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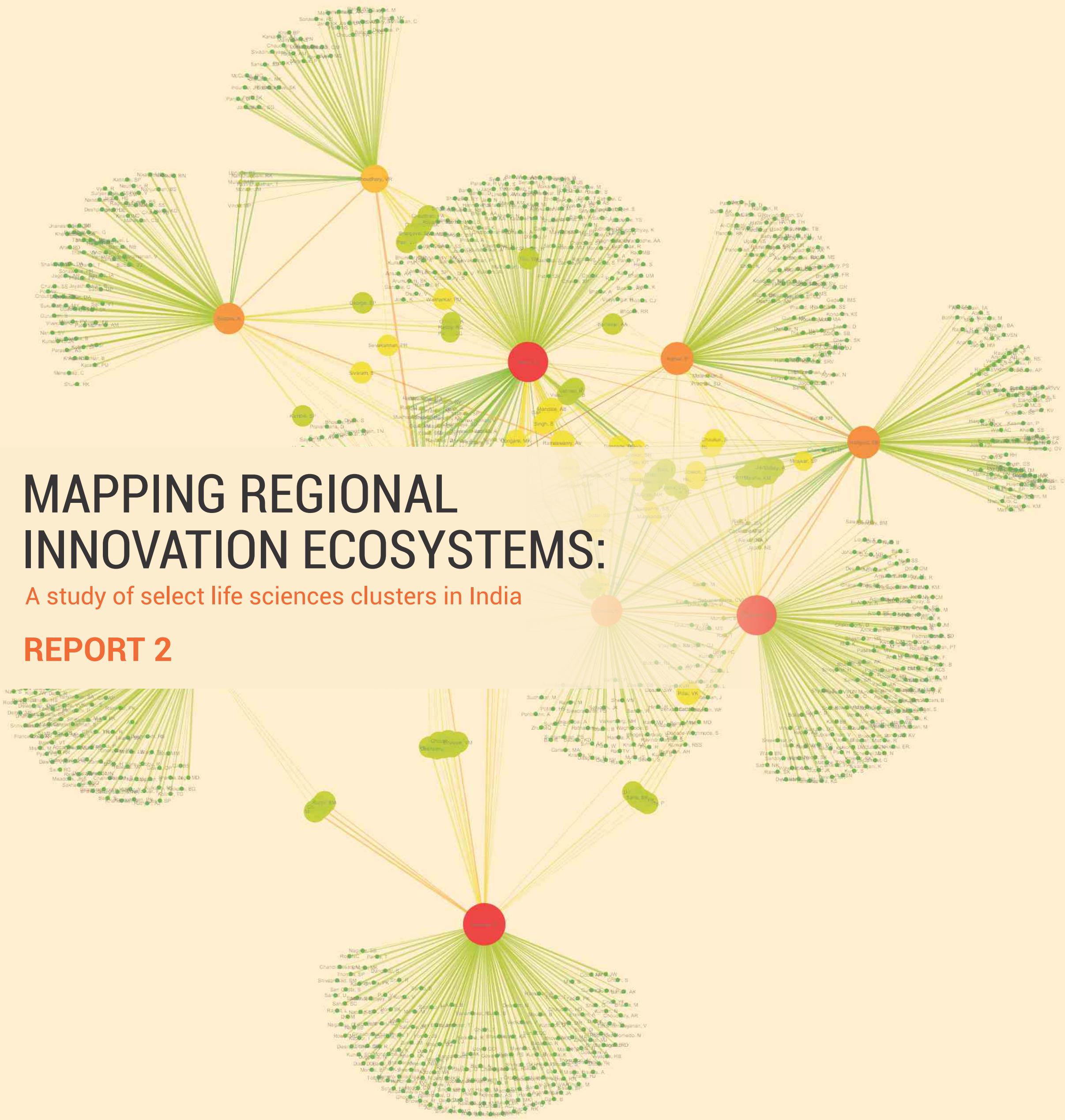

MAPPING REGIONAL INNOVATION ECOSYSTEMS:

A study of select life sciences clusters in India

REPORT 2

BRIC
A BIRAC-IKP Initiative

A report from the BIRAC Regional Innovation Centre (BRIC) at IKP Knowledge Park, October 2017

birac

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Biotechnology Industry
Research Assistance Council

BIRAC is a Section 8 (not for profit) company setup by the Department of Biotechnology (DBT), Government of India in 2012 to stimulate, foster and enhance strategic research and innovation capabilities of the Indian Biotech Industry and to serve as DBT's interface agency for supporting Industry-Academia interaction.

BIRAC's mandates include providing targeted funding for all aspects of bio innovation, incubation, technical and business mentoring, IP support, creating and providing access to global and national networks for bio innovation.

IKP KNOWLEDGE PARK

Innovation. Knowledge. Progress.

IKP Knowledge Park is a 200-acre premier Science Park and Incubator in Hyderabad and Bengaluru, India. It is set up with the mission to create a world-class ecosystem for fostering leading-edge innovation in the country. IKP promotes the advancement of technology-based innovators, entrepreneurs and small and large companies through customised space, shared equipment, incubation, mentorship, and funding. In the last 17 years of operations, IKP has supported over 280 companies from seven countries, 80% of which are startups.

Inspired by TechShop and MIT FabLab, IKP set up IKP-EDEN™ to help the product development ecosystem in Bengaluru. IKP-EDEN™ is a membership-based Do-It-Yourself fabrication studio and a startup accelerator. Building on the vast experience gained from helping Med-Tech startups and managing scientific research facilities, IKP is working towards furthering engineering and hardware product design startups.

IKP Knowledge Park launched its Grants Management Programme in 2011 and conducts Grand Challenges and other innovation scouting programmes in partnership with the Bill & Melinda Gates Foundation, USAID, DFID, BIRAC, DBT, NSTEDB, DST and the Government of Karnataka.

The Biotechnology Industry Research Assistance Council (BIRAC), in partnership with IKP, set up the BIRAC Regional Innovation Centre (BRIC) in 2013 to further BIRAC's mandate of building a deeper understanding of the capacity and gaps in innovation, commercialisation and technology absorption ecosystems, and developing targeted programmes. IKP has partnered with BIRAC on several rogrammes including the Biotechnology Ignition Grant (BIG), Biotechnology Incubation Support Scheme, Grand Challenges in TB control, Grand Challenges Explorations in global health, BRIC, BioNEST and BIRAC SEED Fund.

ABOUT THE REPORT

The BIRAC Regional Innovation Centre at IKP Knowledge Park is conducting a study of select life sciences clusters in India to develop a deeper understanding of the capacity and gaps in the life sciences innovation ecosystem and develop targeted programmes to stimulate, foster and enhance biotech innovation and entrepreneurship in the country. It maps the knowledge generation capacity, interaction between various stakeholders and gaps that hinder commercialisation of innovations.

The study is being conducted in phases. Report on the Phase 1 study on four biopharma and medical technology clusters in southern India was published in 2016. Phase 2 of the study conducted during 2016-2017 focused on mapping six life sciences clusters in western and central India.

This report consolidates the results of the two phases of the study on the ten innovation clusters. The findings are intended to provide inputs for framing policies for sustained development of life sciences innovation ecosystems.

MAPPING REGIONAL INNOVATION ECOSYSTEMS:

A study of select life sciences clusters in India

REPORT 2

TEAM

Ms. Deepanwita Chattopadhyay

Dr. Rakshambikai R

Mr. Rajendher Vadlakonda

Dr. Satya Prakash Dash

Dr. Vinita Jindal

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COVER PAGE IMAGE: Collaboration Map of CSIR-NCL, Pune

BACK COVER IMAGE: Collaboration Map of IIT Bombay

DISCLAIMER

सत्यमेव जयते

डॉ० रेनू स्वरूप
वरिष्ठ सलाहकार/वैज्ञानिक 'एच'
Dr. Renu Swarup
Senior Adviser / Scientist 'H'
& Managing Director, BIRAC

भारत सरकार
विज्ञान और प्रौद्योगिकी मंत्रालय
बायोटेक्नोलॉजी विभाग
ब्लाक-2,7 वां तल, सी० जी० ओ० कम्पलेक्स
लोधी रोड, नई दिल्ली-110003
GOVERNMENT OF INDIA
MINISTRY OF SCIENCE & TECHNOLOGY
DEPARTMENT OF BIOTECHNOLOGY
Block-2, 7th Floor C.G.O. Complex
Lodhi Road, New Delhi-110003

MESSAGE

BIRAC established BRIC (BIRAC Regional Innovation Centre) in partnership with IKP Knowledge Park in Hyderabad to gain a deeper understanding of India's biotechnology sector by studying life science innovations at the cluster level.

BRIC has catalysed several other activities for nurturing the Innovation Ecosystem including helping startups in understanding issues such as business models, IP, licensing and in navigating regulatory requirements for productisation, creating platforms such as technology showcasing, and connecting startups to relevant networks, especially with investors.

The report highlights the dynamism of the biotech sector in southern, western and central India, through a detailed mapping of stakeholders, the drivers, the opportunities and the gaps that exist in 10 selected clusters. The report has highlighted the unique elements for each cluster studied and their rapid evolution. BIRAC will endeavour to foster and facilitate the growth of the biotech sector and the learnings from the report would help distil possible routes to create further impact.

The teams at BRIC, IKP Knowledge Park and BIRAC have synergistically collaborated to bring out this report. The contributions by the experts of the BRIC Advisory Committee and all experts are greatly appreciated. Their insights for the report will help in developing new models of collaboration between Industry and Academia and their work take the Indian biotechnology sector to the next level.

I congratulate all the team members for bringing out such a comprehensive report.

(Renu Swarup)

Tel : +91-11-24360064 * Fax : +91-11-24363018 * E-mail : swarup.dbt@nic.in

CONTENTS

FOREWORD

IKP Knowledge Park has been keen to engage in policy making and bring about forward looking changes in the innovation ecosystem in the country. IKP's partnership with BIRAC to set up the BIRAC Regional Innovation Centre (BRIC) in 2013 provided an opportunity to study regional life sciences innovation systems as a first step towards improving the innovation capacity of these regions or clusters. Four clusters around Hyderabad, Bengaluru, Chennai and Thiruvananthapuram-Kochi were selected for the first phase of the study. Six more life sciences clusters in western and central India, Ahmedabad, Mumbai, Pune, Bhopal-Indore, Bhubaneswar and Visakhapatnam were added in the 2nd phase of the study. Data was collected from secondary sources, surveys and interviews of Key Opinion Leaders and the consolidated data from the two phases were analysed to identify the inherent strengths and existing gaps in these clusters including the nature of interactions among the stakeholders as well as their expectations and demands. This report is an outcome of the study.

The thrust of the study was on understanding the research and innovation capacity of academia through the extent and quality of publications, collaborations and patents. Industry and startups were studied to understand their needs and capabilities and enablers, to see their service offerings.

The purpose of the study was not to create an Innovation Index for each cluster and rank them, but to see where each cluster stood in terms of innovation capacity and what policy level interventions could be brought in to enhance its performance.

The report contains a set of recommendations that will hopefully be adopted by policy makers. A lot more data was collected during the course of the study than what is presented here. The authors have distilled the findings into a report that is detailed enough to elicit the interest of the ecosystem stakeholders, people interested in innovation studies and policy makers who want to usher change.

I hope readers will find the analysis interesting and useful.

Deepanwita Chattopadhyay

Chairman & CEO, IKP Knowledge Park

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This Report by BRIC was prepared by a team led by Ms. Deepanwita Chattopadhyay at IKP Knowledge Park and BRIC. The work was carried out under the general guidance of Dr. Rakshambikai Ramaswamy with Mr. Rajendher Vadlakonda, Mr. Vineet Punnoose, Dr. Ramjee Pallela and Mr. Vikraman Venu Saranyan contributing at various phases. Dr. Satya Prakash Dash and Dr. Vinita Jindal at BIRAC also contributed throughout the study and preparation of the report.

Our appreciation to the BRIC Advisory Committee chaired by Dr. Renu Swarup with expert members consisting of Prof. Gowrishankar J, Dr. Ajith Kamath, Dr. Ramesh Byrapaneni and Dr. Rabindranath Mukhopadhyaya for overall guidance to BRIC as well as for this report. We thank Mr. Ranajit Sen, startup mentor at IKP for his support throughout the study.

The initial findings of the Report were also discussed at several conferences and workshops and annual stakeholder meetings especially at the focused Roundtables held during IKP's International Knowledge Millennium Conferences, IKMC 2014 to IKMC 2016 chaired by several eminent scientists and experts including Dr. MK Bhan, Dr. Vijay Chandru and Prof. Ambuj Sagar. We appreciate the guidance and contributions made by the experts at the Roundtables.

Several experts in the ten clusters under study provided helpful comments and insights, made other contributions, and participated in consultative meetings/interviews. The team would like to thank the 158 experts who provided their perspectives for the study:

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Avin Agarwal, Uber Diagnostics
B Gurumoorthy, IISc
Balachandran A, VIT-TBI
Balganesh S. Tanjore, Gangagen Biotechnologies
Balram S, TIMED-SCTIMST
Bishor Ibrahim, Ubio Biotechnology
BV Sandeep, Andhra University
C Satyanarayana, Laurus Labs
Chadrasekhar Srivari, CSIR-IICT
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Kiranam Chatti, Zephase Therapeutics
Kishore Paknikar, Agharkar Research Institute
Kishore Parsa, Reddy's Institute of Life Sciences
KMS Rao, Ion Exchange India Limited
Lakshmi Kantam M, CSIR-IICT
LS Shashidhar, IISER Pune
MA Vijayalakshmi, VIT
Manish Gupta, DA-IICT
Manivannan M, IIT Madras
Manjula Reddy, CSIR-CCMB
Manoj Kumar Bhat, NCCS
Mathukumilli Sribharat, GITAM University
Meenakshi Sundaram, Anna University
MNA Rao, Divis Laboratories Limited
Mrutyunjay Suar, KIIT-TBI
Mukesh Doble, IIT Madras
Nagaraju Karumuri, Sai Prani Biopharma
Nandakumar S, Perfint Healthcare
Navakant Bhat, IISc
Nihal Thomas, CMCH
Nitin Deshmukh, Kotak Private Equity
Nitin Kale, Nanosniff Technologies
Nitya Venkataraman, H3Me Lifesciences
NV Satyanarayana, CCMB-IICT
P Gautham, Anna University
P Kaliraj, Anna University
Palok Aich, NISER
Pankaj Chandra, Ahmedabad University
PN Rangarajan, IISc
Poyni Bhatt, SINE
PR Ganapathy, Villgro Foundation
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R Sukumar, USV Pharma
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Radha Rangarajan, Vitas Pharma
Raghu Dharmaraju, Embrace Innovations

Rajendra Jagdale, Step-Pune
Rajeshwari K, Bioklone Biotech
Rakesh Basant, Gujarat University
Ramanujam Srinivasan, NISER
Ramaswamy S, C-CAMP
Rashna Bhandari, CDFD
Ravi Bhogu, Monitra Healthcare
Ravichandra Beeerum, Revelations Biotech
Ravikumar Banda, Xcyton Diagnostics
Redanna P, University of Hyderabad
Rishikesh Krishnan, IIM Indore
Rohit Srivastava, IIT Bombay
RR Hirwani, CSIR-URDIP
Rudrapratap P, IISc
S Dayananda, University of Hyderabad
Sabuj Sahoo, Utkal University
Sai Siva Gorthi, IISc
Salil N.Vaniawala, SN Gene Lab
Sambaru Prasad, Lipicard Technologies
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Sateesh Andra, Endiya Partners
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Vineet Sharma, IISER-Bhopal
Vipen Seth, Synokem Pharma
Vipla Puri, PD Hinduja Hospital
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The team apologises to any individual or organization inadvertently omitted from this list.

LIST OF ABBREVIATIONS

ABLE	Association of Biotechnology Led Enterprises
AcE	Accelerating Entrepreneurs
ACRI	International Advanced Research Centre for Powder Metallurgy and New Materials
AIIMS	All India Institute of Medical Sciences
AMR	Antimicrobial Resistance
API	Active Pharmaceutical Ingredient
BARC	Bhabha Atomic Research Centre
BIG	Biotechnology Ignition Grant
BIPP	Biotechnology Industry Partnership Programme
BIRAC	Biotechnology Industrial Research Assistance Council
BMCRI	Bangalore Medical College and Research Institute
BRIC	BIRAC Regional Innovation Centre
C-CAMP	Centre for Cellular and Molecular Platforms
CCMB	Centre for Cellular and Molecular Biology
CDFD	Centre for DNA Fingerprinting and Diagnostics
CDSCO	Central Drug Standard Control Organisation
CIFA	Central Institute of Freshwater Aquaculture
CIFT	Centre for Fisheries Technology
CLRI	Central Leather Research Institute
CMCH	Christian Medical College and Hospital
CPCB	Central Pollution Control Board
CRAMS	Contract Research and Manufacturing Services
CRO	Contract Research Organisation
CRS	Contract Research Scheme
CSIR	Council for advanced Scientific and Industrial Research

NCL	National Chemical Laboratories
DBT	Department of Biotechnology
DFID	Department for International Development
DIPP	Department of Industrial Policy and Promotion
DMARD	Disease-Modifying Anti-Rheumatic Drugs
DRILS	Dr. Reddy's Institute of Life Sciences
DSIR	Department of Scientific and Industrial Research
DST	Department of Science and Technology
FDF	Finished Dosage Form
GCE-I	Grand Challenges Explorations India
GCRI	Gujarat Cancer & Research Institute
GITAM	Gandhi Institute of Technology and Management
GM crops	Genetically Modified crops
GST	Goods and Services Tax
HRA	House Rent Allowance
IBAB	Institute of Bioinformatics and Applied Biotechnology
ICMR	Indian Council for Medical Research
IDPL	Indian Drugs and Pharmaceuticals Limited
IICT	Indian Institute of Chemical Technology
IKP	IKP Knowledge Park
IKP-EDEN	IKP-Engineering, Design and Entrepreneurship Network
IMMT	Institute of Minerals and Materials Technology
IIPME	Industry Innovation Programme on Medical Electronics
IISc	Indian Institute of Science
IISER-TVM	Indian Institute of Science Education and Research, Trivandrum
IITB	Indian Institute of Technology Bombay
IITM	Indian Institute of Technology Madras
IKRDC	Institute of Kidney Diseases and Research Center
ILS	Institute of Life Sciences
INPADOC	International Patent Documentation
INSPIRE	Innovation in Science Pursuit for Inspired Research

InSTEM	Institute of Stem Cell Biology and Regenerative Medicine
IOB	Institute of Bioinformatics
IT	Information Technology
JNCASR	Jawaharlal Nehru Centre for Advanced Scientific Research
KEM	King Edward Memorial
KIIT	Kalinga Institute of Industrial Technology
KITVEN	Karnataka Information Technology Venture Capital Fund
KMIO	Kidwai Memorial Institute of Oncology
KOL	Key Opinion Leaders
LVPEI	LV Prasad Eye Institute
mAbs	Monoclonal Antibodies
MeitY	Ministry of Electronics and Information Technology
MNC	Multi National Corporation
MSME	Micro Small and Medium Enterprises
MSU	Maharaja Sayajirao University
NCBS	National Centre for Biological Sciences
NCCS	National centre for Cell Sciences
NCD	Non-communicable diseases
NIIST	National Institute for Interdisciplinary Science and Technology
NIMHANS	National Institute for Mental Health and Neurosciences
NIN	National Institute for Nutrition
NIO	National Institute of Oceanography
NIRT	National Institute for Research in Tuberculosis
NISER	National Institute of Science Education and Research
NSAID	Nonsteroidal Anti-Inflammatory Drugs
NSTEDB	National science & Technology Entrepreneurship Development Board
NSTMIS	National Science & Technology Management Information System
PHC	Primary Health Centre
PSU	Public Sector Units
R&D	Research and Development

RCGM	Review Committee on Genetic Manipulation
RGCB	Rajiv Gandhi Centre for Biotechnology
RIS	Regional Innovation Systems
SBIRI	Small Business Innovation Research Initiative
SCTIMST	Sree Chitra Tirunal Institute for Medical Sciences and Technology
SME	Small and Medium Sized Enterprises
SPARSH	Social Innovation programme for Products: Affordable & Relevant to Societal Health
TBI	Technology Business Incubator
TIFR	Tata Institute of Fundamental Research
TMC-ACTREC	Tata Memorial Centre-Advanced Centre for Treatment, Research and Education in Cancer
TTO	Technology Transfer Office
UAS	University of Agricultural Sciences
UGC	University Grants Commission
UGC-DAE CSR	UGC-DAE Consortium for Scientific Research
UoH	University of Hyderabad
USAID	United States Agency for International Development
US-FDA	United Stated Food and Drug Administration
VAT	Value Added Tax
VES	Vivekananda Education Society
VIT	Vellore Institute of Technology

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Innovation is often defined as a process that involves bringing together novel products, processes, services, technologies, or business models for the benefit of society. The role of technology and information flow among people, enterprises and institutions which are key to the innovation process can be better understood by having a systemic approach towards innovation. India has domain and cluster specific innovation hubs spread across the country. Studying these regional innovation systems could provide granularity in the process of diffusion of knowledge, skills and best practices, in addition to understanding the infrastructural advantages and specific gaps at the level of a particular geography.

To understand the evolving nature of the life sciences regional ecosystems in the country an extensive Regional Innovation Systems (RIS) study was undertaken in the first phase between 2014 and 2016 largely around four biopharma and medical technology clusters in southern India, Hyderabad, Bengaluru, Chennai-Vellore and Thiruvananthapuram-Kochi, and the findings were published as a report in October 2016. In 2016 and 2017, the methodology and learnings in Phase I was extended as a Phase II study to six other clusters in western and central India namely Ahmedabad, Mumbai, Pune, Bhopal-Indore, Bhubaneswar and Visakhapatnam. This report summarises the findings from both phases of the study and is intended to provide inputs for framing science and technology policies for sustained development of life sciences innovation ecosystems in the country.

The report aims to analyse the current status of innovation in the ten clusters by studying the four major stakeholders - Academia, Industry, Enablers and Startups. The focus has been on the academic research capabilities in pharma, biopharma, medical technology and healthcare. Agri-biotech, and industrial biotech are only included while discussing the overall sector in totality. Primary analysis was carried out by interviewing Key Opinion Leaders (KOLs) in each stakeholder category to seek their opinion on current status of the innovation ecosystem. The trends identified through this exercise were supplemented through analysis of data of various markers that define a regional innovation ecosystem such as publications, patents, company incorporations etc.

Distribution of stakeholders in the clusters under study

The number of academic institutions in Bengaluru, Chennai and Mumbai are high compared to the other clusters. The large pharmaceutical industry in Hyderabad and Mumbai, dominated by Active Pharmaceutical Ingredient (API) and formulation companies, has contributed to the large industrial base in these two regions as reflected by the fact that over 50% of the 1500+ pharma companies are in these two regions. Ahmedabad also has a large pharma generic manufacturing base with over 100 small and large pharma players. Naturally, in mature clusters such as Mumbai, Hyderabad, Bengaluru and Chennai, the overall spread of stakeholders is well balanced. Mumbai being the financial hub clearly dominates in the number of enablers providing business and financial services. As per the recent Association for Biotechnology Led Enterprises (ABLE) white paper on Indian biotech startups, the number of startups in the biotechnology space between January 1, 2012 and December 31, 2016 is over 1022. The Thiruvananthapurum+Kochi and Bhubaneswar are emerging clusters with low count of industry players as well as suppliers. However, the level of activity in these two clusters show greater industrial biotech activity than Bhopal-Indore or Visakhapatnam.

Study of academic output

Academic institutions comprise the base of the innovation pyramid contributing to knowledge generation. Out of the large pool of academic institutions in the ten clusters, 65 institutes (6 from Hyderabad, 11 from Bengaluru, 9 from Chennai+Vellore, 7 from Thiruvananthapurum+Kochi, 7 from Mumbai, 6 from Pune, 6 from Ahmedabad, 5 from Bhopal+Indore, 6 from Bhubaneswar and 2 from Visakhapatnam), were chosen, based on their research capabilities and focus for analysing their research output and contribution to the innovation ecosystem.Chennai and Mumbai have a long history of academic pedagogy and with good number of research institutions, these clusters have the maximum number of publications in diverse streams. Bengaluru and Hyderabad are two other mature clusters with large multidisciplinary institutes which is conducive for a vibrant collaborating environment. Pune has the highest number of patents, mostly from CSIR-NCL, due to well established processes for academia-industry collaboration. CSIR-NCL also has a culture of faculty led startups. It was observed that faculty in medical institutes tend to collaborate more for clinical trials and those from smaller institutes, for access to equipment and expertise. Emerging clusters have relatively new institutes and therefore do not have many publications and patents. These clusters have younger faculty who have strong interests in translational research and are expected to evolve into more established ecosystems.

Research productivity has been a clear focus for the government, and therefore several government and international funding schemes have been made available after early 2000s. Several new schemes such as INSPIRE in 2011-2012, Ramalingaswamy fellowship in 2006 and other International Science and Technology collaboration schemes for promoting research were introduced in 2009-2010. Although there was an exponential growth in the number of publications, there were several publications which have poor citations. Most notably, most of the publications lie in the bottom 20% of total citations with not more than 10 citations in emerging clusters and not more than 18 citations in mature clusters above the threshold. This indicates that a large number of publications from most of these clusters are not of very high quality and the focus is more on the volume of publication. Mature clusters however have a number of publications with over 200 citations, a trend which could possibly spur off better quality research. With increasing funding opportunities from both national and international grants and government support for commercialisation, the output would only get more promising.

Subject areas

Across clusters, India's strength in life sciences seemed to be in various disciplines of chemistry followed by biochemistry & molecular biology and pharmacology. Certain cities have expertise in specific disciplines that are related to the presence of specialised institutes and in some cases presence of a particular industry.

It is important to note that out of a total of 90 subject areas related to life sciences, not a single city had a good representation of all the fields. In fact all ten clusters had very few subject areas where the minimum threshold of 50 publications in any year was exceeded.

Industry

The clusters studied here had initial beginnings due to either the presence of anchor institutions like IISc in Bangalore or industries like IDPL in Hyderabad etc. The economic reforms of 1991 in India comprising of liberalisation, privatisation and globalisation saw a large number of companies being incorporated and created an entrepreneurial culture. This led to a spurt in the economic activities which prior to the reforms were growing at a moderate rate.

The Hyderabad cluster is dominated by the pharmaceutical sector. In 1961, the incorporation of Indian Drugs and Pharmaceuticals Limited (IDPL) had a significant role in the city's growth as a pharma innovation cluster. Bengaluru has a strong research culture with presence of IISc for over a century and more recently JNCASR and NCBS as well as several other research institutes and Public Sector Units (PSUs). Several MNCs started their operations in this region from the 70's leading to creation of a huge wealth of knowledge and talent pool that has translated into growth in applied and interdisciplinary areas. It also has a large pool of service providers and contract research/outsourcing Bengaluru companies. This trend has led to Bengaluru being one of the most sought after innovation clusters in India. Chennai has had a strong pharma and automobile/engineering base. With a strong base of universities, engineering and medical schools, and knowledge transfer from academia, several medical device companies have come up in this region. The number of biopharma companies is fairly low in Thiruvananthapuram which could be attributed to the prevailing industrial environment in the state. There is however immense potential in this cluster.

The western region especially Mumbai and the state of Gujarat have had a strong business presence with access to several financial institutions. Therefore a large number of pharma generics companies were established in this region since 1930s. Some of these companies are among the largest pharma companies in the country, and over a period of time due to diversification have also moved into allied areas such as biotechnology. Presence of such a strong pharma cluster has led to mushrooming of several CROs in the region that work closely with these pharma giants. A large number of pharma MNCs are located in the Mumbai region. Mumbai also being a major port has several lab equipment and chemical suppliers located in the region which serve the pharma companies. Due to the strong startup culture around IIT Bombay and CSIR-NCL Pune, a large number of innovative healthcare companies and startups have sprung up in the region. The new Startup and Biotech policies in Gujarat are expected to provide a boost to the life sciences startup scene in Ahmedabad.

Of the total number of industries in the ten clusters, 108 companies (including startups) were selected for deeper analysis. A general view on the total number of patents, publications and collaborators in each cluster clearly points to the focus on patents in companies, a trend which is understandably different from that in academia. The Indian Patent Act 1970 and the thriving generics industry have greatly increased the number of process patents from several cities. The number of collaborators are not as high as in academia possibly associated with the mismatches in focus areas of research.

Collaborations

Collaboration is an essential aspect of research activities today. It serves various purposes including leveraging expertise and sharing of equipment and infrastructure. Particularly, collaborations have a far reaching impact in interdisciplinary work or co-development projects with industries and hospitals.

The data revealed that most cities have larger number of collaborators outside India than within the country with an average of about 40% of the collaborations within India. Number of truly interdisciplinary research highlights the translation output from an institute and the underlying culture and attitude towards collaboration. Interdisciplinary research is still nascent in these clusters.

There are mismatches in certain focus areas between academia and industry present in the clusters. Although, in principle, collaboration is possible across cities, geographical proximity plays a crucial role especially in co-development projects. There might be a mismatch in focus areas if a niche institute is present in a city without industries in that area. Likewise there might be industries of a specific sector in a city without much research expertise in that area.

Support structure

All the mature clusters in Phases 1 and 2 are well-developed with good support structure for innovation. Mumbai and Chennai have large number of IP firms because of the patent offices located in these cities. Also, since Mumbai is a hub for financial services, most consulting firms have their base in Mumbai.

With respect to state support, Ahmedabad fairs as well as the other mature clusters due to the strong push from the state government through various incentives in its startup policy, a startup cell for single window clearances and supporting a large number of incubation centres. Several states are very proactive in implementing startup policies. Visakhapatnam and Bhubaneswar although new to join the league, are working towards framing several policies that would help these clusters grow rapidly in the near future. During the initial phase of development of an innovation ecosystem, the thrust is invariably on Information Technology (IT) companies due to the promise of quicker turnaround, lower capital expenditure and much larger scope of employment. Also, correlating to the research capacity from anchor institutes and industries in this region, these emerging clusters may not yet be completely geared up for life sciences based startups.

3.2 Recommendations from BRIC

The Indian biopharma and life sciences industry is expected to grow at about an average of 15% Year on Year. India is a leader in generic and API producer with several companies recording over 50% of their revenues in international markets. The strong talent pool, government policies and purchasing power further advance the potential of the sector. The stated goal of the Government of India is to achieve a US$100 billion bioeconomy by 2025. The biotech clusters, including those under study, will play a critical role in achieving the stretched target.

There are several gaps in the ecosystem - as highlighted in the report - that need to be addressed to be able to realise the growth potential. These gaps have been analysed and expectations from the stakeholders in the ecosystem have been captured. Several recommendations were provided in the first Phase of the study with many being addressed through initiatives launched in the past several months. A few recommendations have been retained on the basis of observation of the current status. A set of new recommendations have been proposed that could serve as possible action points for BIRAC.

1. **Knowledge generation:** Ensuring quality and relevance
    - Institutions with at least established scientific credentials through publications in peer reviewed journals and citation indices and innovative work could be selected for targeted translational programmes, primarily to promote truly interdisciplinary collaborations and disruptive technologies. Such collaborations should focus on co-development of products.
    - Capacity building of promising private institutions through increased funding for research and innovation.
    - Longitudinal studies in disease areas that need innovative solutions for diagnosis and treatment should be supported through specific programmes.

2. **Regulations and regulatory bodies**
    - Working with regulatory agencies to improve human resource capacity. PhDs /industry experience in various streams of science and engineering would enable better guidelines, clearances and due diligence. BIRAC could play the role of a facilitator for such initiatives with CDSCO.

3. **Capacity building at cluster level**
    - Programmes for established clusters:
        - Training programmes for individuals in Technology Transfer Offices (TTOs) in academic institutes and incubators to enable them to market technologies and negotiate licensing deals.
        - Setting up regional professionally managed TTOs to help institutes that cannot run their own TTOs effectively.
        - Setting up LARTA like bodies as one-stop solution for startup queries under a public private partnership.
        - Establishing institutes for technical training to strengthen vendor base with possible global collaborations.
        - Setting up incubation centres in a PPP model within industries that could serve as pilot plants for small scale manufacturing.
    - Setting up incubators in Tier II cities and emerging clusters. Well established incubation centres in nearby geographies could serve as mentors. Mentorship could include access to infrastructure, support and mentor network in addition to advice on operational aspects. This could also be viewed as incubating incubation centres and after a few years the new incubation centres could graduate and

independently create their ecosystem. It is however important to identify local challenges that need to be addressed initially and sensitize the ecosystem in a tailor made fashion. Prominent institutes and industries in the region could serve as anchors to develop the ecosystem further. In addition, the emerging clusters could serve as satellite centres to various bodies proposed above.

4. Funding

- Creating a 'CIBIL' like organisation to help funding bodies manage their funding better and also helping innovators secure funding on better terms. This should be available to all bodies to track good startups. The information could be used by VCs to encourage investment in technology heavy startups.
- Cluster led activities: It is important for emerging clusters to focus and collaborate to accelerate growth and achieve critical mass. A government funded innovation grant which encourages collaboration between two or more institutes and at least one industry could possibly serve as the catalyst for this. Separate programmes for emerging and established clusters could be framed specifically to account for the advantages established clusters enjoy.

5. Platform for commercialisation of medtech products

- Several medtech startups struggle to commercialise their products due to their inability to offer an attractive product portfolio to its customers and face the competition from MNCs, and their lack of understanding of the sales and marketing channels. It will be useful to help build an aggregator platform that startups could leverage for marketing their products. Joint programmes in alignment with ICMR will be required to enable government procurement.

