ABOUT THE REPORT

The study was undertaken with a mandate to build a deeper understanding of the capacity and gaps in the life sciences innovation ecosystem in India and develop targeted programmes to stimulate, foster and enhance biotech innovation and entrepreneurship in the Country.

This report maps the knowledge generation capacity, interaction between various stakeholders and gaps that hinder commercialisation of innovations largely around four biopharma and medical technology clusters in southern India (Hyderabad, Bengaluru, Chennai+Vellore and Thiruvananthapuram+Kochi). The findings of the study are intended to provide inputs for framing policies for sustained development of life sciences innovation ecosystems.

IKP KNOWLEDGE PARK

Innovation. Knowledge. Progress.

birac

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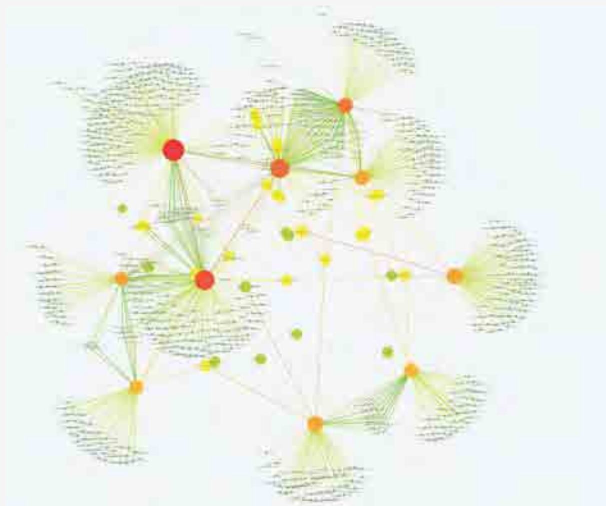
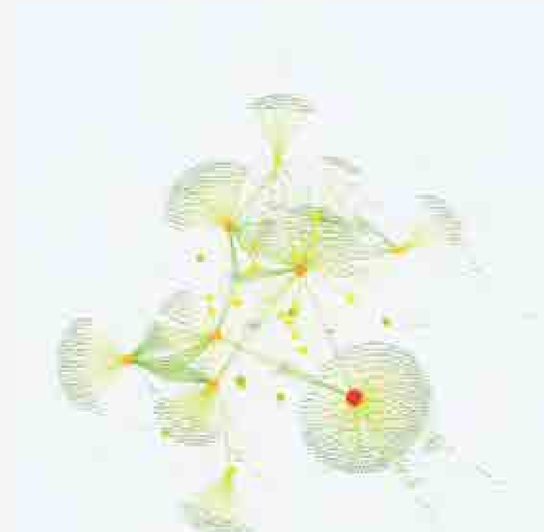
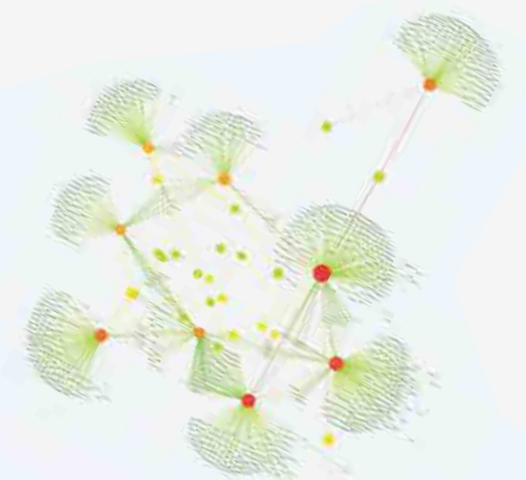
Biotechnology Industry Research Assistance Council

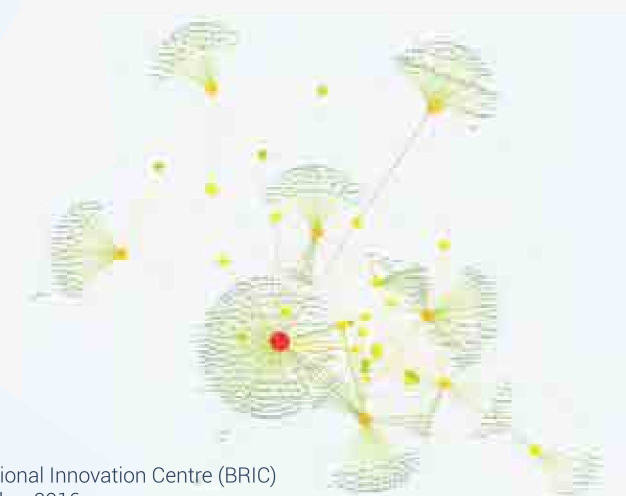




MAPPING REGIONAL INNOVATION ECOSYSTEMS:

A study of four life sciences clusters in southern India





BRIC

A BIRAC-IKP Initiative

A report from the BIRAC Regional Innovation Centre (BRIC) at IKP Knowledge Park, October 2016

MAPPING REGIONAL INNOVATION ECOSYSTEMS:

A study of four life sciences clusters in southern India

TEAM

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DISCLAIMER

This report was prepared by BRIC, a joint initiative by BIRAC and IKP Knowledge Park. The report leveraged from primary and secondary data as well as information drawn from various sources such as articles (peer reviews & general) including interviews with leading experts. The views expressed by experts are personal and should not be ascribed to the organisations that they are professionally engaged with. While due care has been taken to acknowledge all available sources and ensure accuracy of the information, however, no warranty, express or implied, is being made or will be made by BIRAC and IKP as regards to accuracy of the information contained within the report. Any omission is inadvertent and the copyright of the secondary information resides with the original source of information. The information and the views expressed in this document are not the stated official policy of BIRAC or the Government of India. This document intends to provide a general guide to the life sciences sector in the clusters of Hyderabad, Bengaluru, Chennai and Thiruvananthapuram.

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, especially in South India, which has been growing over the last decade. BRIC has catalysed several other roles including helping start-ups in understanding issues such as business models, IP, licensing and in navigating regulatory requirements for productisation, creating platforms such as technology showcasing, and connecting start-ups to relevant networks, especially with investors.

The report highlights the dynamism of the biotech sector in South India, particularly in the clusters of Hyderabad, Bengaluru, Chennai and Thiruvananthapuram through a detailed mapping of stakeholders, the drivers, the opportunities and the gaps that exist. 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 distill possible routes to create further impact.

The teams at BRIC, IKP Knowledge Park and Strategy Partnership & Entrepreneurship Development (SPED) division at BIRAC have synergistically collaborated to bring out this report. We appreciate the contributions by the experts of the BRIC Advisory Committee and all experts who have shared their insights for the report that will help us take the Indian biotechnology industry to the next level.

Dr. Renu Swarup

MD, BIRAC & Senior Adviser/Scientist H DBT

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FOREWORD

IKP Knowledge Park (IKP) has been keen to engage in policy making to give credence to its mission of building a world-class ecosystem for fostering leading edge innovation. The opportunity came three years back when IKP partnered with BIRAC to set up the BIRAC Regional Innovation Centre (BRIC) to map 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. Data was collected from secondary sources, surveys and interviews of Key Opinion Leaders and 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 start-ups 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. Vikraman Venu Saranyan, Mr. Neeraj Kathuria and Ms. Neeta Rai contributing at various phases. Dr. Satya Prakash Dash and Dr. Vinita Jindal at BIRAC also contributed throughout the study and preparation of the report.

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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, IKMC2014 and IKMC2015, chaired by Dr. MK Bhan. We appreciate the guidance and contributions made by the experts at the Roundtables.

Several experts in the four clusters covered by the study provided helpful comments and insights, made other contributions, and participated in consultative meetings/interviews. The team would like to thank the following:

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The team apologises to any individuals or organisations inadvertently omitted from this list.

LIST OF ABBREVIATIONS

API	Active Pharmaceutical Ingredient
BIRAC	Biotechnology Industrial Research Assistance Council
BMCRI	Bangalore Medical College and Research Institute
BRIC	BIRAC Regional Innovation Centre
CCMB	Centre for Cellular and Molecular Biology
CDFD	Centre for DNA Fingerprinting and Diagnostics
CDSCO	Central Drug Standard Control Organisation
CIFT	Centre for Fisheries Technology
CLRI	Central Leather Research Institute
CMC&H	Christian Medical College and Hospital
CPCB	Central Pollution Control Board
CRAMS	Contract Research and Manufacturing Services
CRO	Contract Research Organisation
DBT	Department of Biotechnology
DeitY	Department of Electronics and Information Technology
DIPP	Department of Industrial Policy and Promotion
DSIR	Department of Scientific and Industrial Research
DST	Department of Science and Technology
FDF	Finished Dosage Form
GM Crops	Genetically Modified crops
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
IISc	Indian Institute of Science
IISER-TVM	Indian Institute of Science Education and Research, Thiruvananthapuram
IITM	Indian Institute of Technology Madras
INPADOC	International Patent Documentation
InSTEM	Institute of Stem Cell Biology and Regenerative Medicine
IOB	Institute of Bioinformatics
IT	Information Technology
JNCASR	Jawaharlal Nehru Centre for Advanced Scientific Research
KMIO	Kidwai Memorial Institute of Oncology
KOL	Key Opinion Leaders
LVPEI	LV Prasad Eye Institute
mAbs	Monoclonal Antibodies
MNC	Multi-National Corporation
MSME	Micro, Small and Medium Enterprises
NCBS	National Centre for Biological Sciences
NIIST	National Institute for Interdisciplinary Science and Technology
NIMHANS	National Institute for Mental Health and Neurosciences
NIN	National Institute for Nutrition
NIRT	National Institute for Research in Tuberculosis
PSU	Public Sector Unit
R&D	Research and Development
RCGM	Review Committee on Genetic Manipulation
RGCB	Rajiv Gandhi Centre for Biotechnology
SCTIMST	Sree Chitra Tirunal Institute for Medical Sciences and Technology
SME	Small and Medium-sized Enterprises
TTO	Technology Transfer Office
UAS	University of Agricultural Sciences
UGC	University Grants Commission
US-FDA	United Stated Food and Drug Administration
VIT	Vellore Institute of Technology

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EXECUTIVE SUMMARY

In the current global scenario of liberalisation, globalisation and digitisation, several factors affect growth and changes in economies thus creating a need to study innovation. Innovation can be visualised as a complex interlinked network of various stakeholders in the ecosystem.

This report aims to understand the current status of the innovation ecosystem in four leading bio-pharma clusters in southern India through the analysis of primary and secondary data sources.

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 Start-ups were studied.

Primary analysis was carried out by interviewing Key Opinion Leaders (KOLs) 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 markers that define a regional innovation ecosystem such as publications, patents, company incorporations etc.

Distribution of stakeholders in southern clusters

This report focuses on studying various stakeholders in the four selected clusters - Hyderabad, Bengaluru, Chennai+Vellore, Thiruvananthapuram+Kochi. The number of academic institutions in Bengaluru and Chennai are high compared to the other two clusters. The Bengaluru and Chennai clusters exhibit a very similar distribution of the four stakeholders, the former led by innovative biopharma companies and strong basic research, and the latter by pharma and medical devices companies and strong technology institutions.

The large pharmaceutical industry in Hyderabad, dominated by API and formulation companies, has contributed to the large industrial base in the region as reflected by the fact that 48.8% of the 850 companies in the four clusters are in Hyderabad.

The Thiruvananthapuram+Kochi cluster lags behind in the count of industry players as well as suppliers, thus making it an emerging cluster.

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 four clusters, 33 institutes, with six from Hyderabad, eleven from Bengaluru, nine from Chennai+Vellore and seven from Thiruvananthapurum+Kochi, were chosen based on their research capabilities and focus for analysing their research output and contribution to the innovation ecosystem. The primary focus in most academic institutes is on publications and not patents. Chennai and Bengaluru have large institutes that are multidisciplinary and with a good number of scientists which is conducive for a vibrant collaborating environment. Scientists from Hyderabad have the maximum number of patents. 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.

The research productivity has been a clear focus area and therefore, several government and international funding schemes have been 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 . The yearwise number of publications per institution therefore shows a steady increase over the last 19 years. Although there was an exponential growth in the number of publications, there were several publications with poor citations. This phenomenon was observed in all clusters, but Hyderabad displayed a significantly better performance over other cities, having been able to maintain less than 10% publications with zero citation since 1998. There were very few publications in Thiruvananthapuram in the early 2000s and in comparison to other clusters, a larger fraction of these publications haven't been well cited.

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 the four clusters had very few subject areas where the minimum threshold of 50 publications in any year was exceeded.

Industry

The economic liberalisation in India which was initiated in 1991 led to a large number of companies being incorporated and created the much needed entrepreneurial culture.

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 owing to the presence of IISc for over a century and more recently, JNCASR and NCBS as well as several other research institutes and PSUs. Several MNCs started their operations in this region from the 70s leading to the 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 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 background. 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 are fairly low in Thiruvananthapuram, which could be attributed to the prevailing industrial environment in the State. There is, however, immense potential in this cluster.

Of the total number of industries in the four clusters, 85 companies (including start-ups) were selected for deeper analysis. A general view of the total number of patents, total number of publications and total number of collaborators in each cluster clearly points towards the focus on patents in companies, a trend which is starkly different from 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 far reaching impact in interdisciplinary work or co-development projects with industries and hospitals.

The data revealed that most cities have a larger number of collaborators outside India than within the country with an average of about 40% of the collaborations within India.

The number of truly interdisciplinary research programmes 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

For entrepreneurs to thrive, in addition to research infrastructure, an entire support structure is required especially during initial stages. Bengaluru, Hyderabad and Chennai are well-developed clusters with a good support structure. Also, these states have start-up policies specifically focused on improving the overall hygiene factors that attract enterprise. Kerala is catching up with these cities with its new start-up policy.

