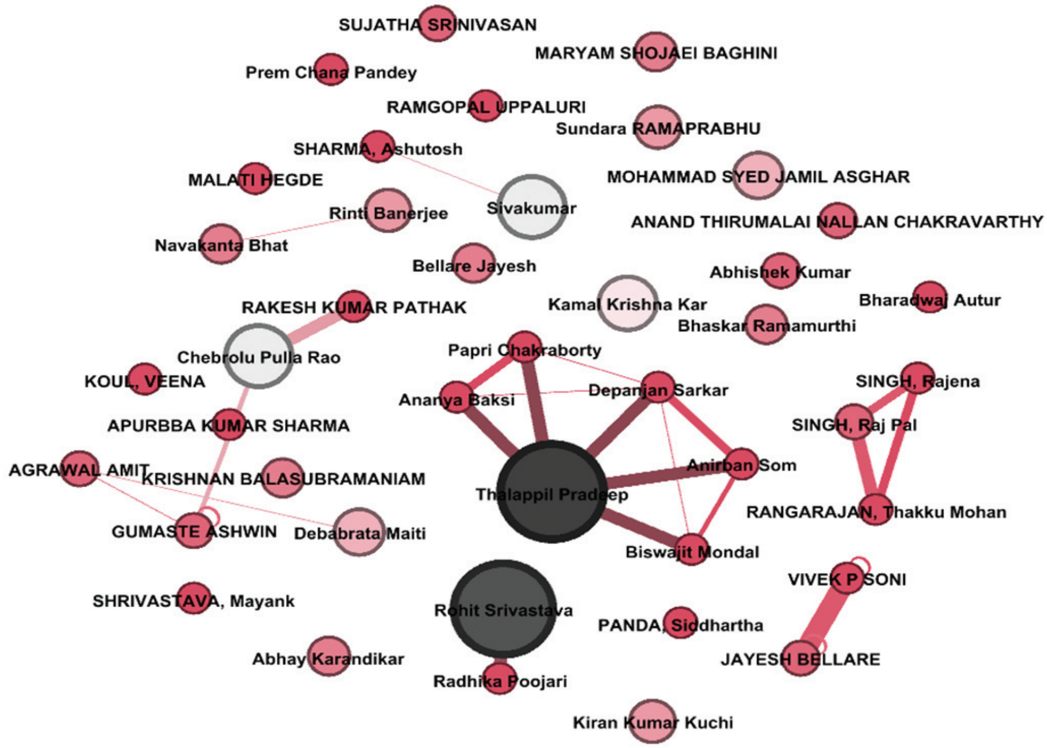

Figure 4. Top inventors (n>4) in Indian academia.

are situated alone. The network indicates that Prof. Thalappil Pradeep is mostly connected with other inventors and have a strong relationship with other inventors, however, Prof. Rohit Srivastava has the almost the same number of patents as Prof. Pradeep but is less connected with other inventors. Another inventor, Prof. Kar who could be found in a relatively central position (highest closeness centrality value) have various ties with distant inventors but not any fixed inventor group(s). On the other hand, Vivek Soni and Raj Pal Singh have less number of patents but have established a strong connection with other inventors. The betweenness centrality in Network theory suggests to what extent a node serves as a bridge in collaboration. The higher value of centrality has always had a relation with the number of patents the inventor had. Therefore the position of Prof. Debabrata Maiti, just after Prof. Thalappil Pradeep indicates that the inventors are serving more as a bridge between inventors.

6. CONCLUSION

This study intended to analyse how far the 'third mission of universities' is successfully achieved in the Indian academic setup by conserving the patents publication of selected top academic institutions of India. The irony of identifying such issues is to understand how much universities in India are engaging directly to the external world and in particular to the economy. Our findings have several policy relevance. While looking at the WIPO dataset of applied patents by these universities during this period, the figure comes to around 5200. However, when we talked about the granted patents the same figure was reduced to only 18 per cent.

One of the objectives of this study was to what extent India's top-ranked academic institutions are participating in the accomplishment of the third mission (TM) by developing patents? Our result shows that among the eight engineering institutes (IITS), the major share is mainly coming from five IITs and among universities, the considerable share is only from IISc, Bangalore. This suggests that despite the fact that there is widespread recognition in Indian universities about the idea of 'Third Mission', the concept remains nebulous. These academic institutions are quite productive in scientific research articles but not in generating patents. Universities having more students and having wide subject diversification are producing less number of patents. In other words, 'student-centric' universities are performing less in patents development compared to the 'research-centric' universities.

The literature predominantly states that although universities of the US are increasing their entrepreneurial activities in many areas, including patenting and licensing, building science parks promoting academic spine-off, the universal concept of the third mission (TM), whether technological and societal, simply does not exist and that there is no consensus either regarding what functions may, or may not be included in the concept of TM[22]. It arises a question 'why has the notion of 'entrepreneurial university or 'commercialisation of innovation' been connected to the third mission and not for instance to the ability of a scholar to develop new original research or teaching curricula?

For the next objective, it is significant to note that Indian inventors have demonstrated their skill in patenting in a wide spectrum of areas such as Chemical technologies, especially nano-science and nano-products, mechanical engineering, pharmaceuticals, and polymer technology. However, attention is needed from inventors of other fields for innovation that have a more direct relation with the society or economy of our nation. At this juncture, investment from the government is expected in those fields where academicians are putting their brains towards invention, because university ownership is more effective in making the invention available to the public.

Another objective of this study was to understand at what extent top ranked Indian academics collaborate with industry, government and other civil societies for developing patents. Based on our results, it is clear that Indian academics do contribute moderately to patenting by collaborating mainly with their same counterparts, still not with the industry. Almost 71 % of collaborations were made within the university and only 9 % with the industry. Only 2.45 per cent of patents were the results of collaboration with foreign countries, mostly with Germany and USA. The findings, therefore, suggest that definite policy-related initiatives are highly needed to enhance the collaboration with industry or with the inventors of other nations. There may be a need for awareness of opportunities for such collaboration and the promotion of a conscious public-private partnership model to motivate patenting. For the present study, only inventors of the top few universities in India have been considered, it may be important to know what drives ownership of all academic patents with a large set of data.

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