Chapter 1

INTRODUCTION

1.1 Overview

BIRAC Regional Innovation Centre (BRIC)

The Biotechnology Industrial Research Assistance Council (BIRAC) in partnership with IKP Knowledge Park (IKP) set up the BIRAC Regional Innovation Centre (BRIC) in 2013, to further BIRAC's mandate of building a deeper understanding of the capacity and gaps in innovation, commercialisation and technology absorption ecosystems and developing targeted programmes to fulfil its broad vision of stimulating, fostering and enhancing biotech innovation and entrepreneurship in the country.

To understand the evolving nature of regional ecosystems an extensive Regional Innovation Systems (RIS) study is being undertaken in phases. The first Phase of the study was conducted between 2014 and 2016 largely around four biopharma and medical technology clusters in southern India. A report on the Phase 1 study was published in 2016. During 2016-2017, the methodology and learnings in Phase I was extended as a Phase II study to six other clusters in western and central India, namely Ahmedabad, Mumbai, Pune, Bhopal-Indore, Bhubaneswar and Visakhapatnam. The primary aim was to understand the knowledge generation capacity and interaction between various stakeholders in the ecosystems and identify gaps that hinder commercialisation of innovations. Regional level studies are useful to capture disaggregated data and enable comparison of clusters so that strengths of certain clusters could also be appropriately adopted to improve the performance of other emerging clusters.

This report summarises the findings from both phases of the study and is intended to provide inputs for framing science and technology policies for sustained development of life sciences innovation ecosystems.

BIRAC

BIRAC is a Section 8 (not for profit) company setup by the Department of Biotechnology (DBT), Government of India in 2012 to stimulate, foster and enhance strategic research and innovation capabilities of the Indian Biotech Industry and to serve as DBT's interface agency for supporting Industry-Academia interaction.

BIRAC's mandates include providing targeted funding for all aspects of bio innovation, incubation, technical and business mentoring, IP support, creating and providing access to global and national networks for bio innovation.

IKP Knowledge Park

IKP Knowledge Park is a 200-acre Science Park and Incubator in Hyderabad and Bengaluru, India. It is set up with the mission to create a world-class ecosystem for fostering leading-edge innovation in the country. IKP promotes the advancement of technology-based innovators, entrepreneurs and small and large companies through customised space, shared equipment, incubation, mentorship, and funding. In the last 17 years of operations, IKP has supported over 280 companies from seven countries, 80% of which are startups.

IKP Knowledge Park launched its Grants Management Programme in 2011 and conducts Grand Challenges and other innovation scouting programmes in partnership with the Bill & Melinda Gates Foundation, USAID, DFID, BIRAC, DBT, NSTEDB, DST and the Government of Karnataka. IKP set up IKP-EDEN™ in 2015 to help the product development ecosystem in Bengaluru. IKP-EDEN™ is a membership-based Do-It-Yourself fabrication studio and a startup accelerator.

The Biotechnology Industry Research Assistance Council (BIRAC), in partnership with IKP, set up the BIRAC Regional Innovation Centre (BRIC) in 2013 to further BIRAC's mandate of building a deeper understanding of the capacity and gaps in innovation, commercialisation and technology absorption ecosystems, and developing targeted programmes. Apart from BRIC, IKP has partnered with BIRAC on several other programmes including the Biotechnology Ignition Grant (BIG), Biotechnology Incubation Support Scheme, Grand Challenges in TB Control, Grand Challenges Explorations in global health, BioNEST and BIRAC SEED Fund.

1.2 An introductory note on innovation mapping

Innovation is often defined as a process that involves bringing together novel products, processes, services, technologies, or business models for the benefit of society. Studying regional innovation systems often provides granularity in the process of diffusion of knowledge, skills and best practices, in addition to understanding the infrastructural advantages and specific gaps, at the level of a particular geography.

The Phase I Report provided an overview of various landmark studies on the study of regional innovation systems. A detailed note on several models that were used to study innovation were compared and contrasted. The benefits of studying the ecosystem in a dynamic manner while identifying various stakeholders and studying their roles through the helix models were also outlined. The Phase 1 report can be accessed at http://www.ikpknowledgepark.com/images/BRIC REPORT 1.pdf

No standard model could directly be adopted at the national level to map the life sciences innovation status as the country is still emerging as an innovation hub with several cities /regions at various stages of maturity as innovation clusters and transfer and translation of technology are not common. As discussed in the earlier report, the aim of the study is to identify gaps that hinder innovation rather than attempting to provide a measurement of innovation through an index.

The framework adopted for the Phase II study is similar to that of Phase I. According to the framework, there are primarily four stakeholders - academia, industry, government and enablers (Figure 1.1). Each of these stakeholders either interact directly or indirectly through other stakeholders.

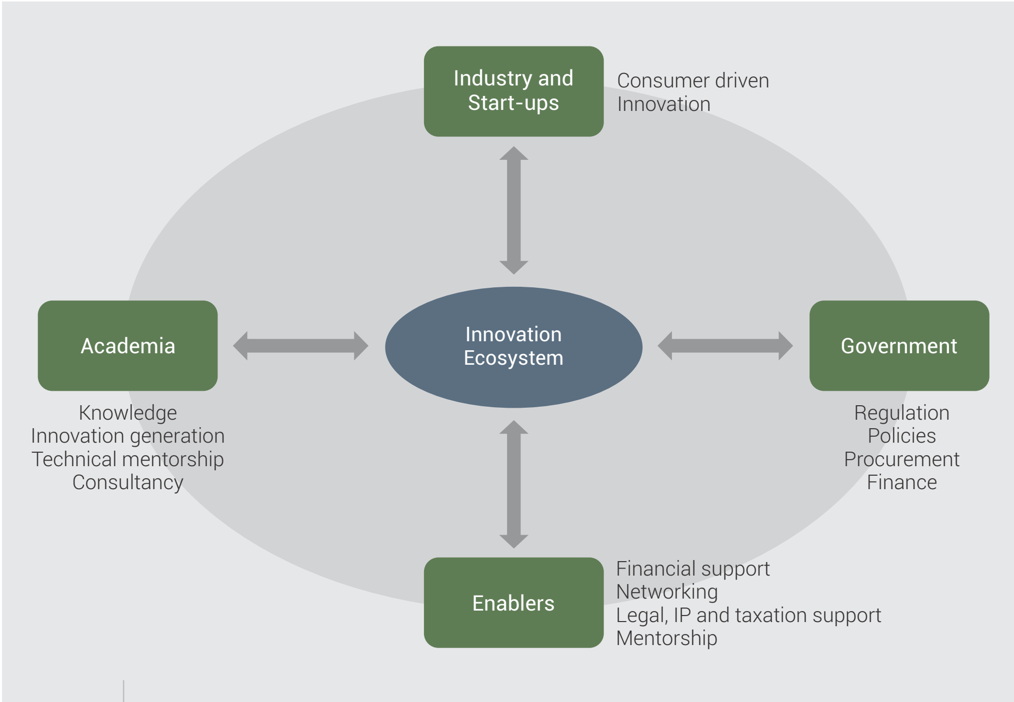


Figure 1.1 | Framework used in the study

The primary role of each stakeholder is as follows:

Academia: The primary role of academia is knowledge generation, technical mentorship, providing consultancy to industry projects and can therefore be seen as an innovation organiser.

Industry and startups: Large industries and startups are very different in their focus on innovation and the obstacles that plague them. Since industries are profit driven, they serve as liaison between market and research and are responsible for commercialisation of innovations that exist in the ecosystem.

Enablers: Enablers play various roles in supporting SMEs and startups through incubation, financial support, and business, legal and regulatory mentorship. In an ecosystem that is at its infancy enablers take a central role in networking between stakeholders.

Government: The government plays a crucial role in catalysing innovation through policies, regulation. In a growing ecosystem the government also plays a crucial role in funding innovation and procuring innovations that are supported through various programmes.

Since transfer of technology is not common, the innovation potential is studied through analysis of publications and collaborations between scientists in industry and academia. Survey/interviews with various stakeholders in each city aims to capture the current status in terms of knowledge, interaction and support. Various organisations and institutions covered either through primary or secondary modes are enlisted in Table 1.1.

Direct influence						Indirect influence	
Finance	Support	Policy	Research and Development	Human capital	Markets	Infrastructure	Culture
Banks	Incubators	National government	Public research centres and laboratories	Universities	Domestic corporations	Electricity providers	Media
Venture capital, Private equity firms	Accelerators	State government	Private research centres and laboratories	Technical training institutes	International corporations	Transport providers	Government
Angel investors	Industry associations/	Local government	Teaching hospitals	Colleges	Consumers	Communications (mobile, internet)	Schools
Foundations	Legal services				Distribution networks; suppliers	Other utility providers (gas, water)	Professional associations
Microfinance institutions	IP services				Retail networks		Social organisations
Public capital markets	Accounting services				Marketing networks		
Government	Technical experts / mentors						
Development finance institutions	Credit rating agencies						
	Agencies for regulatory compliance						
	Specialised infrastructure, e.g. preclinical facilities, pilot plants, production facilities on contract, testing labs, fab labs						

Table 1.1 | Institutions and organisations influencing the innovation ecosystem

1.3 Cluster led innovation

In recent times several economists have highlighted the need for framing policies at the level of individual clusters. New research confirms that strong clusters tend to deliver positive benefits to workers, firms, and regions. Policymakers prioritize and maximize the impact of their efforts, even with constrained resources, by drawing attention to the grainy, real-world dynamics of regional economies.

There have been several publications highlighting the salient aspects of creating a thriving innovation cluster. While the government has a crucial role to play, a market led approach is rather critical. The pre-existence of a cluster usually indicates an industry hotspot that has passed the market test. Therefore, it may be worthwhile to let the private sector lead in creating a cluster. The government could facilitate the growth of such clusters and focus on specific cluster initiatives in regions where there is an empirically measured evidence of under-capacity.

There is also a crucial role to be played by state policymakers and key regional stakeholders who strategically invest their own resources in cluster-led economic development and make objective assessments about the nature, competitive prospects, and specific needs of different regions. Regional champions of innovation work in close association with state policymakers to identify cluster challenges and coordinate cluster based actions.

Therefore, an innovation cluster should be viewed as a vibrant collaborating ecosystem and not just a collection of firms in the same region. Talent across various streams becomes an equally important factor in developing successful clusters. A vibrant cluster is one that has a culture of innovation and entrepreneurship, and competition and focus on identified sectors could be a way to create the culture.

An example of such a cluster led initiative is the Indiana Life Sciences Cluster which was spurred by the efforts of the Biocrossroads cluster initiative. It has been anchored by several large pharmaceutical, agricultural feedstock, and medical device companies. In addition to developing a concentration of 50 companies and over 8,000 skilled workers specialized in sophisticated biopharma services such as contract research, contract manufacturing, and logistics, the initiative led to a job growth in the state at 17.2 percent versus 15.8 percent at the national level from 2001 to 2008 and provided employment to over 52,800 workers.

1.4 Recent Indian startup policies

There has been a huge thrust in the country since 2015, both at the central and state government levels, to incentivise and stimulate the entrepreneurial ecosystem. Startup India and Make in India are the flagship initiatives of the Government of India to build a strong ecosystem for nurturing innovation, entrepreneurship and manufacturing in the country. The schemes are being implemented by the Department of Industrial Policy and Promotion (DIPP) under the Ministry of Commerce and Industry. The Action Plan of these initiatives were largely based on the following three pillars: Simplification and Handholding; Funding Support and Incentives; Industry-Academia Partnership and Incubation.

As per the Startup India policy, a private limited company or registered partnership firm or limited liability partnership would qualify as a startup under the following conditions:

- Up to 7 years from the date of its incorporation / registration, and up to 10 years for a Biotechnology Startup
- If its turnover for any of the financial years has not exceeded INR 25 crore, and
- It is working towards innovation, development, deployment or commercialisation of new products, processes or services driven by technology or intellectual property

Startups may voluntarily register with DIPP for recognition and benefits. As on August 2017 2,865 startups have been recognised by DIPP as innovative startups with about 60 receiving tax benefits. A Startup India hub has been established which mentors more than 430 startups. Other incentives provided by this programme include patent benefit, relaxed norms of procurement, access to fund of funds, tinkering labs and incubators.

As per the recent Association for Biotechnology Led Enterprises (ABLE) white paper on Indian biotech startups, the number of startups in the biotechnology space between January 1, 2012 and December 31, 2016 is over 1022. BIRAC has introduced several schemes to boost life sciences startups across their life cycle, starting from the Biotechnology Ignition Grant (BIG), Social Innovation programme for Products: Affordable & Relevant to Societal Health (SPARSH), Grand Challenges Explorations India (GCE-I) to Small Business Innovation Research Initiative (SBIRI), Biotechnology Industry Partnership Programme (BIPP), Contract Research Scheme (CRS) and Industry Innovation Programme on Medical Electronics (IIPME). A biotech equity fund has been established and being managed by leading bio-incubators. An equity linked fund of funds is expected to be operational soon. BIRAC is also spearheading various handholding programmes through setting up of new bioincubators and enhancing the capacity of existing ones, establishing Technology Transfer Offices in various institutions and setting up Regional Innovation and Entrepreneurship Centres in Hyderabad and Bangalore.

In addition to the polices of the central government, 15 states in the country have announced their own policies and vision documents to promote a vibrant startup culture in their states over the next 10 years with a mandate to grow the economy and create jobs. While each state tends to focus on specific sectors that are inherently thriving in the region, most of the initiatives are largely focused on Information Technology and allied sectors. The incentives provided by the state governments complement and supplement the central government programmes through incubation centres in Tier I as well as Tier II cities, addressing state level challenges through competitions, equity linked funds and creating nodal departments that serve as a single point of contact for startups.

Chapter 2

ANALYSIS OF TEN LIFE SCIENCES CLUSTERS

2.1 Framework and rationale used for the study

This report aims to understand the current status of the innovation ecosystem in six life sciences clusters in central and western India through analysis of primary and secondary data sources and then collate and analyse the data along with that from the Phase I report on the four leading life sciences clusters in southern India. The report largely focuses on the academic research capabilities in pharma, bio-pharma, medical technology and healthcare. Agri-biotech, and industrial biotech are only included while discussing the overall sector in totality.

Majorly, four stakeholders - Academia, Industry, Enablers and Startups were studied. The role of academia in an innovation system is very significant as it is involved in the generation of technological knowledge and skilled human resource. It also participates in diffusion of knowledge through publications, conferences and other knowledge exchange platforms. Industry plays a key role in the innovation system in which it looks to exploit the generated knowledge and use it to provide products and services to consumers. It also plays a major role in the employment of human resource. Enablers play a key role in the innovation ecosystem as intermediaries at various stages of product development and commercialisation. While startups are a part of industry, they have been studied as a separate category because of their ability to innovate rapidly and disrupt the system.

Primary analysis was carried out by interviewing Key Opinion Leaders in each stakeholder category to seek their opinion on the current status of the innovation ecosystem. The trends identified through this exercise were supplemented through rigorous data analysis of various input markers that define a regional innovation ecosystem such as publications, patents, company incorporations etc.

2.1.1 Definition of some key terms

Academia: In this study we have considered universities, technical institutes with research programmes, research institutes and teaching hospitals as academia. Undergraduate colleges have been included only while referring to the total size of the academic fraternity in a cluster.

Academic organisation: Internationally recognised establishment of professional scholars and students - usually a college, technical institute, university or deemed university engaged in higher education and research.

Research institute: An establishment endowed for doing research. A research institute may specialise in basic research or may be oriented to applied research.

Teaching hospital / Medical school: A tertiary educational institution or part of such an institution that teaches medicine and awards a professional degree for physicians and surgeons.

Industry: Large companies, Small and Medium Enterprises (SMEs) and startups, in a particular domain, either collectively or individually constitute that domain industry or are often named after the principle product.

In this study, pharmaceutical, biopharmaceutical, bioinformatics and healthcare companies, pharma contract research and manufacturing firms, and commercial hospitals have been included as part of the bio-pharma industry.

Pharmaceutical company: A company that develops, produces, and markets drugs or pharmaceuticals for use as medication.

Biopharmaceutical company: A company that uses biological systems, living organisms or derivatives thereof, to make or modify products or processes for pharmaceutical use.

Bioinformatics company: A company that employs computational tools for the management of biological information.

Healthcare company: A company that designs, develops and manufactures medical appliances, devices, technologies and diagnostics including those that use sensors and embedded systems.

Contract Research and Manufacturing Services (CRAMS) / Contract Research Organisation (CRO): An organisation that provides support to the pharmaceutical, biotechnology, and medical device industries in the form of research and/ or manufacturing services outsourced on a contract basis.

Startup: An entrepreneurial venture which is typically a newly emerged, fast-growing business that aims to meet a marketplace need by developing or offering an innovative product, process or service. A startup is usually a company such as a small business, a partnership or an organisation designed to rapidly develop a scalable business model.

As per the Startup India policy, a private limited company or registered partnership firm or limited liability partnership would qualify as a startup under the following conditions:

- Up to 7 years from the date of its incorporation / registration, and 10 years for a biotechnology startup
- If its turnover for any of the financial years has not exceeded INR 25 crore, and
- It is working towards innovation, development, deployment or commercialisation of new products, processes or services driven by technology or intellectual property.

Government and public institutions: Government and Public institutions are organisations owned by the local, state or central government and backed by public funds. Besides government departments, the activities of the government is spread over several other government Institutions such as Commissions, Autonomous Bodies, Public Enterprises, Development Authorities, Universities, Public Research Institutions etc. Governing bodies play a major role by formulating and administering policies, providing funding and infrastructure to the innovation ecosystem. Examples of Central Government departments and institutes that govern biopharma innovation include the

Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India; BIRAC, regulatory agencies like the Central Drugs Standard Control Organisation (CDSCO); Review Committee on Genetic Manipulation (RCGM); Central Pollution Control Board (CPCB); Indian Council for Medical Research (ICMR) etc. In addition, the state governments have dedicated departments and units catering to life sciences startups and innovation.

Funding agencies: : Agencies that provide funding to companies or individuals either in the form of grant, debt, equity or any other instrument. Funding agencies enable knowledge generation and knowledge exploitation through financing. Various types of funding bodies such as government funding agencies, venture capitalists, angel investors, private equity players, and national and global foundations are covered in the report.

Enablers: Different categories of enablers have been studied in this report, including:

Technology mediating organisation: An organisation that helps in knowledge diffusion from academia to industry and within industry such as Technology Transfer Office (TTO).

Science park and incubator: An organisation that promotes innovation by incubating startups and providing various services and customised space to innovative companies and institutions and helps in knowledge and technology exchange between various actors.

Business associations: An organisation that represents the cause of businesses at local, national or international level and convey industry requirements to the government.

Law firms, consultancy service providers and consultants: They provide consultancy on legal, business, policy issues and help in innovation protection and technology transfer.

Supplier & vendors: Suppliers and vendors are those firms that provide input material for research including chemicals, reagents, equipment etc. They play a key role in the research and innovation system.

Cluster: Groupings of independent undertakings - innovative startups, small, medium and large undertakings as well as research organisations - operating in a particular sector and region, and designed to stimulate innovative activity by promoting intensive interactions, sharing of facilities and exchange of knowledge and expertise.

For our study, a **mature/ established cluster** is one that has presence of all key innovation stakeholders. An **Emerging cluster** is that where a critical mass of one or more key innovation stakeholders or support structures are absent.

Classification of cities: The classification of Indian cities is a ranking system used by the Government of India to allocate House Rent Allowance (HRA) to public servants employed in different cities in India. As per the sixth pay commission these cities were classified into Tier I (X), Tier II (Y) and Tier III (Z) cities. The clusters considered in this study falling under Tier I are Mumbai, Chennai, Bengaluru, Hyderabad, Pune and Ahmedabad, and those under Tier II are Bhubaneswar, Bhopal+Indore, Visakhapatnam and Thiruvanthapuram+Kochi.

Citation index: A measure of productivity defined as the number of citations per publication.

Normalised citation index = ((Number of citations in a year in an institute / total number of citations for an institute) / (number of publications in a year from the institute / total number ofpublications from the institute)).

Average number of publications per scientist = (Number of publications / Number of scientists in the organisation).

Network analysis

Node: An author who is either one of the ten top performing faculty in the institute or his/ her collaborator.

Edge: A collaboration between one of the top ten performing authors with his/ her collaborator.

Degree of a node: Number of collaborators of the author (redness indicates higher degree).

Degree of an edge: Number of collaborations (thickness indicates higher degree).

Centrality: It measures the importance of the node or the edge in the network by means of number of times it features in shortest paths. Centrality of nodes measures the importance of the author (size). Centrality of edge measures importance of the collaboration (redness).

Classification of collaboration type in network analysis

- Across field: Collaboration between engineering / medical / science authors
- Other faculties in same field: Collaboration with different branches within above fields
- Similar areas: Collaboration within branches / departments

Definition of some key funding terms for startups

Seed: Seed capital is the initial capital used when starting a business, often coming from the founders' personal assets, friends or family, for covering initial operating expenses and attracting venture capitalists (VCs). Early stage VCs also invest in Seed capital.

Angel: Capital raised from angel groups.

Series A: Series A round of financing is the first round of financing that a startup receives from a venture capital firm i.e. the first time when company ownership is offered to external investors.

Series B: Series B financing is the second round of financing for a business through any type of investment including private equity investors and venture capitalists. Successive rounds of financing or funding a business are consecutively termed Series A, Series B and Series C financing.

Acquired: If the latest form of funding received in a company is through acquisition by a bigger firm then it is annotated as acquired.

Public: A public company, publicly traded company, publicly held company, publicly listed company, or public corporation is a corporation whose ownership is dispersed among the general public in many shares of stock which are freely traded on a stock exchange or in over the counter markets.

Funded: If a company has received some amount of funding, but the quantum or source or round is not disclosed or available on the database, those are annotated as funded companies.

2.1.2 Data sources

All the publication and patent datasets in this report were collected from Derwent Innovation (previously known as Thomson Innovation) database. More specifically, publication data was sourced from Thomson Reuter's database underlying Web of Science, which gives access to conference proceedings, patents, websites and chemical structures in addition to journals.

Tracxn database was used to collect information related to companies. Details such as year and city of incorporation, sector of operation, funding information and founder details are available. In addition to this, various web searches and other databases like PubMed, Google scholar, Google patents were used to augment the data set.

2.1.3 Assumptions, hypothesis, limitations

The research and innovation capacity of an innovation ecosystem was analysed on the basis of patents and publications as the primary parameters. Since the focus of Indian academia has historically been more on publications rather than on patents, the number of patents was found to be too few for analysis, and therefore, publications were considered as a surrogate marker of research capacity for the study.

- The list of academic institutions considered in the study was selected based on the number of publications. Though not exhaustive, it is certainly indicative of the trends.
- All scientific publications for a particular scientist were considered for the study. This included articles, book chapters, proceedings papers, biographical items, erratum, and articles about an individual, meeting abstracts, letters, notes, reprints and reviews. However, documents other than articles were very few.
- There are organisations working on research areas other than life sciences. To focus on articles pertinent to life sciences, scientific literature search results were restricted using the standardised subject category feature of Thomson Innovation Literature search.
- For organisations with patents in areas other than life sciences, the IPC code restriction feature of Thomson Innovation was used for restricting patents to life sciences. This was done by selecting only those patents that fall under IPC codes (A61, C07, C12) corresponding to life sciences.

- There are scientists who have worked with organisations other than those under the study and have publications and patents with them. For data on scientific literature, only those publications were considered that had an organisation under the study as an affiliated organisation. For example, Author A has 2 publications with Org. 1 and 3 publications with Org.2 in the last 10 years but organisation under study is Org.1. So, publication count for author A is 2, not 5. In the case of patents, all patents in which the scientist is an inventor were captured. Eg. If Scientist A has 2 patents with Org. A as assignee and 3 patents with Org. B as assignee and Org. A is an organisation under study, then the patent count was taken as 5, rather than 2.
- Patent count is unique. One member per family of an International Patent Documentation (INPADOC) family was considered.
- Hospitals / Medical schools include veterinary colleges / schools, dental colleges, medical centres, research institutes dedicated to a particular disease.
- If no publication for a particular scientist has been recorded, it does not mean that the scientist is not publishing. He may have published with organisations that are not part of the study.
- Research publications have a citation count when they are referred by other publications. Citation count refers to the number of times a publication gets cited by others and it reflects the value of the publication. Hence, citation count is taken as a marker for the relevance of the publication. However, a high citation count does not always correlate to translation and commercialisation of the technology. In addition, the database does not provide yearwise increase in the number of citations for a publication.
- For scientific publications and patents, the period of study in this Phase was from the year 1997 to 2015, whereas in the previous Phase the period under study was 1996 to 2014. Phase 1 data was updated to include data for 2015 and all comparative analysis or the ten clusters was done for the period from 1997 to 2015. Thomson Innovation Literature Search service was used for scientific literature search and Thomson Innovation Patent Search service was used for patent search.
- Collaborations were captured from the affiliation section of any publication. Individual collaborator data was obtained by unique sorting. Different departments of a particular collaborating institute were taken as individual collaborators. For example, if two departments in IISc, say, the Dept. of Physics and the Dept. of Chemistry collaborated with JNCASR that resulted in two publications, these were counted as two collaborators. In case of national institutes in different campuses, each centre was considered as an individual collaborator.
- Sorting of unique collaborators - for publications, an institute or department was considered as a unique collaborator and not individual scientists in the publication. This was to remove any bias that would arise for publications of multicentric clinical trials or databases that usually involve a large number of authors. Individuals have been considered as unique collaborators for network analysis only.

- Collaboration across four categories - within the institute, with other institutes within the state, across the states in India and across the countries in the world - was analysed to see the extent of collaboration by faculty in the four clusters.

- In network analysis, the top ten authors on the basis of highest citation index were chosen to understand their collaboration networks. Individual collaborating authors were uniquely sorted. Organic layouts were chosen to understand the interaction patterns. Further, the extent and importance of collaboration were studied using measures of degree and centrality as described in section 2.1.1.

- In network analysis, edges between various authors collaborating with a high performing author in an institute were not considered separately. To elaborate, if a publication has five authors all collaborating with one primary author of an institute, the number of edges would be five. Although directionality is not represented, it is implicitly considered since the driving force for the collaboration comes from the faculty and not every author listed in a publication. The values of centrality and degree are with respect to an individual institute and cannot be compared across maps.

- Traxcn (a data analytics company) data provides details only on companies that have registered websites and are startups with a limited database of their own. Therefore, several early stage companies might not have been included. However, the data captured in this Phase has increased from about 900 life sciences companies in the previous phase to about 2,000 companies in this Phase. Also, Traxcn database does not only list startups but companies in all stages including public listed companies

- IP analysis is based on the requests received by BRIC and not an exhaustive representation of the ecosystem.

2.1.4 Dataset

To understand the life sciences innovation ecosystem in southern, western and central India, a detailed study of key stakeholders, academia, industry, suppliers and enablers around the cities of Ahmedabad, Mumbai, Pune, Bhopal+Indore, Bhubaneswar and Visakhapatnam regions was performed, in addition to the data from Phase 1 on Hyderabad, Bengaluru, Chennai+Vellore and Thiruvananthapuram+Kochi was also updated to include 2016 and compared with the above six clusters.

In Phase 1, 33 key academic institutes, 85 key industry players, and 94 KOLs (33 in Hyderabad, 31 in Bengaluru, 26 in Chennai+Vellore and 4 in Thiruvananthapuram+Kochi) were selected for the study. In Phase 2, 31 academic institutes, 23 key industry players and 59 KOLs (9 in Ahmedabad, 13 in Mumbai, 20 in Pune, 8 in Bhubaneswar, 4 in Bhopal-Indore and 3 in Visakhapatnam) were selected. Scientific and innovation capacity and knowledge generation were analysed from publication and patent data of these academic institutes and industries. KOL interviews were used to understand gaps in innovation policy, facilitating agencies or enablers, funding and infrastructure.

The list of academic institutes studied in both Phases is provided in Table 2.1.

Hyderabad	Bengaluru	Chennai+ Vellore	Thiruvanantha-puram+Kochi	Mumbai	Pune	Ahmedabad	Bhopal+Indore	Bhubaneswar	Visakhapatnam
CSIR-CCMB	BMCRI	Anna University	Amrita University	BARC	CSIR-NCL	MSU, Baroda	Raja Ramana Centre Adv. Tech.	Utkal Univ.	Andhra University
CDFD	IBAB	CSIR-CLRI	CIFT	TMC-ACTREC	University of Pune	Gujarat University	Devi Ahilya Vishwavidyalaya	CSIR-IMMT	GITAM University
CSIR-IICT	IISc	CMC&H	IISER-TVM	IIT Bombay	NCCS	GCRI	IISER Bhopal	NISER	
LVPEI	InSTEM	IIT-M	NIIST	KEM Hospital	IISER Pune	LM College of Pharmacy	IIT Indore	ILS	
NIN	IOB	NIRT	RGCB	ICT	Bharati Vidyapeeth University	IKRDC	UGC DAE CSR	CIFA	
University of Hyderabad	JNCASR	Sathyabama University	SCTIMST	University of Mumbai		Nirma University		KIIT	
	KMIO	SRM University	University of Kerala	TIFR					
	NCBS	University of Madras							
	NIMHANS	VIT UNIV							
	ST JOHNS								
	UAS								

Table 2.1 | The list of institutes selected for detailed study in ten clusters

2.2 Analysis of clusterwise data

This report focuses on studying various stakeholders in the four selected clusters of Phase 1 and six in Phase 2 of the study. In total 10 clusters have been mapped- Hyderabad, Bengaluru, Chennai+Vellore, Thiruvananthapuram+Kochi from Phase 1 and Ahmedabad, Mumbai, Pune, Bhopal+Indore, Visakhapatnam and Bhubaneswar from Phase 2. Figure 2.1 gives the overall distribution of the four major stakeholders - academia, industry, suppliers and enablers, in these clusters.

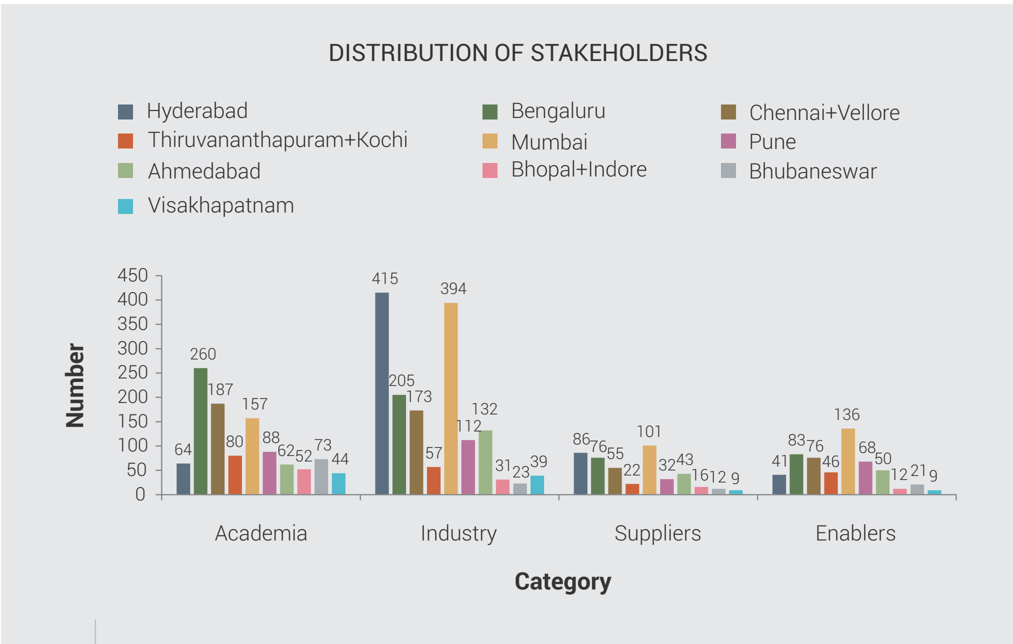


Figure 2.1 | Distribution of stakeholders (academia, industry, suppliers and enablers) in ten clusters

The number of academic institutions in Bengaluru, Chennai and Mumbai are high compared to the other clusters.

The large pharmaceutical industry in Hyderabad and Mumbai, dominated by Active Pharmaceutical Ingredient (API) and formulation companies, has contributed to the large industrial base in these two regions as reflected by the fact that over 50% of the 1500+ companies are in these two regions. Ahmedabad also has a large pharma generic manufacturing base with over 100 small and large pharma players. Naturally, in mature clusters such as Mumbai, Hyderabad, Bengaluru and Chennai, the overall spread of stakeholders is well balanced. Mumbai being the financial hub, clearly dominates in the number of enablers providing business and financial services.

The Thiruvananthapurum+Kochi and Bhubaneswar are emerging clusters with low count of industry players as well as suppliers. However, these two clusters show greater levels of biopharmaceutical activity than Bhopal-Indore or Visakhapatnam.

2.2.1 Study of academic output

2.2.1.1 Publication output, growth, quality, impact

Academic institutions comprise the base of the innovation pyramid contributing to knowledge generation. The report classifies these institutions into three categories - academic organisations, research institutes and teaching hospitals / medical schools, to ascertain the role being played by each one of them. Academic organisations constitute internationally recognised establishments of professional scholars and students, usually centred in colleges and universities engaged in higher education and research. Research Institutes are establishments endowed for doing research, maybe in basic research or applied research streams. Teaching hospitals / Medical schools are tertiary institutes that teach medicine and award professional degrees to physicians and surgeons.

Figure 2.2 depicts the distribution of academic institutions in the ten clusters. It has been globally observed and also shown in our study that a good number of research institutes have been attributed to knowledge creation and providing access to sophisticated equipment. Institutes such as IISc, IITM, IITB, IICT, CSIR-NCL, CCMB etc. have been instrumental in creating the wealth of knowledge in these clusters. These institutes also contribute to a large number of highly trained personnel at senior positions to lead the research setups in the industry. Bengaluru is an innovation hub largely due to the fact that it has a good mix and balance in the number of institutions across categories.