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 production with several companies recording over 50% of their revenues from 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 in south India, will play a critical role in achieving the stretched target. However, there exist 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 to provide the following recommendations:

1. Knowledge generation

Ensuring quality and relevance:

- Making it mandatory to include parameters such as H index for appraisals and promotions; Tenure track positions to be awarded on review after a few years
- Encouraging sabbaticals to explore new frontiers and stay up-to-date with emerging applications
- Incentivising younger faculty by reducing number of years of service to qualify for sabbaticals; promotions and incentives to be given for faculty who manage to succeed and return back to academia
- Institutions with good publishing records could be selected for targeted translational programmes primarily to promote truly interdisciplinary collaborations; such collaborations could look beyond publications and include co-development of products
- Bringing in the culture of translational research in academia and research institutions through sensitisation and awareness programmes, and create a vibrant conducive ecosystem
- Change in academic policy to include performance matrix which takes into account entrepreneurial achievements, IP, technology licensing for faculty promotion
- Capacity-building of promising private institutions through increased funding for research
- Connecting private academic institutions with public institutions for joint innovation research
- Greater emphasis on academia-industry collaborations especially in the realm of product development

2. Regulations and regulatory bodies

- Improving the human resource capacity of the regulatory agencies especially provision for wider backgrounds of regulators rather than purely pharma graduates. PhDs/industry experience in various streams of science and engineering would enable better guidelines, clearances and due diligence
- Policy changes in public procurement of innovative products, greater transparency in public procurement
- Greater fiscal and tax credits to support innovation driven R&D in industry; special tax provisions/incentives in VC/Angel investments for R&D core companies in defined focus areas; these could be adapted from Israel, Singapore or New Zealand
- Antidumping duties on imported goods in specific focus areas would benefit DIPP recognised start-ups by enabling competitive pricing of their technologies

3. Capacity-building in enabling ecosystems

- Training programmes for individuals in Technology Transfer Offices (TTOs) in academic institutes to be able to market technologies and negotiate for reasonable valuations
- Setting up regional professionally managed TTOs to help institutes that cannot run their own TTOs effectively
- One-on-one networking forums especially for entrepreneurs, through incubators; although this is implicit, certain number of unique, value-added interactions should be mandated
- Presence of active clinical advisors in incubators to help improve connect with clinical requirements and enable easier acceptance when clinicians are end users
- Setting up Technology Business Incubators in veterinary institutes for conducting large animal studies and trials
- Incubators, science parks to be supplemented with pilot scale plants and packaging facilities to accelerate the manufacturing capabilities of start-ups
- Setting up LARTA like bodies as a one stop solution for start-up queries under a PPP
- Establishing more institutes for technical training to strengthen the vendor base with possible global collaborations

4. Funding

- Need for follow-on funding: To initiate a greater number of follow-on funding schemes through public agencies as well as through PPP models
- Large ticket size grants: There is a need for larger quantum of grants especially beyond the proof of concept stage for high risk product development; this could be both in the areas of national priority and in high global opportunity segments
- Sensitisation: Sensitising Angel and VC funders on the intricacies of life science product development and need for more events connecting start-ups to private funders
- Creating a 'CIBIL' like organisation to help funding bodies manage their funding better and also help innovators secure funding on better terms. This should be available to all bodies to track good start-ups. The information could be used by VCs to encourage investment in technology heavy start-ups
- Policies on engaging the diaspora would be advantageous in the long run not only monetarily but also in the transfer of technological knowhow

Chapter 1

SETTING THE CONTEXT

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 was undertaken largely around four biopharma and medical technology clusters in southern India. The aim was to understand the knowledge generation capacity and interaction between various stakeholders in the ecosystem and identify gaps that hinder commercialisation of innovations.

This report summarises the findings 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), GoI 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 is a science park and incubator with over fifteen years experience in promoting research-based companies and creating an ecosystem for fostering leading-edge innovation. IKP has partnered with BIRAC on several programmes including the Biotechnology Ignition Grant (BIG), Biotechnology Incubation Support Scheme, Grand Challenges in TB Control and Grand Challenges Explorations in health.

1.2 An introductory note on innovation mapping

1.2.1 Need for mapping

In the current global scenario of liberalisation, globalisation and digitisation, several factors affect growth and changes in economies driven by knowledge flows and interactions among the various elements of an innovation ecosystem, thus creating a need to study innovation.

Figure 1.1 | Factors impacting Innovation at the global scale
Adapted from M. Nair, 2011

Mapping innovation ecosystems primarily aids in understanding the process of innovation. In addition, it assists in determining the impact of innovation on multiple interconnected topics such as economic growth, human development and social / institutional endowment. Such studies provide grounds for new approaches for technology policies of governments.

Traditionally, most government interventions in the technological areas have been directed towards correcting market failures. With the motive of maximising returns to the society, governments have relied on instruments such as R&D tax credits and subsidies. Understanding National Innovation Systems as a concept provides a systemic approach and directs the attention of policy makers to systemic failures that impede innovation in industries and public agencies. Several factors such as lack of interaction between the actors in the system, mismatch between basic research in academia and applied research in industry, malfunctioning of technology transfer institutions, and information and absorptive deficiencies on the part of enterprises may all contribute to the poor innovation performance of a country.

A systemic study could help identify networking schemes, lay emphasis on improving interaction between stakeholders in enterprises and institutions, enhance the innovative capacity of firms, and promote research and advanced technology partnerships with government. Technology policies should aim at increasing the capability to innovate and adapt new technologies, as well as the diffusion of available equipment and technologies.

Such an exercise can provide insight into areas requiring further study and / or intervention. Moreover, tracking the changes in inputs, capabilities and outputs over time can help ascertain the success / failure and effectiveness of interventions in these areas. It also forms a platform to identify indices for measurement of outputs. Thus, beyond passive reporting of facts, such studies would provide actionable insights to policymakers.

> *The trick for governments is to strike the balance between trying to let as many flowers bloom as possible and recognising those which are really not going to bloom and to stop feeding that pot plant.**
>
> David Gill
> Managing Director of St. John's Innovation Centre

In the Indian context, studying innovation ecosystems at sectoral and regional levels are particularly relevant to identify important systemic roadblocks which may be lost within an aggregate measure.

Finally, innovation mapping is an evolving process. Several shortcomings in data collection processes could be revealed in the course of undertaking an innovation assessment exercise, which could eventually lead to more robust data and better analysis.

The past few decades have seen significant interest in innovation studies among research scholars, national governments and global agencies. The Global Innovation Index, co-published by Cornell University, INSEAD, and the World Intellectual Property Organisation (WIPO), for example, with its rich database of detailed indicators serving as a tool for evaluation and improvement, has attracted much attention. The box on the adjoining page captures some important innovation measurement frameworks.

**Lawlor, A. "Innovation ecosystems. Empowering entrepreneurs and powering economies." The Economist Intelligence Unit (2014)*

Measurement frameworks: Chronological listing

Many of the studies have evolved based on the models of innovation and appropriate definitions of the concept of innovation. The 1960s saw proxy-based surveys and studies on innovation using patents and publications. The first proper innovation survey conducted by NSF, USA between 1963 and 1967 examined 567 technical innovations from 121 firms in 5 manufacturing industries. The study examined sources, nature, costs and impact of innovations. During the 70s and 80s, Germany and other member countries of the Organisation for Economic Cooperation and Development (OECD) had adopted several approaches that combined both activity- and impact-based approaches.

Representative studies on innovation:	
1972-1986	OECD: Innovation policies
1973-1976	OECD: Innovation in services
1978-1981	OECD: Innovation in SMEs
1981-1989	OECD: Review of innovation policies (France, Ireland, Spain, Yugoslavia and Western Canada)
1992-2015	OECD: Oslo manual
1994-1998	OECD: Best practices in technology policies
1994-2001	OECD: National Systems of Innovation (NSI)
1996-1997	OECD: Technology diffusion
2006-2009	OECD: Innovation microdata project
2008- 2015	OECD: Innovative learning environments
2011-2013	OECD: Innovation, research and higher education
2013	WIPO: The informal economy, innovation and intellectual property - concepts, metrics and policy considerations

1.2.2 Models for studying innovation

Understanding of the nature of innovation processes has evolved over the last two decades. It began with the linear or static model of innovation which assumes a unidirectional flow of information and a well-defined set of stages that innovations are assumed to go through. The assumption is that research is followed by development, and finally leads to production and marketing. Since research comes first, it is easy to think of this as the rate limiting or causative step in innovation. However, there are problems associated with this model. First, the model generalises the chain of processes but this might only account for a minority of innovations. Industrial innovations are normally motivated by market demand and expected commercial gains and commonly begin with reviewing and combining existing knowledge. In many settings, the experience of users, not science alone, is considered to be the most important source of innovation. Second, this model ignores the existence and need for feedbacks and loops that occur between different stages of the process. Shortcomings and failures that occur at various stages may lead to a reconsideration of earlier steps, and this may eventually lead to totally new innovations. Effective innovation happens only with rapid and accurate feedback accompanied with appropriate follow-on actions.

Considering the dynamic nature of innovation processes, scientists and policymakers have often argued to look at innovation from its systemic characteristics instead of the traditional linear model. The concept of innovation system stresses that innovation should be seen as an evolutionary, non-linear and iterative process requiring intensive communication and collaboration between different actors of the system including within companies, and between firms and other organisations such as universities, research institutes, funding institutions, standard setting bodies, industry associations and government agencies (Figure 1.2). This necessitates policy makers to strengthen the innovation system so that knowledge is generated and flows smoothly among different actors of the system.

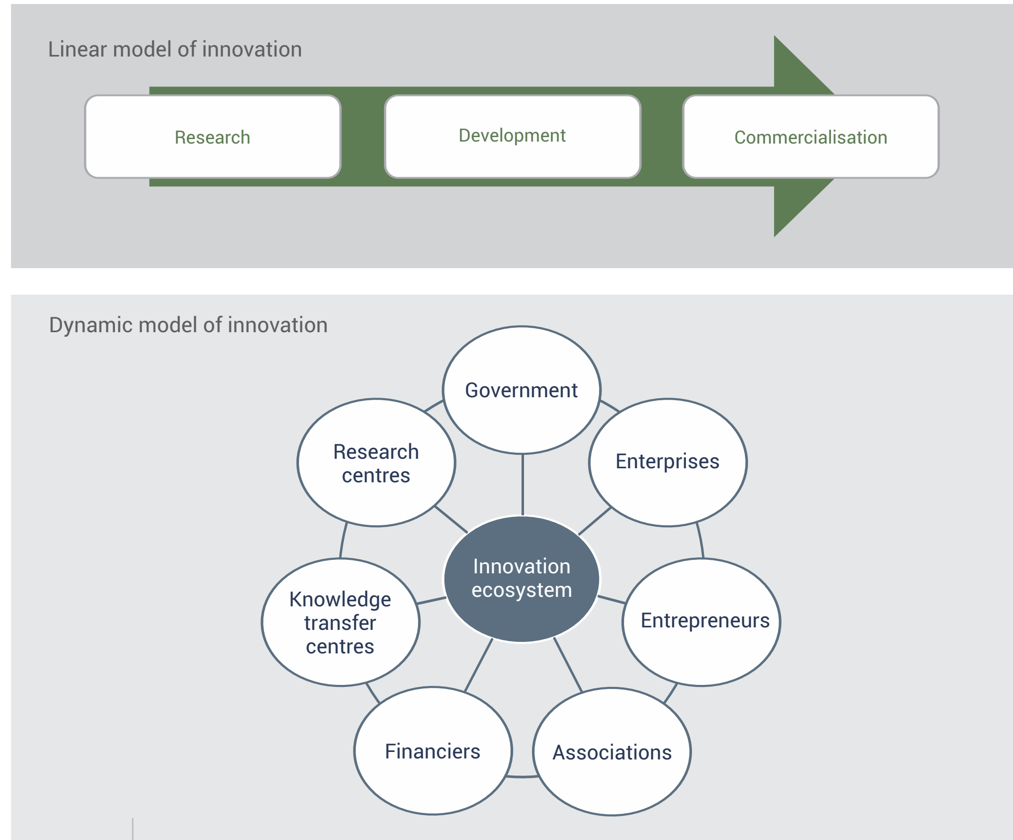


Figure 1.2 | Linear and dynamic models of innovation

The Dynamic model differs from the Linear model in a number of ways. There are multiple paths from which innovations may arise with many forms of feedback. Research is not normally considered to be the initiating step and is a contributing factor to all phases in the innovation process. Therefore, a holistic model of innovation attempts to understand the role of knowledge, design and development capacity in the context of a dynamic interaction between markets, production, design and development (D&D), industrial research and development (R&D) and basic research.

Firm-centric innovation

Assessment of the state of innovation of an ecosystem goes beyond the impact of individual programmatic efforts. The economic success of an ecosystem depends on the social as well as technological indicators. Therefore, innovation can be visualised as a complex interlinked network of various stakeholders in the ecosystem where the firm features at the centre of the ecosystem.

As per this framework:

- Knowledge generation primarily happens at universities / research institutes / government bodies / industries and these may be either in a communicated format such as patents / publications / reports or human capital and the knowledge is represented by the ideas from which novel products and processes emerge.
- Innovation facilitation is taken up by enablers who play intermediary roles in facilitating through financial support, networking capabilities and mentoring / advice.
- Policy-making in the areas of trade, intellectual property, sector specific regulations, governance, transparency and corruption could affect the health of an ecosystem.
- Demand is a crucial component which reflects the needs and preferences of market customers, other end users, and governments.

The Triple helix and Quadruple helix models

The Triple helix model is a dynamic model where the strands of the helix (or institutional spheres) are represented by three influencing stakeholders, namely academia, industry and government, with the possibility of different types of outcomes when two or more stakeholders interact. The Quadruple model is an extension of this model where the fourth stakeholder is the citizen group of an innovation ecosystem. In these models, the institutional spheres of university, industry, and government, in addition to performing their traditional functions can assume the roles of the others. Examples would include spin-offs from universities or universities performing a quasi-governmental role as a regional or local innovation organiser and internalisation of the R&D division in industries leading to complex organisations.

Each of the above models has its own merits and adoption of a model would depend on the purpose for which an innovation system is being studied.

1.2.3 Framework used in the current study

The current study uses a framework that is a variant of the dynamic model and adopts elements from the firm centric and the two helix models. The aim of this report is to identify gaps that hinder innovation rather than measurement of innovation through an index. This is primarily because the life sciences innovation ecosystem in India is still emerging, and transfer and translation of technology are not yet common.

According to the framework, there are primarily four stakeholders - academia, industry, government and enablers (Figure 1.3). Each of these stakeholders either interacts directly or indirectly through other stakeholders. The primary role of each stakeholder is as follows:

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

Industry and start-ups: Large industries and start-ups are very different in their focus on innovation and the obstacles that plague them. Since industries are profit driven, they serve as a 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 start-ups through incubation, financial support, business, and legal and regulatory mentorship. In an ecosystem that is in its infancy, enablers take a central role in networking between stakeholders.

Government: The government plays a crucial role in catalysing innovation through policies and 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 an analysis of publications and collaborations between scientists in industry and academia. A detailed survey with various stakeholders in each city aims to capture the current status in terms of knowledge, interaction and support.

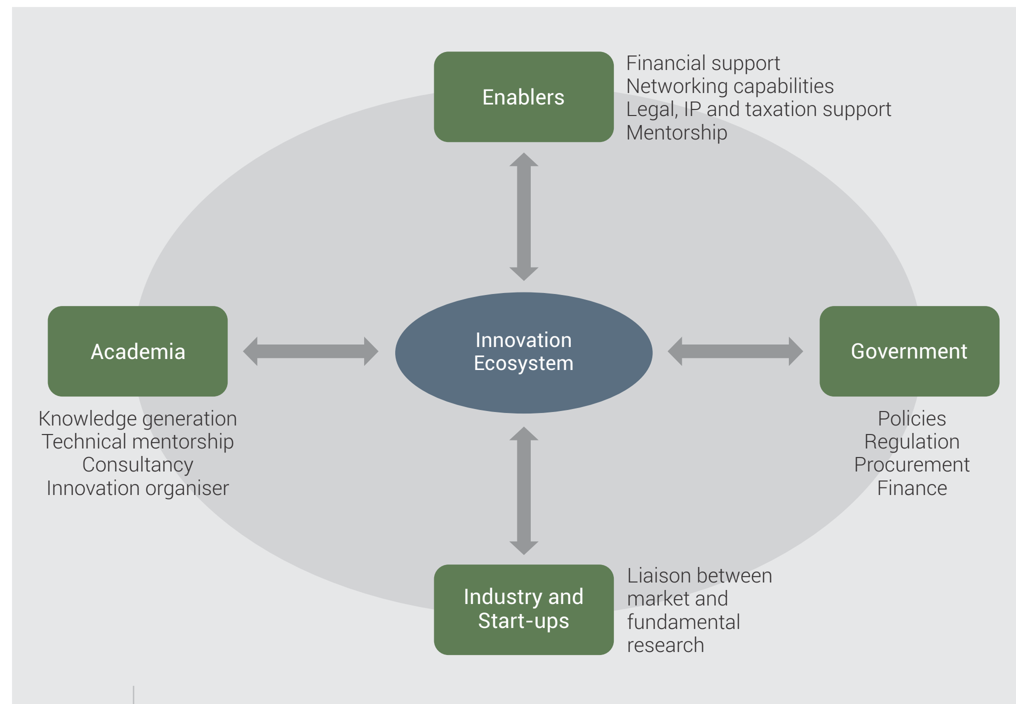


Figure 1.3 | Framework used in the study

Institutions / organisations that could be studied while assessing the health of an innovation ecosystem are given in Table 1.1 below.

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/ networks	Local government	Teaching hospitals	High schools	Consumers	Communications (mobile, internet)	Schools
Foundations	Legal services			Colleges	Distribution networks; suppliers	Communications (mobile, internet)	Professional associations
Microfinance institutions	IP services				Retail networks	Other utility providers (gas, water)	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 | Various bodies to be studied while understanding current status of ecosystem

1.2.4 Mapping innovation at various levels

Innovation can be mapped at various levels depending on the scope of the study and the inputs that may be derived from it. The National Innovation System (NIS) and the Regional Innovation System (RIS) approaches use geographic demarcations to elucidate the systems while the Sectoral Innovation System (SIS) approach focuses on innovations pertaining to specific sectors of the economy (Figure 2.4).

Studying sectoral systems are particularly useful since these are prone to change that may be caused by technology advancements in the sector coupled with patterns of innovation which require new competencies. Consumer demand can also serve as another source which may cause the birth of new firms that are disruptive in nature.

Overall, these dynamics are co-evolutionary in nature, eliciting change at the levels of technology, knowledge, actors and institutions. Therefore, a multilevel model has been adopted in this report where we have used a combination of regional and sectoral innovation (SIS in this study involves a specific sector within the RIS) systems mapping in light of national level policies to be able to capture the finer details while retaining the systemic flavour.

A

	NIS	RIS	SIS
Main actors	• Industry • Government • Education and research organisations	• Universities • Industrial establishments • Public research organisation • Local government / city councils	• Firms • Universities • Government • Technical associations • Individuals
Institution	• National policies • Laws • National finance supports	• Informal institutions depending on trust and reliability among actors • Support institutions (VCs, incubators, law firms etc.) • Informal associations (angel networks, mentors, associations)	• Standards • Regulations
Main interaction	• Joint industry activities • R&D collaboration • Technology diffusion • Personnel mobility	• Inter-firms activities • External interactions for firms with research organisations • R&D collaboration	• Inter-industry interactions • Interactions among firms and non-firm organisations

B

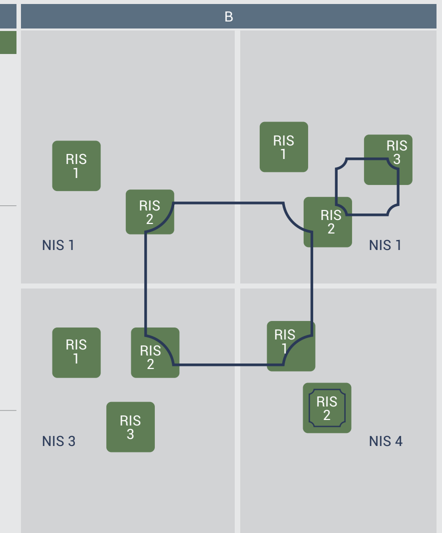


Figure 1.4 |
a) Table summating main differences between various approaches to study innovation
b) Schematic representation differentiating NIS, RIS and SIS approaches; SIS may be at three levels spanning internationally, across multiple RISs and within an RIS (indicated as black boxes) - Adapted from S. Gao et al

Chapter 2

ANALYSIS OF FOUR 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 four leading life sciences clusters in southern India through analysis of primary and secondary data sources. 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 Start-ups 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 start-ups 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 Start-ups, in a particular domain, either collectively or individually constitute that domain industry and 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 services outsourced on a contract basis

Start-up: 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 start-up is usually a company such as a small business, a partnership or an organisation designed to rapidly develop 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 start-up under the following conditions:

- Up to 5 years from the date of its incorporation / registration, and
- 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: Governing bodies play a major role by formulating policies, providing funding and infrastructure to the innovation ecosystem. Examples of Central Government 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 start-ups and life sciences.

Funding agencies: 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 start-ups and providing various services and customised space to innovative companies and institutions and helps in knowledge and technology exchange between various actors.

Business associations: They represent the cause of businesses at local, national or international level and convey industry requirements to the government.

Law firms 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.

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 of publications from the institute)).

Clusterwise normalised citation index = (Normalised citation index / number of institutes).

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

2.1.2 Data sources

In this report, all the publication and patent datasets were collected from Thomson Reuters database. More specifically, publication data was sourced from Thomson Reuters 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 taken for the study which included articles, book chapters, proceedings papers, biographical items, erratum, 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, the period of study was from year 1996 to 2014, whereas that for patents was all years. 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 start-ups with a limited database of their own. Therefore, several early stage companies might not have been included.

- 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 India, a detailed study of key stakeholders, academia, industry, suppliers and enablers around the cities of Hyderabad, Bengaluru, Chennai+Vellore and Thiruvananthapuram+Kochi regions was performed.

Chennai+Vellore cluster includes the city of Vellore as it has renowned colleges such as VIT and CMCH and is proximal to Chennai. In Kerala, Thiruvananthapuram+Kochi were studied together as a single emerging cluster.

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 across the four clusters for the study. 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, funding, infrastructure and enablers. The list of academic institutes in the four clusters is provided in Table 2.1. UAS in Bengaluru was considered due to its proximity to NCBS and involvement in several agri-biotech projects for field trials.

Hyderabad	Bengaluru	Chennai+Vellore	Thiruvananthapuram+ Kochi
CCMB	BMCRI	Anna University	Amrita University
CDFD	IBAB	CLRI	CIFT
IICT	IISc	CMC&H	IISER-TVM
LVPEI	InSTEM	IIT-M	NIIST
NIN	IOB	NIRT	RGCB
University of Hyderabad	JNCASR	Sathyabama University	SCTIMST
	KMIO	SRM University	University of Kerala
	NCBS	University of Madras	
	NIMHANS	VIT UNIV	
	ST. JOHNS		
	UAS		

Table 2.1 | The list of institutes selected for detailed study in Hyderabad, Bengaluru, Chennai+Vellore and Thiruvananthapuram+Kochi

2.2 Analysis of clusterwise data

This report focuses on studying various stakeholders in the four selected clusters of Hyderabad, Bengaluru, Chennai+Vellore, Thiruvananthapuram+Kochi. Figure 2.1 gives the overall distribution of the four major stakeholders - academia, industry, suppliers and enablers, in the selected clusters. The number of academic institutions in Bengaluru and Chennai are high compared to the other two clusters. The Bengaluru and Chennai clusters exhibit a very similar distribution of the four stakeholders, the former led by innovative biopharma companies and strong basic research, and the latter by pharma and medical devices companies and strong technology institutions.

The large pharmaceutical industry in Hyderabad, dominated by Active Pharmaceutical Ingredient (API) and formulation companies, has contributed to the large industrial base in the region as reflected by the fact that 48.8% of the 850 companies in the four clusters are in Hyderabad.

The Thiruvananthapuram+Kochi cluster lags behind in the count of industry players as well as suppliers, thus making it an emerging cluster.

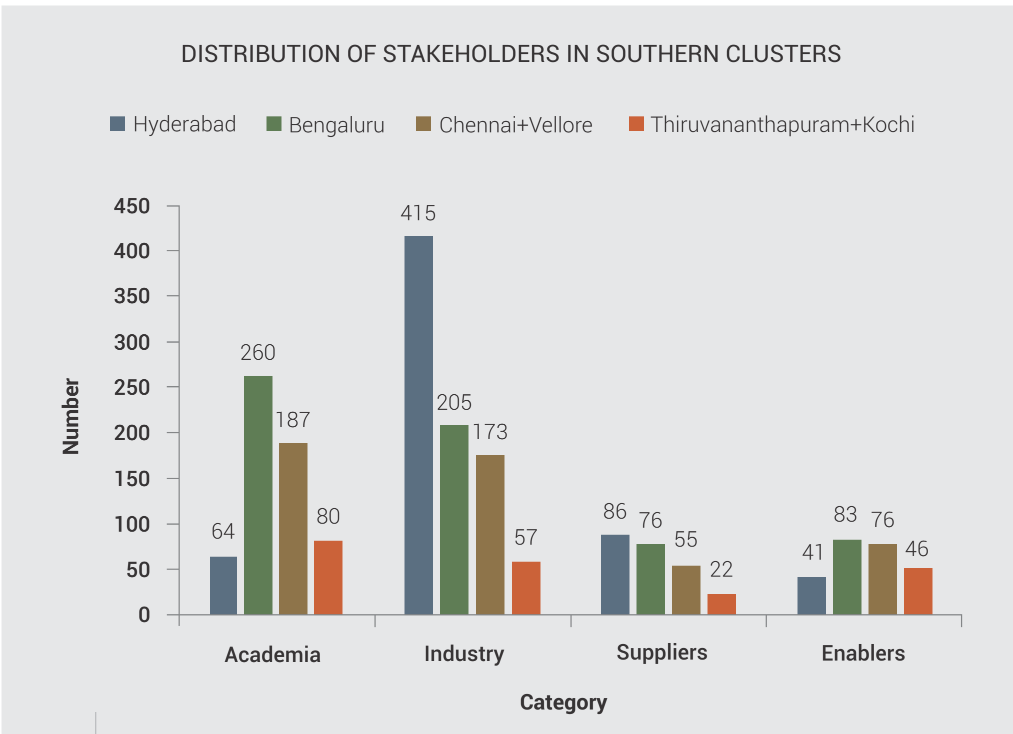


Figure 2.1 | Distribution of stakeholders (Academia, Industry, Suppliers and Enablers) in Hyderabad, Bengaluru, Chennai+Vellore and Thiruvananthapuram+Kochi
The scale represented gives the raw numbers of these stakeholders

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 be able to ascertain the role 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, may be 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 four 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 access to several sophisticated equipment. Institutes such as IISc, IITM, CMC, IICT have been instrumental in creating the wealth of knowledge in these clusters. They 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 and Bengaluru 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 the stream of life sciences, academic institutes alone cannot contribute to all aspects of innovation for commercialisation. Support through the clinical community provides an edge to the Bengaluru cluster.

Thiruvananthapuram seems to have fewer numbers of institutions across all categories indicating that it is still an emerging cluster.

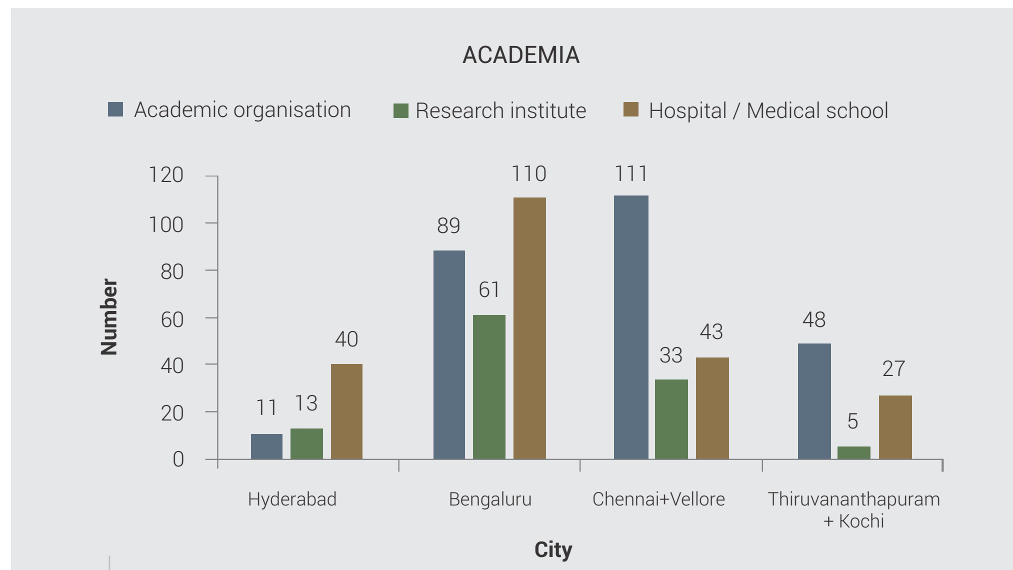


Figure 2.2 | Distribution of academic institutes in four south Indian clusters

Number of publications

Out of the large pool of academic institutions in the four clusters, 33 institutes (6 from Hyderabad, 11 from Bengaluru, 9 from Chennai+Vellore and 7 from Thiruvananthapuram+Kochi), were chosen, based on their research capabilities and focus on analysing their research output and contribution to the innovation ecosystem. Figure 2.3 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 Bengaluru have large institutes that are multidisciplinary and with a good number of scientists which is conducive for a vibrant collaborating environment. Scientists from Hyderabad have the maximum number of patents. 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.