Chennai, Bengaluru and Mumbai have a large number of academic organisations, especially private colleges affiliated to universities, providing basic degree courses and thereby creating a large pool of students that are employable in the nearby industries. However, in life sciences, especially in biopharma and medical technology academic institutes alone cannot contribute to all aspects of innovation for commercialisation. Support through the clinical community provides an edge to the Bengaluru and Mumbai clusters.

Thiruvananthapuram, Bhopal+Indore, Visakhapatnam have very few research institutes making them fledgling life sciences innovation ecosystems. Bhubaneswar on the other hand has a large number of research institutes in diverse streams that have been opened recently, such as NISER, IIT, AIIMS, with a promising trend for collaboration and translational research.

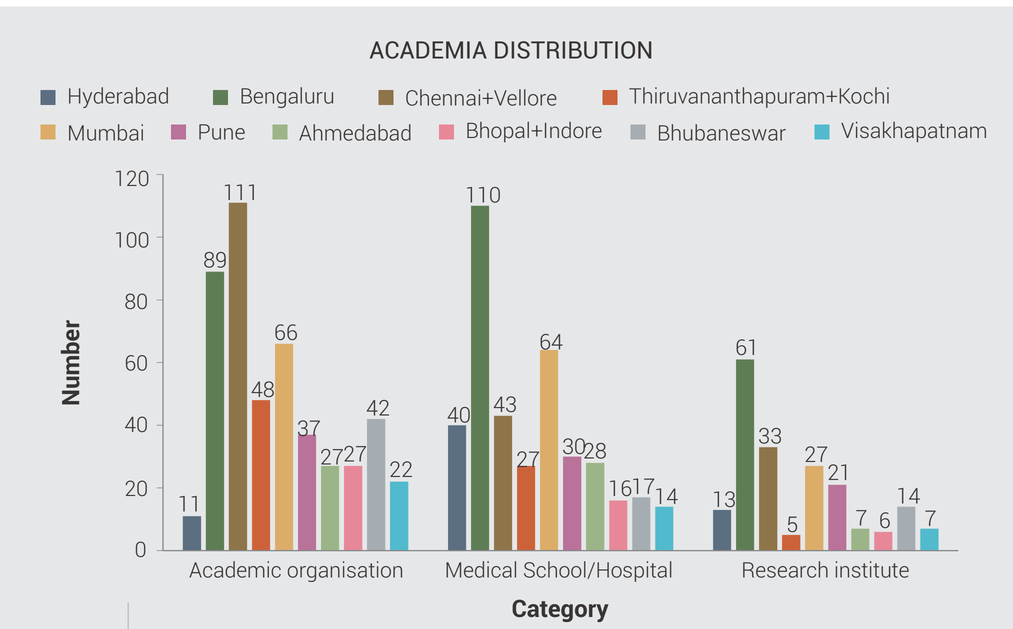


Figure 2.2 | Distribution of academic institutes in ten Indian clusters

Number of publications

Selection of academic institutions for further analysis:

Out of the large pool of academic institutions in the clusters, 65 institutes (6 from Hyderabad, 11 from Bengaluru, 9 from Chennai+Vellore, 7 from Thiruvananthapurum+Kochi, 7 from Mumbai, 6 from Pune, 6 from Ahmedabad, 5 from Bhopal+Indore, 6 from Bhubaneswar and 2 from Visakhapatnam), were chosen, based on their research capabilities and focus for analysing their research output and contribution to the innovation ecosystem. For Phase 2 study, since several cities do not have a good representation of research institutions a quartile based approach was adopted to identify the top institutions in each cluster. Even with this approach, several institutions were identified with less than 100 publications over the last 20 years. Therefore, the top 20 institutes were shortlisted in each city on the basis of number of publications and upper quartile was identified for further analysis. In clusters like Mumbai and Bhubaneswar, few institutions such as the University of Mumbai, TIFR; KIIT had a deviation from the cut-off range by less than 5% and those were also included in the study. In the Ahmedabad region MS University Baroda with good quality research output was included for detailed analysis. In emerging clusters such as Visakhapatnam, except for two institutions, other institutions had less than 100 publications over the last 20 years and therefore were not considered for further analysis. Clearly a significant difference is seen between emerging and mature clusters as depicted in Figure 2.3. Pune has few institutions such as CSIR-NCL, that have very comparable numbers to mature clusters while there are several institutions which are very niche in their area of expertise. There were few research labs or new institutions in each city that show a lot of promise but did not have large enough number of publications to be included in the dataset.

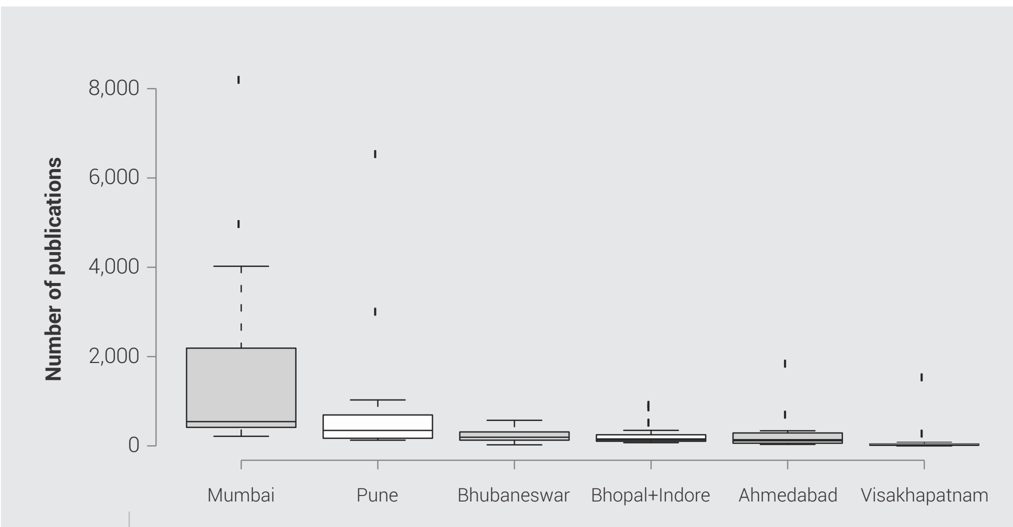


Figure 2.3 | Box plot showing distribution in number of publications across the six clusters

Figure 2.4 depicts the total number of scientists, publications, patents and collaborators in the selected institutes in each cluster. The primary focus in most academic institutes is on publications and not patents. Chennai and Mumbai have a long history of academic pedagogy and with good number of research institutions have the maximum number of publication in diverse streams. Bengaluru and Hyderabad are two other mature clusters with large institutes that are multidisciplinary and with a good number of scientists which is conducive for a vibrant collaborating environment. Pune has a clearly the highest number of patents mostly from CSIR-NCL due to well established processes for academia-industry collaboration. CSIR-NCL also has a culture of faculty led startups. It was observed that faculty in medical institutes tend to collaborate more for clinical trials and those from smaller institutes, for access to equipment and expertise. Emerging clusters have relatively new institutes and therefore do not have many publications and patents. These clusters have younger faculty who have stronger interests in translational research. Since many of these institutions are still framing their technology commercialisation policies and processes, it is likely that there will be favourable mechanisms to create a vibrant startup culture in the coming years.

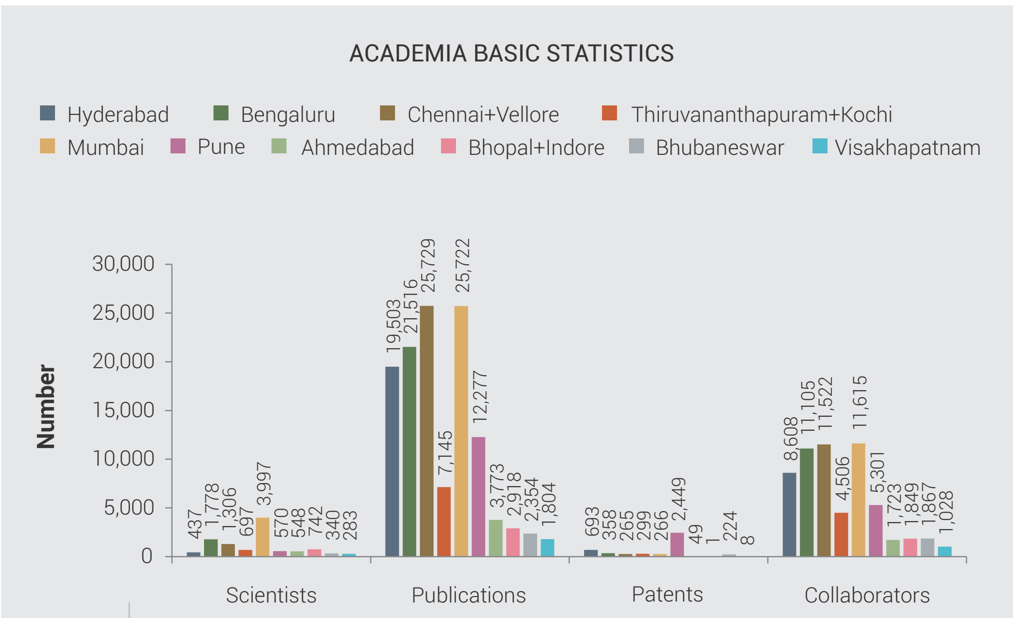


Figure 2.4 | A glimpse into knowledge creation in academic institutes through publications, patents and collaborations.

To avoid bias due to the size of institutes, the number of publications was normalised to the number of scientists and displayed as an average. Figure 2.5 highlights the research productivity of each institute as a function of the average number of publications per scientist.

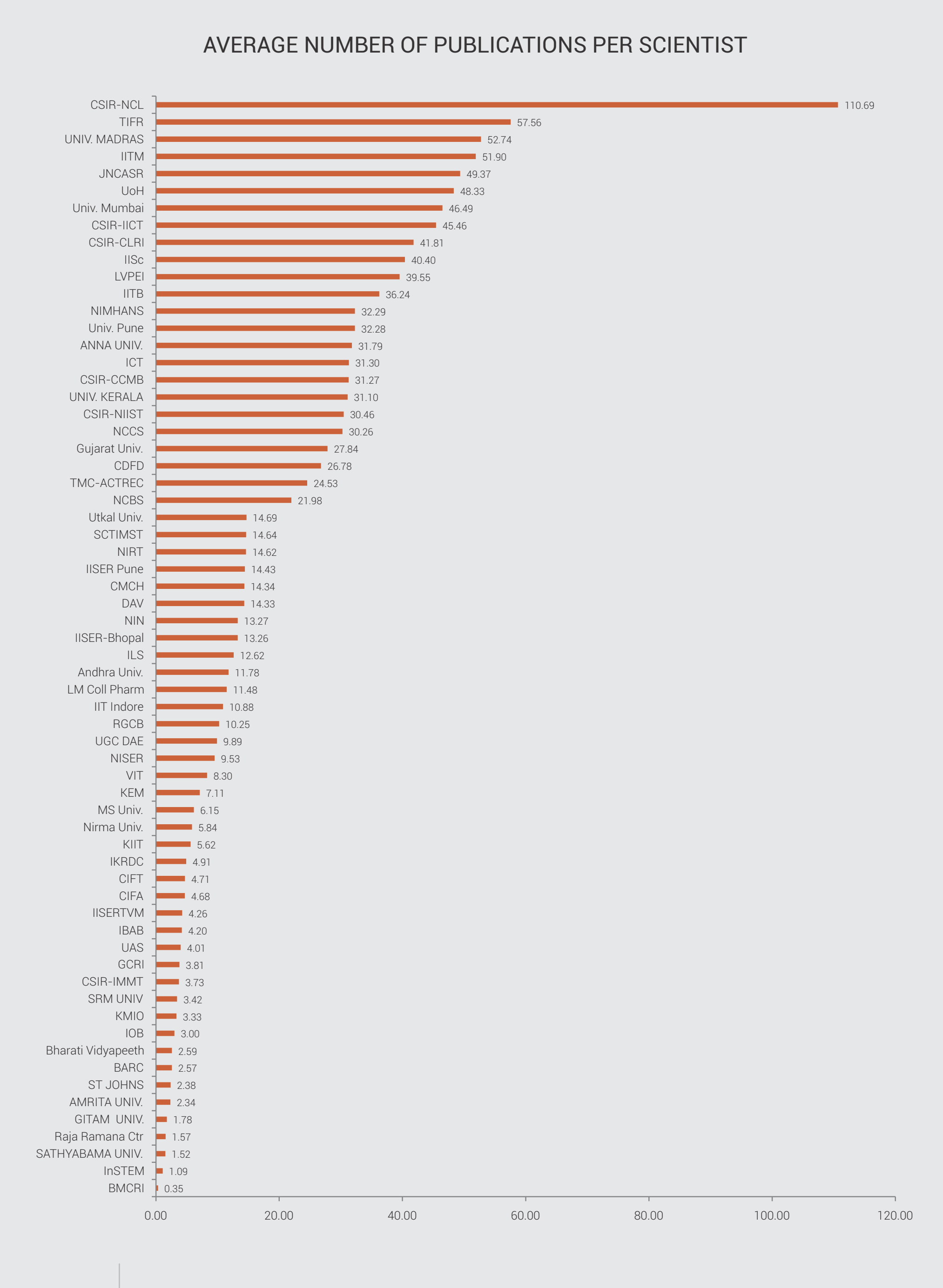


Figure 2.5 | Graphical representation of average number of publications per scientist in the institutes under study

Hospital / Medical schools in Bengaluru, Chennai+Vellore and Thiruvananthapuram+Kochi clusters have high number of medical scientists (doctors) but their publication (research) activity is comparatively lower, thus leading to lower average number of publications. Although in principle their work has a more holistic approach, the workload due to attending to patients leaves little time for research and publications. In addition, several innovations in such reputed hospitals are restricted to new treatments and surgical procedures that cannot be patented. A similar trend is seen in BARC which has the highest number of publications in Mumbai, but has a low average number of publications per scientist. This could be because institutes like BARC have mission oriented defence projects and their primary focus may not be publications although some of the most cutting edge research might be happening in these labs.

From Figure 2.5, it is seen that some institutes have a very high average number of publications per scientist while others have poor averages. Some of the reasons for the same are hypothesised below:

- CSIR labs such as NCL Pune have a strong R&D base with well-trained faculty in chemical engineering and recently in biocompatible materials. Their focus on industry and academic collaboration has led to several translational projects.
- Institutes such as IISc, CSIR-IICT and JNCASR have high average number of publications. In institutes such as IISc and JNCASR, there are a few scientists (at least three in our study) who have more than 300 publications and several more with an average number of publications around 100.
- Larger institutes have several scientists working in theoretical areas where the churn rate of publications is higher than those working in areas that involve clinical studies.
- There are several niche small institutes that have several projects with translational potential but a less number in overall publications.
- Older institutes tend to have an advantage over newer institutes with respect to funding, access to sophisticated equipment and other facilities. It takes several years to establish such facilities, and the faculty in newer institutes are dependent on the established ones through collaborations or sharing of facilities which pose logistical difficulties to publish more frequently. For example, institutes such as IISc and CSIR-NCL were established in 1909 and 1950 respectively and have almost several decades of experience in research activities in comparison to institutes such as Amrita University and InSTEM that were established only in 2003 and 2009 respectively. Also, private institutes typically take longer to establish good publication records due to funding and infrastructure constraints in the early years.

Yearwise trends

The yearwise number of publications per institution showed a steady increase over the last 19 years. Research productivity has been a clear focus area and therefore, several government and international funding schemes were made available after the early 2000s. Several new schemes such as INSPIRE in 2011-2012, Ramalingaswamy Fellowship in 2006 and other International Science and Technology collaboration schemes for promoting research were introduced in 2009-2010.Compared to post 2010 period, the trend in number of publications between 2008 and 2010 shows a slower growth in some clusters like Hyderabad and Bengaluru possibly linked to lower research budget in preceding years (Figure 2.6).

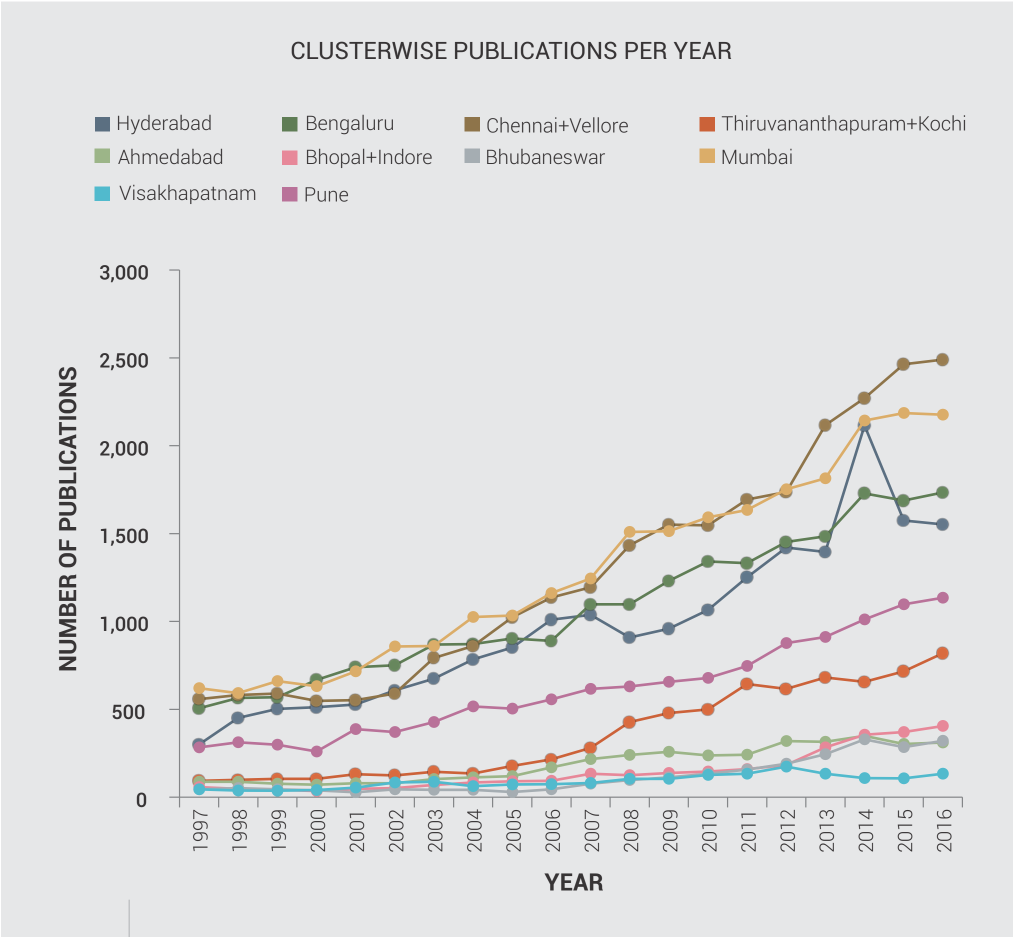


Figure 2.6 | Yearwise growth in number of publications across clusters under study

As per NSTMIS data on national R&D spending by central, state and private sectors, there has been a steady increase in R&D spend after 2000 with a marginal increase from 2006 to 2009. Post 2010 there has been considerable investment from central government and the private sector, although not much expenditure from state government funds. This was highlighted in few state funded institutes such as IBAB in Karnataka. Funding schemes for translational research have been established which could also be accessed by researchers in academic institutes.

Citation index

Citation index gives a measure of how well the research is received. This is particularly relevant because the number of publications is not indicative of quality. Most publications take about two to three years to gain traction and therefore citations for publications after 2013 may not be very relevant to analyse.

A clusterwise analysis of citation for publications from selected institutes was done as indicated in Table 2.2. Overall publications from Pune have the highest number of citations probably because the key institutions in this region have wide range of publication in areas related to chemistry, chemical engineering and biomaterials. Other mature clusters like Hyderabad, Bengaluru and Mumbai have comparable numbers although Chennai+Vellore cluster has a relatively lower average. Most notably, most of the publications lie in the bottom 20% of total citations with not more than 10 citations in emerging clusters and not more than 18 citations in mature clusters above the threshold. This indicates that a large number of publications from these clusters are not of very high quality and the focus is more on the volume of publication. Mature clusters on the other hand have a number of publications with over 200 citations, a trend signifying better research quality. With increasing funding opportunities from both national and international grants and government support for commercialisation, the output is expected to improve.

	Hyderabad	Bengaluru	Chennai+ Vellore	Thiruvananthapuram+ Kochi	Mumbai	Pune	Ahmedabad	Bhopal+ Indore	Bhubaneswar	Visakhapatnam
Total number of citations	278,950	318,234	230,899	70,852	312,956	209,122	35,599	29,991	24,338	13,015
Total number of publications	19,353	21,516	25,729	7,145	24,168	12,277	3,773	2,918	2,353	1,804
Average number of citations per publication	14.41	14.79	8.97	9.91	12.95	17.03	9.43	10.28	10.34	7.21
Citation range for bottom 20% of citations	0-13	0-15	0-9	0-11	0-12	0-16	0-9	0-9	0-10	0-8
Number of publications in bottom 20% of citations (N)	13,481	16,351	19,103	5,399	18,553	8,545	2,669	2,018	1,701	1,364
Percentage of N to total number of publications	69.7	76	74.2	75.6	76.8	69.6	70.7	69.2	72.3	75.6
Citation range for top 20% of citations	88- 1,377	178 -2,725	69-1,440	88-563	82-1,947	113-896	58-346	64-587	80-418	22-418
Number of publications in top 20% of citations (C)	349	169	386	87	398	186	77	53	38	271
Percentage of C to total number of publications	1.8	0.79	1.5	1.22	1.65	1.52	2.04	1.82	1.61	15.02

Table 2.2 | Citation trends across ten clusters

In the first phase, citations were filtered out to remove both poor citations (publications which have zero citations) as well as unusually high citations (publications with more than 34 citations). In the second phase such an exercise has not been done and the general trends in each city were compared. Clusterwise citation index was used as a measure to understand the productivity in a yearwise manner rather than looking at averages. Overall, the yearwise patterns indicate highest values in Pune, Hyderabad, Bengaluru and to a certain degree in Mumbai as shown in Figure 2.7. The emerging clusters such as Ahmedabad, Bhubaneswar and Visakhapatnam have few peaks but an overall publication trend that is low. There are several peaks in each city with years 2001, 2004 and 2009 showing an upward trend.

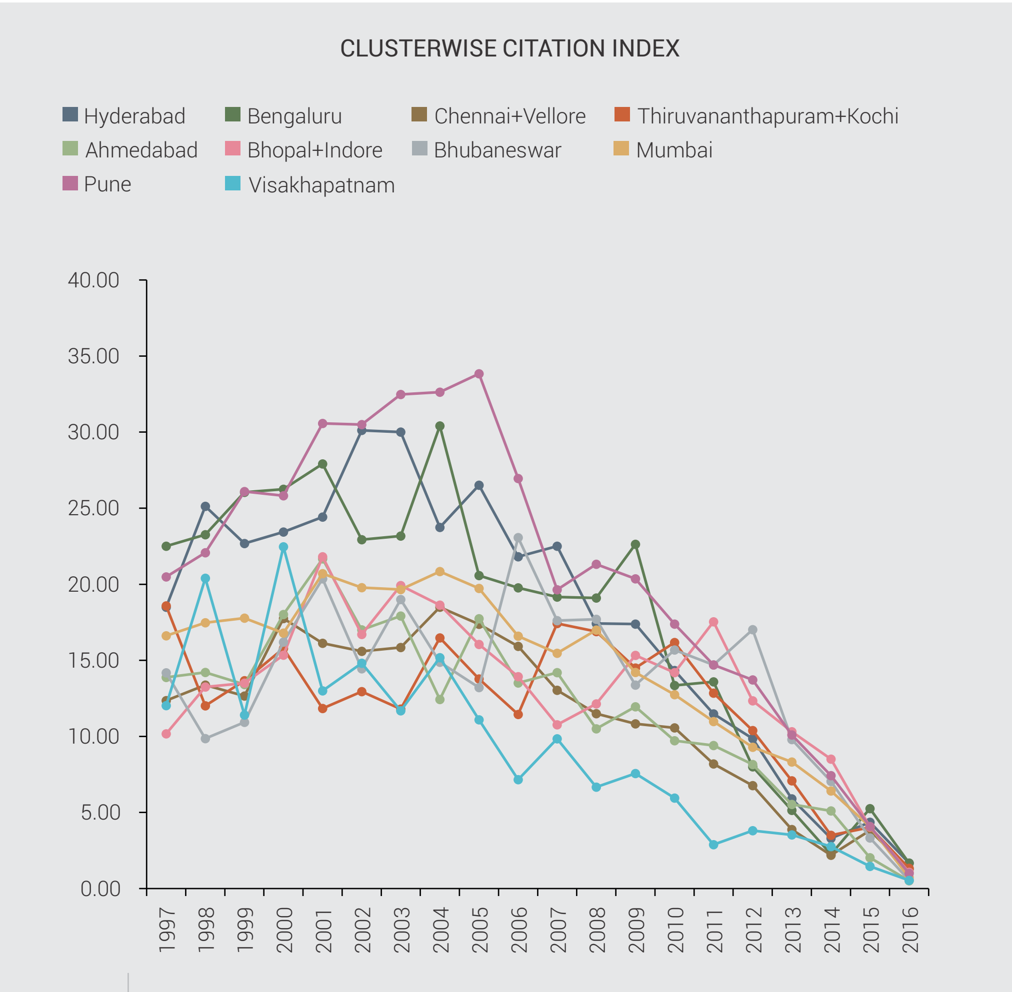
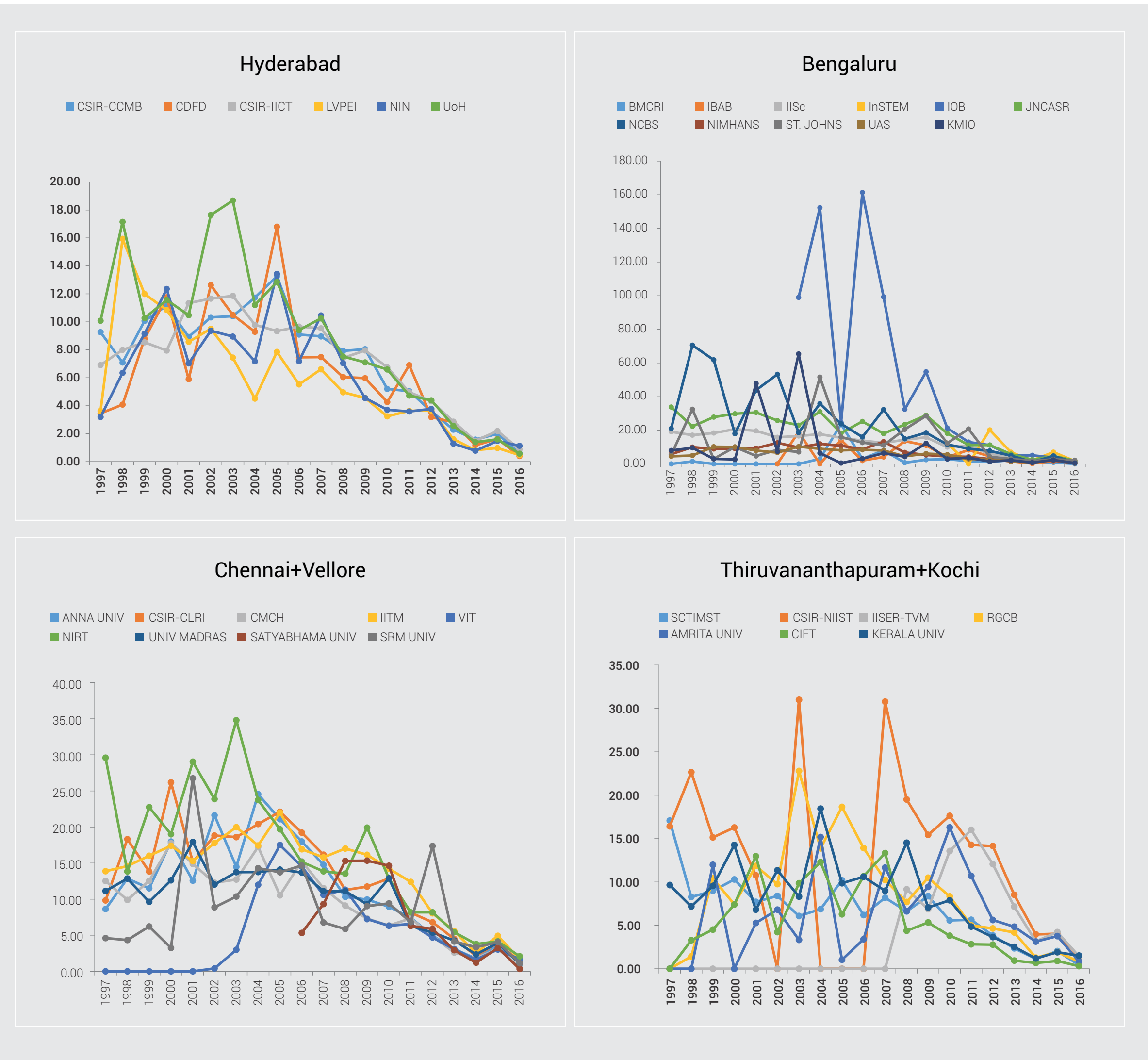


Figure 2.7 | Yearwise trend of clusterwise citation index across institutes in the ten clusters under study

A steady line without much fluctuation is indicative of uniform research productivity. Institutes in Thiruvananthapuram+Kochi cluster have large fluctuations in their citations indicating that the citations of those publications donot follow a steady pattern. Figure 2.8 describes the trend across individual institutes in each of these clusters. Such trends are also indicative of the maturity of a cluster or an institution. While older and well-established institutions such as IISc, IICT, IITM from Phase I and institutes in Mumbai, MSU and NCL show more stable or continuous trend lines, younger institutions such as InSTEM and some other young institutions because of induction of new faculty display peaking phenomenon. This peaking phenomenon is particularly evident in the Phase II clusters because several institutes are less than 10 years old and there is a critical mass of young faculty doing high quality research.



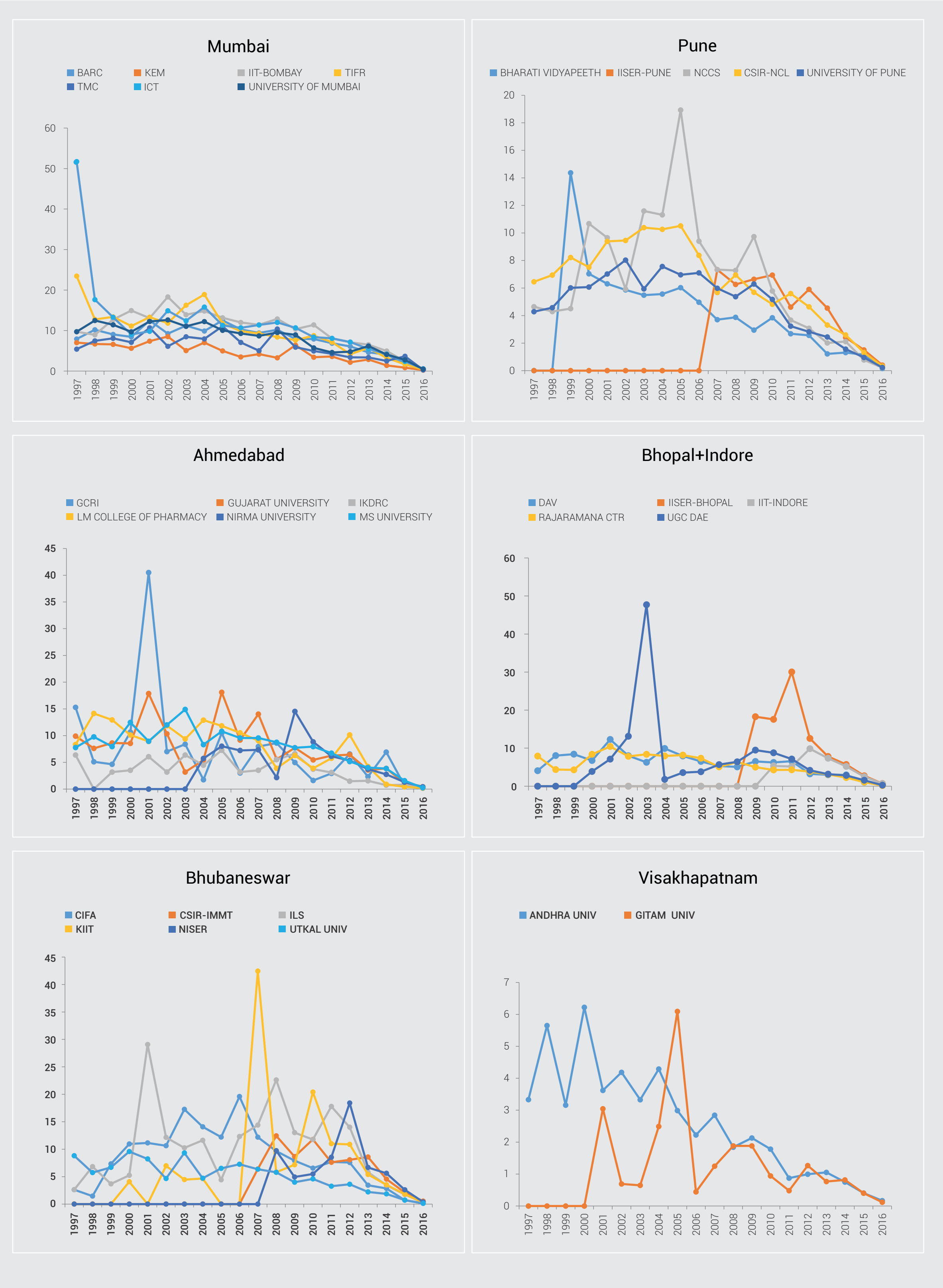


Figure 2.8 | Variation of normalised citation index within each institute across the ten clusters under study

Although there was an exponential growth in the number of publications, there were several publications with poor citations (Figure 2.9). This phenomenon was observed in all clusters, but Pune and Hyderabad displayed a significantly better performance over the other cities having been able to maintain less than 10% publications with zero citation since 1998. Cities such as Thiruvananthapuram and Visakhapatnam have a larger fraction of publications that have not been well-cited. As pointed out by several individuals, these cities are focusing on establishing a foothold in research and aiming for quantity although the vision and commitment to better quality research is clearly there, as seen from several collaborative programmes being planned with well-established institutes.