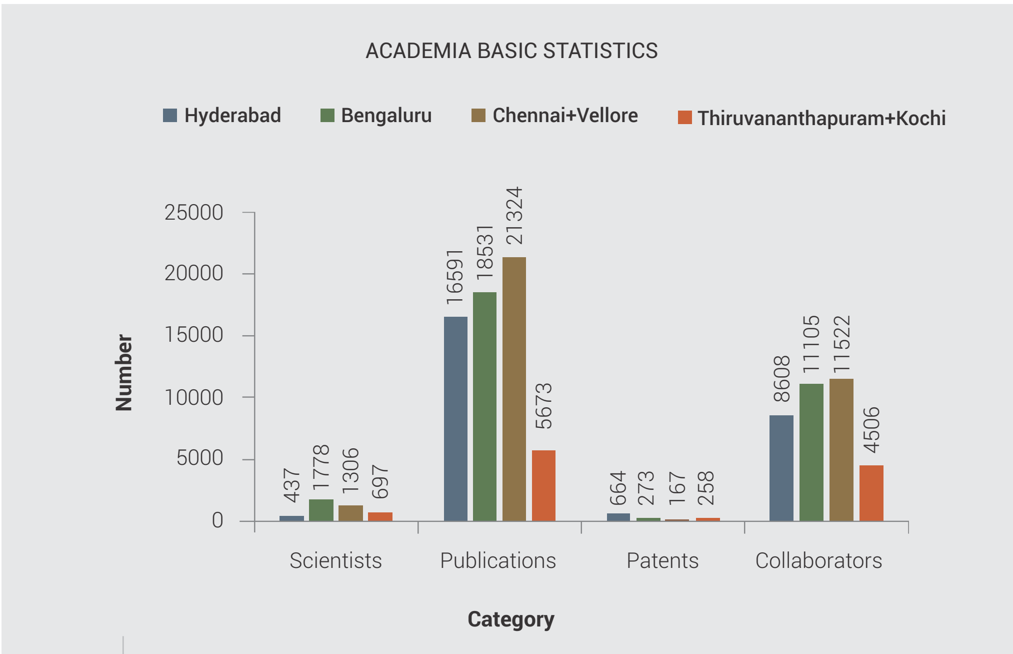


Figure 2.3 | A glimpse into knowledge creation in academic institutes through publications, patents and collaborations

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 2.4 highlights the research productivity of each institute as a function of the average number of publications per scientist.

Hospital / Medical schools in Bengaluru, Chennai+Vellore and Thiruvananthapuram+Kochi clusters have high number of scientists (doctors) but their publication (research) activity is comparatively much lower, thus leading to lower averages. Research institutes that are part of hospitals may have a disadvantage in comparison to pure research institutes. 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 is restricted to new treatment or surgical procedures and occasionally, clinical trials.

From Figure 2.4, 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:

- Institutes such as IISc, IICT and JNCASR have very 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.
- In addition, 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 inputs or cell lines.
- Older institutes always 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 IICT were established in 1909 and 1944 respectively and have almost a century of experience in research activities in comparison to institutes such as Amrita University and InSTEM that were established only in 2003 and 2009 respectively.

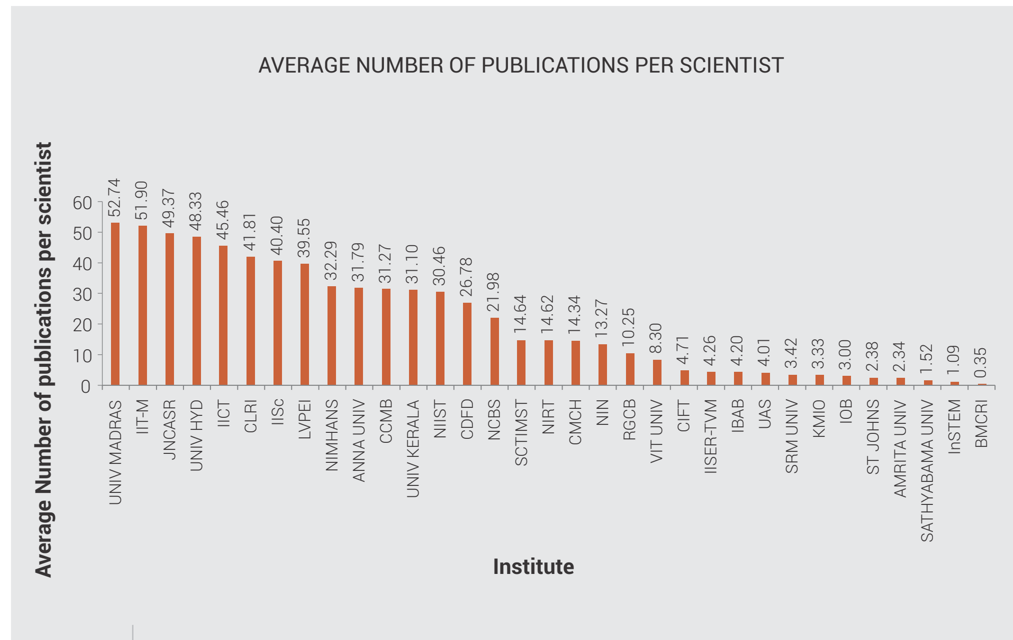


Figure 2.4 | Graphical representation of average number of publications per scientist in the institutes under study

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 .

A stagnation or drop in the number of publications was observed between 2008-2010 possibly linked to overall budget cuts in funding (Figure 2.5). The exact period, extent and pattern varied across institutions depending on the nature of work. Institutes that are into theoretical work show a quicker drop than those working in areas that take longer time periods to publish. However, with improved funding and several schemes to promote cross-country collaborations, the numbers across most institutions were observed to be increasing with a peak from 2014 .

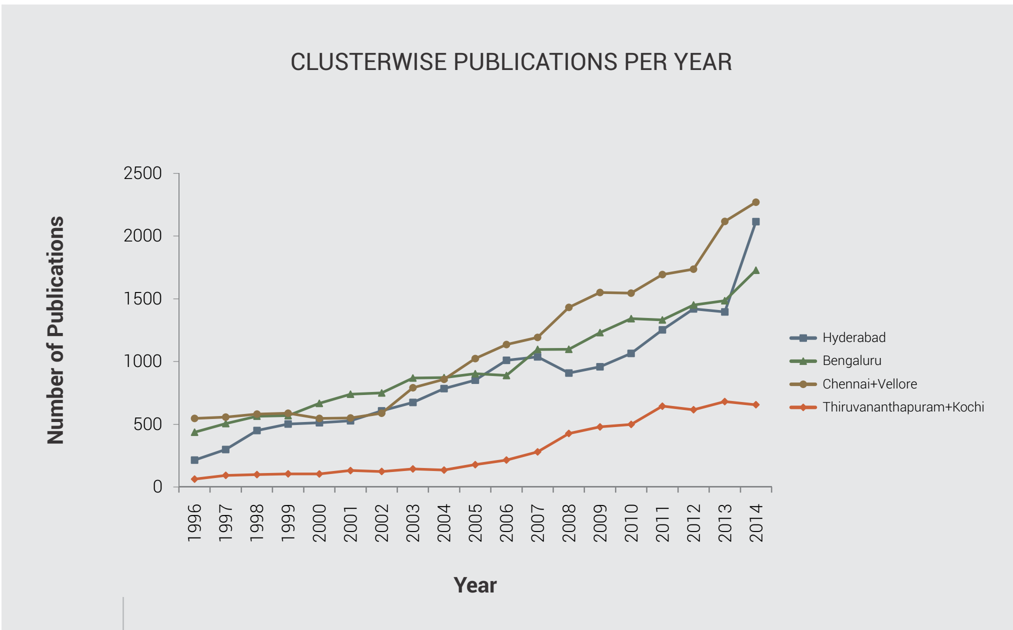


Figure 2.5 | Yearwise growth in publication number in the four clusters

Citation index

A measure of how well the research is received is through citation index which 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.

Initially, institutewise citation indices were analysed in each of the clusters. It was observed that several institutions had an abnormally high number of citations. Certain types of studies such as clinical trials or databases yield high citations due to their wide applicability. Such publications are however, not commonly observed. The publications which cause a peak in normalised citation index are listed in Table 2.2.

CLUSTER	INSTITUTE	YEAR	TITLE	AUTHOR	NO. OF TIMES CITED
HYDERABAD	CCMB	2005	Mechanism of thioflavin T binding to amyloid fibrils	Singh, S	285
	CDFD	2000	Beta- and gamma-turns in proteins revisited: A new set of amino acid turn-type dependent positional preferences and potentials	Guruprasad, K	103
	CDFD	2002	Distinct role of CD80 and CD86 in the regulation of the activation of B cell and B cell lymphoma	Agrewala, JN	115
	CDFD	2005	Single-walled carbon nanotube induces oxidative stress and activates nuclear transcription factor-kappa B in human keratinocytes	Manna, SK	372
	CDFD	2005	Human resistin stimulates the pro-inflammatory cytokines TNF-alpha and IL-12 in macrophages by NF-kappa B-dependent pathway	Mukhopa-dhyay, S	238
	IICT	2001	Lithium perchlorate catalysed reactions of indoles: An expeditious synthesis of bis(indolyl)methanes	Yadav, JS	242
	IICT	2002	Layered double hydroxide supported nanopalladium catalyst for Heck-, Suzuki-, Sonogashira-, and Stille-type coupling reactions of chloroarenes	Sreedhar, B	552
	IICT	2003	Natural product hybrids as new leads for drug discovery	Chandra-sekhar, S	228
	LV PRASAD	1998	The epidemiology of dry eye in Melbourne, Australia	Bansal, AK	289
	NIN	2000	Prevention of diarrhoea and pneumonia by zinc supplementation in children in developing countries: Pooled analysis of randomised controlled trials	Shankar, A	386
	NIN	2005	Human resistin stimulates the pro-inflammatory cytokines TNF-alpha and IL-12 in macrophages by NF-kappa B-dependent pathway	Silswal, N	238
	UNIV. OF HYD.	1998	Crystal engineering and organometallic architecture	Desiraju, GR	1097
	UNIV. OF HYD.	1998	C-H center dot center dot center dot F interactions in the crystal structures of some fluorobenzenes	Desiraju, GR	488
	UNIV. OF HYD.	2002	Hydrogen bridges in crystal engineering: Interactions without borders	Desiraju, GR	1377
	UNIV. OF HYD.	2003	Recent advances in the Baylis-Hillman reaction and applications	Basavaiah, D	1366
BENGALURU	IISc	2000	Dielectric relaxation and solvation dynamics of water in complex chemical and biological systems	Biman Bagchi	558
	INSTEM	2012	Harnessing the Mesenchymal Stem Cell Secretome for the Treatment of Cardiovascular Disease	Abramson, Jeff	132

CLUSTER	INSTITUTE	YEAR	TITLE	AUTHOR	NO. OF TIMES CITED
	IOB	2003	Development of human protein reference database as an initial platform for approaching systems biology in humans	Pandey, A	616
	IOB	2004	Oncomine: A cancer microarray database and integrated data-mining platform	Pandey, A	841
	IOB	2006	Human protein reference database - 2006 update	Pandey, A	366
	IOB	2007	Global proteomic profiling of phospho-peptides using electron transfer dissociation tandem mass spectrometry	Pandey, A	344
	JNCASR	2004	Metal carboxylates with open architectures	Rao CNR	1606
	JNCASR	2009	Graphene: The New Two-Dimensional Nanomaterial	Rao CNR	1584
	KMIO	2003	Human papillomavirus and oral cancer: The international agency for research on cancer multicenter study	Pintos, J	556
	KMIO	2001	Superior efficacy of letrozole versus tamoxifen as first-line therapy for postmenopausal women with advanced breast cancer: Results of a phase III study of the international letrozole breast cancer group	Bapsy, PP	606
	NCBS	1998	GPI-anchored proteins are organised in submicron domains at the cell surface	Mayor, S	839
	NCBS	1999	Emergent properties of networks of biological signaling pathways	Bhalla, US	904
	NCBS	2002	Chronic stress induces contrasting patterns of dendritic remodeling in hippocampal and amygdaloid neurons	Chattarji, S	650
	ST. JOHNS	2004	Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies	Kurpad, A	2024
	ST. JOHNS	2009	Dabigatran versus Warfarin in Patients with Atrial Fibrillation	Xavier, D	2725
CHENNAI+ VELLORE	ANNA UNIV.	2004	Adsorption of lysozyme over mesoporous molecular sieves MCM-41 and SBA-15: Influence of pH and aluminum incorporation	Murugesan, V	258
	CLRI	2000	Synthetic applications of indium trichloride catalysed reactions	Perumal, PT	210
	IITM	2005	Synthesis, characterisation, electronic structure, and photocatalytic activity of nitrogen-doped TiO2 nanocatalyst	Viswana-than, B	456
	NIRT	1997	Inherited resistance to HIV-1 conferred by an inactivating mutation in CC chemokine receptor 5: Studies in populations with contrasting clinical phenotypes, defined racial background, and quantified risk	Kumara-swami, V	303
	NIRT	1999	Socio-economic impact of tuberculosis on patients and family in India	Venkatesan, P	80

CLUSTER	INSTITUTE	YEAR	TITLE	AUTHOR	NO. OF TIMES CITED
	NIRT	2001	Genetic polymorphisms in molecules of innate immunity and susceptibility to infection with Wuchereria bancrofti in South India	Kumara-swami, V	84
	NIRT	2003	Origins of highly mosaic mycobacteriophage genomes	Kumar, V	333
	SRM	2001	Dimethylnitrosamine-induced liver injury in rats: the early deposition of collagen	Chandra-kasan, G	84
	SRM	2012	A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010	Bala-krishnan, K	1440
THIRUVANAN-THAPURAM+ KOCHI	AMRITA	2004	Effect of intravenous corticosteroids on death within 14 days in 10008 adults with clinically significant head injury (MRC CRASH trial): Randomised placebo-controlled trial	Olldashi, F	362
	AMRITA	2010	Novel chitin and chitosan nanofibers in biomedical applications	Jayakumar, R	298
	IISER-TVM	2011	Soft optical devices from self-healing gels formed by oil and sugar-based organogelators	Sureshan, KM	73
	KERALA UNIV.	2004	Synthesis of 1, 2, 4-triazoles and thiazoles from thiosemicarbazide and its derivatives	Krishna Pillai, S	200
	KERALA UNIV.	2008	Biological activities of curcumin and its analogues (Congeners) made by man and Mother Nature	Rajasekharan, KN	375
	NIIST	1998	Avidin-biotin immobilization of unilamellar liposomes in gel beads for chromatographic analysis of drug-membrane partitioning	Miyake, J	70
	NIIST	2003	Fluorescent chromophore functionalised single-wall carbon nanotubes with minimal alteration to their characteristic one-dimensional electronic states	Kim, Y	83
	NIIST	2007	pi-organogels of self-assembled p-phenylenevinylenes: Soft materials with distinct size, shape, and functions	Ajaya Ghosh, A	556
	RGCB	2003	Emodin induces apoptosis of human cervical cancer cells through poly (ADP-ribose) polymerase cleavage and activation of caspase-9	Karuna-garan, D	104
	SCTIMST	1997	Use of chitosan as a biomaterial: Studies on its safety and hemostatic potential	Rao, SB	354

Table 2.2 | List of publications causing sudden increase in normalised citation index in selected institutes in four clusters in South India

Note: Some institutes display a steady pattern of normalised citation index; publications from these institutes, although impactful, may not be captured after normalisation and therefore were not listed in the table

Citations were therefore filtered out to remove both poor citations (publications which have zero citations) as well as unusually high citations (publications with more than 34 citations) and the data that is most representative of the general trend is depicted in Figure 2.6, which highlights that publications from institutes in Bengaluru have a higher citation index.