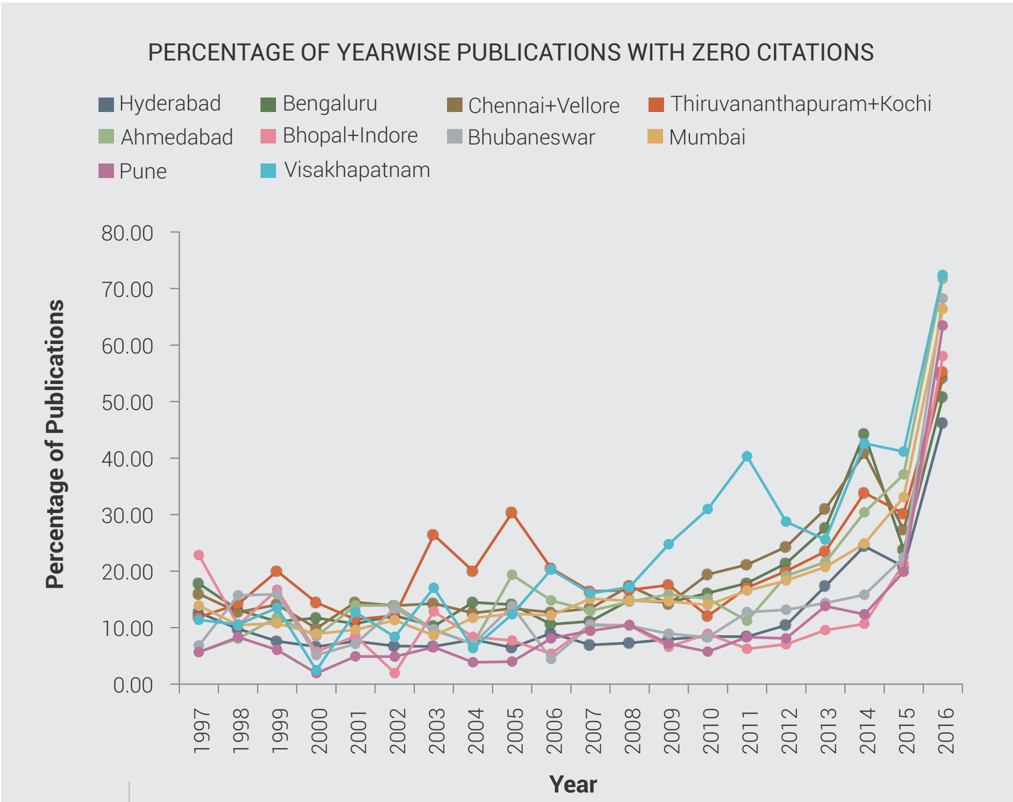
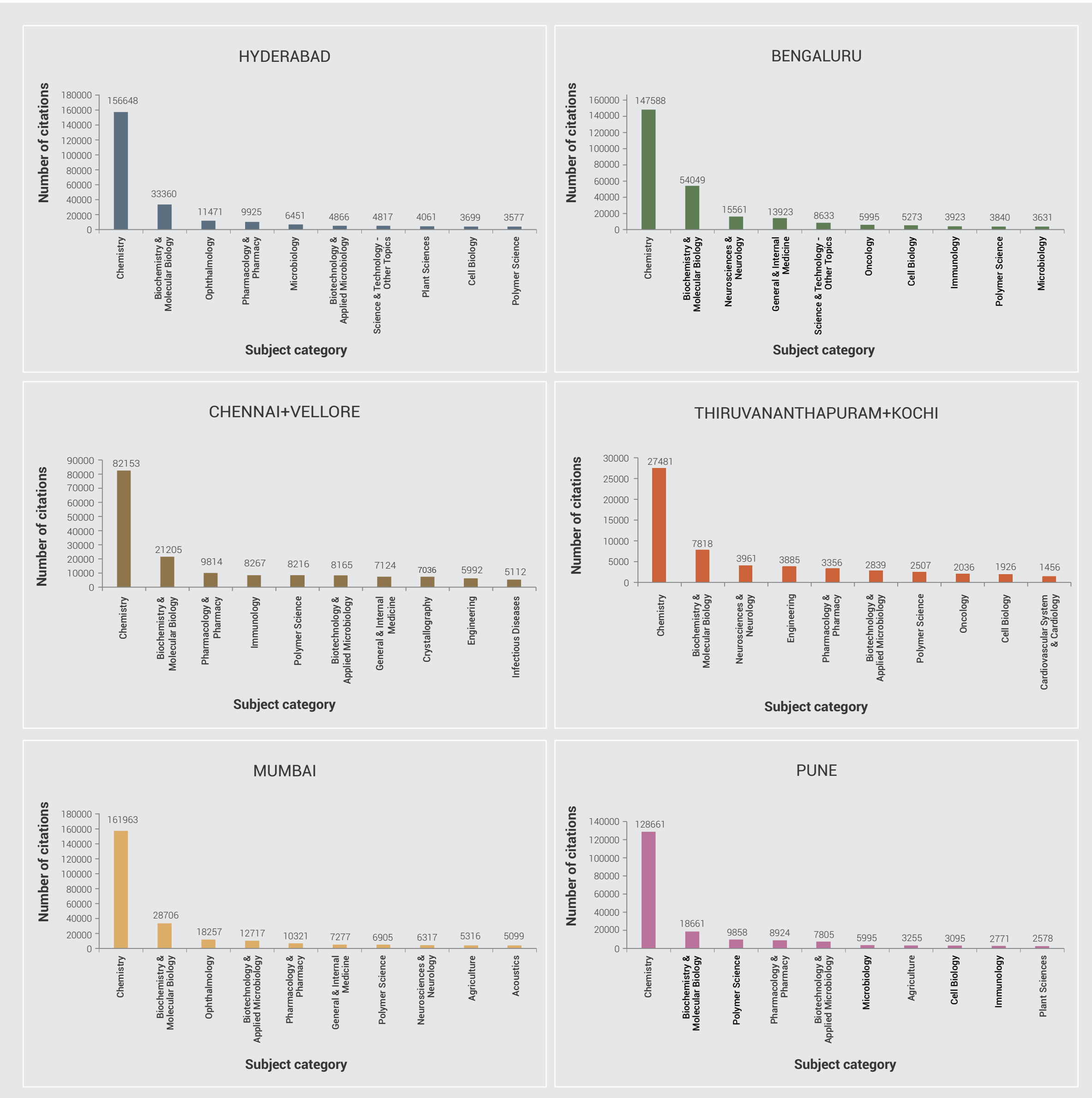


Figure 2.9 | Yearwise growth of publications with zero citations

Subject areas

The top ten subject areas in life sciences that academic institutes in the ten clusters focused on are represented in Figure 2.10. Across clusters, India's strength in life sciences seemed to be in various disciplines of chemistry followed by biochemistry & molecular biology and pharmacology (Figure 2.10).Certain cities have expertise in specific disciplines that are related to the presence of specialised institutes and in some cases, presence of a particular industry. For example, in addition to Hyderabad and Mumbai there are several other pharma hubs in the cities under study which have a strong focus on pharmacology and pharmacy. Specialised institutes such as LV Prasad Eye Institute in Hyderabad and TMC-ACTREC in Mumbai produce a large number of publications in ophthalmology and oncology respectively.

Bengaluru and Chennai have a greater focus on polymer science due to the strength of the chemistry and chemical engineering departments in several institutes in these clusters. Likewise, Chennai showed strength in Crystallography due to the research divisions established by GN Ramachandran in Madras University and many of his students establishing their work in other institutes in Chennai. Coastal cities like Visakhapatnam and Bhubaneswar have focus on various aspects of marine biotech and fisheries.



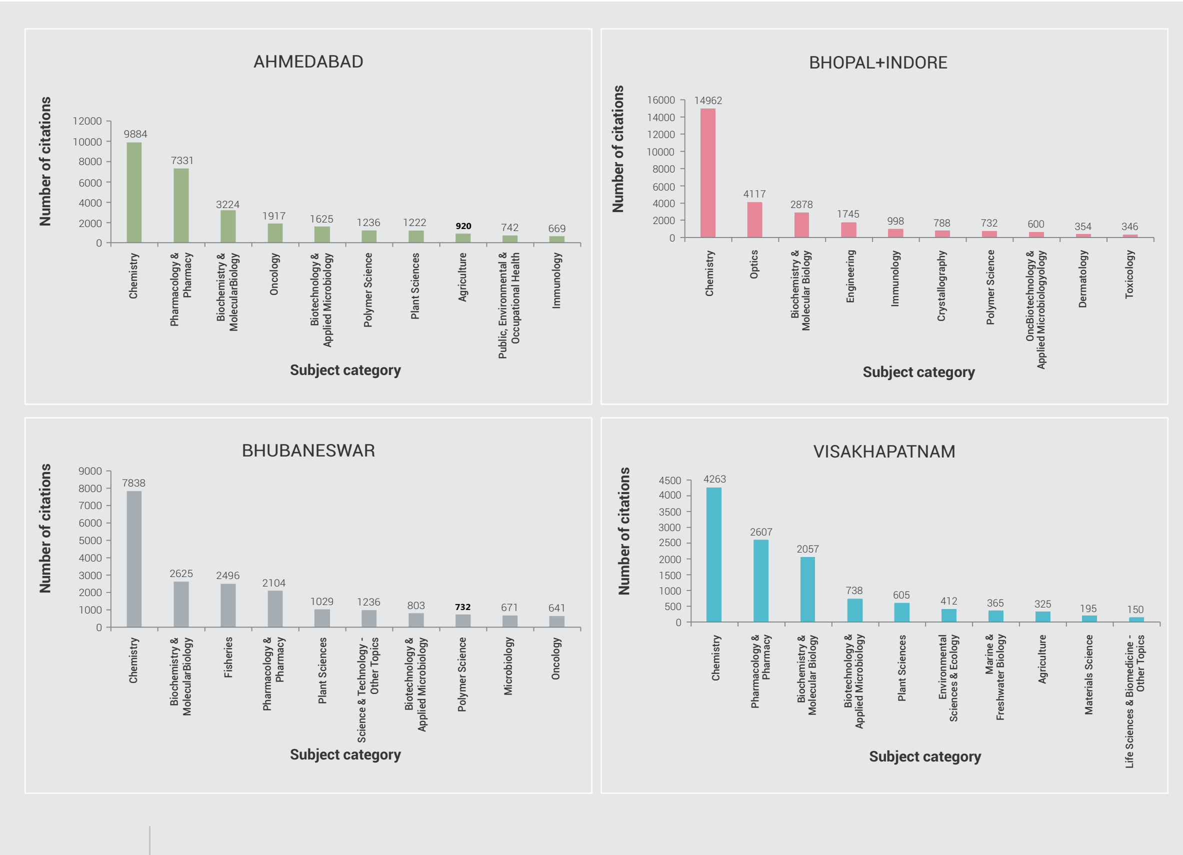


Figure 2.10 | Top ten subject areas of academic publications across ten clusters

Yearwise trends in each subject category

As mentioned before, an overall strength in chemistry followed by biochemistry & molecular biology were noticed with good quality research across cities. Each city, in addition to its strengths as mentioned in the earlier section, has also been developing strengths in other scientific areas. Number of publications grouped and colour coded in four bands of >50, 50 – 99, 100 – 500 and <500were plotted subjectwise over time for each cluster to observe the emergence of expertise in various fields over time (Fig.2.11 -2.20). It is important to note that out of a total of 90 subject areas (Table 2.3) related to life sciences, not a single city had a good representation of all the fields. However representation in multiple fields was seen in older cities that have had prominent institutes from pre independence era. In fact, in all ten clusters had very few subject areas where the minimum threshold of 50 publications in any year was exceeded.

Subject areas in Figures 2.11 to 2.20			
1	Agriculture	49	Meteorology & Atmospheric Sciences
2	Allergy	50	Microbiology
3	Anatomy & Morphology	51	Microscopy
4	Anaesthesiology	52	Mycology
5	Anthropology	53	Neurosciences & Neurology
6	Audiology & Speech-Language Pathology	54	Nuclear Science & Technology
7	Biochemistry & Molecular Biology	55	Nursing
8	Biodiversity & Conservation	56	Nutrition & Dietetics
9	Biophysics	57	Obstetrics & Gynecology
10	Biotechnology & Applied Microbiology	58	Oncology
11	Cardiovascular System & Cardiology	59	Ophthalmology
12	Cell Biology	60	Optics
13	Chemistry	61	Orthopedics
14	Crystallography	62	Otorhinolaryngology
15	Demography	63	Parasitology
16	Dentistry, Oral Surgery & Medicine	64	Pathology
17	Dermatology	65	Pediatrics
18	Developmental Biology	66	Pharmacology & Pharmacy
19	Electrochemistry	67	Physiology
20	Emergency Medicine	68	Plant Sciences
21	Endocrinology & Metabolism	69	Polymer Science
22	Energy & Fuels	70	Psychiatry
23	Engineering	71	Psychology
24	Entomology	72	Public, Environmental & Occupational Health
25	Evolutionary Biology	73	Radiology, Nuclear Medicine & Medical Imaging
26	Family Studies	74	Rehabilitation
27	Fisheries	75	Reproductive Biology
28	Food Science & Technology	76	Research & Experimental Medicine
29	Forestry	77	Respiratory System
30	Gastroenterology & Hepatology	78	Rheumatology
31	General & Internal Medicine	79	Science & Technology - Other Topics
32	Genetics & Heredity	80	Spectroscopy
33	Geochemistry & Geophysics	81	Substance Abuse
34	Geriatrics & Gerontology	82	Surgery
35	Health Care Sciences & Services	83	Thermodynamics
36	Hematology	84	Toxicology
37	Immunology	85	Transplantation
38	Infectious Diseases	86	Tropical Medicine
39	Instruments & Instrumentation	87	Urology & Nephrology
40	Integrative & Complementary Medicine	88	Veterinary Sciences
41	Legal Medicine	89	Virology
42	Life Sciences & Biomedicine - Other Topics	90	Zoology
43	Marine & Freshwater Biology		
44	Materials Science		
45	Mathematical & Computational Biology		
46	Mechanics		
47	Medical Informatics		
48	Medical Laboratory Technology		

Table 2.3 | List of subject areas considered in figures 2.11 to 2.20
where the numbers correspond to the number in the figure on the Y axis

Hyderabad, Mumbai and Ahmedabad with strong pharma industry, had the best record in chemistry and microbiology. As pointed out earlier, niche institutes publish in certain areas e.g. LVPEI in ophthalmology (Figure 2.11).While Hyderabad displayed a strong pursuit in chemistry (Figure 2.11), biochemistry research was found to grow faster in Bengaluru (Figure 2.12).

Chennai showed growth in biotechnology and applied microbiology with several institutes establishing departments / centres of excellence in these areas. Chennai was also gaining strong momentum in the areas of applied engineering, optics, internal medicine, immunology, neurosciences and public health - a large chunk of which was because of the research from CMC Vellore (Figure 2.13).

Mumbai cluster due to the presence of BARC and TMC-ACTREC produces several publications in oncology, nuclear medicine, radiology and medical imaging (Figure 2.15). Emerging clusters like Bhopal+Indore, Bhubaneswar and Visakhapatnam have new institutes with comparatively fewer publications in the study period considered (Figures2.18- 2.20).

In conclusion, fields such as chemistry and biochemistry have maximum number of publications across ten clsuters. Each cluster also has a specific domain that is being pursued as discussed in the previous section, and while the institutes are promising and vibrant it would take them several years to gain a critical mass of publications

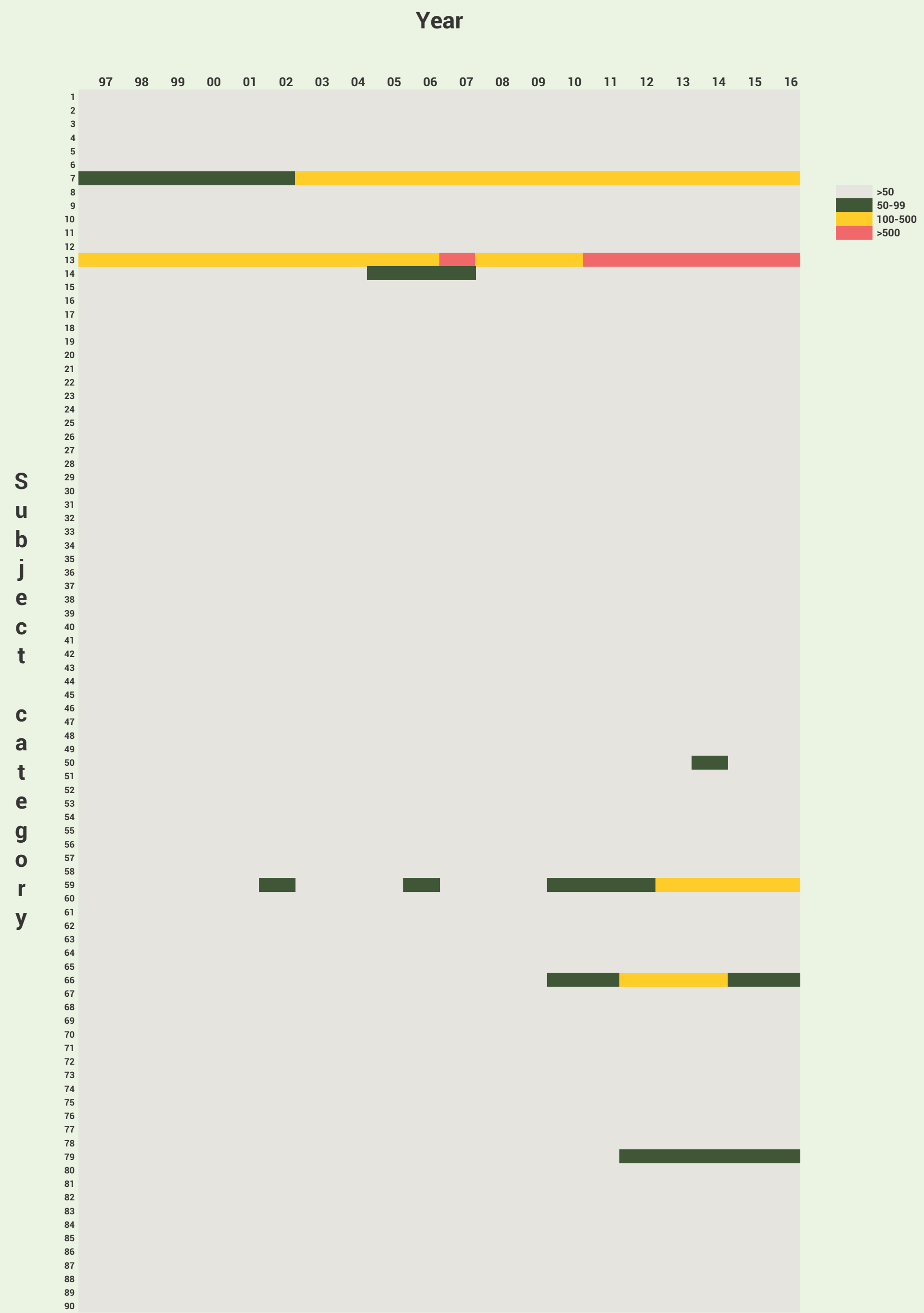


Figure 2.11 | Trends in number of publications on the basis of subject areas in Hyderabad

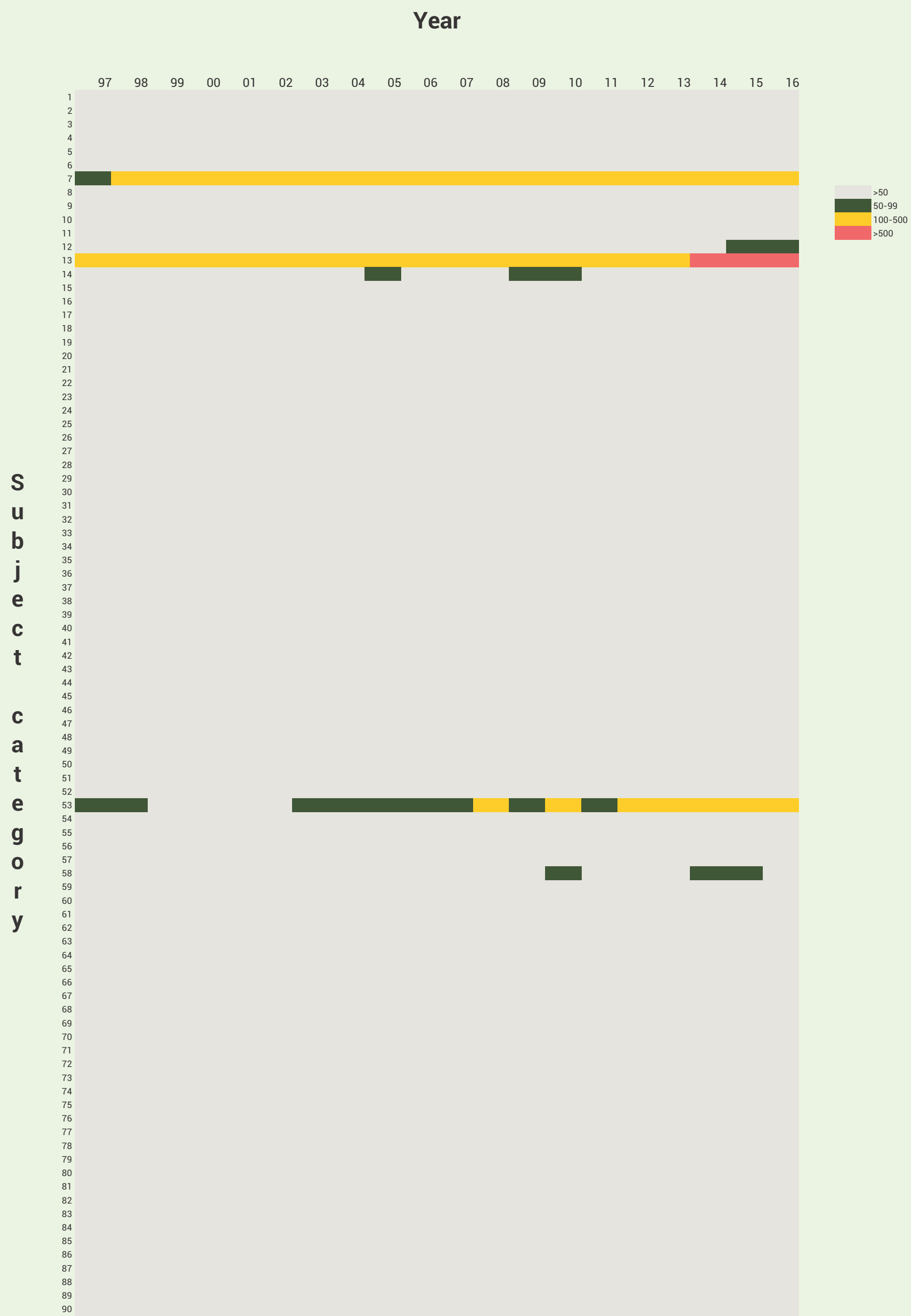


Figure 2.12 | Trends in number of publications on the basis of subject areas in Bengaluru

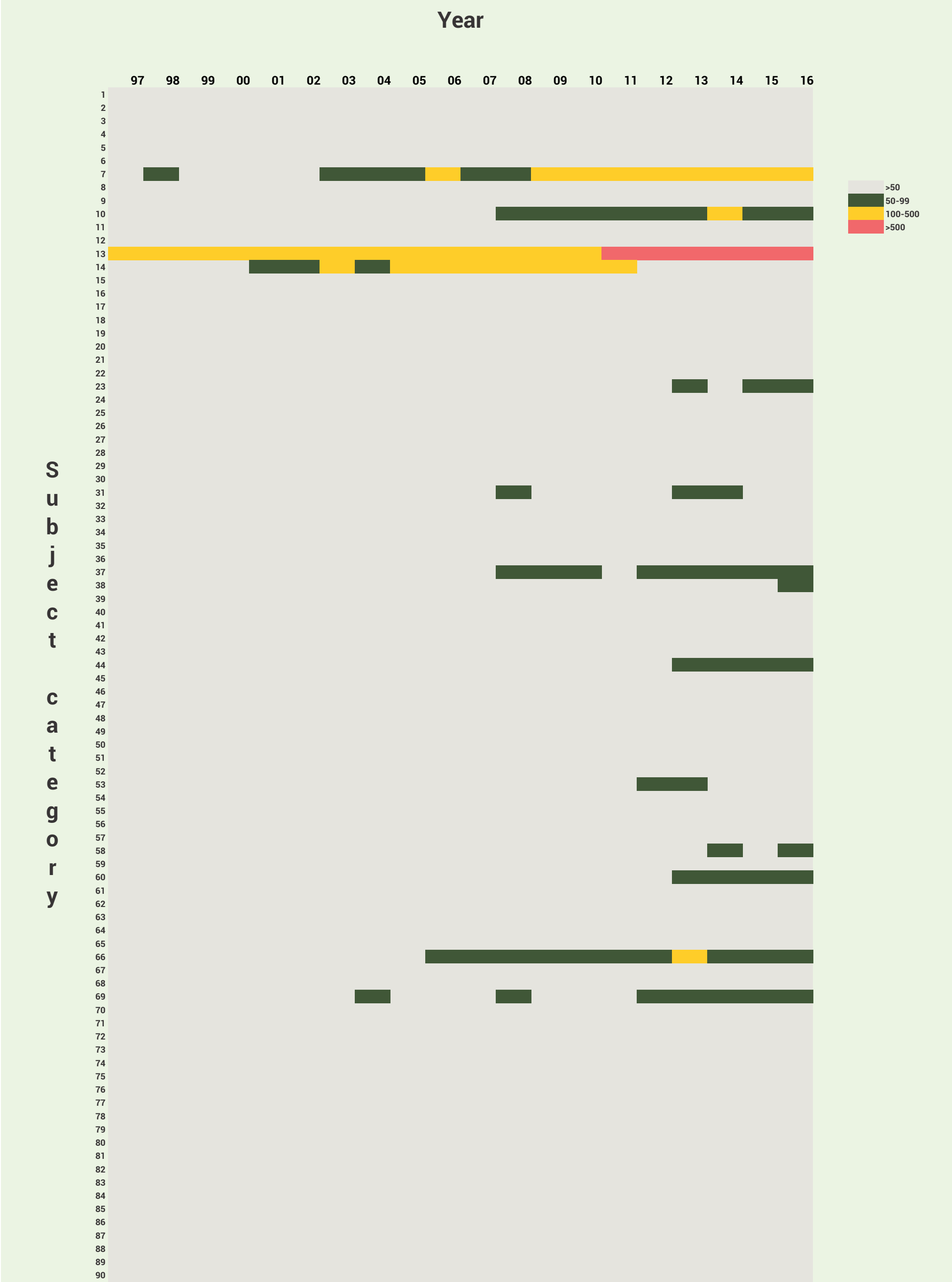


Figure 2.13 | Trends in number of publications on the basis of subject areas in Chennai+Vellore

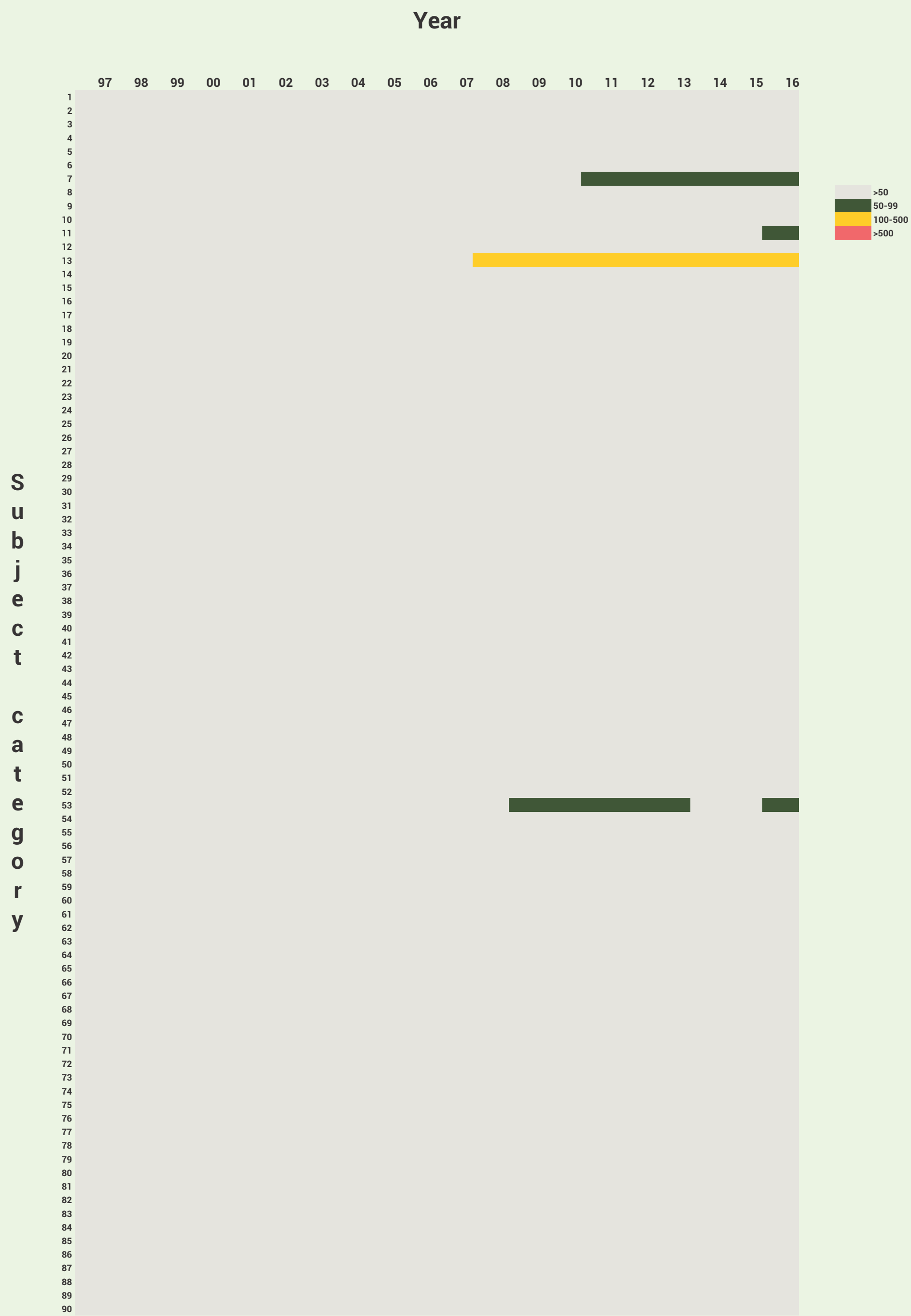


Figure 2.14 | Trends in number of publications on the basis of subject areas in Thiruvananthapuram+Kochi

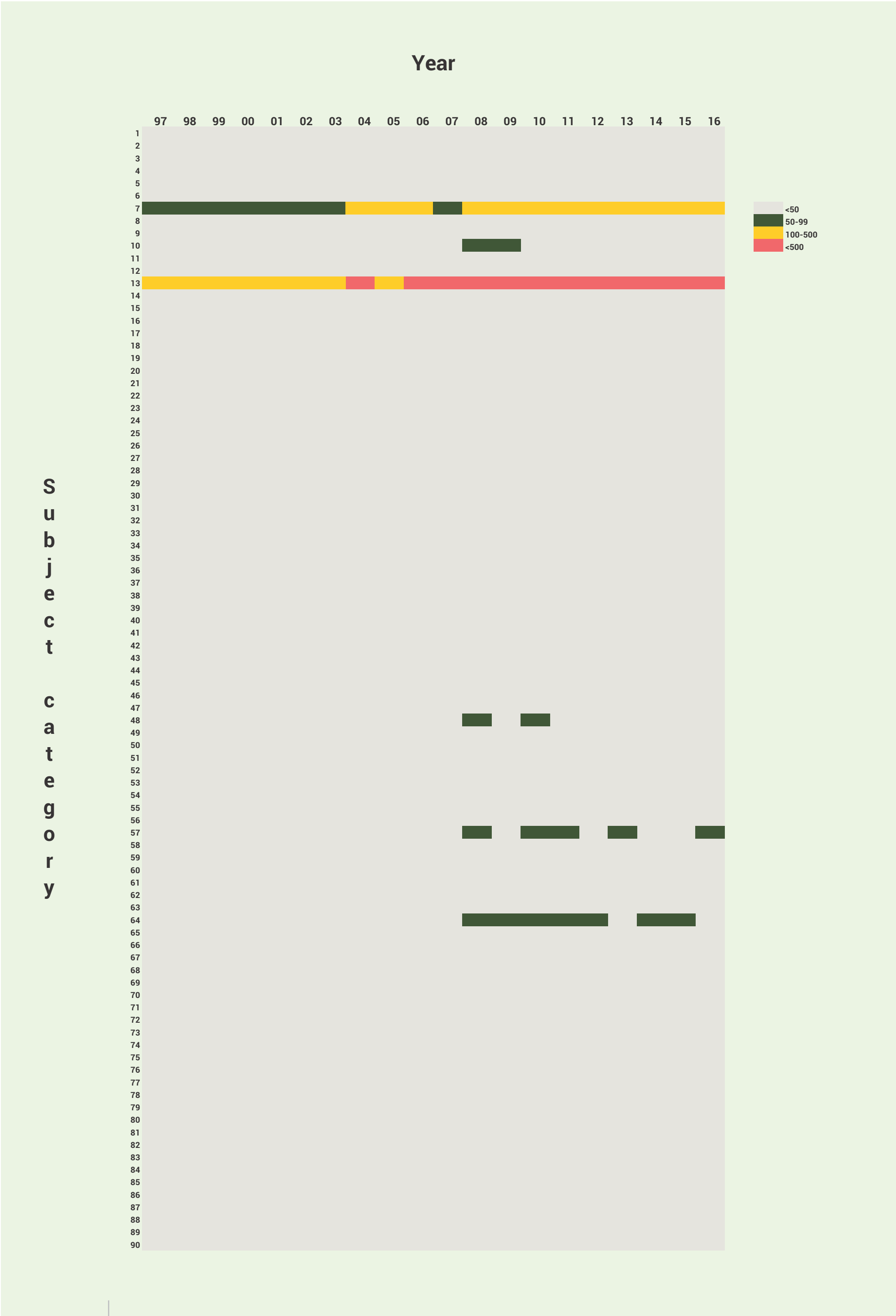


Figure 2.15 | Trends in number of publications on the basis of subject areas in Mumbai

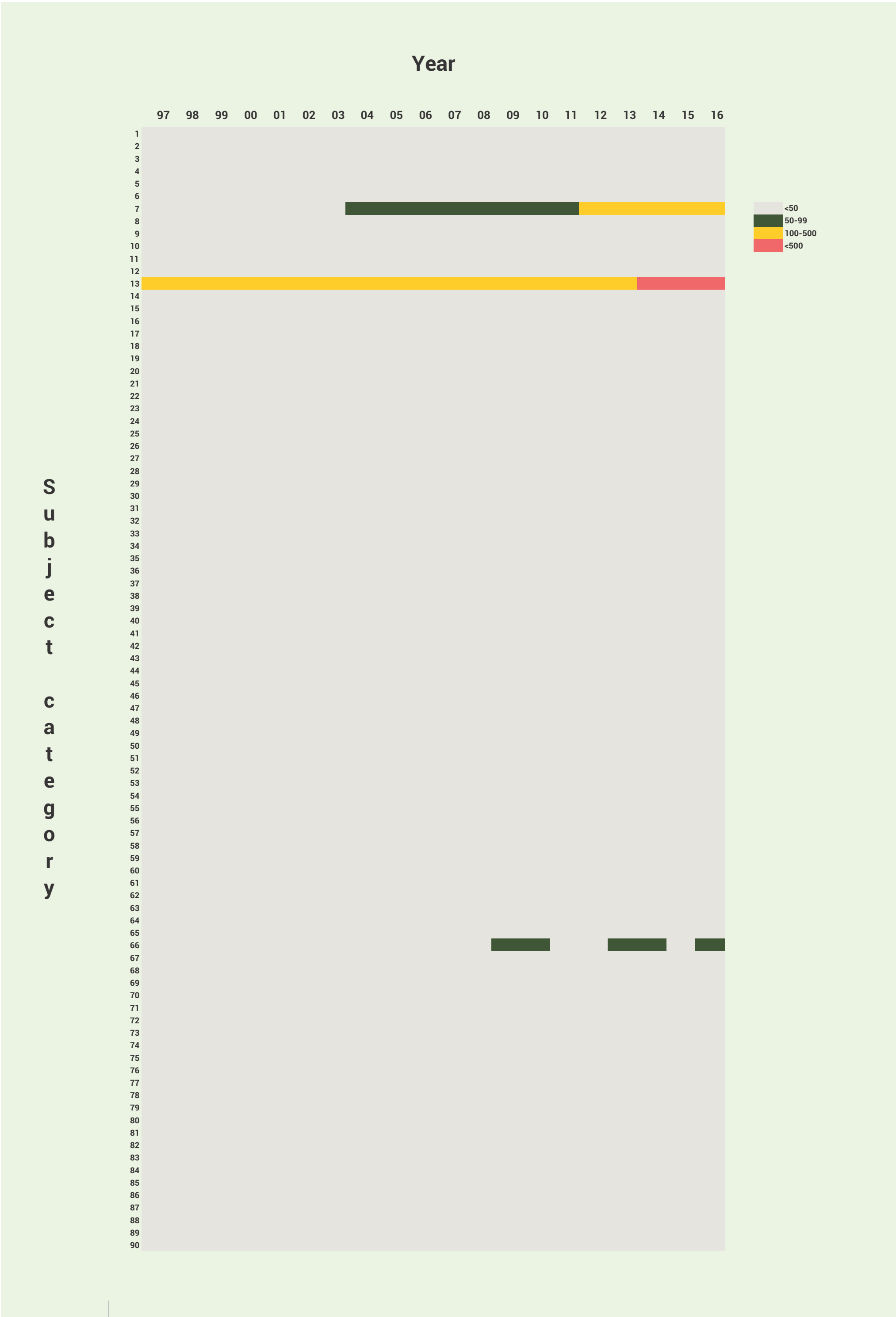


Figure 2.16 | Trends in number of publications on the basis of subject areas in Pune

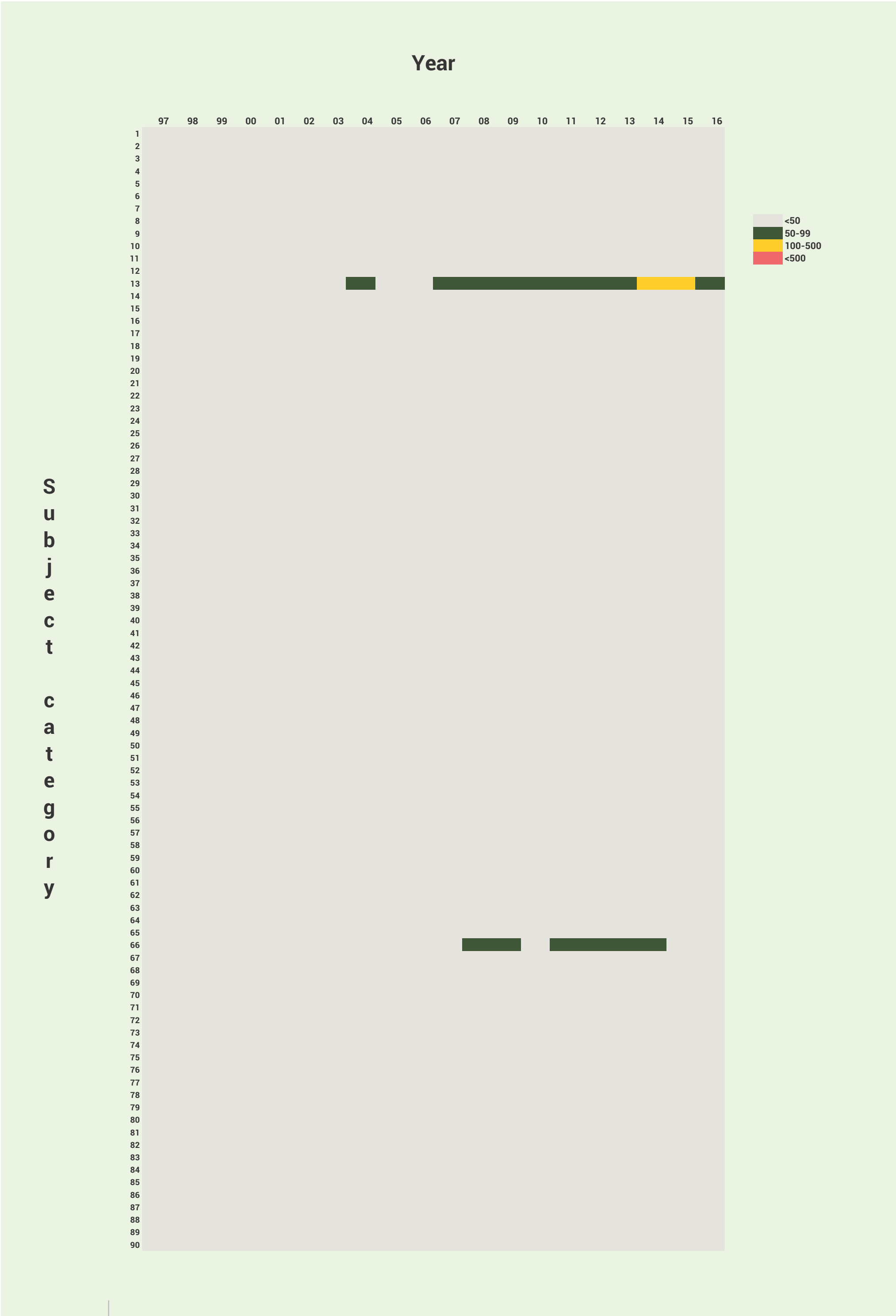


Figure 2.17 | Trends in number of publications on the basis of subject areas in Ahmedabad

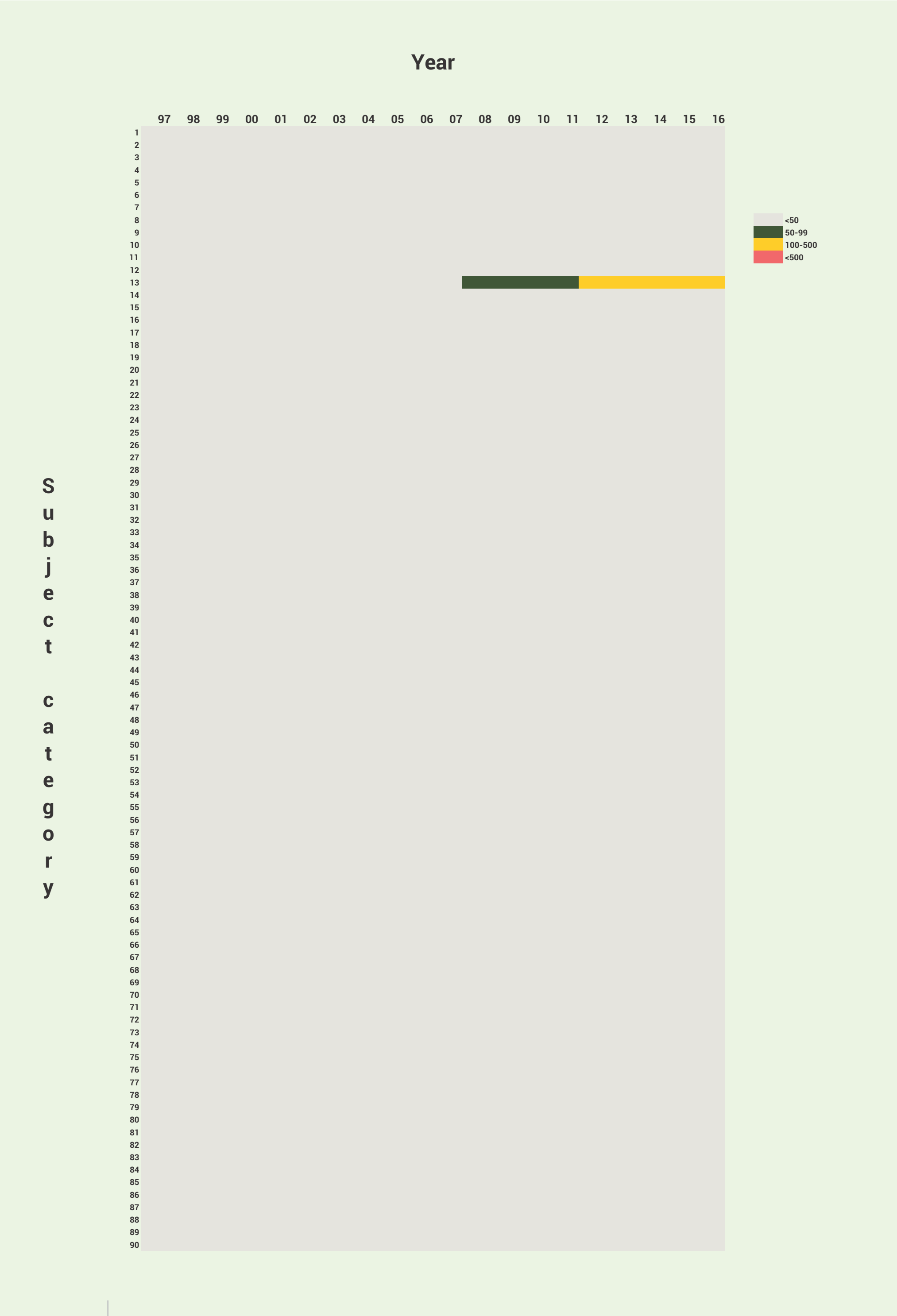


Figure 2.18 | Trends in number of publications on the basis of subject areas in Bhopal+Indore

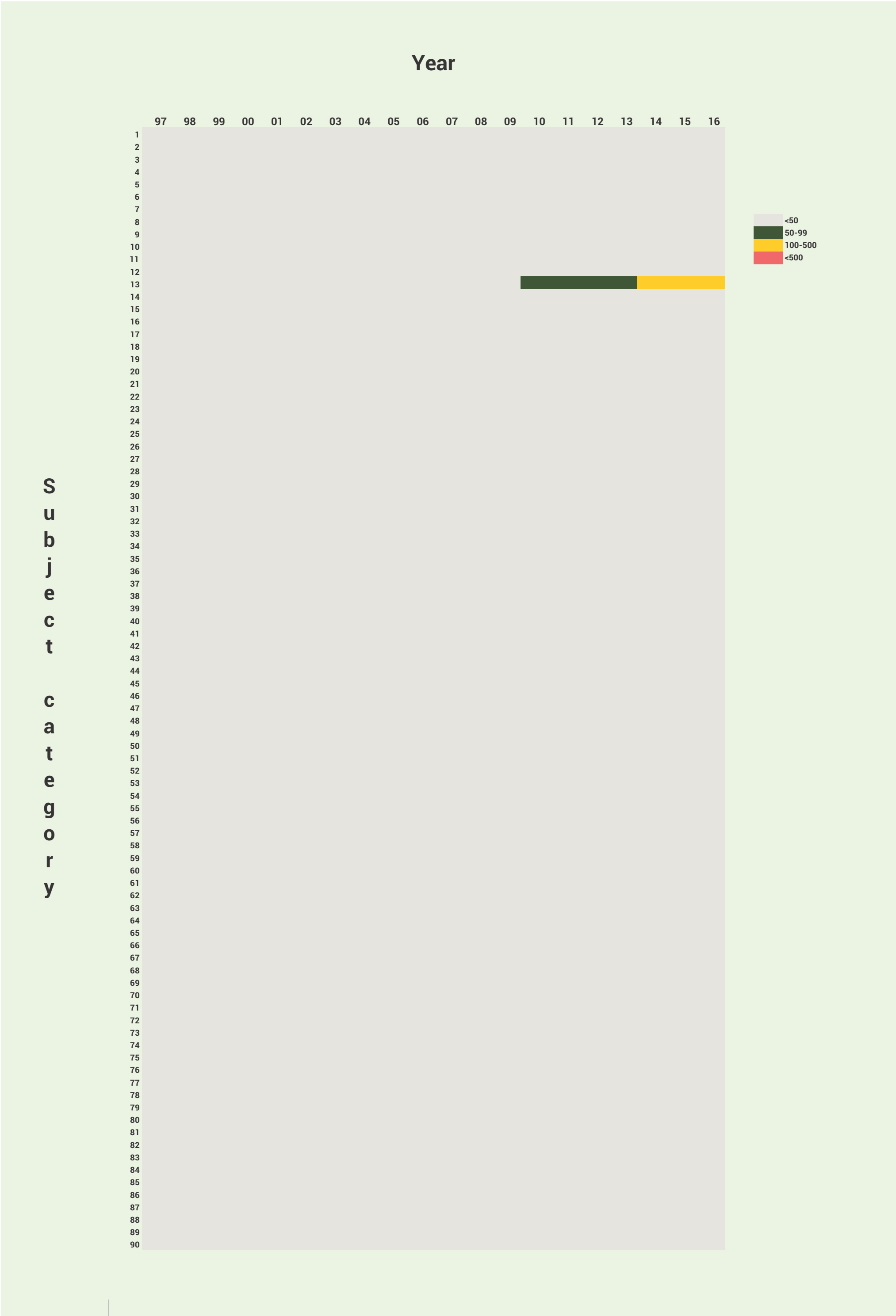


Figure 2.19 | Trends in number of publications on the basis of subject areas in Bhubaneswar

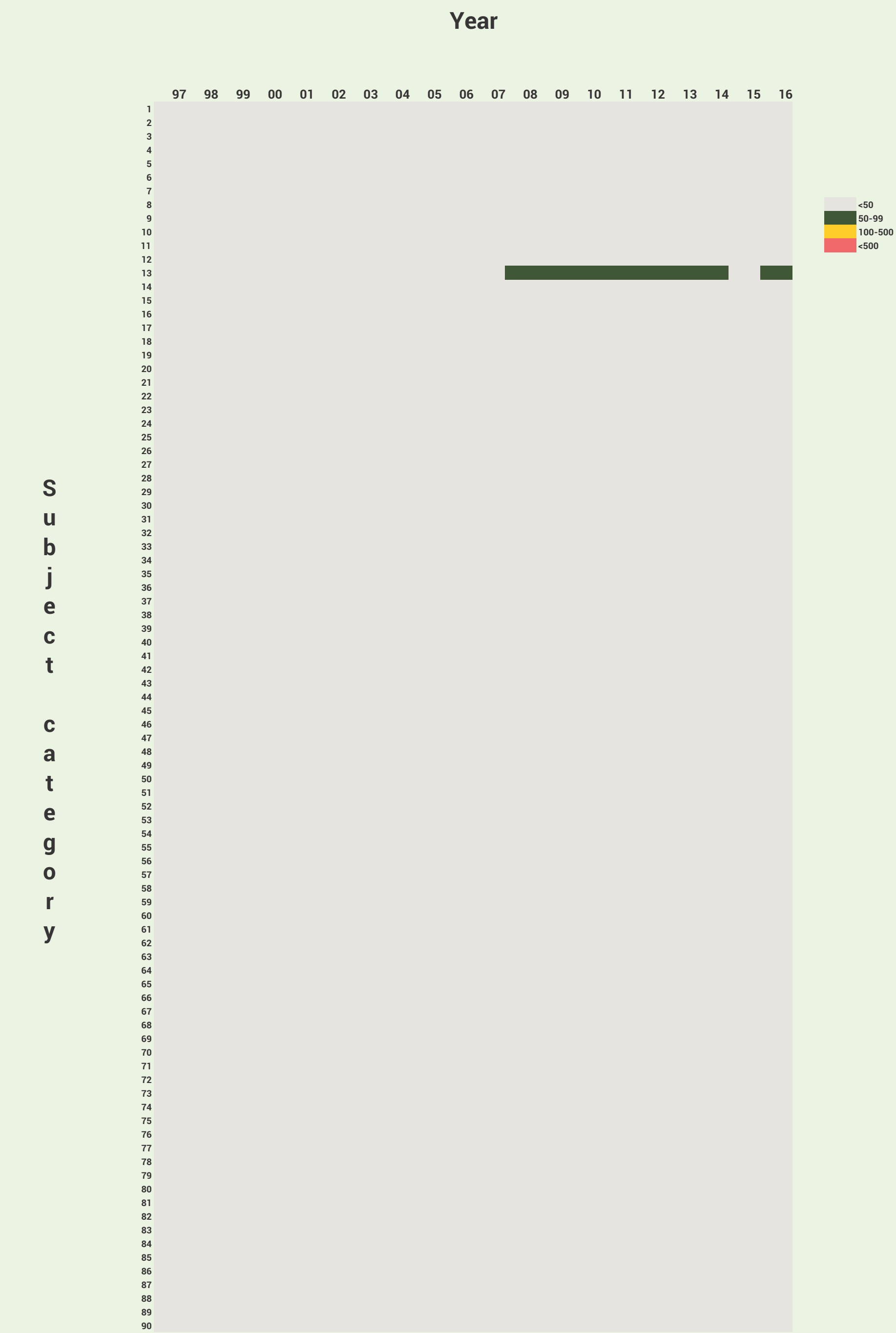


Figure 2.20 | Trends in number of publications on the basis of subject areas in Visakhapatnam

2.2.1.2 Knowledge exchange / transfer from academic perspective

Collaboration is an essential aspect of research activities today. It serves various purposes including leveraging expertise and sharing of equipment and infrastructure. Particularly, collaborations have a far reaching impact in interdisciplinary work or co-development projects with industries and hospitals. For this study, collaborators working within India, with foreign universities, and those who work with collaborators both within and outside India have been identified and included. Within India, they have been categorised based on geography as described in section 2.1.3.

Data revealed that most of the mature clusters have a larger number of collaborators outside India than within the country (Figure 2.21). However, since many new institutes and those in emerging clusters have most of the collaborations within India, the average collaborations within India is about 54%. Indian medical institutes like St. John's, TMC-ACTREC and NIMHANS associated with several multicentre trials and older institutes like IISc who have faculty with several international contributions have a greater tendency to collaborate with institutes outside the country (Figure 2.22A). However, private institutes, state universities and newer institutes have maximum number of collaborations within the country (Figure 2.22A). New institutes and those in emerging clusters have challenges with respect to infrastructure, young faculty and lack of critical mass of scientists in similar areas to carry out cutting edge research at a desired pace.

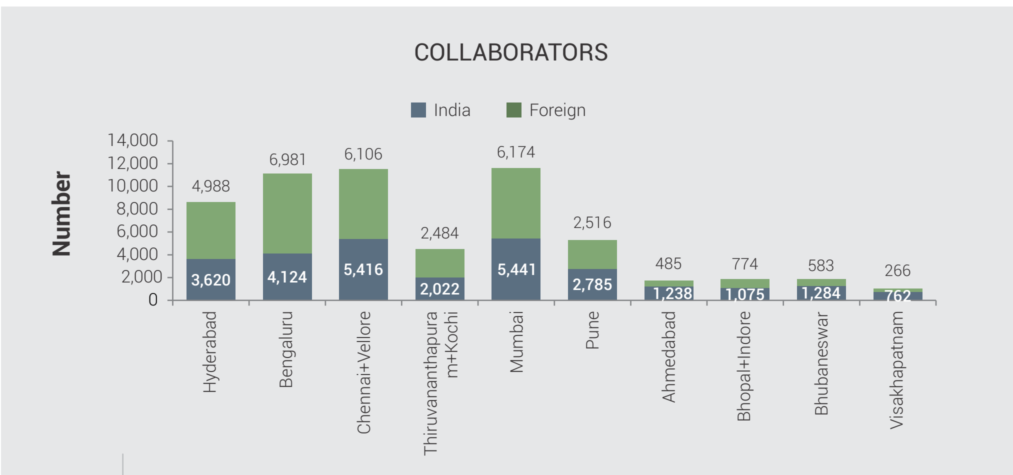


Figure 2.21 | Number of collaborators of select academic institutes in ten clusters

Upon analysis of collaborations within India, the largest fraction constituted collaboration across states followed by collaborations within the state and lastly within the institute (Figure 2.22B).The trend was different only in Visakhapatnam and Chennai. The prominent modes of networking could possibly include conferences facilitating scientists to reach out to peers in other states. In the case of Visakhapatnam, since the city is beginning to focus on research in life sciences, there seems to be a tendency to collaborate within the cluster.

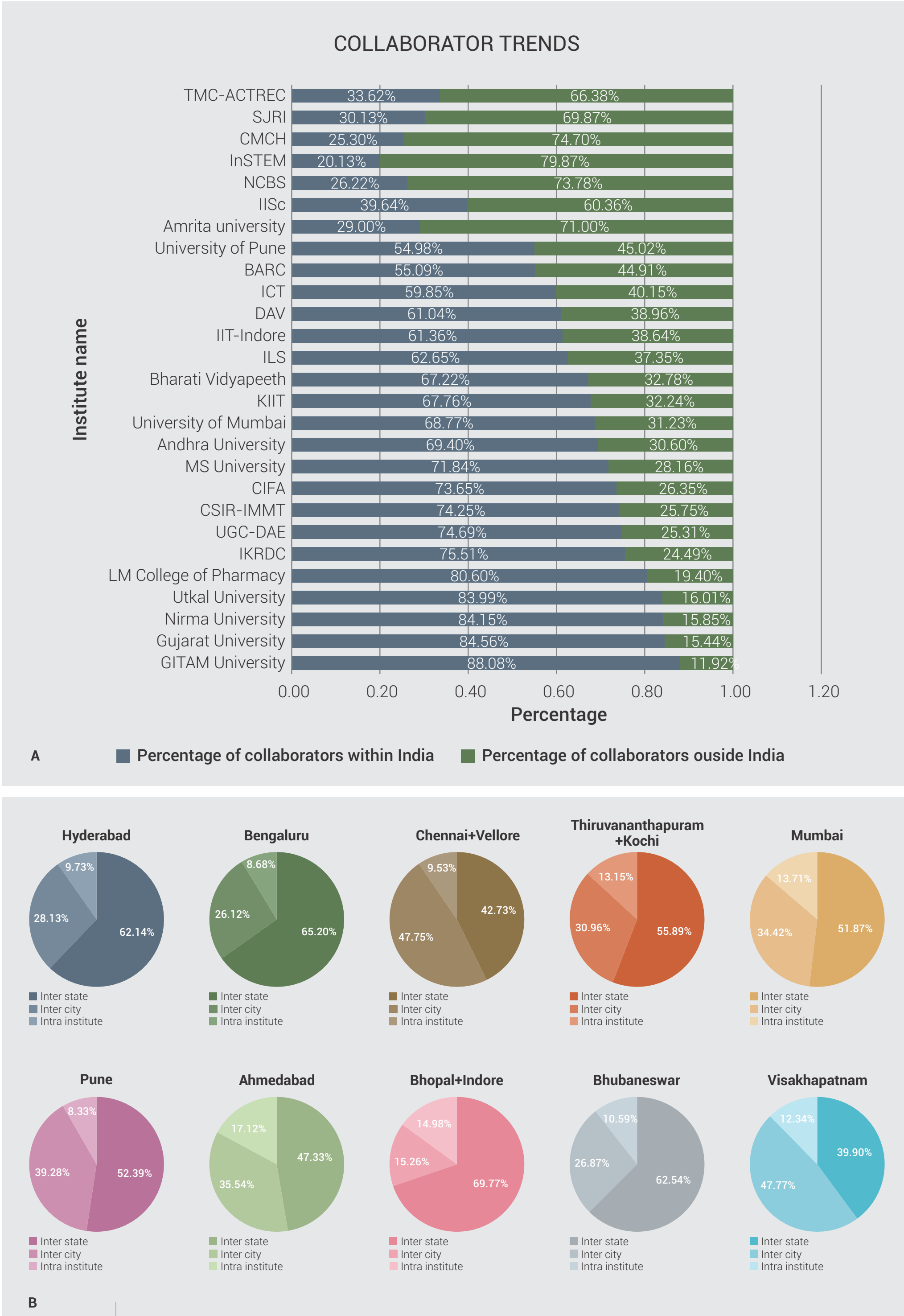


Figure 2.22 | A) Percentage of collaborators for select institutes
B) Distribution of collaborators within India in institutes within the ten clusters

Network maps and analysis

To understand the various trends in collaboration and identify key faculty and collaborations in institute, a graph-based approach was used. The details of construction of these networks and the underlying assumptions has been discussed in section 2.1.3. The graphs provide deep insights into several aspects of collaboration.

Almost all institutes had several common institutional collaborators. A reason for this could be that many faculty members in Indian institutes work in related areas and have common forums for interaction. The movement across institutes is not very common and as tenured faculty, their network pool over a period of time gets limited.

In Phase I, four different types of networks were observed; authors formed major networking hubs with several common collaborators, institutes with few connections among their top performing faculty, institutes characterised by the presence of one key academic expert who was central to the entire network, displayed several networking hubs and spatial proximity of scientists in diverse fields, highlighting interdisciplinary research. The institutes in Phase II also fell in similar categories. Collaboration networks for the selected institutes across the ten clusters were analysed.

Collaboration patterns in large institutes: Figure 2.23 shows the similarities between CSIR-IICT, UoH and IISc. Large institutes have several departments across diverse streams and centres established of multidisciplinary research. Also since these institutes have a long history of research, they have several processes established to facilitate good collaboration and funding to carry out cutting edge research with a commercial potential. Since the faculty in these institutes were well established in their respective areas (identified by red and large circles), there tends to be a closer network between them.

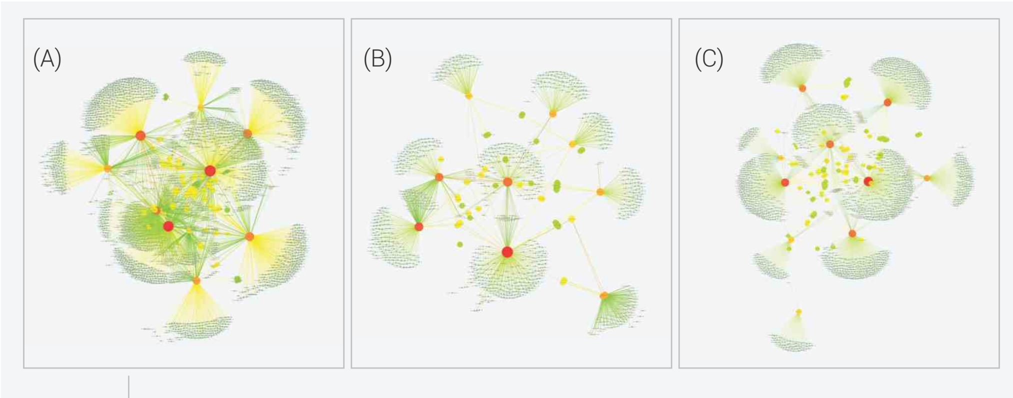


Figure 2.23 | Collaboration patterns in large institutes A) CSIR-IICT, B) UoH, C) IISc

Collaboration networks at IITs: While six IITs were studied across the two phases only three of them were considered for comparison since the newer IITs did not have sufficient number of publications in life sciences to compare collaboration patterns. There is a clear distinction between the older and new IITs as shown in Figure 2.24. The older IITs show a pattern that is similar to other large institutes with multiple disciplines and strong collaboration between them. In addition, the older IITs have also established processes for IP, industry and clinical collaborations. The newer IITs typically have few well established faculty who have moved from older institutes and the new faculty are relatively young and still working to establish themselves in the research community in the country. As a consequence, there tends to be a large number of collaborations with the senior faculty or collaborations that are enabled by them. Over time the trajectory of collaboration networks of newer IITs may well mirror those of older IITs.

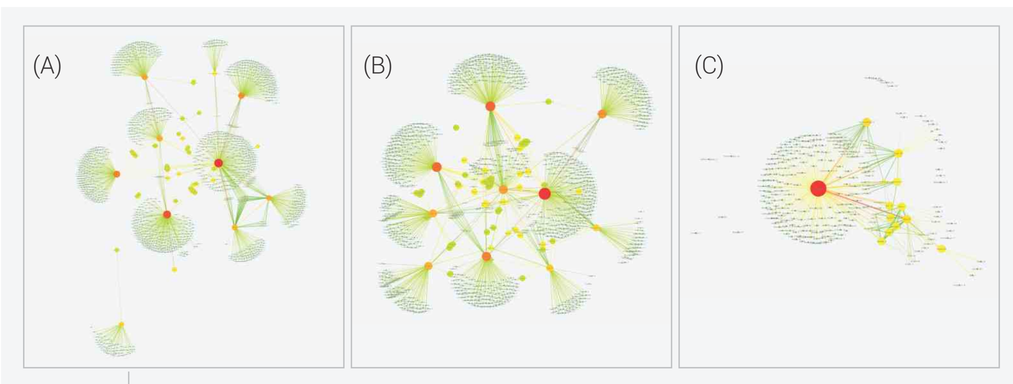


Figure 2.24 | Collaboration patterns across IITs A) IITM, B) IITB, C) IIT Indore

Collaboration networks at IISERs: The IISERs show a similar pattern to that of newer IITs where an older established faculty is central to the institute as shown in Figure 2.25. However, there are subtle differences with the newer faculties within a particular stream who were found to be more inclined to collaborate with each other, a trend which is more dominant in IISER Trivandrum. This pattern indicated a sharing culture between younger faculty who face similar challenges and stand to gain by working together. IISER Pune seemed to be slightly ahead of other IISERs with the faculty establishing their own areas of research. An advantage with this institute was that it is located in a moderately muture cluster and within close proximity to well established institutes like CSIR-NCL.