A steady line without much fluctuation is indicative of uniform research productivity. Institutes in Kerala have large fluctuations in their citations indicating that the citations of those publications do not follow a steady pattern. Figure 2.7 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, University of Madras, CMC, IITM and Anna University show more stable or continuous trend lines, younger institutions such as InSTEM and CDFD have more energy and hence the peaking phenomenon. Although there was an exponential growth in the number of publications, there were several publications with poor citations (Figure 2.8). This phenomenon was observed in all clusters, but Hyderabad displayed a significantly better performance over other cities having been able to maintain less than 10% publications with zero citation since 1998. There were very few publications in Thiruvananthapuram in the early 2000s and in comparison to other clusters, a larger fraction of these publications have not been well-cited.

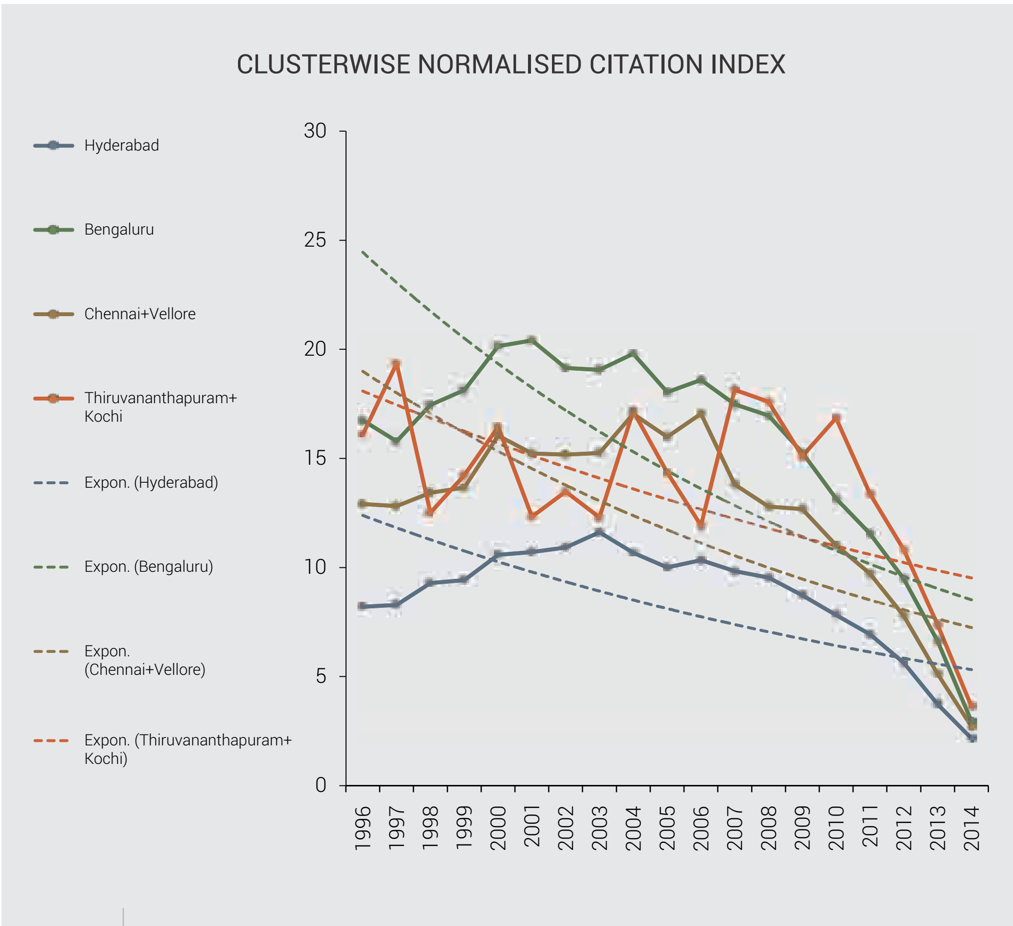


Figure 2.6 | Yearwise trend of clusterwise normalised citation index across institutes in the four clusters under study

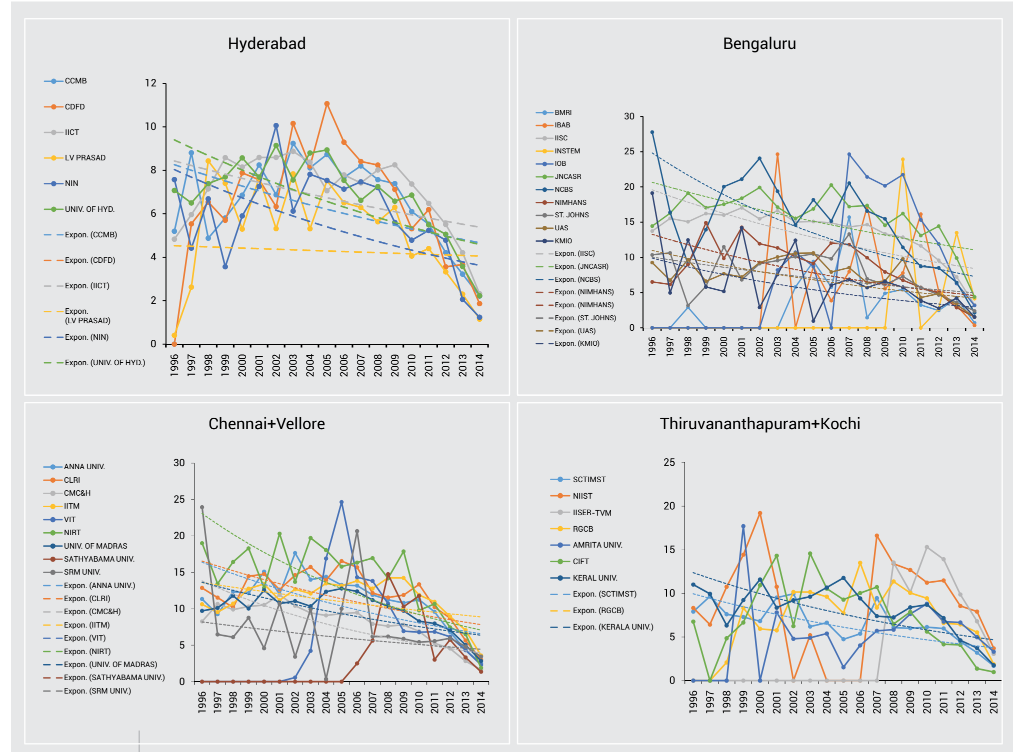


Figure 2.7 | Variation of normalised citation index within each institute across the four clusters under study

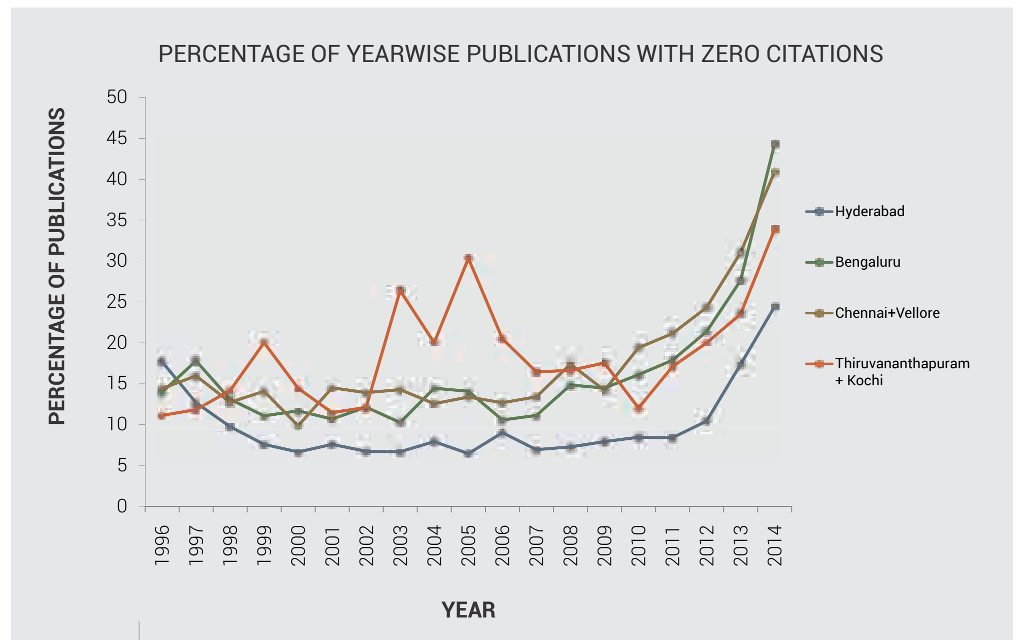


Figure 2.8 | Yearwise growth of publications with zero citations

Subject areas

The top ten subject areas in life sciences that academic institutes in each of the four clusters focused on were represented in Figure 2.9. To identify trends, only publications that did not have extremely low or high citations were considered. Across clusters, India's strength in life sciences seemed to be in various disciplines of chemistry followed by biochemistry & molecular biology and pharmacology (Figure 2.9).

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, Hyderabad-based institutes have a focus on pharmacology and pharmacy related areas owing to the presence of a large pharma industry, and on ophthalmology because of the ongoing research at LV Prasad Eye Institute.

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.

Bengaluru and Thiruvananthapuram have a keen focus on neurosciences, primarily attributable to the presence of NIMHANS and the neuroscience department in SCTIMST.

Figure 2.9 | Trends across subjects: Publications that have citations in median range

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 <500 were plotted subjectwise over time for each cluster to observe the emergence of expertise in various fields over time (Fig.2.10 -2.13). 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. In fact, the four clusters had very few subject areas where the minimum threshold of 50 publications in any year was exceeded.

Hyderabad due to strong pharma presence, had the best record in chemistry and microbiology. As pointed out earlier, niche institutes publish in certain areas e.g. LVPEI in ophthalmology.

Bengaluru had several publications in the area of protein structure analysis and crystallography which can be traced to GN Ramachandran's stint at IISc. Further, the presence of several ICAR and regional institutes in agriculture and allied fields in Bengaluru showed potential in these areas. Bengaluru was also gaining strength in oncology, polymer sciences and materials research. On an interesting note, although Hyderabad displayed a strong pursuit in chemistry, an applied area, biochemistry grew faster in Bengaluru than in Hyderabad.

Chennai showed growing popularity 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, internal medicine, immunology, neurosciences, optics and public health - a large chunk of which was because of the research from CMC Vellore.

Thiruvananthapuram+Kochi showed emerging strengths in medicine-related areas such as anaesthetics, biotech, cardiology, neurosciences, oncology and imaging and radiology with two medical institutes in this region stressing on research capabilities.

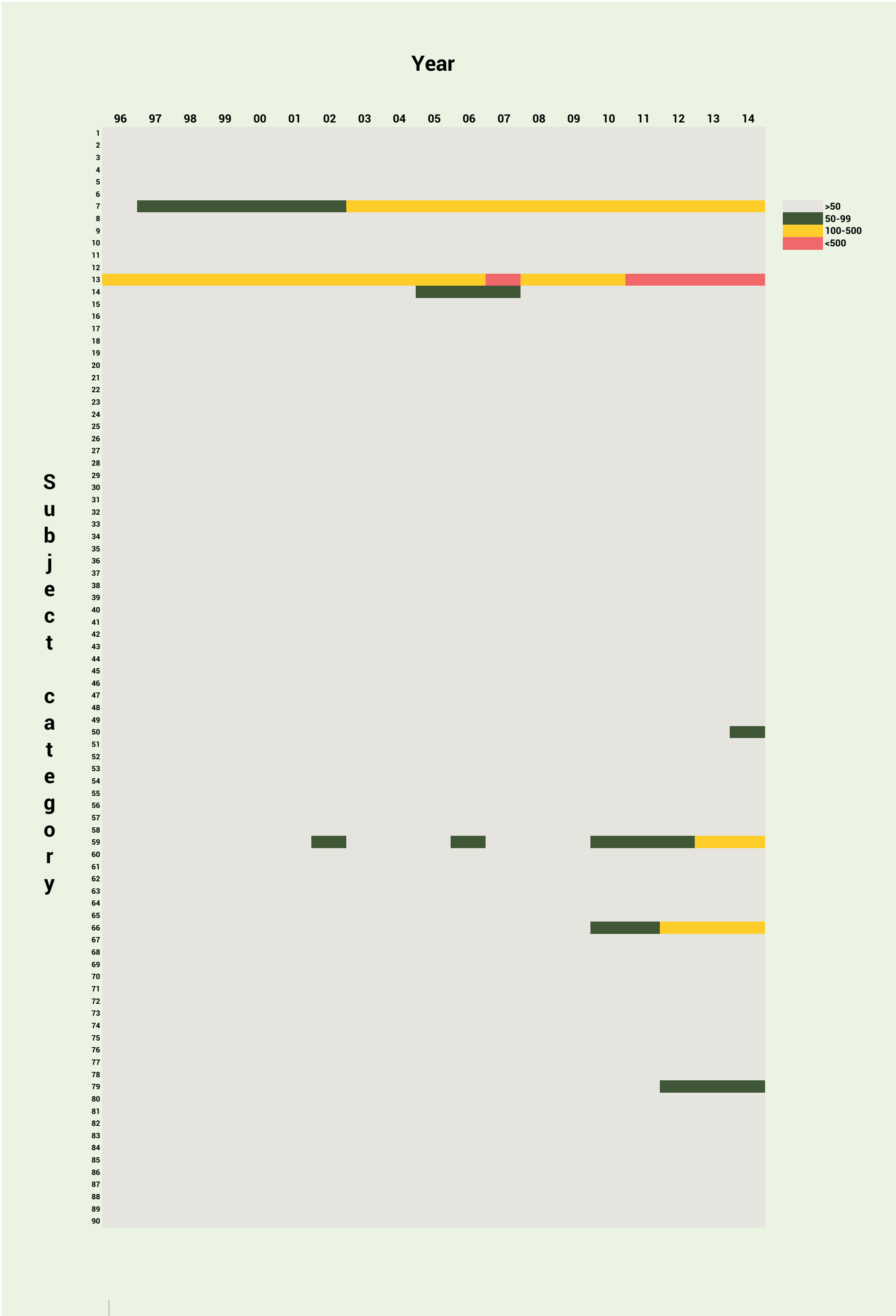


Figure 2.10 | Trends in number of publications on the basis of subject areas in Hyderabad