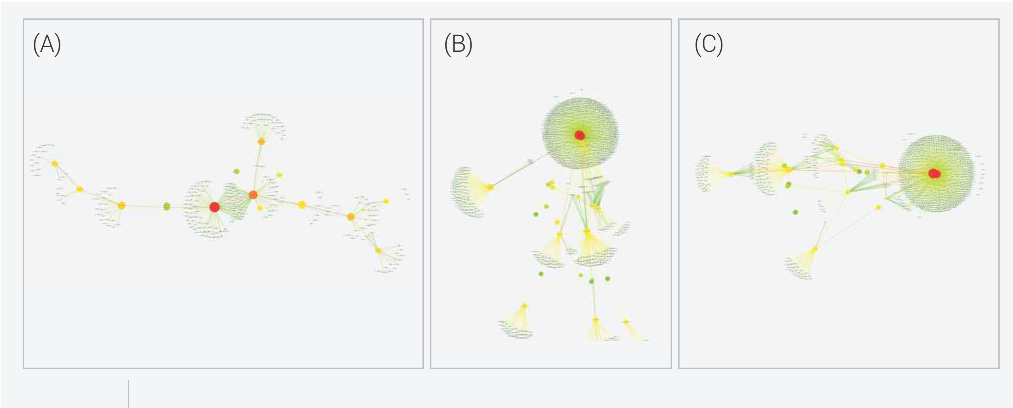


Figure 2.25 | Collaboration patterns across IISERs A) IISER, Trivandrum, B) IISER, Pune, C) IISER, Bhopal

Collaboration at smaller or new institutes: Some institutes appeared to be growing organically and therefore intra-institutional collaboration between the faculties may take time to evolve as shown in Figure 2.26. In some private institutes like Sathyabama University or GITAM, there are large number of disciplines with few faculty in each and minimal interaction across disciplines. In addition teaching and undergraduate programs being primary focus in some of these institutes, collaboration may not be a priority. On the other hand, institutes such as InSTEM showed a lot of promise although they also displayed similar collaboration patterns. This was due to the large network that would become accessible with time and the growth in internal interactions, and geographical proximity to well established institutes such as NCBS, JNCASR, IISc which have a strong research culture.

Figure 2.26 | Collaboration patterns of smaller/new institutes A) GITAM, B) Sathyabama, C) InSTEM

Institutes with single prominent authors: A few such institutes such as NIRT, IOB, KEM Mumbai and IKRDC have one leading scientist upon whom several research activities in the institute are dependent (Figure 2.27). Although these are niche institutes, there is a possible risk that the output of the institute may be impacted once the leading academic expert leaves the institute.

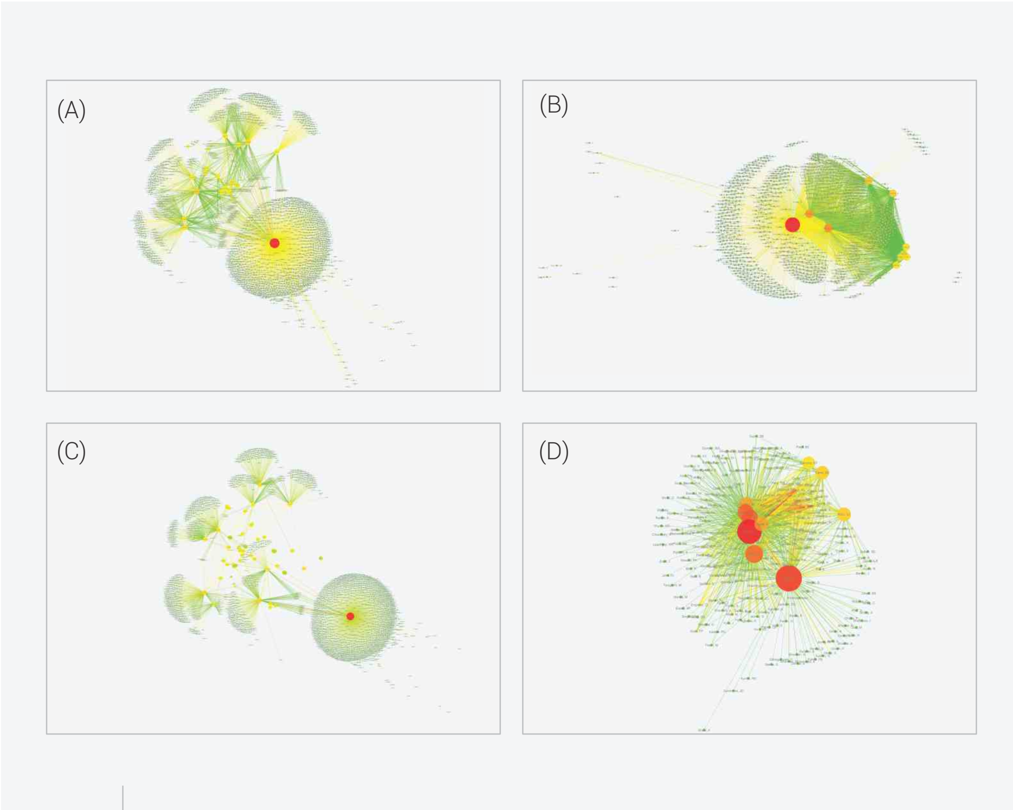


Figure 2.27 | Collaboration patterns of institutes with single prominent authors
A) NIRT, B) IOB, C) KEM Mumbai, D) IKRDC

Analysis on nature of collaborations from networks

Each of the institute networks was analysed to identify important authors and important collaborations as described in section 2.1.3. Once this was done, the focus areas of the authors were identified to classify the nature of the interactions. The 'number' of important interactions was one of the parameters to assess the patterns in an institute.

Too few important interactions in an institute indicate that the network relies on select faculty and their collaborations reflecting a skewness in the collaborative nature of the institute.

The data revealed that interdisciplinary research was nascent in most clusters (Figure 2.28).Since all clusters have strength in chemistry and molecular biology, the network patterns also indicate high collaboration within these areas.

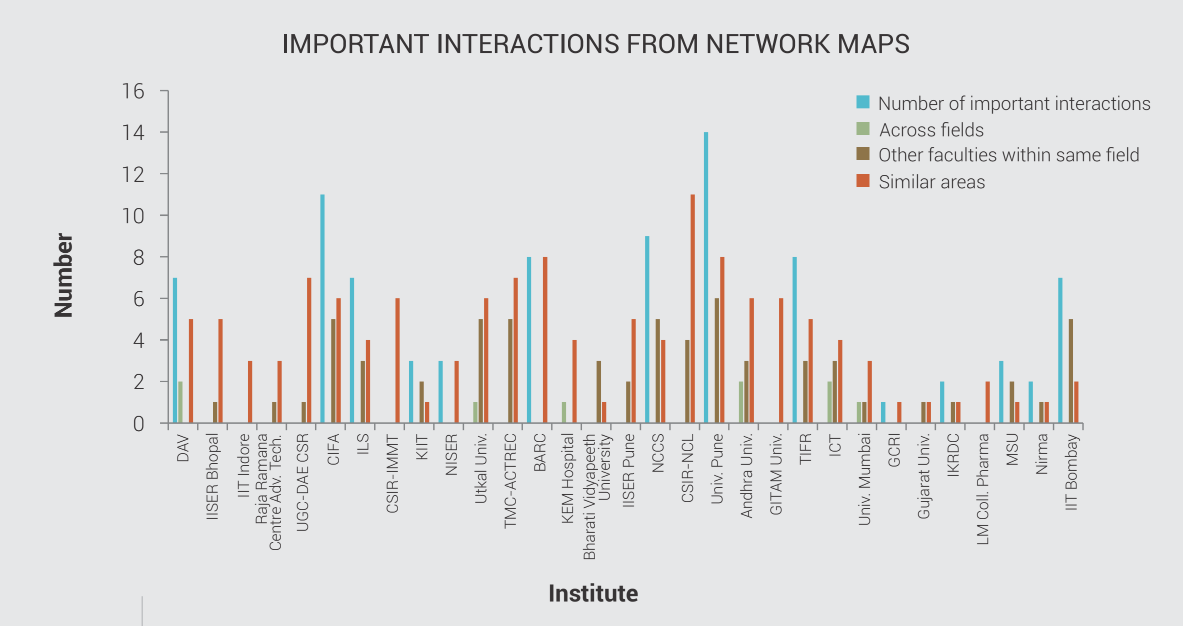


Figure 2.28 | Classification of important interactions identified through network maps

The number of interactions that are interdisciplinary in nature indicate the translation potential of research from the institute and the underlying culture and attitude. It was noticed that Amrita Institute, IITM, InSTEM from Phase I and ICT and KEM from Mumbai were involved in interdisciplinary research.

2.2.1.3 Knowledge exchange / transfer from industry perspective

Publication is the primary focus in academic institutes as discussed in earlier sections. Most of these publications pertain to basic research in areas such as cell biology, biochemistry and microbiology while those produced from the industry tend to be more translational in nature.

Publications in various streams of chemistry are produced in all the ten clusters across academia and industry. However, there are mismatches in certain focus areas between academia and industry present in the clusters (Figure 2.29). Although, in principle, collaboration is possible across cities, geographical proximity plays a crucial role, especially in co-development projects. Hyderabad, Ahmedabad and Mumbai due to the strong Pharma base also have academic institutes publishing in several aspects of chemistry, pharmacology. In Ahmedabad however, much of the interaction is restricted to LM College of Pharmacy which also produces a large number of trained manpower to be employed in the industry. In several cases industries have not been found to be open about their R&D and collaborations. In Mumbai TMC-ACTREC works closely with several companies for their oncology portfolio for clinical validation and trials.

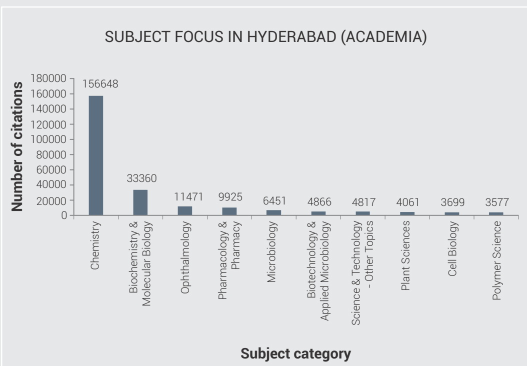
There might be a mismatch in focus areas if a niche institute is present in a city without industries in that area. Likewise, there might be industries of a specific sector in a city without much research expertise in that area. A case in point is the LV Prasad Eye Institute which has strong R&D in ophthalmology. However, Hyderabad has very few companies doing R&D in ophthalmology that

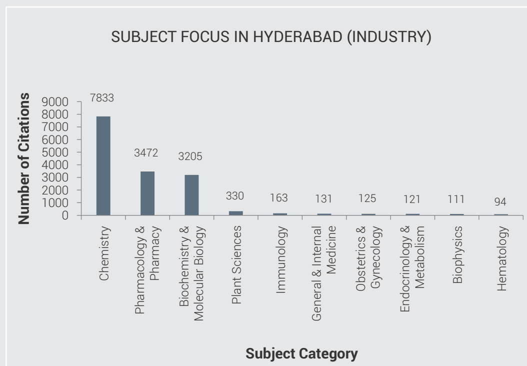
LVPEI can collaborate with. The Srujana Innovation Centre at LVPEI is expected to address this issue. The Dupont Knowledge Centre in Hyderabad focuses on materials research but while the International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI) has been there since 1997, institutes such as IIT Hyderabad and Mahindra École Centrale with research capabilities in material science have only recently been established.

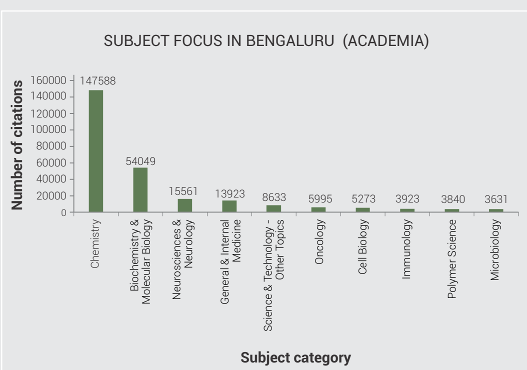
In Visakhapatnam and Indore although there are several manufacturing units of pharma companies, much of the R&D activities happen in other cities such as Hyderabad and Mumbai thereby pointing to the need for building a conducive regional ecosystem for collaboration. Visakhapatnam

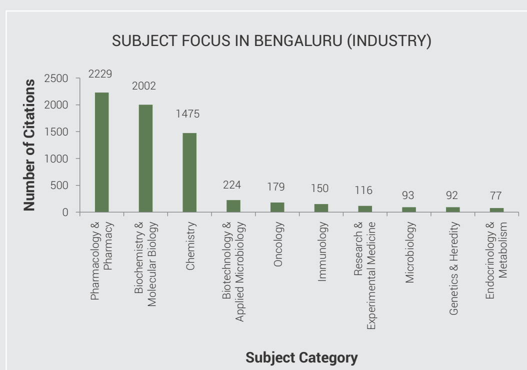
In Bengaluru, a number of industries focus on industrial biotech and applied microbiology while there is no institute with major focus in these areas. This limits the choice of collaborations to certain faculty in the institutes. The other mismatch in Bengaluru is the presence of such a niche institute as NIMHANS which focuses on mental health and neurosciences, but there is no major industrial R&D centre that has neurology and mental sciences as its focus areas.

Similarly, data revealed the misalignment between industry and academia in immunology in Pune and food technology in Thiruvananthapuram.

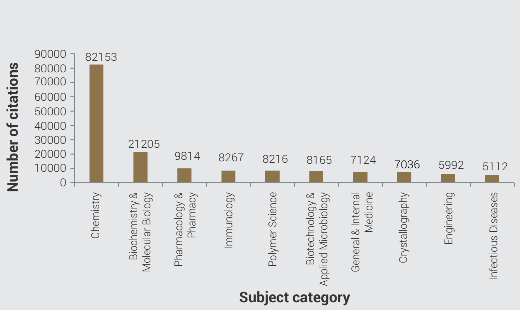




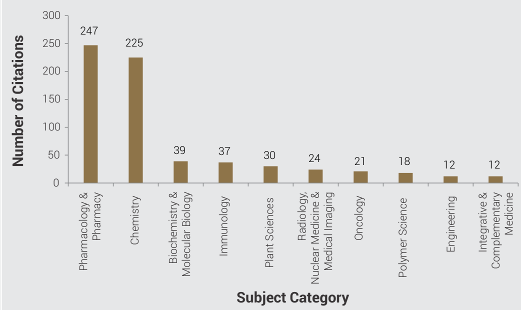




SUBJECT FOCUS IN CHENNAI + VELLORE (ACADEMIA)



SUBJECT FOCUS IN CHENNAI + VELLORE (INDUSTRY)



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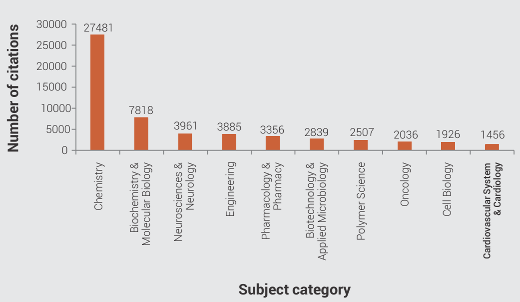

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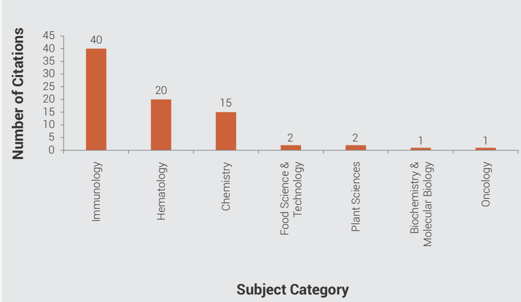

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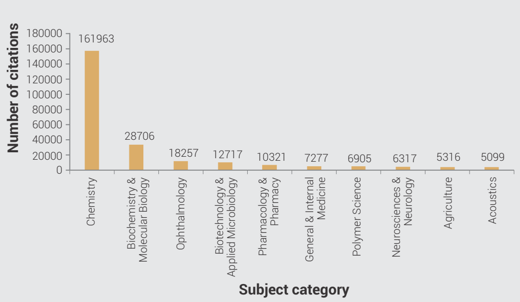
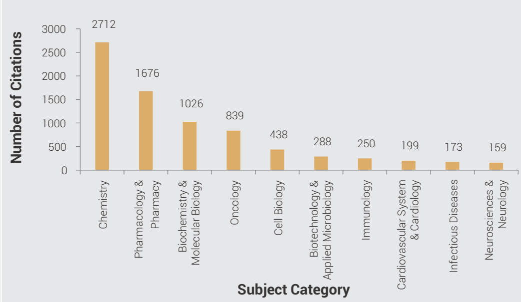
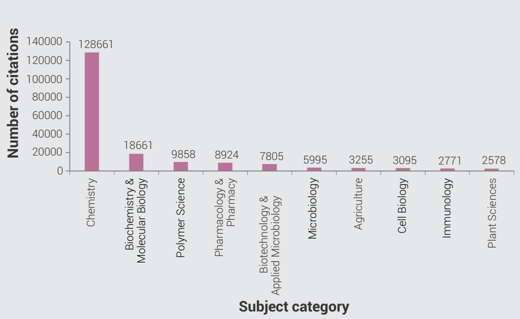


SUBJECT FOCUS IN MUMBAI (INDUSTRY)



SUBJECT FOCUS IN PUNE (ACADEMIA)



SUBJECT FOCUS IN PUNE (INDUSTRY)

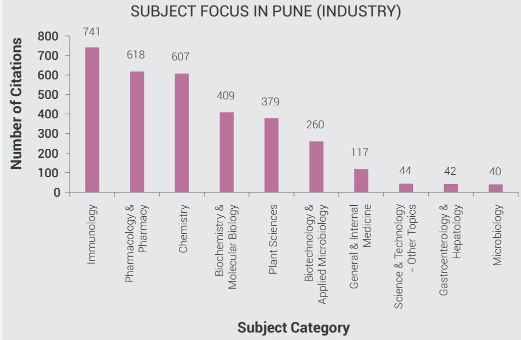


Figure 2.29 | Comparison of publication focus areas in academia and industry across nine clusters

2.2.2 Analysis of Industry and Startup Data

Industries undertake translation of science into commercialisable products. Not only do they acquire technologies and manpower from academia, industries also play the role of advisor providing feedback to academia.

2.2.2.1 Clusterwise focus areas in industry

Till the early 1800s, the Indian economy was mainly dependent on agriculture. Between 1850 and 1860, two factory industries - cotton and jute were established. For the entire half century that followed, these two industries remained the major components of the industrial sector of the Indian economy. The diminishing inflow of British investment enabled Indian merchants and manufacturers to seize the initiative for developing newer industries.

The economic liberalisation initiated in 1991 saw the incorporation of a large number of Indian companies and created an entrepreneurial culture.

The IT sector has shown the highest growth rates consistently over the last two decades. This has initiated innovations and created companies at the intersection of IT and healthcare - e.g. Practo. Innovation in core life sciences needs more strengthening.

CRAMS have also gained importance as Multi National Corporations (MNCs), in their need to optimise costs and maintain profitability for product development, have been outsourcing R&D to contract organisations. India has the dual advantage of a strong chemistry expertise and low operating & capital costs (about 40% less than that of several western nations). India accounts for about 22.7% of the listed API and Finished Dosage Form (FDF) GMP facilities approved by US-FDA globally and is the country with the largest pharma exports to the US.

The Hyderabad innovation cluster is dominated by the pharmaceutical sector (Figure 2.30). The incorporation of Indian Drugs and Pharmaceuticals Limited (IDPL) In 1961had a significant role in the city's growth as a pharma innovation cluster. Led by Biological E Ltd., the first pharmaceutical company in South India established in 1953, Hyderabad is home to a large number of vaccines companies.

The establishment of Indian Institute of Chemical Technology (IICT) and several other institutes such as the Centre for Cellular and Molecular Biology (CCMB) and the Centre for DNA fingerprinting and Diagnostics (CDFD) between the 70s and 90s, and more recently, the National Institute of Pharmaceutical Education and Research (NIPER), have contributed to the maturing of the ecosystem through research inputs and trained human resource. Other regional institutions have also contributed to human resource through several graduate programmes that has helped in the growth of the pharmaceutical and biotechnology industry.

Bengaluru has a strong research culture with the presence of IISc for over a century and more recently, JNCASR and NCBS as well as several other research institutes and Public Sector Units

(PSUs). Several MNCs started their operations in this region from the 70s leading to the creation of a huge wealth of knowledge and diverse globally trained talent pool that has resulted in innovation and growth in interdisciplinary areas. Biocon led the growth of a vibrant biotech industry in Bengaluru. The city also has a large pool of service providers and contract research / outsourcing companies. This trend has led Bengaluru to be one of the most sought after innovation clusters in India.

Chennai has a strong pharma and automobile / engineering presence. With a strong base of universities, engineering and medical schools, and knowledge transfer from academia, several medical devices companies have come up in this region.

The number of life sciences companies in Thiruvananthapuram are fairly low, which could be attributed to the prevailing industrial environment in the state. A cascading effect of this is the lack of availability of proper support structure for life sciences startups in Thiruvananthapuram+Kochi. The State Government has been promoting the IT industry and IT startups in a big way. The life sciences sector is expected to get similar support as new policies by the State Government seek to plug the gaps.

The western region especially Mumbai and the state of Gujarat have had a strong business presence with access to several financial institutions. Therefore a large number of pharma generics companies were established In this region since 1930s. Some of these companies are among the largest pharma companies in the country, and over a period of time due to diversification have also moved into allied areas such as biotechnology. Presence of such a strong pharma cluster has led to mushrooming of several CROs in the region that work closely with these pharma giants. A large number of pharma MNCs are located in the Mumbai region. Mumbai also being a major port has several lab equipment and chemical suppliers located in the region which serve the pharma companies. Due to the strong startup culture around IIT Bombay and CSIR-NCL, a large number of innovative healthcare companies and startups have sprung up in the region. The new Startup and Biotech policies in Gujarat are expected to provide a boost to the life sciences startup scene in Ahmedabad.

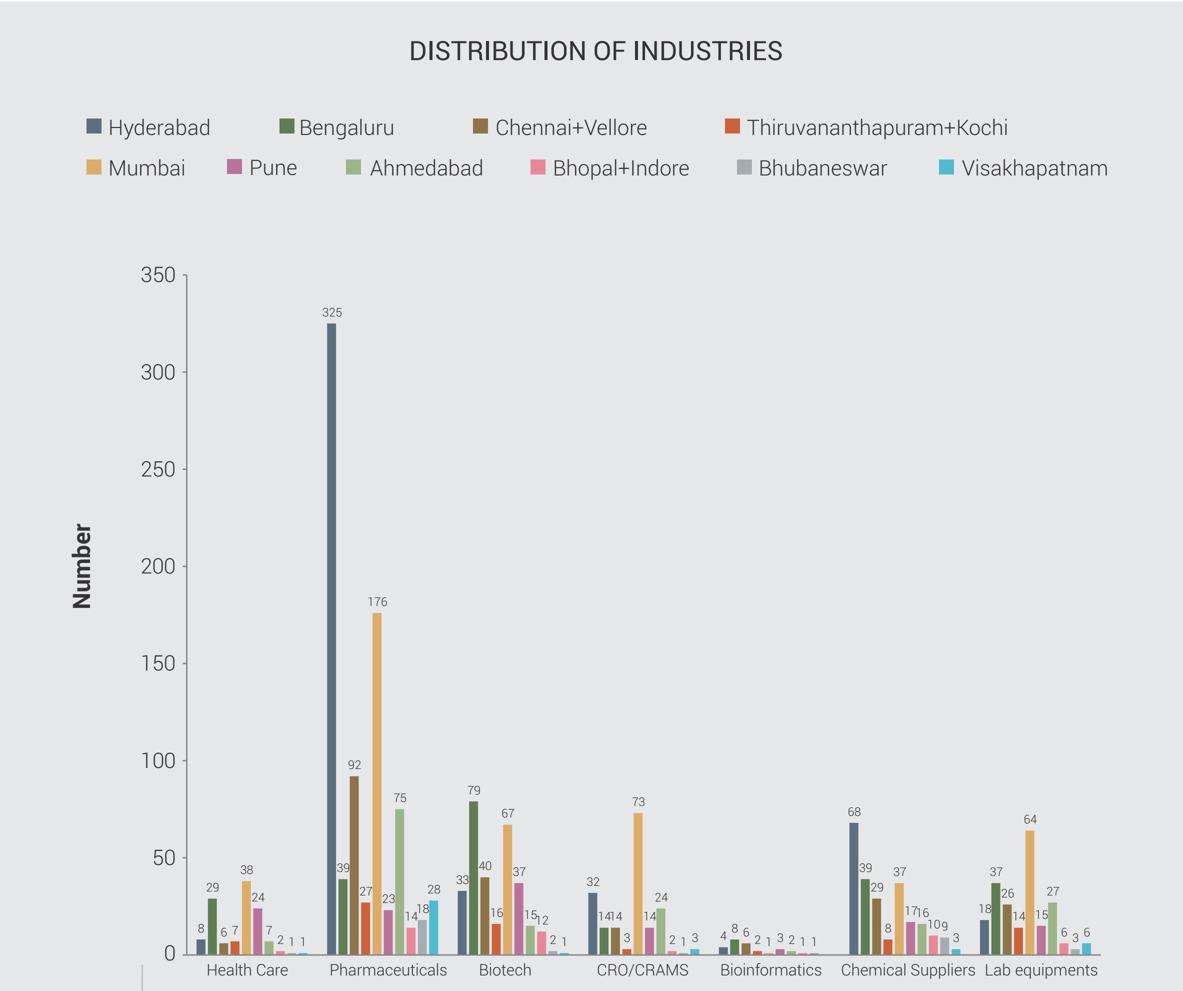


Figure 2.30 | Distribution of different types of organisations in ten clusters under study

Existence of the Pharma City in Visakhapatnam has created a pharma manufacturing hub in the region. The Andhra Pradesh Medtech Zone and other initiatives being planned around Visakhapatnam is expected to translate the cluster into an innovation hub.

Data shows that Bhubaneswar and Bhopal-Indore could need some more time before a critical mass of industries and startups come up in these emerging clusters. The new academic institutes focusing on translational work and thrust on incubators may soon usher in this change.

2.2.2.2 Research output from industry

Of the total number of industries in the ten clusters, 108 companies (including startups) were selected for deeper analysis, as per the criteria described in section 2.1.4. A general view of the total number of patents, publications and collaborators in each cluster clearly points to the focus on patents in companies, a trend which is understandably different from that in academia. Also, mature clusters have far more number of companies involved in R&D activities in comparison to emerging clusters. The Indian Patent Act 1970 and the thriving generics industry have greatly increased the number of process patents (Figure 2.31). The number of collaborators in industrial R&D is not as high as in academia (Figure 2.31), a phenomenon that can possibly be attributed to industry not being very open with their R&D activities and the mismatches in focus areas of research as discussed in section 2.2.1.2.

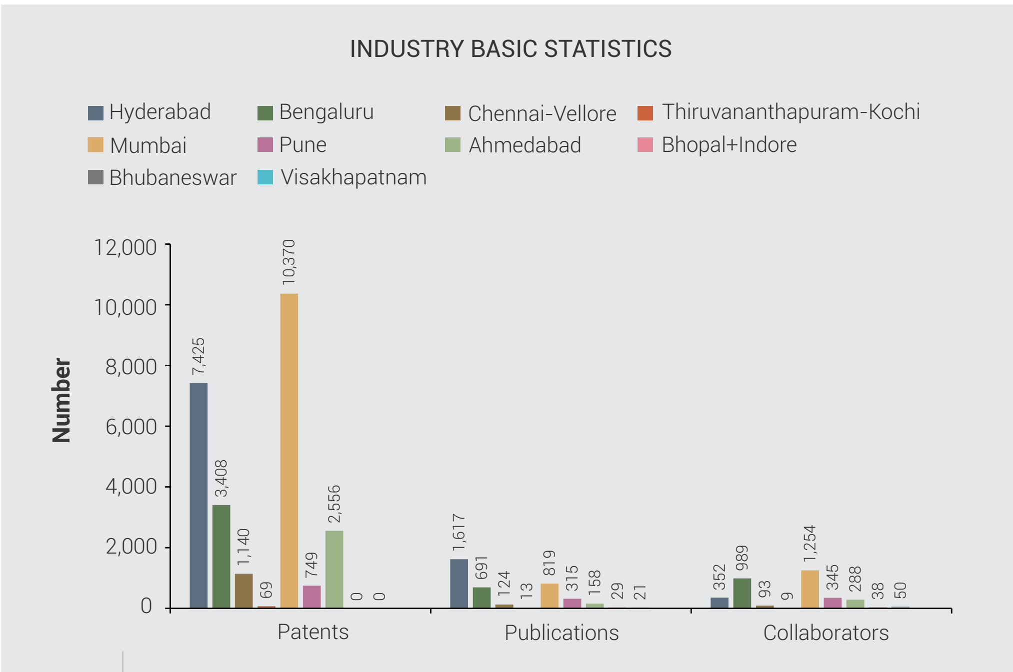


Figure 2.31 | Distribution showing number of patents, publications and collaborators for industries in each cluster under study

Citation index

The purpose of industries is to bring innovations to the market through commercialisation of technologies rather than generation of new knowledge, and hence have greater focus on patents. Bengaluru industries consistently have good citations for their publications (Figure 2.32) which can be correlated to the large number of collaborators. Chennai+Vellore and Thiruvananthapuram+Kochi have a lower average number of citations. A few publications in these cities have higher than average number of citations observed as peaks in Figure 2.32.

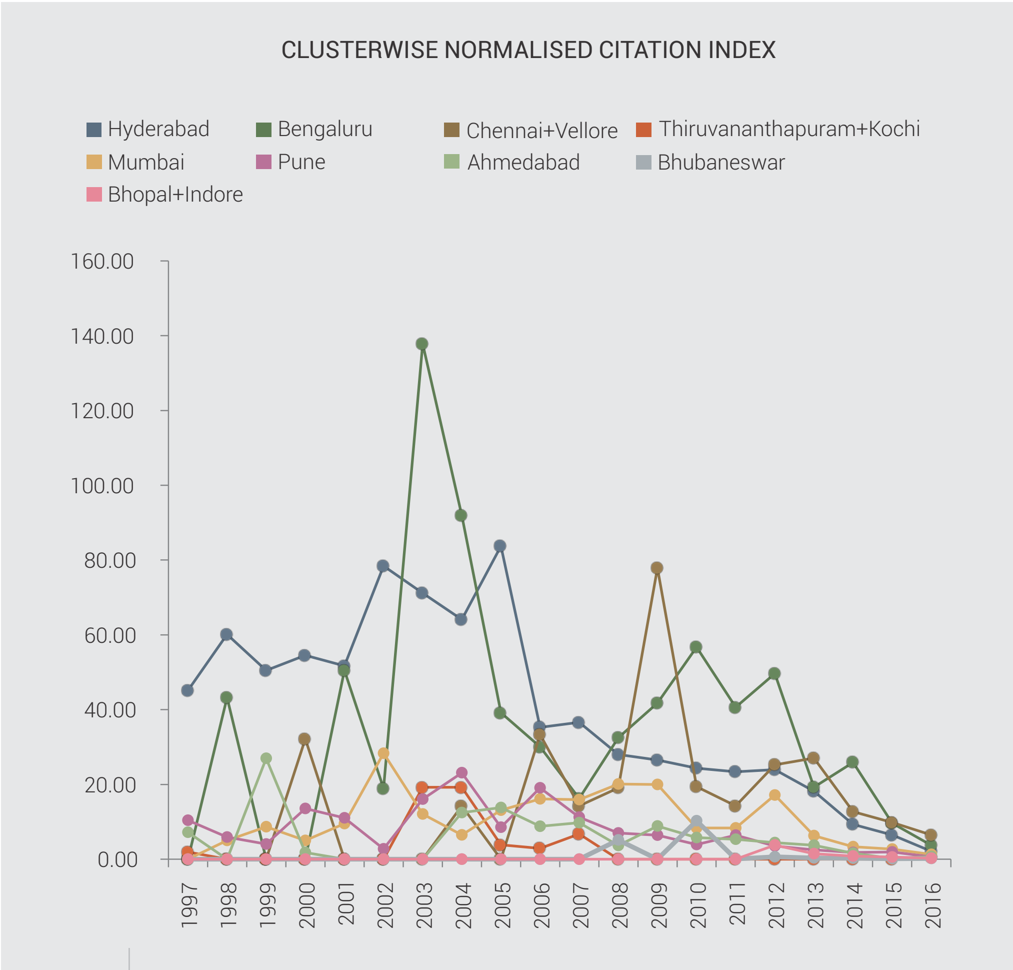


Figure 2.32 | Normalised citation index for select industry publications in the nine clusters

Patents are a good measure of the research output of industries and these patents are often cited in other patent applications to indicate the existing prior art and provide reference to the claims. Forward citations indicate that the patent belongs to a popular area with high impact. On an average, only about 20% of patents filed by Indian industries have forward citations and the average number of citations per patent is low (Figure 2.33). This could probably be the case because Indian industries tend to focus on process patents. Most established clusters and Ahmedabad have a comparable percentage of the patents cited, with those from Bengaluru and Hyderabad being the highest. The emerging clusters have very low number of cited patents. Most other clusters have a low number of citations indicating that the companies may not work on innovation and research as much as those in the more established clusters.

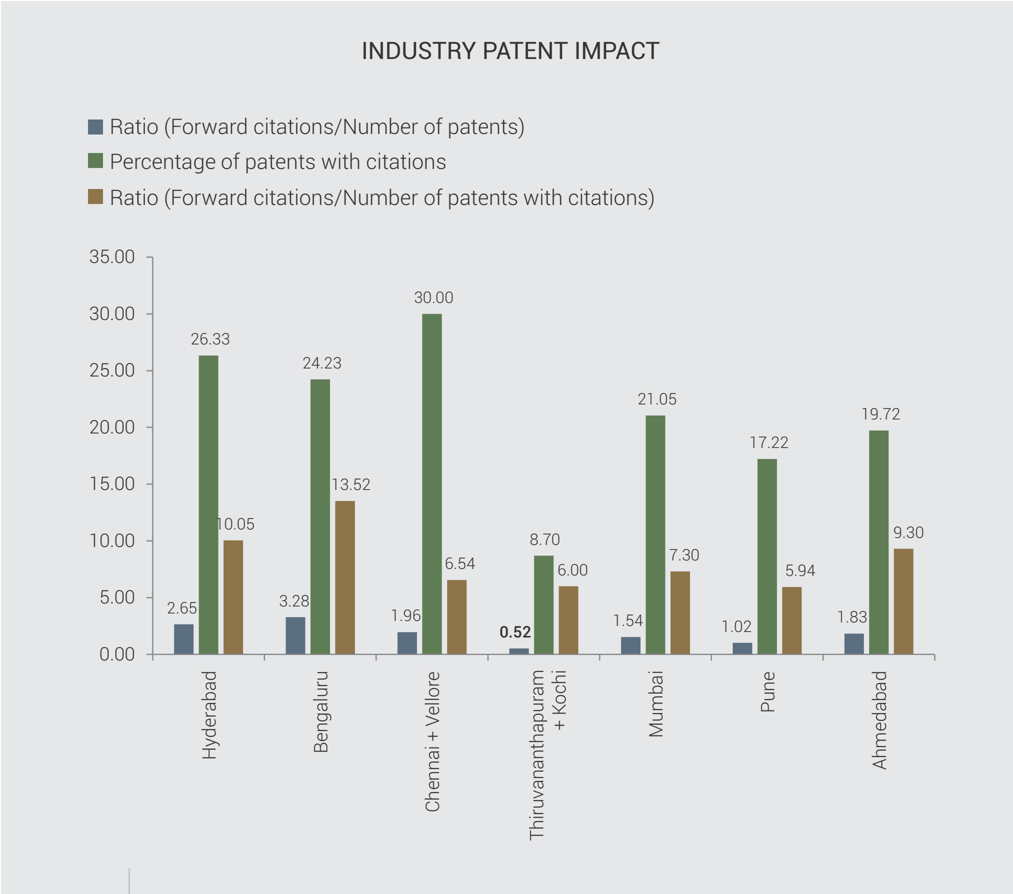
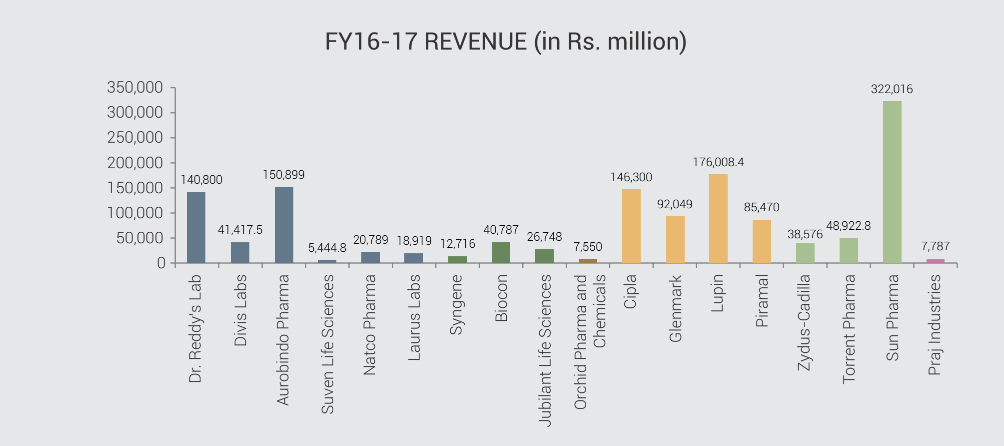


Figure 2.33 | Citations of patents from select industries in the seven clusters

Influence of anchors

Large companies in every growing cluster serve as anchors to support innovation. These companies invest in promising startups and some of them setup research centres such as DRILs, Mazumdar Shaw Cancer Centre and Biocon-BMS Research Centre. The study has identified eleven such anchor companies with annual revenue of over Rs. 1 billion (Figure 2.34), whose R&D investments help turn the clusters globally attractive. Most important is the talent pool generated because of the large number of employees trained in world-class setups (Figure 2.34). When such employees move out to start their own ventures, knowledge disseminates.

About 130 different classes of products and services are generated from these anchor companies, as seen in Table 2.4.



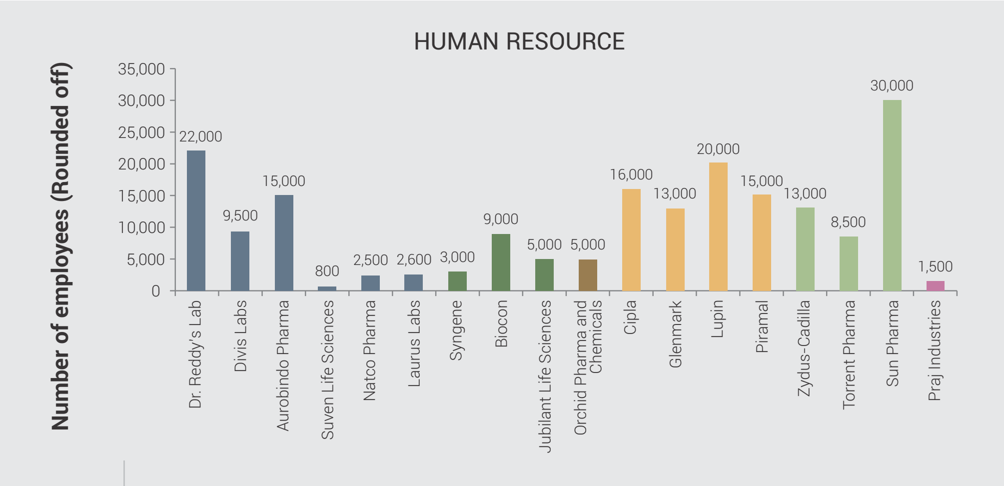


Figure 2.34 | Revenue (FY 2016-17) and Human Resources of anchor companies in clusters under study

Products or services form anchor companies in the clusters

- ACE Inhibitors
- Acne Treatment Preparations
- Agents Affecting Bone Metabolism
- Aminoglycosides
- Anabolic Steroid
- Analgesic
- Analgesics (Non-Opioid) & Antipyretics
- Androgens & Related Synthetic Drugs
- Angiotensin II Antagonists
- Anorectal Preparations
- Antacids, Antireflux Agents & Antiulcerants
- Anti Cholinergic
- Anti Emetic
- Anti Fungal
- Anti Hypercholestrolemia
- Anti Migraine
- Anti Ulcer
- Anti-Alzheimers
- Anti-Anginal Drugs
- Antiarrhythmic
- Antiasthmatic & COPD Preparations
- Antibacterial Combinations
- Antibacterials
- Anti-Cancer
- Anticoagulants, Antiplatelets&Fibrinolytics (Thrombolytics)
- Anticonvulsants / Antiepileptics
- Antidepressants
- Antidepressants / Antipsychotics

Products or services form anchor companies in the clusters		
• Antidiabetic Agents • Antidiabetics • Antidiarrheals • Antidotes, Detoxifying Agents & Drugs Used in Substance Dependence • Antiglaucoma • Antiglaucoma Preparations • Antihistamines &Antiallergics • Antihistaminics, Antiasthamatics • Antihyperlipoproteinemics • Antihyperparathyroid • Antihypertensives • Anti-Infective • Anti-Inflammatory • Antimalarials • Antimigraine Preparations • Antineoplastic • Antiobesity • Antiosteoporotics • Antiparkinsonian • Antipsoriatic/ Antiacne • Antiretroviral • Antispasmodic • Antithrombotics • Antivirals • Anxiolytics • Beta-Blockers • Bronchodilator • Calcimimetic • Calcium Antagonists • Cardiac Drugs • Carotenoids • Cephalosporins • Cholagogues, Cholelitholytics& Hepatic Protectors • Clinical Trial Intelligence • CNS Agents • Commercial Products • Cough & Cold Preparations • Cough Suppressant	• Curcuminoids • Custom Curation Services (Biology, Chemistry And Clinical Trial) • Cytotoxic Chemotherapy • Diabetes drugs • Digestives • Disease-Modifying Anti-Rheumatic Drugs (DMARDs) • Diuretics • Drugs Acting on the Uterus • Drugs fo memory Impairments With Aging • Drugs for Bladder & Prostate Disorders • Drugs for cardiovascular disease • Drugs for Erectile Dysfunction • Drugs for feeding disorders • Dyslipidaemic Agents • Entry Inhibitors • Erectile Dysfunction drugs • Eugeroics • Eye Anti-Infectives& Antiseptics • Eye Corticosteroids • Flavonoids • For Chronic Constipation • For Hyper Uracemia • For Overactive Bladder • Genome Data Analysis • GIT Regulators, Antiflatulents& Anti-Inflammatories • Glargine • Heavy Metal Chelator • Hematinics • Hormonal Chemotherapy • Hydroxycinnamic • Hyperphosphataemia • Hyperuricemia& Gout Preparations • Immnunomodulator • Immunosuppressants	• Immunosupressant • Itolizumab • Lispro&Aspart • mAbBiosimilars • Metabolic Disorders • Muscle Relaxant • Mydriatic Drugs • Nasal Decongestants & Other Nasal Preparations • New Drug Delivery Systems • Nonsteroidal Anti-Inflammatory Drugs (NSAIDs) • Ophthalmic Decongestants, Anesthetics, Anti-Inflammatories • Other Antibiotics • Other Cardiovascular Drugs • Other Drugs Acting on the Genito-Urinary System • Pain Management • Patient Monitoring, Computer Tomography, Diagnostic Ecg And Etc. • Pediatrics • Peptide biosimilars • Pharma It Services • Polyphenols • Preparations for Vaginal Conditions • Psoriasis, Seborrhea&Ichthyosis Preparations • Pulmonary Arterial Hypertension • Rh-Insulin • Supplements & Adjuvant Therapy • Target Intelligence And Analytics • Urinary Incontinence drugs • Vitamins

Table 2.4 | Products / Services of anchor companies in the clusters

2.2.3 Supporting ecosystem

In order for entrepreneurs to thrive, an entire support structure is required in addition to research infrastructure, especially during the initial stages.

2.2.3.1 Basic statistics

All the mature clusters in Phases 1 and 2 are well-developed with good support structure for innovation (Figure 2.35). Mumbai and Chennai have large number of IP firms because of the patent offices located in these cities. Also, since Mumbai is a hub for financial services, most consulting firms have their base in Mumbai.

With respect to state support, Ahmedabad fairs as well as the other mature clusters due to the strong push from the state government through various incentives in its startup policy, a startup cell for single window clearances and supporting a large number of incubation centres. Several states are very proactive in implementing startup policies. Visakhapatnam and Bhubaneswar although new to join the league, are working towards several innovation policies to ensure rapid growth. During the initial phase of development of an innovation ecosystem, the thrust is invariably on Information technology (IT) companies due to the promise of quicker turnaround, lower capital expenditure and much larger scope of employment. Also, correlating to the research capacity from anchor institutes and industries in this region, the clusters may not be completely geared up for life sciences based startups.

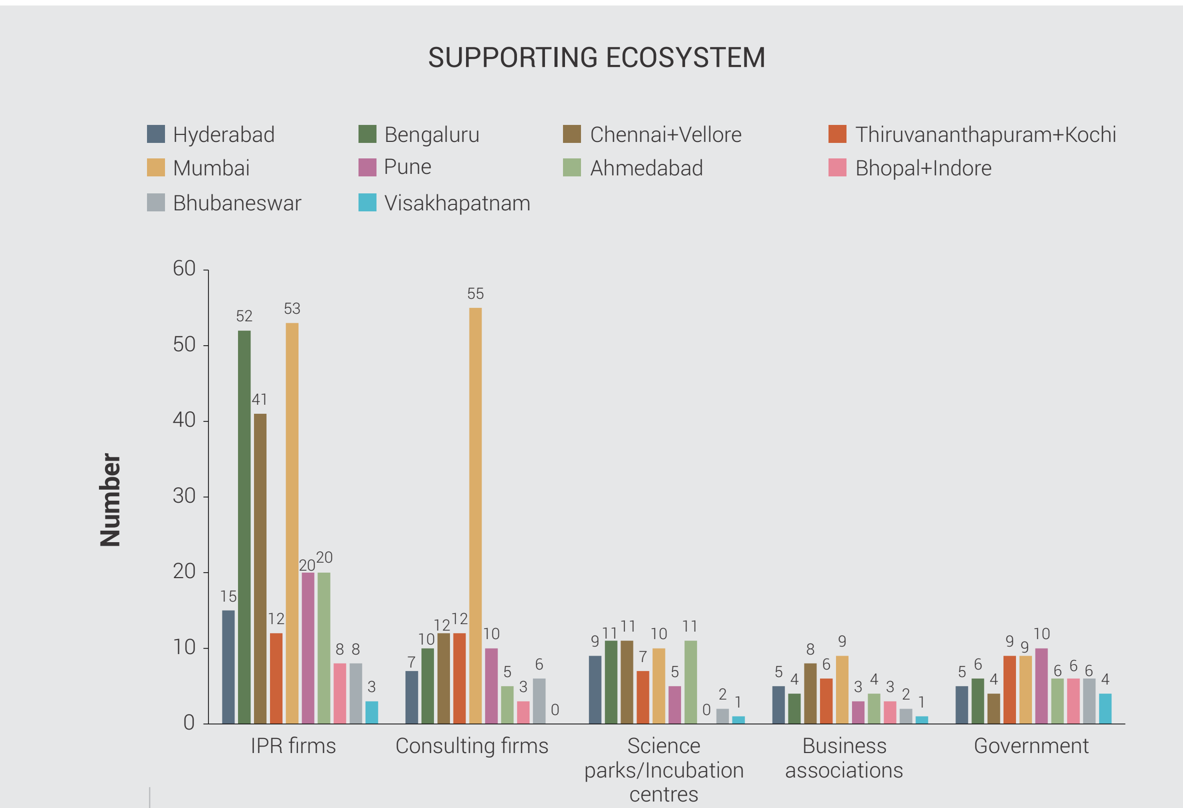


Figure 2.35 | Distribution of various startup enablers in the clusters under study

2.2.3.2 Funding support

The pharmaceutical industry in India ranks 3rd in the world in terms of volume and 14th in terms of value. The provision of process patents fuelled the growth of the generics pharma industry. With 70 per cent market share (in terms of revenues), generic drugs form the largest segment of the Indian pharmaceutical sector. India has a competitive edge over several other developed nations due to a significant difference in the cost of production.

In terms funds raised, as per Tracxn data (Traxcn data is not exhaustive and is only suggestive of general trend), the pharma sector comprising of traditional pharma, generics and biopharma, is the most prominent sector with 46% companies having raised about 50% of the total funds (Figure 2.36). The next major sector that attracted funding was CRAMS / CRO / API at about 20%. Other areas such as Medical Devices, Bioinformatics and Nutraceuticals have also started atracting capital.

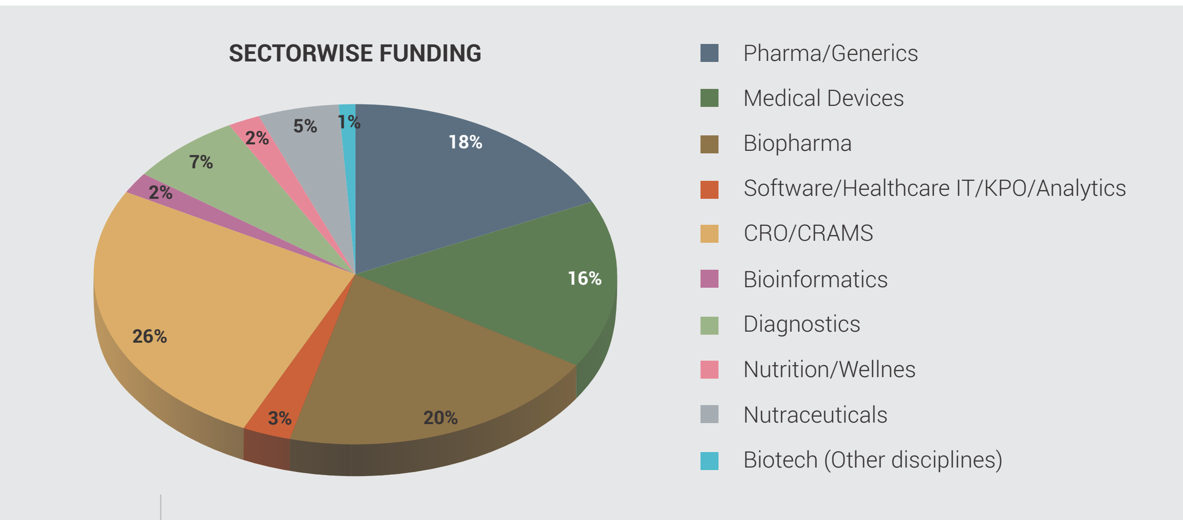


Figure 2.36 | Funding raised by life science companies in India

Citywise analysis on funding patterns

Innovation funding patterns for the cities under study were analysed. Out of these, Bengaluru and Mumbai reported the highest number of companies that have received external funding in some form (Figure 2.37). Mumbai and Hyderabad have the highest number of public limited pharmaceutical companies (Figure 2.37). Both these cities are known pharma clusters and are home to some of the country's top pharma companies like Sun Pharma, Cipla, Dr. Reddy's and Aurobindo Pharma. Ahmedabad and Pune also have several large public limited pharma companies. Many traditional pharma companies have now diversified into biopharma, particularly biosimilars and vaccines. Although Bengaluru does not have the advantage of these pharma clusters, it has the largest number of life sciences companies that have attracted seed, angel, VC and private equity funding. Figure 2.37 gives distribution of types of institutional funding raised in each cluster. Companies which do not disclose the amount or nature of funding have been marked as "funded" without being further classified.

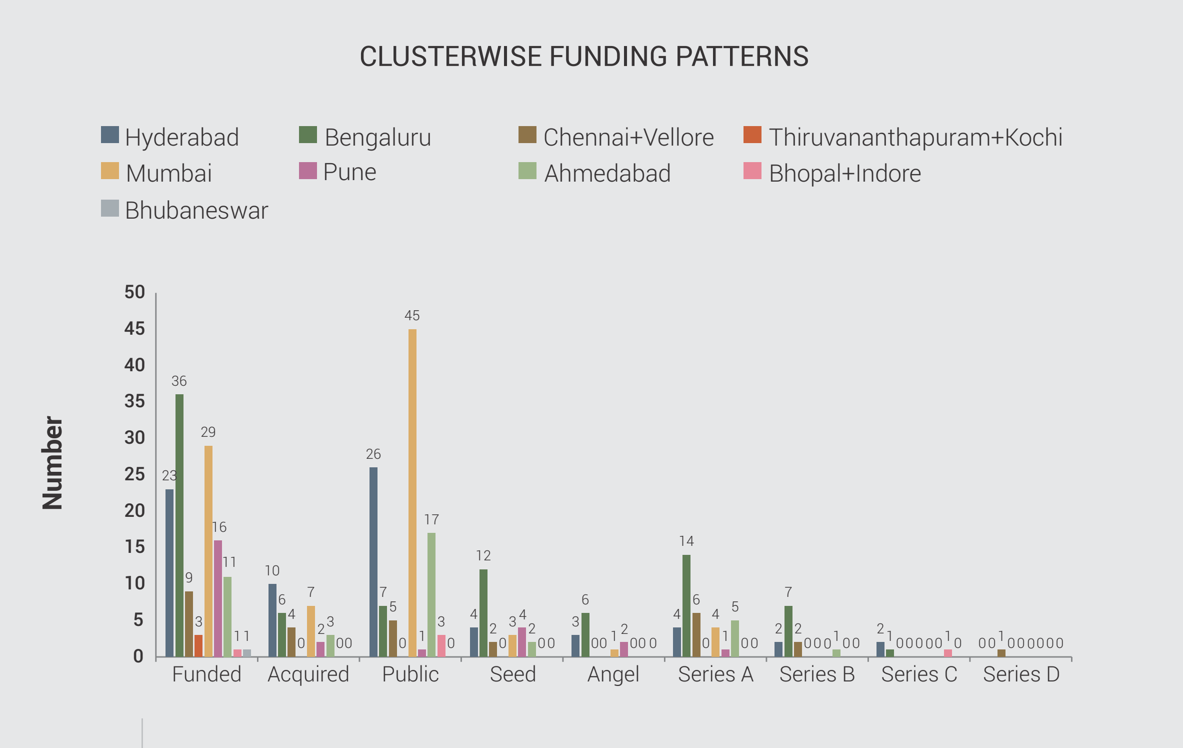


Figure 2.37 | Clusterwise funding patterns

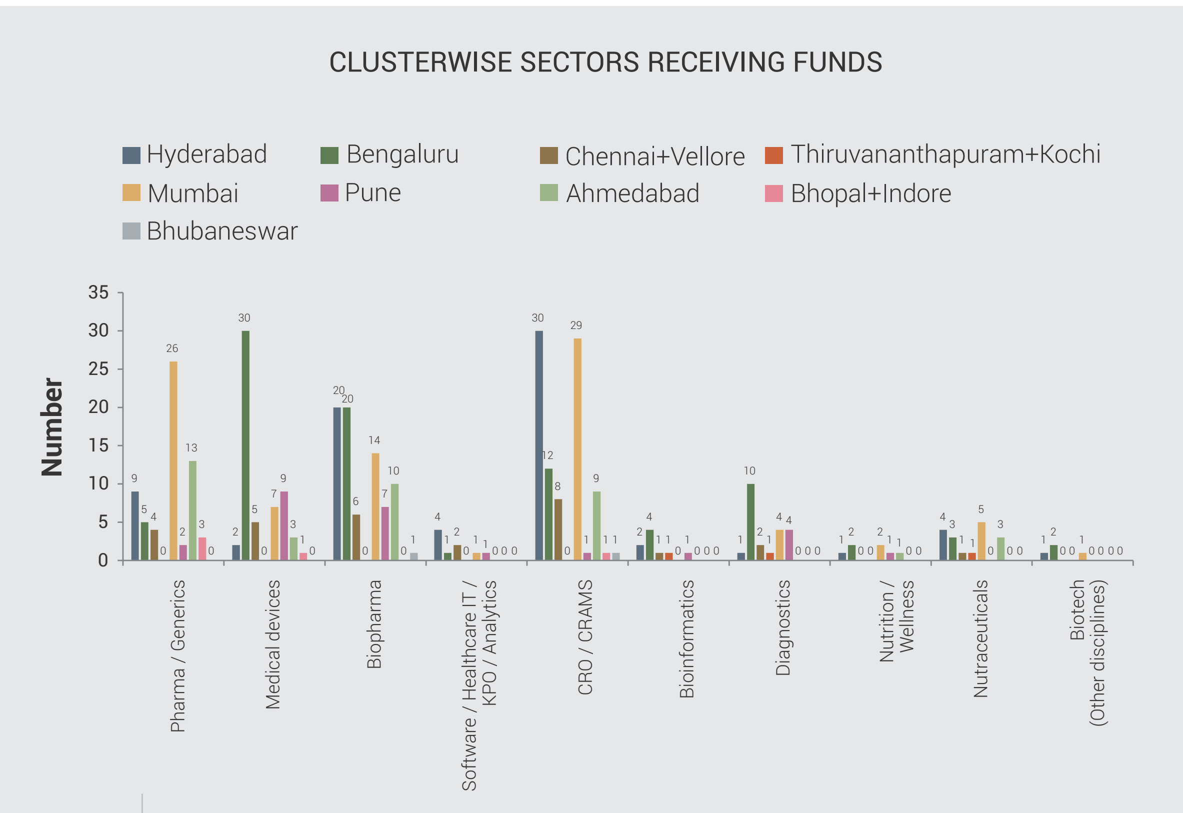


Figure 2.38 | Sectorwise funding patterns of clusters under study

Bengaluru is one of the most hi-tech entrepreneurial cities in India. It has the highest number of venture-funded life sciences companies in multiple domains including biopharma, medical devices and diagnostics in addition to diverse streams of biotech (Figure 2.38). Mumbai, Hyderabad and Ahmedabad have largely attracted funding in traditional pharma, healthcare and allied areas. Chennai and Pune have strength in automotive and manufacturing sectors. This has played a role in the development of medical device companies in these two clusters (Figure 2.38). Chennai and Pune are emerging as strong biotech clusters which can rapidly grow through appropriate support. The remaining clusters are still nascent with very few listed and funded companies (Figure 2.38).

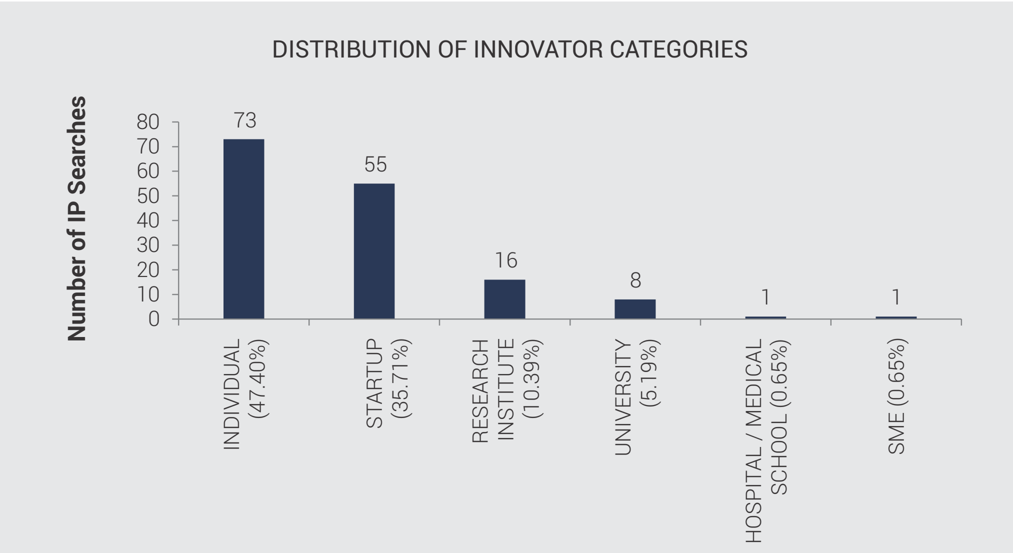
2.2.4 Other observations

IP experiences from BRIC

The IP cell of BRIC closely interacts with several individuals and organisations who seek help in patent related matters. Analysis of Phase I and II data showed that the maximum interest in IP services was among startups and individuals who wish to start a venture (Figure 2.39 A). In Phase 1, mostly national level institutes with in-house Technology Transfer Offices or IP cells sought help in technology transfer services, while universities and colleges needed help with IP awareness among faculty and students. Between 2013 and 2016 interest levels in IP services in most institutions were found to be tepid even with incentives such as highly subsidized or free services. The attitude was more positive in 2017. Several national level institutes by now have IP cells or are in the process of setting up one. IP awareness is gradually increasing with several state and central government programmes to support IP filings. However, in many emerging clusters, the awareness is still quite poor, and while the number of queries from academic institutes in these clusters were high, these did not necessarily translate into IP searches. There is a clear gap and a need for entrepreneurship development activities in these institutes.

Out of 154 patentability searches conducted by BRIC, over 50% of the search queries were not novel pointing to poor awareness about prior art and existing competition. About 16% technologies were found to be truly novel and the number has slightly increased in the recent years (Figure 2.39 B). Although Indian innovators tend to work on incremental innovations as low hanging fruits and not disruptive technologies, the awareness and support in recent years is expected to gradually lead to better quality of IP.

Among the various sectors healthcare was the most sought after area for prior art searches, and within this the maximum number of searches were in the area of new diagnostics as shown in Figure 2.39 C. Other areas where active work is going on are industrial processes and biomedical devices.



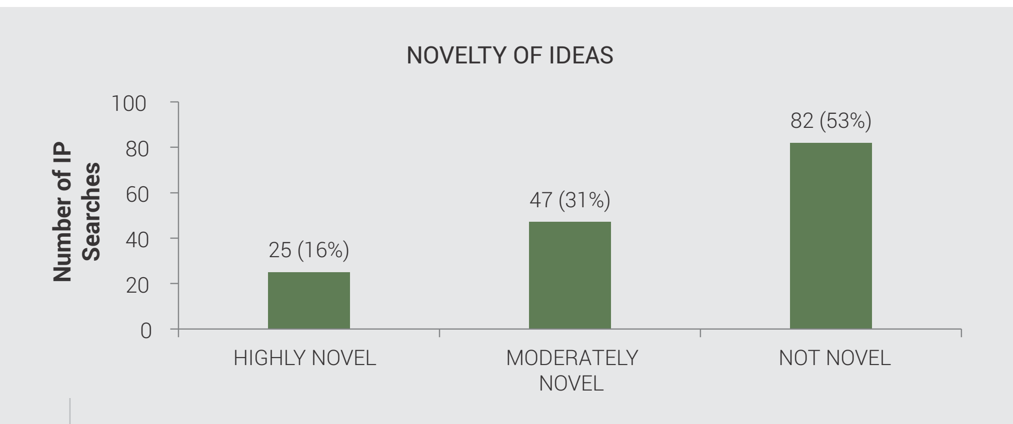


Figure 2.39 | Experiences of BRIC in IP culture in the ecosystem
A) Distribution of innovator categories, B) Novelty of ideas

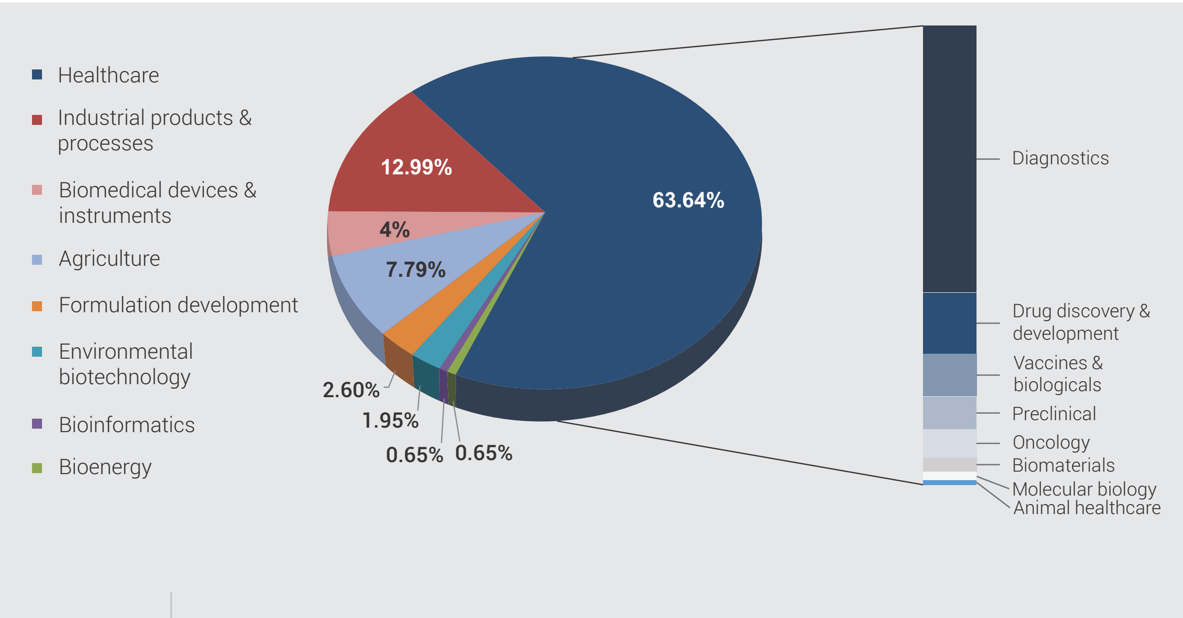


Figure 2.39 | Experiences of BRIC in IP culture in the ecosystem C) Sector distribution

2.3 Key findings from KOL survey

To understand an ecosystem, it is imperative to analyse ground realities that would not necessarily be reflected through secondary data analysis. Primary methods such as cold surveys and interviews often help in completing trends obtained through secondary analysis. The interviews with Key Opinion Leaders (KOLs) were broadly woven around the following topics:

Current status of innovation ecosystem in their respective cities in terms of strengths and weaknesses and what can be done to increase the innovation level

- Collaboration status with other stakeholders
- Availability of funding
- Issues related to intellectual property rights
- Regulatory hurdles in commercialisation
- Expectations towards policy level changes

The commonalities have been compared and discussed. The advantages have been compared and contrasted among the four major clusters. Disadvantages were found to be specific to stakeholders across cities. Finally, the expectations from the players have been captured.

2.3.1 Overview of innovation ecosystem across clusters

Hyderabad, Bengaluru and Mumbai are the most mature of the ten clusters under study. Strong research capacity, presence of anchor industries and a thriving startup culture are some of the key features. The support of the state government with forward looking startup and biotech policies, and establishment of state-supported incubation centres are an added advantage for Hyderabad and Bengaluru clusters. Bengaluru has a large and diverse experienced talent pool, alumni networks of several renowned institutions and networking forums that help entrepreneurs exchange ideas and benefit from experiences of their peers. The presence of a strong research oriented clinical community with institutions like St. Johns Medical College in Bengaluru is a huge value addition for companies looking to partner for clinical validation. Finally, several entrepreneurs preferred Bengaluru because of its pleasant weather, cosmopolitan nature and diversity of job opportunities across a wide range of sectors. The Hyderabad cluster with similar support structure was rated better than Bengaluru in infrastructure and access to community investors. Hyderabad however is heavily skewed towards the pharma sector. Mumbai like Hyderabad has a dominant pharma presence. Mumbai being one of the oldest ports and financial centre of the country provides diverse job opportunities and has better infrastructure compared to most cities. With respect to suppliers, distributors and vendors, Mumbai was rated highest among the clusters in terms of efficiency in delivery of services.

Chennai has had a history of strong manufacturing capabilities especially in the automobile sector. This, coupled with a tech-savvy clinical community and presence of institutes like CMC, Vellore has led to the growth of the medical devices sector. The Golden Jubilee Women's Biotech Park in Chennai was pointed out by several women entrepreneurs as a mark of a friendly, gender sensitive and supportive environment for innovation .