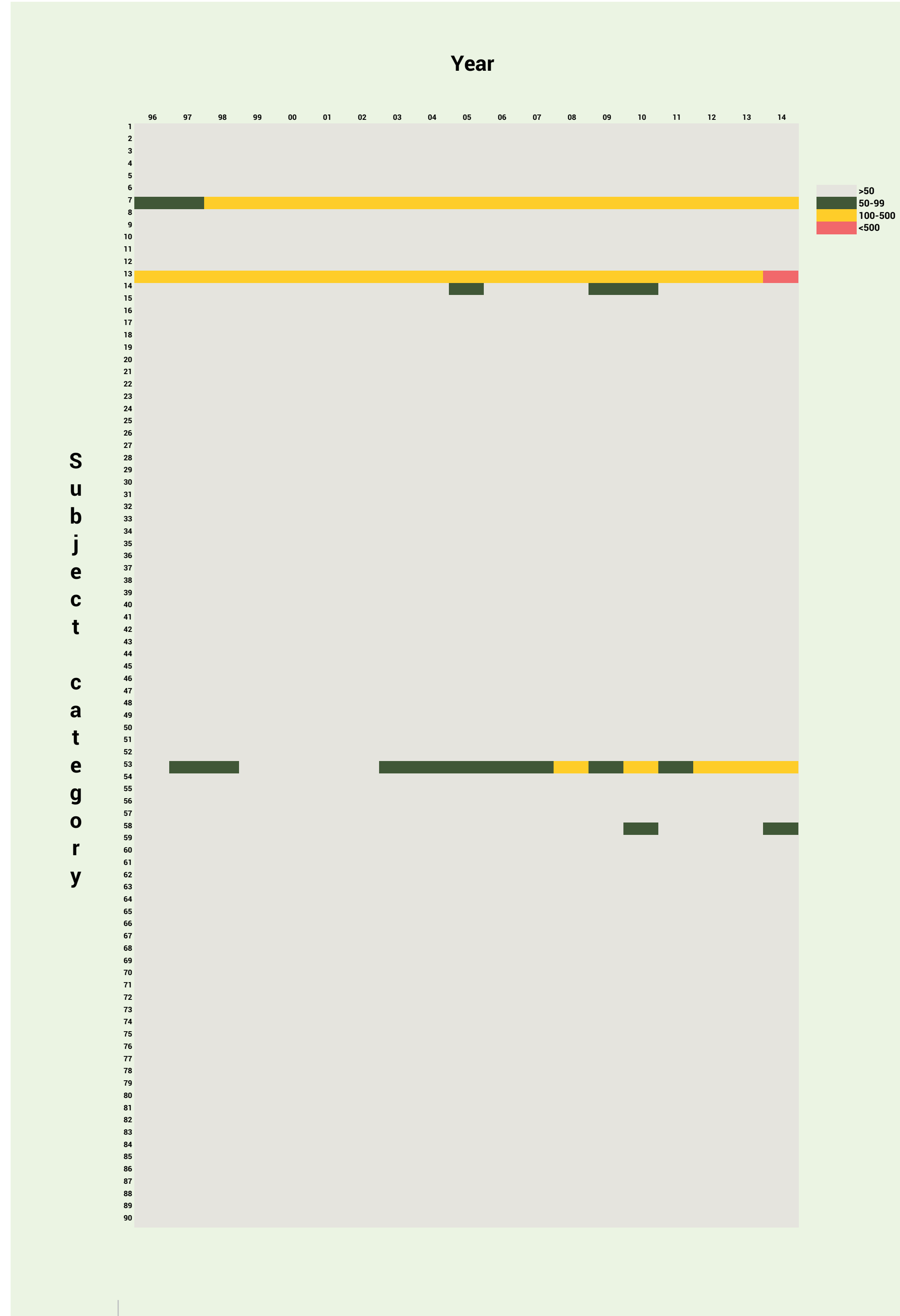


Figure 2.11 | Trends in number of publications on the basis of subject areas in Bengaluru

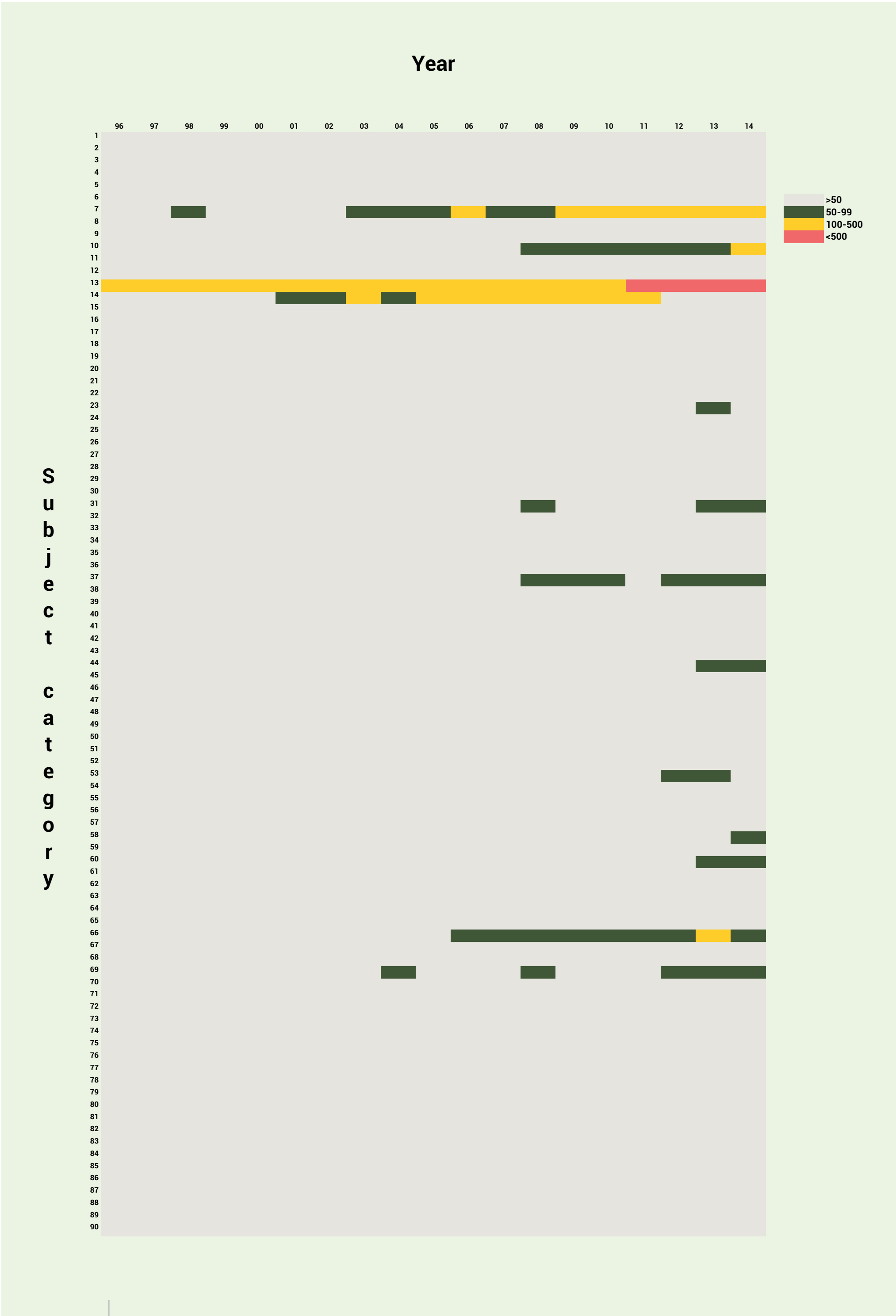


Figure 2.12 | Trends in number of publications on the basis of subject areas in Chennai+Vellore

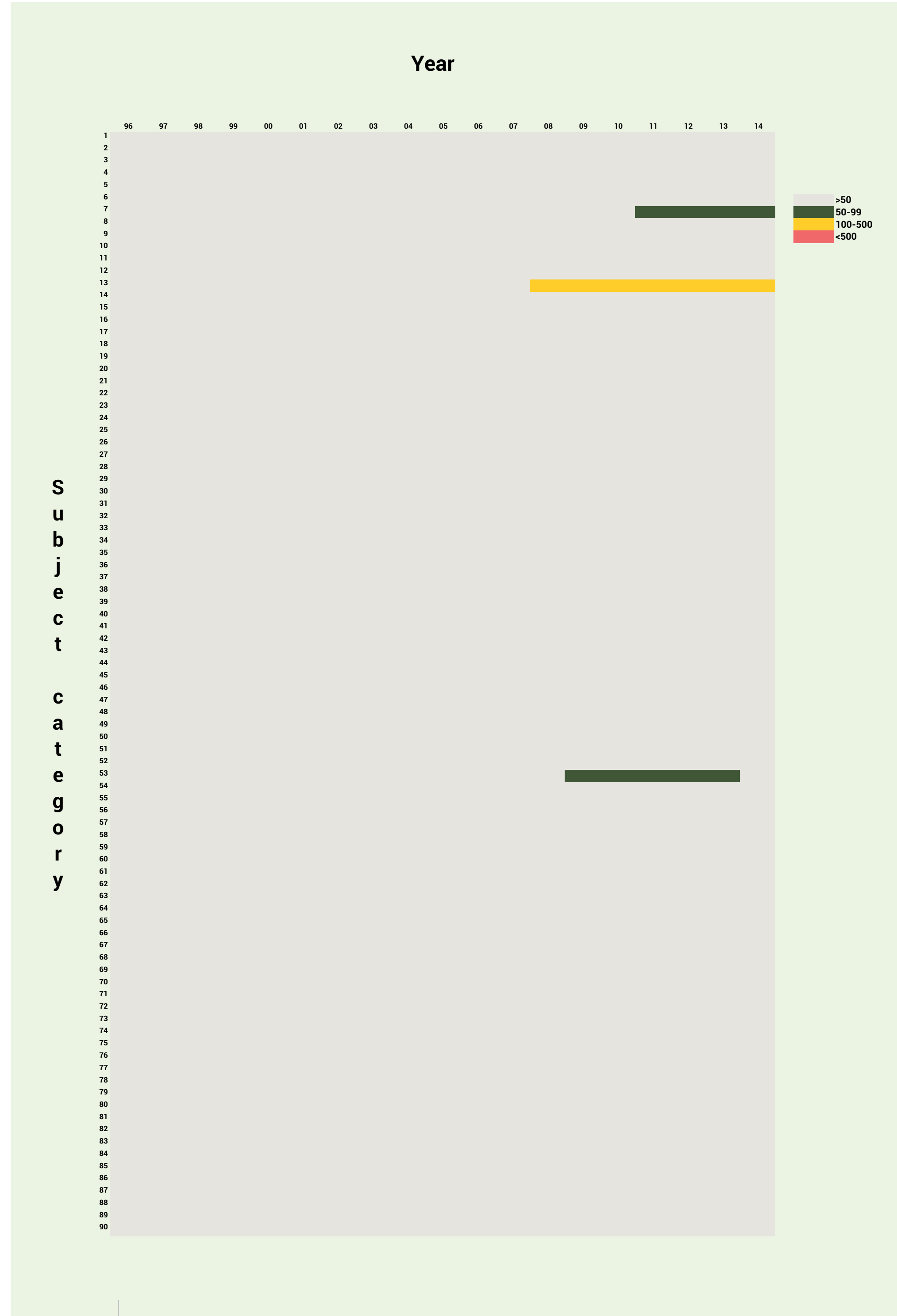


Figure 2.13 | Trends in number of publications on the basis of subject areas in Thiruvananthapuram+Kochi

Subject areas in Figures 2.10 to 2.13			
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 Figure 2.10 to 2.13
The numbers correspond to the number in the figure on the Y axis

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 cities have a larger number of collaborators outside India than within the country (Figure 2.14) with an average of about 40% of the collaborations within India. Indian medical institutes like KMIO, St. John's and NIMHANS are associated with several multicentre trials and therefore have a greater tendency to collaborate with institutes outside the Country (Figure 2.15A). However, institutes such as Sathyabama University, University of Kerala, Anna University, BMCRI, CLRI have maximum number of collaborations within the Country, perhaps indicating collaboration within their peer groups and a focus on local problems (Figure 2.15A).

Upon analysis of collaborations within India, the largest fraction constituted collaborations within the state followed by collaboration across states and lastly within the institute (Figure 2.15B). Proximity within the city seemed to promote far greater chances for networking and discussions that are likely to culminate into collaborations. Other modes of networking could possibly include conferences facilitating scientists to reach out to peers in other states.

An analysis of the key areas and universities from the top five collaborating countries for each of these institutes was mapped. Apart from USA, UK, Germany and a few other European nations, there have been only a handful of interactions with other countries. Examples would include InSTEM's collaboration with institutes in Uruguay primarily in the area of RNA biology and developmental neurobiology mediated through Prof. John Mercer, and KMIO's collaborations with Poland on phase 2 and phase 3 studies of several anticancer drugs (both small molecules and mAbs).

The study revealed that inducting faculty from foreign universities was a large contributing factor to expanding collaborations.

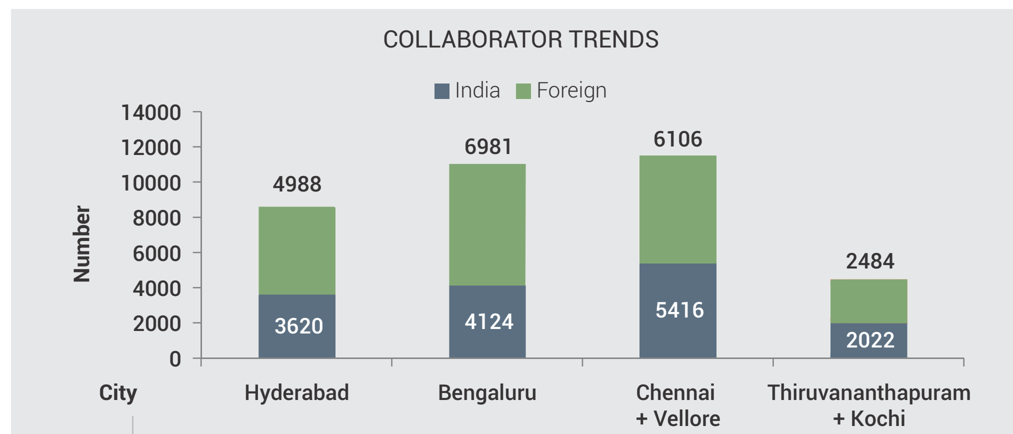


Figure 2.14 | Number of collaborators of selected academic institutes in the four clusters

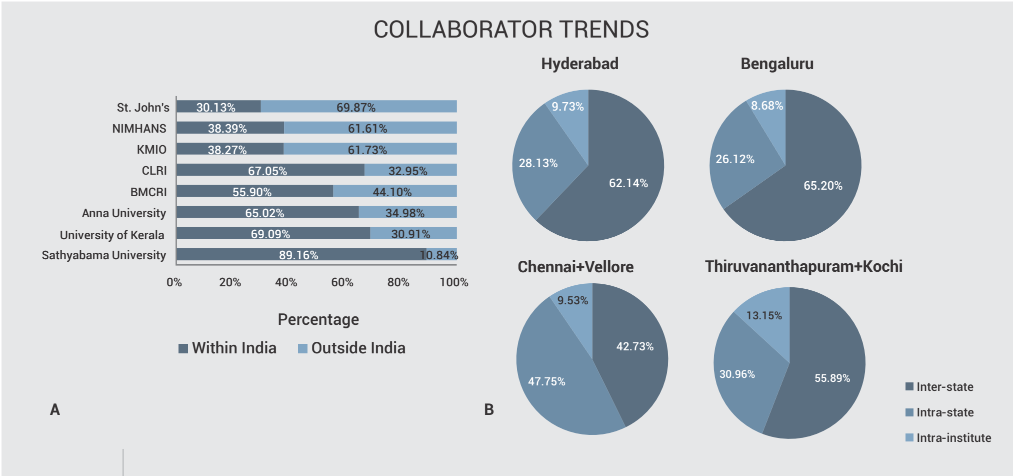


Figure 2.15 | A) Percentage of collaborators for select institutes
B) Distribution of collaborators within India in institutes within four clusters

Network maps and analysis

To understand the various trends in collaboration and identify key faculty and collaborations in every 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.

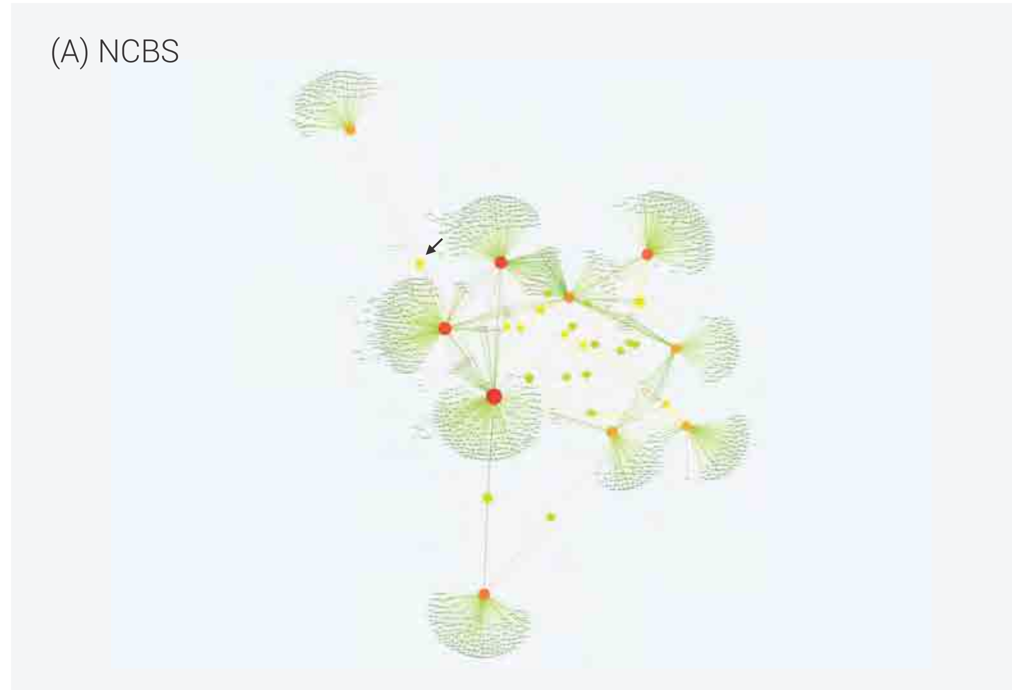
Four different types of networks were observed. Almost all institutes had several common institutional collaborators. A reason for this could be that many faculty members in Indian institutes work in related areas and have common forums for interaction. The movement across institutes is not very common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

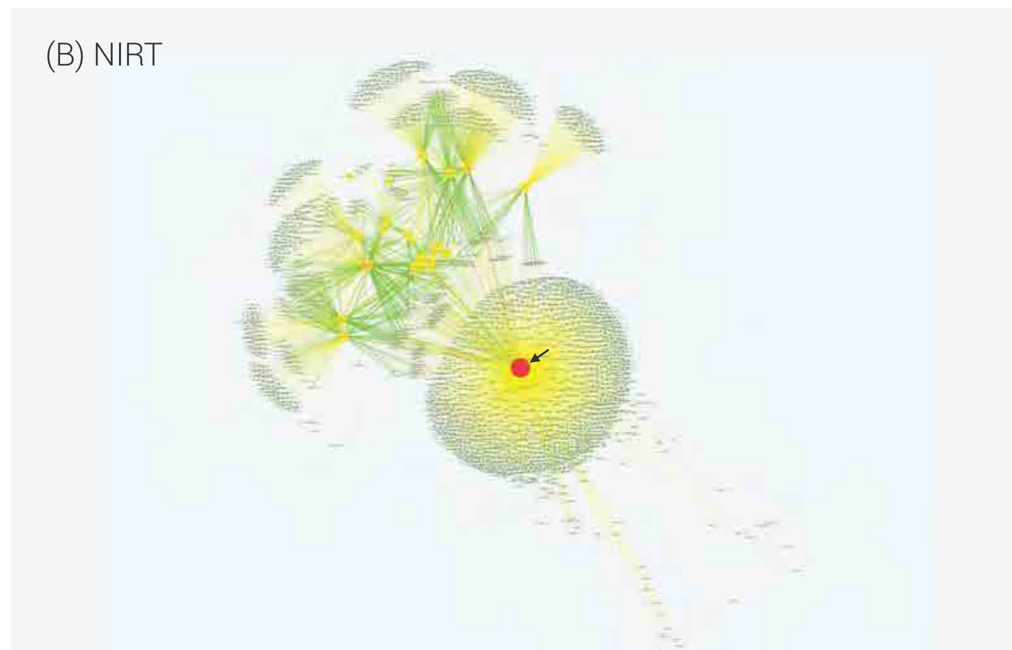
In institutes such as LVPEI, the top performing authors have a high number of collaborations since institute has developed a good reputation as an R&D institution in several areas of interest in ophthalmology. About ten authors formed major networking hubs with several common collaborators.

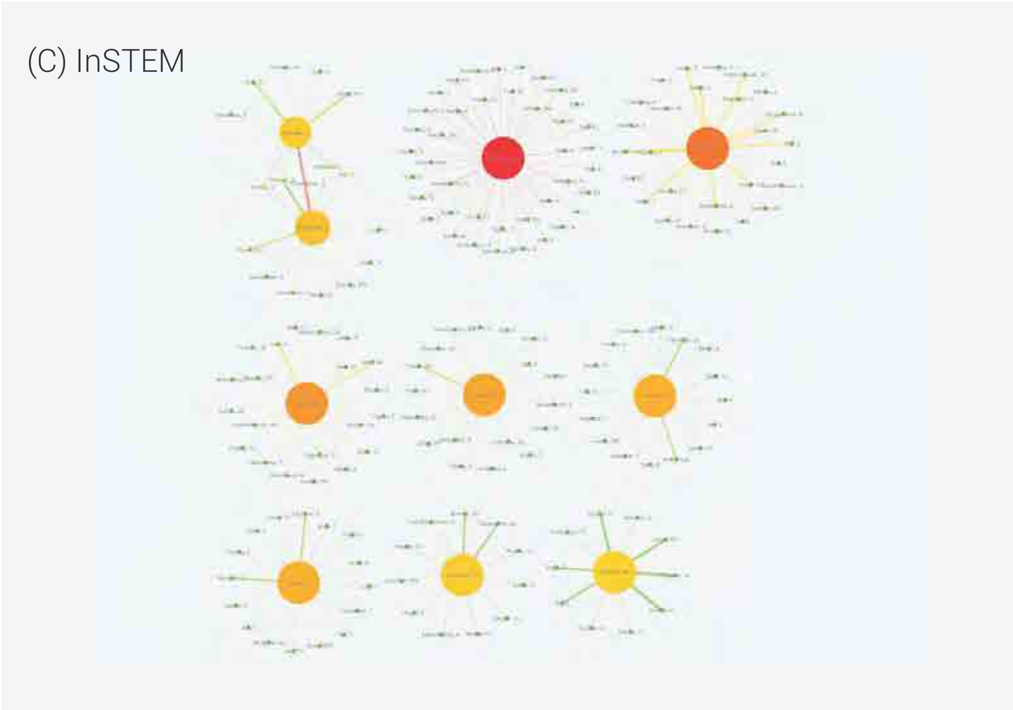
It is interesting to note that institutes such as InSTEM have few connections between their top performing faculty. This could be because of a multitude of reasons including the fact that it is a new institution growing organically and therefore intra-institutional collaboration may take time to evolve. Such institutes showed a lot of promise due to the large network that would become accessible with time and the growth in internal interactions.

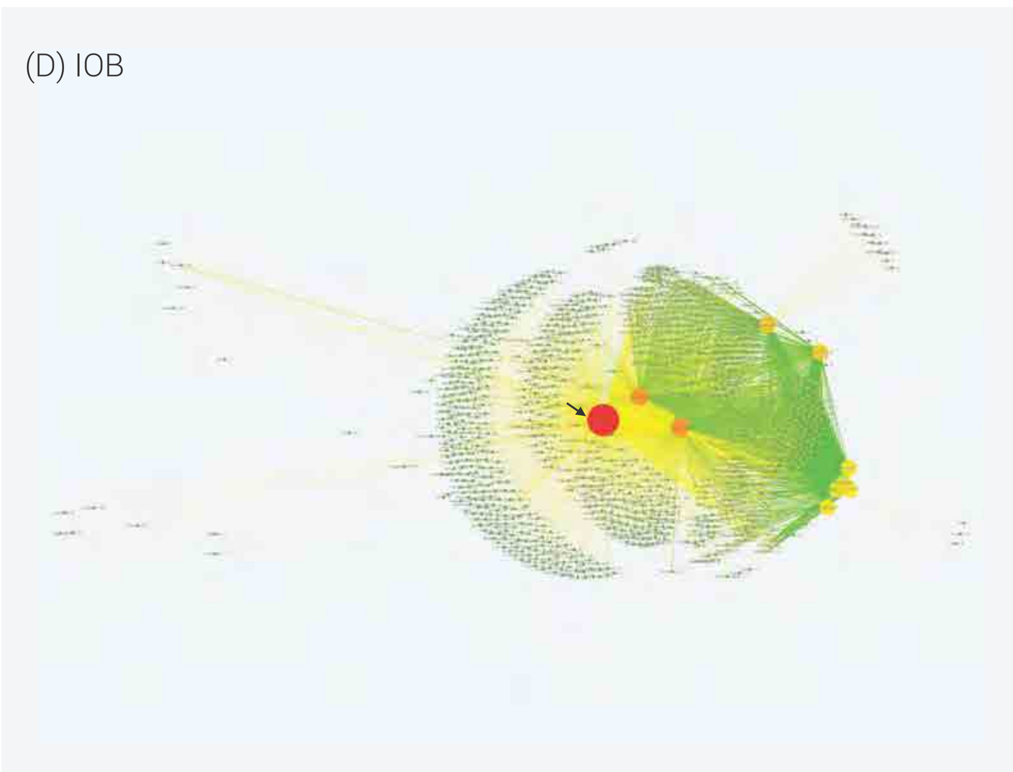
A few institutes were characterised by the presence of one key academic expert who was central to the entire network such as one leading scientist each at NIRT (black arrow pointing to author node in NIRT network) and in IOB (black arrow pointing to author node in IOB network). In IOB, a dense network of interactions among other faculty was observed but it was centrally held by the leading scientist. Although these were niche institutes, there is a possible risk that the output of the institute may be impacted once the leading academic expert left the institute.

The NCBS network displayed several networking hubs and spatial proximity of scientists in diverse fields, highlighting interdisciplinary research. The networks help identify upcoming authors (black arrow pointing to author node in NCBS network) whose work has started showing in the growing networks being laid by the scientists.