Pune likewise has a strong automobile and manufacturing industry. The presence of CSIR-NCL which has nurtured a culture of working on commercial products was rated highly. One big advantage highlighted about Pune was the geographical proximity of all the major research institutes in the city. This has created an active culture of collaboration and exchange of ideas. Although many of these interactions currently happen informally, several KOLs felt that over a period of time these would get formalised. The presence of NCL-Venture Centre has been instrumental in driving a vibrant startup culture in the research community. The upcoming Pune Biocluster initiative is expected to enhance the ecosystem further.

Thiruvananthapuram and Kochi were together considered an emerging biopharma cluster with several life sciences research institutions and a biotech park in Kochi. The presence of Sree Chitra Tirunal Institute of Medical Sciences and Technology clearly stood out as a high point for this cluster since it was the only facility in the country to carry out large animal studies in addition to bio-compatibility studies.

Ahmedabad and Visakhapatnam are large pharmaceutical manufacturing hubs. Some of the leading pharma companies in Ahmedabad have diversified into biopharma and have large R&D facilities, whereas in Visakhapatnam the activities are restricted to manufacturing and quality control. There is strong government support in both these states with special focus on these cities. Therefore a lot of incentives and are being planned to improve the overall ecosystem, including setting up Centres of Excellence in various domains. However, the research capacity and locally available talent in these two clusters are not yet geared for cutting edge innovation and therefore efforts in attracting talent from outside are underway. One observation was that Visakhapatnam's strength as a naval base and presence of NIO were not being leveraged to connect current efforts in innovation to these streams to create a niche expertise in this region.

Bhubaneswar has several new research institutes and the state is very active towards providing various incentives and support to biotech startups. The presence of ICMR institutes and AIIMS is a huge advantage for collaboration with the clinical community. In addition the local community is also working closely to reach out to mentors abroad to guide the startups. Although the overall innovation ecosystem is still nascent the cluster has promise to evolve into a vibrant startup ecosystem.

Bhopal and Indore have been considered as a single cluster for the purpose of this study to understand if this region has potential to emerge as a life sciences cluster. IISER Bhopal and IIT Indore are new institutes with several young faculty who are very keen on translation. However, the research environment is nascent and the institutes would take a few years to establish themselves as life sciences R&D hubs. Lack of job availability for spouses and a good education system for children pose as a huge roadblock to attract talent to join these institutes. In addition, there is no biotech incubation centre in the entire state that can serve as a nodal point for innovation activities. The proposed plan of incubation centre at IISER Bhopal would probably fill this gap. Currently the government is also in the process of coming up with several schemes to develop the regional innovation ecosystem. Indore has a reasonable IT community that could be leveraged.

Figure 2.40 is a comparative table of attributes indicating the quality of the innovation ecosystem in the ten clusters compiled from KOL interviews. The degree of satisfaction for each attribute has been captured qualitatively through a **green dot** indicating good, **yellow dot** for okay but could be better, **orange dot** signifying need for improvement and **red dot** indicating a gap.

Figure 2.40 | Overview of innovation clusters through the eyes of KOLs

2.3.2 Stakeholder specific gaps

The challenges / issues expressed by various stakeholders in the ten clusters were analysed. While many of the issues were common across clusters, the degree and extent of the problems were found to vary depending on the stage of maturity of a cluster, with specific issues adversely affecting the growth of emerging clusters. Startups and large companies have several problems in common but many were found to be specific to the age and size of company and therefore have been categorised separately.

The biggest hurdle faced by all stakeholders was with regulatory compliances. It ranged from lack of guidelines for several areas such as medical devices, stem cells to conflicting opinions on the procedures to be followed. The red-tape and bureaucratic delays added to the uncertainties. Conducting large animal studies, seeking ethical clearances and conducting clinical trials were stated as most difficult by small companies. Many stakeholders felt that the situation may take several years to improve and therefore sought alternate geographies to work from during the stage of commercialisation.

Duty and taxation also adversely affect several innovative projects and was mentioned as a big hurdle in Phase I study. However, several stakeholders felt that this has been addressed with several policies in the last year and the situation has improved. With respect to anomaly between import duties on raw materials and finished goods many stakeholders still pointed this as an impediment in providing Indian startups a competitive edge. However, they were hopeful that with ease in government procurements the situation will improve.

Vendor base for engineering prototypes / manufacturing was a problem faced by SMEs and startups. Large companies have deep pockets to either outsource or hire trained personnel for design and productisation of their prototypes, especially in the area of medical devices. Entrepreneurs usually dealt with local vendors with smaller manufacturing factories. While most of these vendors possessed good skills, they lacked design capabilities or creativity to be able to manufacture from drawings or explanations. Startups were often found to import the initial prototype from elsewhere and then needed several iterations to obtain a product of desired quality. Although it served as a workaround, these problems could pose serious issues in the establishment of strong long-term manufacturing capabilities in the country. In addition to skill and quality, several KOLs in emerging clusters pointed out that vendor base in their city was very poor due to lack of critical mass of customers. They also pointed that the eastern region was particularly slow with distribution networks which led to several delays and a huge challenge for startups to compete on cutting edge areas.

Lack of talent for pursuing innovation was pointed out as a huge shortcoming across stakeholders. Startups as well as established industry felt that the training of talent through various academic programmes was inadequate, and retaining people after providing training was a challenge due to the demand supply gap. Enablers also pointed this as an issue. Many incubators especially in emerging clusters felt that getting good managers to run various aspects of incubation was a challenge. This was particularly highlighted in incubators within academic setups.

Indian academia seemed to lack awareness of industry needs and seemed to be less aligned with current trends and practices leading to poor knowledge flow within the ecosystem. On the other hand, several academics felt that Indian industry was risk averse and not geared to taking up new innovations. Discussion on poor collaboration trends often led each stakeholder (industry and academia) to point at the lack of capabilities in the other. They also pointed out that industries usually have a closed door policy with respect to R&D and several projects were not known to anybody to even seek collaboration. A more detailed discussion on issues with collaboration have been taken up in the subsequent section.

2.3.3 A deeper dive into challenges

Collaboration, intellectual property, regulatory guidelines and funding were found to be the four major hurdles to innovation and for each hurdle, likely causes were identified. In additional specific cultural challenges faced by emerging clusters were identified. Figure 2.41 gives a glimpse of what percentage of KOLs thought what the critical issues were for each challenge. The findings are discussed below.

2.3.3.1 Collaboration

Knowledge transfer and information flow across stakeholders is necessary for establishing feedback loops and long term sustenance of the ecosystem. During the Phase I study, several scientists had pointed that attitude and archaic rules in academic institutions were bottlenecks that needed reforms to enable a conducive innovation ecosystem in academia. This seemed to have made some progress in the last one year with several academic researchers transitioning into entrepreneurs.

In this phase of the study, discrepancy in pace of working was cited as one of the biggest hurdles (over 40%) in industry-academia collaboration. Industries and startups opined that the pace of work in Indian academia was often slow because of lack of motivation to focus on commercialising a technology. While enquiry and fundamental research were paramount in establishing a sound research foundation, this often led to mismatches in timelines required by a profit-driven organisation that has to align with shareholder demands. Also, the industry KOLs felt that Indian academia lacked the ability and desire to develop their technologies to a stage where it was commercialisable, either readily or within a short time frame. Prolonged periods for licensing negotiations added a huge uncertainty not only in the potential of the technology but also in the patent timelines. This often led to undervaluation or termination of collaboration over IP rights.

The lack of strong technology transfer offices in institutes with well-trained negotiators was highlighted as an issue by all KOLs from the academic fraternity who felt they were often denied a fair deal by the industry and opined that there was a need for bridging partners who could mediate collaboration with industries. Collaborations therefore tended to exist more as consulting projects rather than as co-development of products.

Although not mentioned by all stakeholders and in all cities, certain other important aspects emerged from the interviews. Clinicians pointed to the lack of focus on medical research at the policy/management level. In private and corporate hospitals the emphasis was on patient load and in large public hospitals in addition to patient load, teaching was the other equally important aspect that did not allow any meaningful time for research. The research divisions usually limited their work to clinical validations and conducting trials. Several new institutes pointed out that since the focus was to establish themselves as a research institute, focus was on setting up infrastructure and publishing. However lack of well-defined processes and disconnect from end users were a huge impediment in commercialisation of technologies. With the trend among younger faculty towards translation along with conducive policies and processes, it is hoped that the scenario will change in the near future.

2.3.3.2 Intellectual Property Rights

Protecting technologies from infringement or copying through filing of patents was recognised by academia as important. Several lacunae in various aspects of IP that were pointed out during the Phase I study seemed to have improved significantly over the last one year. However, institutes in emerging clusters such as Ahmedabad, Bhopal+Indore and Visakhapatnam felt that lack of awareness and support from the ecosystem were hurdles that needed to be addressed. They added that setting up of incubation centres with tech transfer offices in these regions would be a good solution. to address this issue.

2.3.3.3 Regulatory hurdles

A key obstacle pointed out by entrepreneurs was regulatory hurdles. One of the biggest challenges as pointed out by over 40% KOLs was the lack of good partners to carry out clinical validation or trials for regulatory requirements. Many KOLs in industry mentioned that the expertise in many CROs was not at par with global standards and therefore preferred carrying out preclinical and clinical studies abroad since there was also no significant cost or time advantage for conducting the studies in India.

Lack of clarity on certification authority and guidelines for certifying medical technologies developed in India is another impediment. Since most technologies are unregulated in India, it posed uncertainty in the regulatory pathway to be adopted by startups who wanted to access global markets. Without a formal certification from the host country even entering several emerging markets becomes challenging. Healthcare, pharma and biotech sectors are governed by the Drugs and Cosmetics Act of 1940 that has caused a lot of uncertainty in the applicable rules. The industry was looking forward to the new Medical Device Rules, 2017 on medical devices and in vitro diagnostics regulations issued by CDSCO that will take effect from January 2018.

It was felt that transparency in the regulatory process has improved over last few years. Some KOLs alluded that within CDSCO, whose manpower primarily has a pharma background, there was a need for training and improving the understanding of emerging technologies such as synthetic biology, biosimilars, CRISPR and new disruptions in medical technologies, which would otherwise lead to slowing down the regulatory approval timelines. The new biosimilars guidelines promises to have long ranging implication on the growing biosimilars industry in the country with good checks and balances in requirement of safety and efficacy studies and post marketing risk management. Lack of awareness on regulatory aspects were identified as a major issue in startups from emerging clusters and those born out of new academic and research institutes.

Lack of clarity on financial regulations with respect to transferring funds outside the country or receiving grants from international agencies further complicated expanding in other markets. The increased regulatory requirements have imposed additional burden on startups since these aspects require the services of a certified Chartered Accountant. With the introduction of GST, the threshold for registration for GST was Rs. 20 lakhs turnover thus exempting many small businesses including startups from payment of tax. However since the turnover limit has been reduced to Rs 20 lakhs the tax burden for many manufacturing startups could increase. Several aspects of GST still needed clarity. Several startups acknowledged that online simpler procedures have eased out the effort for various registrations.

2.3.3.4 Funding

Scarcity of funding has always been an issue in most fronts of research. This was raised by KOLs for academic institutes with relatively low quantum of funding that did not enable research in cutting edge areas. In comparison to countries like Israel, Singapore, China and South Korea, many KOLs pointed out that India had a lot of catching up to do. To add to the quantum of funding, cash flow issues and recent budget cuts were highlighted by about 40% of KOLs across stakeholder categories.

Lack of funding in development phase for startups and a limited number of players in angel and early stage VC rounds was pointed out as a reflection of a broken ecosystem. Several startups and enablers praised the contribution of government grants and the role of BIRAC in kick-starting the life science startup ecosystem. They however highlighted that most government grants were largely democratic and did not necessarily have a mechanism to seek out the most promising startups for accelerated funding. The lack of synergy in focus areas between government and institutional funding was pointed out by over 30% of KOLs as an obstacle to scaling up. It was pointed out that impact based funds were too few in the country and the need for government support in funding and procurement for startups developing technologies relevant to improving public health in India. .

Although only about 8% of KOLs mentioned this as an issue, lack of funds for longitudinal studies was an aspect to be addressed. The low number is primarily because not many clinicians or scientists work on longitudinal studies, however with threat of AMR and NCDs increasing in the country, encouragement through various programmes was necessary.

2.3.3.5 Cultural aspects in emerging clusters

During interviews several issues faced by startups in emerging clusters came to the fore. Much of this was because there was not enough critical mass of innovators in the city. One of the major barriers as pointed by over 60% of the KOLs was the constraint of research infrastructure and logistics. Simple issues like electricity fluctuations often led to disturbance in conducting experiments and appropriate affordable infrastructure for startups was not available. Also, there were huge delays in procurement and supply due to lack of lab equipment and chemical suppliers. Logistical issues like road permits added to the delays especially when they were dependent on distributers from larger cities. Several startups pointed out that they needed to maintain inventory of consumables which added to their cash flow issues. In Bhubaneswar startups within the TBIs have to some extent circumvented these issues by sharing and creating a common inventory.

Finding mentors and support structure was another issue mentioned by over 60% of KOLs. Since the first wave of entrepreneurs are emerging now from some of these newer clusters, finding mentors locally was not easy and they have been largely dependent on mentors from other cities. Although incubators typically try to bridge this gap by inviting mentors over events, one on one interaction has not been effective. Also, startups typically do not have large travel budgets to travel every time to seek support. An issue pointed out by several startups who have progressed to seeking institutional funding and regulatory processes was that there were several individuals and firms providing consultancy services to startups often with little expertise. This could have a demoralising effect on startups.

Many KOLs pointed that the approach towards R&D was very conventional in most cities both in academia and industry. Therefore there were not enough industry led activities or even specific focus areas within the cluster to create an actively collaborating innovation community.

Lastly, there was a huge disconnect between policy makers, thought leaders and senior management of leading industries in emerging clusters and their managers at the ground level which translated to a poor morale among young innovators. More active engagement with state level policies and plans could greatly encourage the innovators. Clusters like Bengaluru have an active entrepreneurial culture with networking events, hackathons and awareness sessions organised on a weekly basis by various forums and institutes. Emerging clusters could adapt some of these cultural aspects to create similar ecosystems.

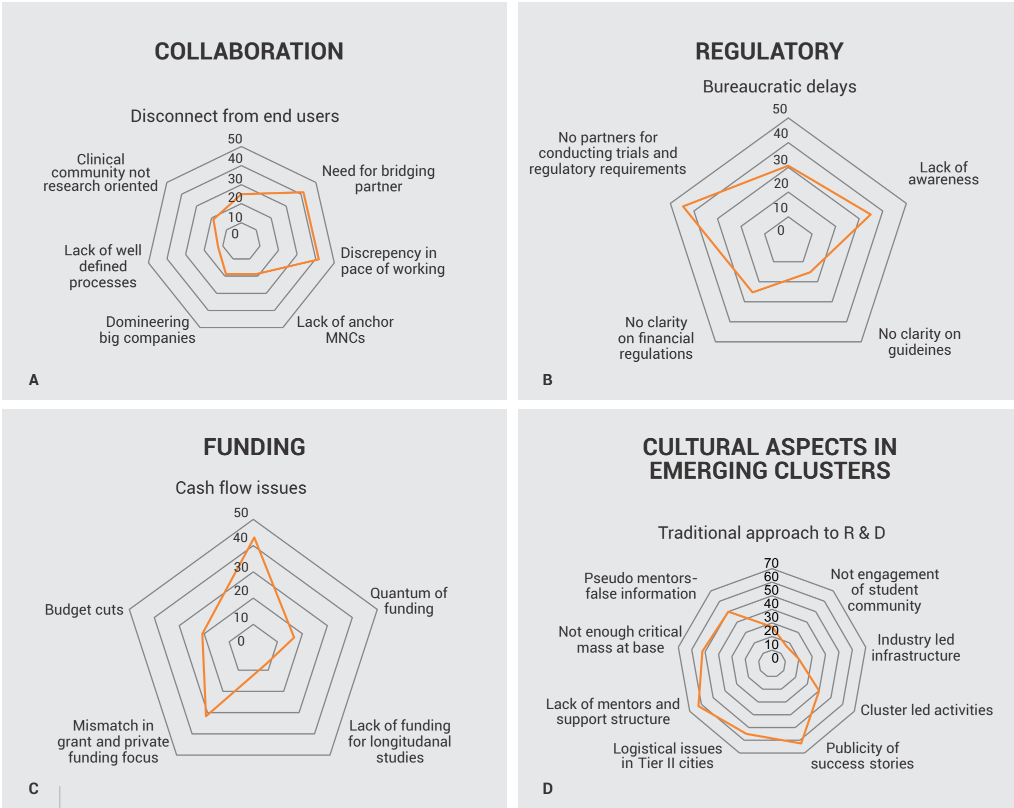


Figure 2.41 | Major hurdles discussed by KOLs; percentage of KOLs pointing out various issues in (A) collaboration (B) regulatory hurdles and (C) funding (D) Cultural aspects in emerging clusters are represented

2.3.4 Expectations of KOLs to improve the ecosystem

During interviews, KOLs were asked to list changes they would expect in order to improve the regional innovation ecosystem. The expectations of KOLs were classified into three broad levels, national government, state government and individual players based on who would drive the change.

2.3.4.1 National level policy incentives from the government

Globally, governments bear the technology risk of disruptive innovations. Invention-based technology innovations like what is needed in life sciences cannot happen without long-term focused investment by the government in translational research and product development. Funding for R&D and recently startup grants has been possible because of government funding through DBT, BIRAC, the Department of Science and Technology (DST), Council for Scientific and Industrial Research (CSIR), ICMR, Ministry of Electronics and Information Technology (MeitY) and other science and technology led departments.

A large number of KOLs expressed the need for specific types of funding schemes including special grant schemes in basic research and clinical research for longitudinal studies. Several KOLs felt the need to set up reference laboratories to cover a larger number of diseases for conducting studies, as has been already commissioned by ICMR for certain types of diseases. Another form of funding requested was competitive cluster specific grants which could be thematic and would enable better focused interaction in emerging clusters.

With regard to infrastructure, expectation from KOLs in emerging clusters was to establish centres of excellence to improve the research capacity in these cities. The mature clusters requested for setting up of Fab Labs and research parks for medical devices which have facilities for small scale manufacturing and testing.

Policies on engaging the diaspora would be advantageous in the long run not only in monetary terms but also in transfer of technological knowhow. Further reforms in the government procurement policy were necessary in order that the government has schemes to adopt supported technologies rather than traditional procurement through a tendering process. While both the aspects are currently being addressed through Startup India policy and other programmes, further innovative reforms would be necessary.

2.3.4.2 State level policy changes

Matters related to infrastructure, education, local taxes being state matters, state level policies also needed to be aligned with the national level incentives.

First and foremost was establishing single window clearances for all state government registrations and clearances. State level taxes and labour laws also need to be aligned to the state's focus on incentivising the biotech sector. State level startup policies of the governments of Kerala, Telangana, Andhra Pradesh, Gujarat and Karnataka reflect the proactive role played by the states in promoting startups. However, KOLs from Maharashtra and MP felt that the processes are still not in place in these two states. Cold storage and distribution networks are some logistical issues which could be eased out by specific policies from the respective state governments.

Better infrastructure such as improved roads, electricity and water supply as well as management of traffic, environment and safety were highlighted as deciding factors for all, and especially for large establishments.

Lastly, with several states providing research grants, better funding for state universities and aligning the grant schemes with central government schemes especially for improving research capacity in emerging clusters would be beneficial.

2.3.4.3 Stakeholder level changes

With the government incentivising startups through various schemes, it was also the responsibility of the individual stakeholders to adopt changes that favour and nurture innovation. Information portals on funding, regulation, vendors would improve awareness. Specifically, if this role were to be played by large academic institutes and incubators, the reach would be deeper and farther. While several incubators in mature clusters are playing this role actively, there is a need for an active arm in incubation centres of emerging clusters to spread awareness through roadshows and workshops. Also, mentoring by established incubation centres can improve the quality of new incubation centres.

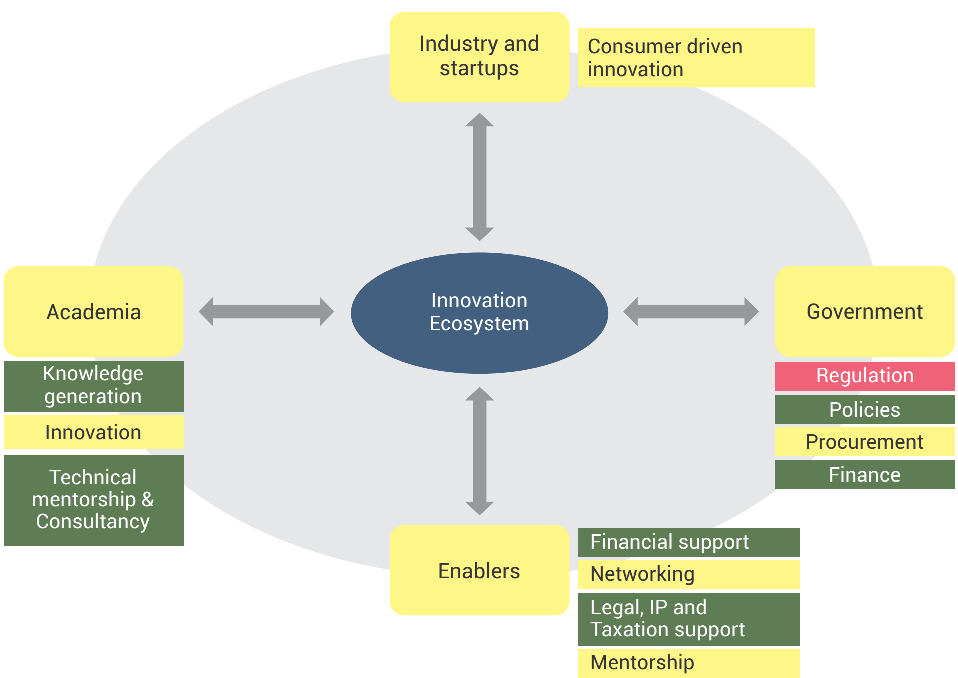
A nodal centre that works in close association with incubators could serve to provide an accredited list of consultants and mentors. These nodal centres could also facilitate various cluster led activities. In addition, industry setting up facilities in academic institutes, like the Robert Bosch centre at IISc and IBM centre in IITB, could account for need based innovation and greater industry-academia collaboration.

Chapter 3

SUMMARISING CURRENT STATUS AND RECOMMENDATIONS

3.1 Current status of ecosystem and classification of capabilities of stakeholders

As discussed in the introductory chapter, the innovation capability of an ecosystem depends on the various stakeholders in the region and the interactions among them. The study reveals wide variation in maturity of innovation capacity among the ten clusters, and therefore generalisations on the status of innovation ecosystems beyond a city/cluster may not be pertinent. Figure 3.1 tries to capture the current status with a colour coding that classifies the stakeholders and their interactions into vibrant (green), improving but needs more focus (yellow) and lastly those that need serious attention and support (red) to achieve the desired growth.



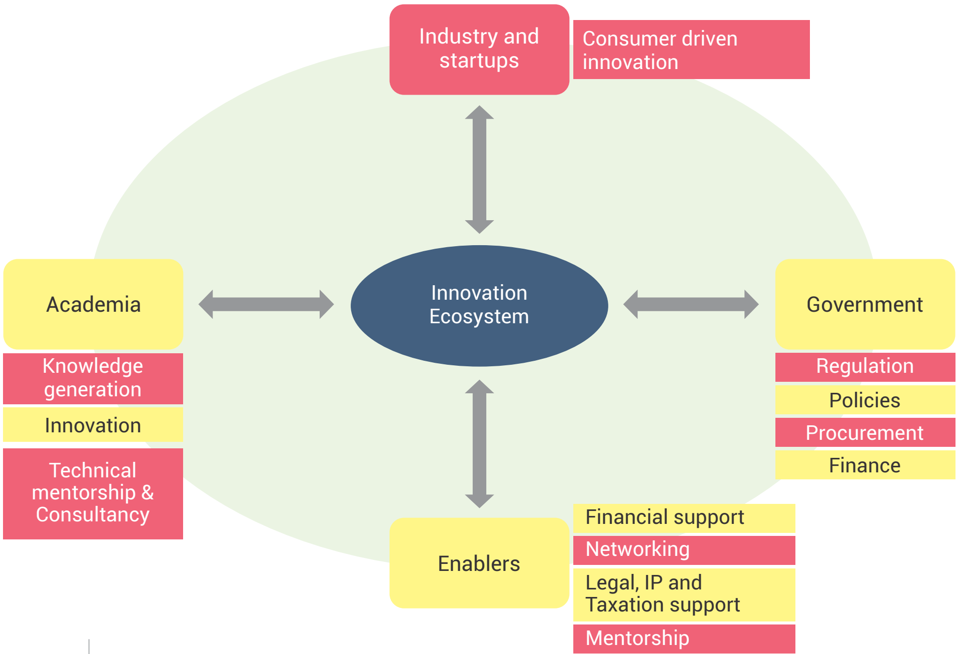


Figure 3.1 | Current status of ecosystem across A) Established clusters B) Emerging clusters

The present study focused on the underlying dynamics of ten clusters spread across south, central and western India- viz. Bengaluru, Hyderabad, Mumbai, Chennai, Pune, Ahmedabad, Thiruvananthapuram+Kochi, Bhopal+Indore, Bhubaneswar and Visakhapatnam. The report documents the inherent strengths and existing gaps in each of these clusters including the nature of interactions among the four stakeholders. Three of the ten clusters, Mumbai, Hyderabad, Bengaluru under study, are recognised as leading clusters in pharma and biotech in the country thus attracting new talent in industry, academia and enablers that come together to create a virtuous cycle. Chennai and Pune are making rapid strides in biopharma innovation, Chennai with its long standing pharma industry base and both cities leveraging their strengths in automotive and manufacturing industries as well as academic excellence. The Ahmedabad region on the other hand has been slow in adopting innovation in biopharma by leveraging its large pharma manufacturing base. Ahmedabad lacked the presence of strong life sciences research institutes like some of its more established peers and has only recently started establishing them. Other emerging life science clusters under study are still very nascent although several efforts are being taken by the state governments in Thiruvananthapuram, Visakhapatnam and Bhubaneswar.

Through a combinatorial approach of primary and secondary data and interviews with KOLs, the present study has teased apart the underlying tendencies of the ten clusters. Procurement by Government and public agencies is slowly improving in several areas. Many PHCs and district-level hospitals exercise their discretionary option to procure affordable equipment. The most viable model seems to be a Business to Business (B2B) model because convincing the clinical community on the benefit of a device is easier as compared to Business to Government (B2G) or Business to Consumer (B2C) approaches. . B2G models work well for public heath related and low cost technologies especially in India where there is a mismatch in focus areas with private investors and grant funding. The recent partnership of ICMR and BIRAC to promote life sciences startups displays positive trend towards better government procurements. With the Government encouraging entrepreneurship, further support in the last mile of public procurement would further add to the success of translation of innovation. Certain state governments like Karnataka have taken up initiatives such as grand challenges to enable procurements from well deserving startups at the end of the challenge grant. B2C models are often difficult for entrepreneurs considering the sales, distribution and marketing costs. In the last one year there have been several schemes by both central and state governments that have created a conducive environment for entrepreneurs. However the lack of regulatory transparency, standards and guidelines could pose a huge obstacle in the coming years if not addressed on priority. This lack of clarity also acts as a deterrent for early stage investors to fund startups.

India has over 150 Technology Business Incubators (TBIs) and incubation facilities supported by various national bodies such as NSTEDB, BIRAC and NITI Aayog. In addition to this there are a number of state supported incubation facilities. The government has played a significant role in providing support for initial establishment of several bio-incubation centres in majority of the clusters. As per the new Startup India Action Plan, there is a proposal to increase this number manifold. Many of these enablers currently play an important role in not only providing access to high end instrumentation facility to entrepreneurs and SMEs, but also facilitate networking and cross-domain interactions and more crucially, mentorship on various fronts including business and technical aspects. While infrastructural support for incubators is important, merely setting up more facilities would not address the numerous challenges that entrepreneurs face. Although cities like Bengaluru and Hyderabad have good support through mentor network, the emerging clusters are still working towards creating the vibrant culture.

On the funding front, various government schemes for innovation grant support are available today in India for taking an idea to the proof-of-concept stage - the first hurdle in the productisation value chain. Recent government initiatives such as the BIRAC AcE fund and the KITVEN equity fund provide early stage equity support to startups. The recently launched 'Innovate in India' (i3) programme of DBT plans to invest US$250 million in partnership with the World Bank over the next five years to accelerate the biopharmaceutical product development ecosystem. BIRAC is the implementing partner of this National Biopharma Mission. Although there was some stagnation in VC funding in India, the healthcare sector received over US$100 million investment in 2016. Several VC funds are expected to invest more in this sector in the following years. With all the recent developments there is now need for greater synergy between institutional funding and government grants to ensure adequate support for scaling deserving startups.

Academia plays a crucial role in any innovation ecosystem. There has been significant improvement in the research capacity of Indian academia. However several challenges still persist, especially in the realm of high quality basic research as well as translational research. Several national institutes of repute have adopted policies to encourage budding technopreneurs. Processes and policies in new institutes, especially in emerging clusters, are still evolving and several of them are working towards balancing basic and translational research capacity. Several new private universities have been trying to transform themselves from 'teaching only' institution to research driven institutes. Private universities such as KIIT, Amrita and VIT are partnering with industries and global research institutes to strengthen their research capacity in an accelerated manner. However many other private institutions need to still work on developing such programmes. Alignment with state policy instruments can help private universities make this transition smoothly.

Overall, reforms could be classified into short-term and long-term; short-term measures involve fixing of gaps in existing cluster support mechanisms like incubators, TTOs, instrumentation facilities etc., government procurement process and funding schemes that need further refinement; long-term involves reforms in education, research and regulations that are crucial in creating a suitable environment for innovation and entrepreneurship. The innovation status of emerging clusters in contrast to the mature clusters emphasises the need for long term reforms to enable development of innovation hubs across the country beyond a few mature clusters.

3.2 Recommendations from BRIC

The Indian biopharma and life sciences industry is expected to grow at about an average of 15% Year on Year. India is a leader in generic and API producer with several companies recording over 50% of their revenues in international markets. The strong talent pool, government policies and purchasing power further advance the potential of the sector. The stated goal of the Government of India is to achieve a US$100 billion bioeconomy by 2025. The biotech clusters, including those under study, will play a critical role in achieving the stretched target.

There are several gaps in the ecosystem - as highlighted in the report - that need to be addressed to be able to realise the growth potential. These gaps have been analysed and expectations from the stakeholders in the ecosystem have been captured. Several recommendations were provided in the first Phase of the study with many being addressed through initiatives launched in the past several months. A few recommendations have been retained on the basis of observation of the current status. A set of new recommendations have been proposed that could serve as possible action points for BIRAC.

1. **Knowledge generation:** Ensuring quality and relevance
   - Institutions with at least established scientific credentials through publications in peer reviewed journals and citation indices and innovative work could be selected for targeted translational programmes, primarily to promote truly interdisciplinary collaborations and disruptive technologies. Such collaborations should focus on co-development of products.
   - Capacity building of promising private institutions through increased funding for research and innovation.
   - Longitudinal studies in disease areas that need innovative solutions for diagnosis and treatment should be supported through specific programmes.

2. **Regulations and regulatory bodies**
   - Working with regulatory agencies to improve human resource capacity. PhDs /industry experience in various streams of science and engineering would enable better guidelines, clearances and due diligence. BIRAC could play the role of a facilitator for such initiatives with CDSCO.

3. **Capacity building at cluster level**
   - Programmes for established clusters:
     - Training programmes for individuals in Technology Transfer Offices (TTOs) in academic institutes and incubators to enable them to market technologies and negotiate licensing deals.
     - Setting up regional professionally managed TTOs to help institutes that cannot run their own TTOs effectively.
     - Setting up LARTA like bodies as one-stop solution for startup queries under a public private partnership.
     - Establishing institutes for technical training to strengthen vendor base with possible global collaborations.
     - Setting up incubation centres in a PPP model within industries that could serve as pilot plants for small scale manufacturing.
   - Setting up incubators in Tier II cities and emerging clusters. Well established incubation centres in nearby geographies could serve as mentors. Mentorship could include access to infrastructure, support and mentor network in addition to advice on operational aspects. This could also be viewed as incubating incubation centres and after a few years the new incubation centres could graduate and independently create their ecosystem. It is however important to identify local challenges that need to be addressed initially and sensitize the ecosystem in a tailor made fashion. Prominent institutes and industries in the region could serve as anchors to develop the ecosystem further. In addition, the emerging clusters could serve as satellite centres to various bodies proposed above.

4. **Funding**
   - Creating a 'CIBIL' like organisation to help funding bodies manage their funding better and also helping innovators secure funding on better terms. This should be available to all bodies to track good startups. The information could be used by VCs to encourage investment in technology heavy startups.
   - Cluster led activities: It is important for emerging clusters to focus and collaborate to accelerate growth and achieve critical mass. A government funded innovation grant which encourages collaboration between two or more institutes and at least one industry could possibly serve as the catalyst for this. Separate programmes for emerging and established clusters could be framed specifically to account for the advantages established clusters enjoy.

5. Platform for commercialisation of medtech products

- Several medtech startups struggle to commercialise their products due to their inability to offer an attractive product portfolio to its customers and face the competition from MNCs, and their lack of understanding of the sales and marketing channels. It will be useful to help build an aggregator platform that startups could leverage for marketing their products. Joint programmes in alignment with ICMR will be required to enable government procurement.

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