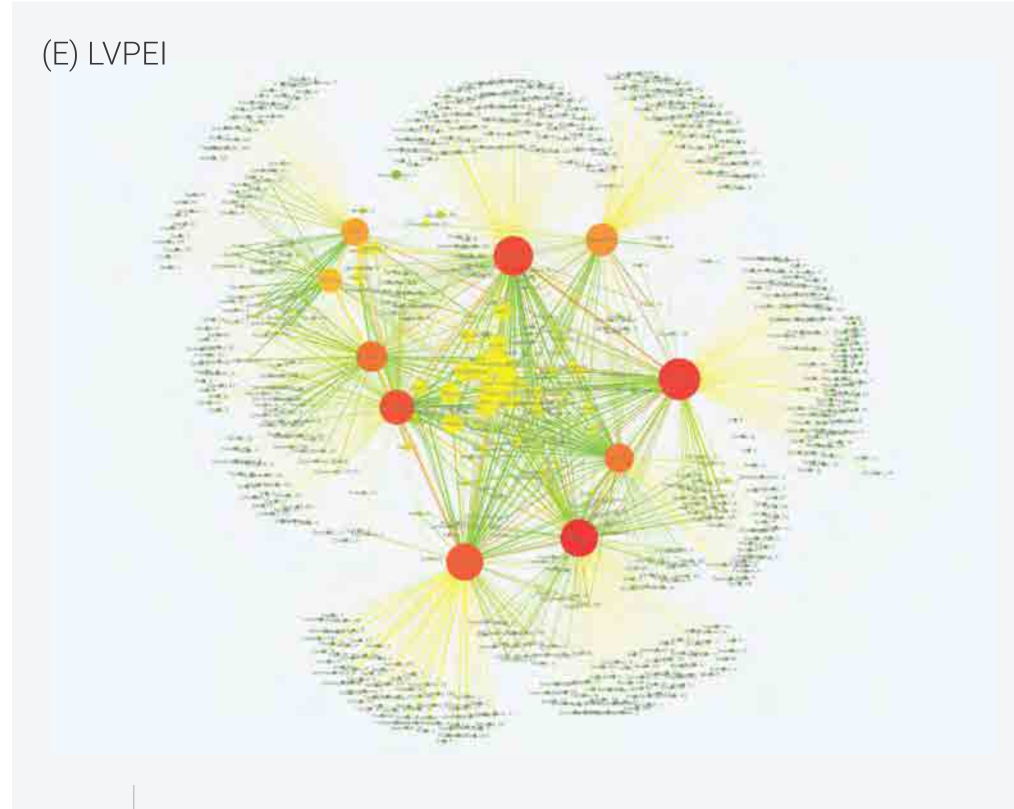


Figure 2.16 | Collaboration maps of A) NCBS B) NIRT C) InSTEM D) IOB E) LVPEI showing different types of topologies

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 pf 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 these clusters (Figure 2.17). The four clusters have strength in chemistry and molecular biology. The network patterns also indicate high collaboration within these areas.

The number of interactions that are interdisciplinary in nature indicate the translation potential of research from the institute and the underlying culture and attitude. Very few institutes - Amrita Institute, IITM, InSTEM were found to be truly involved in interdisciplinary research.

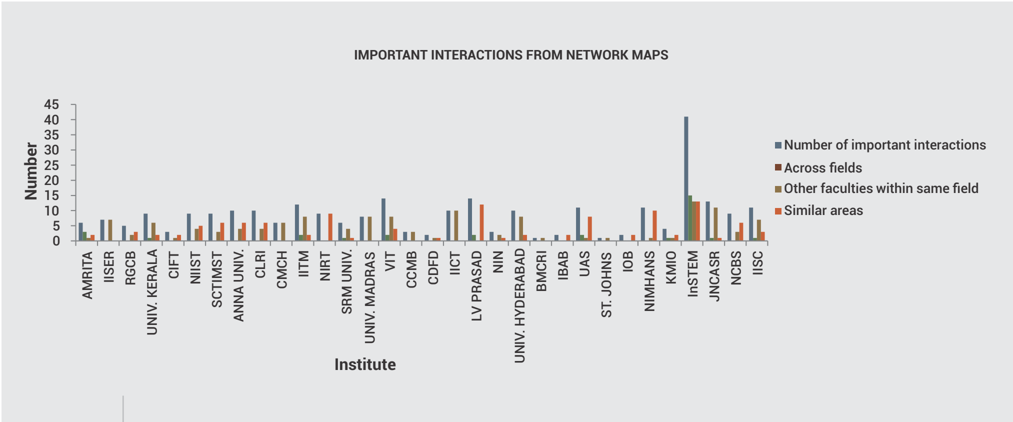


Figure 2.17 | Classification of important interactions identified through network maps

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 four clusters across academia and industry. However, there are mismatches in certain focus areas between academia and industry present in the clusters (Figure 2.18). 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.

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 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 radiology and imaging in Chennai and food technology in Thiruvananthapuram.

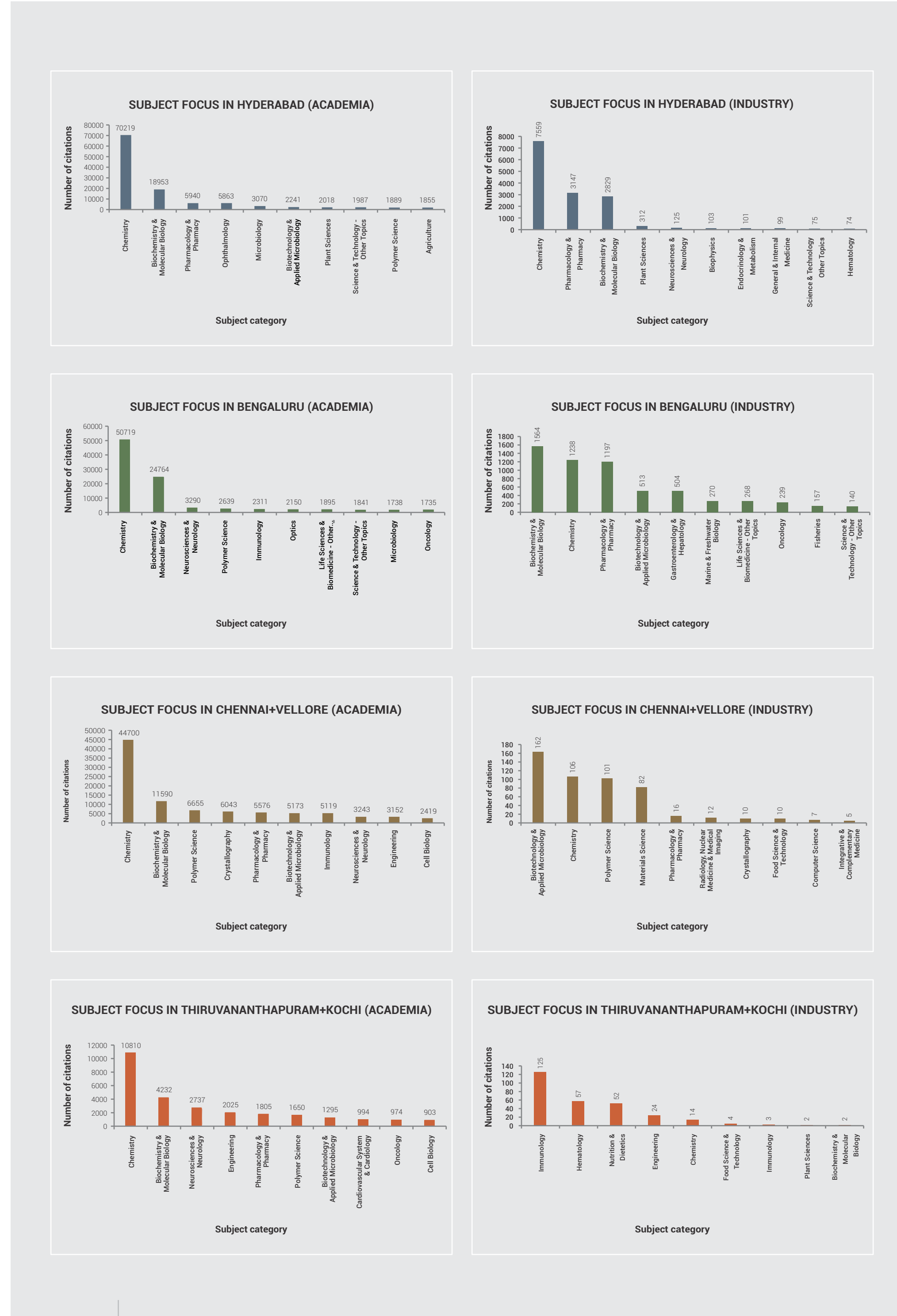


Figure 2.18 | Comparison of publication focus areas in academia (A, C, E, G) and industry (B, D, F, H) across four clusters

2.2.2 Analysis of Industry and Start-up Data

Industries play the role of translation of science into commercialisable products. Not only do they acquire technologies and manpower from academia, industries also play the role of 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. A sectorwise distribution using Traxcn data indicates that currently, Healthcare IT and CRAMS / CRO / API are the prominent sectors in India. 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 and is the country with the largest exports to the US.

On the other hand, growth in the number of innovative product companies in agriculture and industrial biotechnology, healthcare and agriculture, vaccines, biosimilars and CT is lesser than Healthcare IT and CRAMs although vaccines contributed to the highest revenue share in 2012 in the life sciences sector.

The Hyderabad cluster is dominated by the pharmaceutical sector (Figure 2.19). 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. 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 and several other institutes such as Centre for Cellular and Molecular Biology and Centre for DNA fingerprinting and Diagnostics between the 70s and 90s, and more recently, the National Institute of Pharmaceutical Education and Research, have contributed to the maturing of the ecosystem through research inputs and trained manpower. Other regional institutions have also contributed to manpower 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 talent pool that has translated into growth in applied and 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 to Bengaluru being one of the most sought after innovation clusters in India.

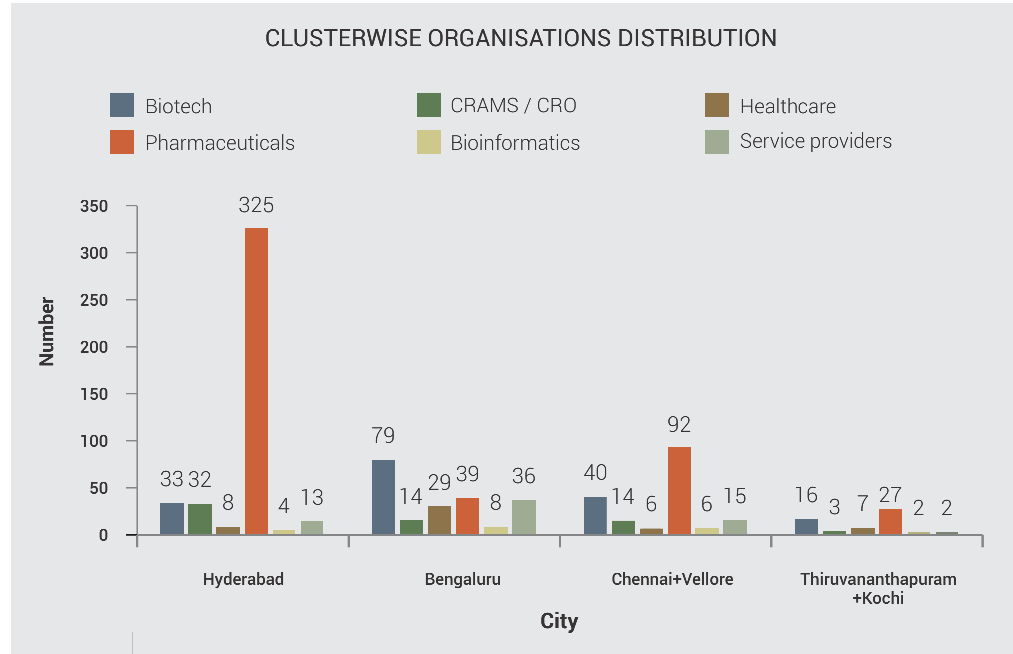


Figure 2.19 | Distribution of different types of organisations in four clusters under study

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 are fairly low in Thiruvananthapuram 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 start-ups in Thiruvananthapuram+Kochi. The State Government has been promoting the IT industry and IT start-ups 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.

2.2.2.2 Research output from industry

Of the total number of industries in the four clusters, 85 companies (including start-ups) were selected for deeper analysis, the criteria for which has been described in section 2.1.4. A general view of the total number of patents, total number of publications and total number of collaborators in each cluster clearly points to the focus on patents in companies, a trend which is starkly different from academia. The Indian Patent Act 1970 and the thriving generics industry have greatly increased the number of process patents from several cities (Figure 2.20). The number of collaborators are not as high as in academia (Figure 2.20), a phenomenon that can possibly be associated with the mismatches in focus areas of research as discussed in section 2.2.1.2.

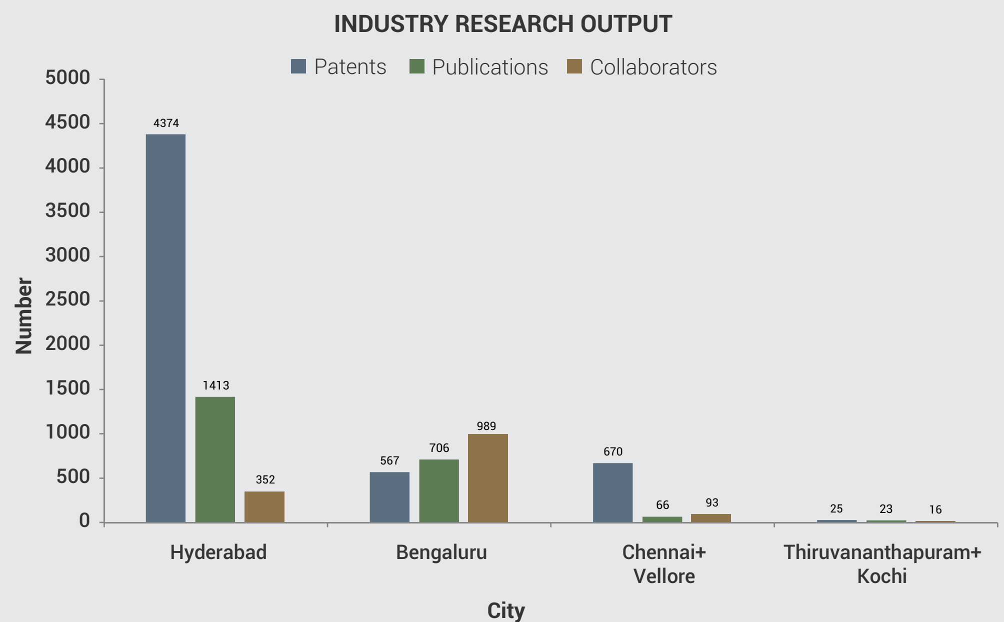


Figure 2.20 | Distribution showing number of patents, publications and collaborators for industries in each cluster under study

Citation index

As seen earlier, industries stress on commercialisation rather than on knowledge generation and hence the greater focus on patents. Interestingly, although the number of publications are less, the average citations for Hyderabad and Bengaluru are relatively high (Figure 2.21). Bengaluru industries consistently have good citations for their publications 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 2.21. The publications that cause peaks in normalised citation index are tabulated in Table 2.4. Although small in number, these publications mostly belong to companies from Hyderabad and describe new analytical chemistry processes or synthesis of molecules of commercial importance.

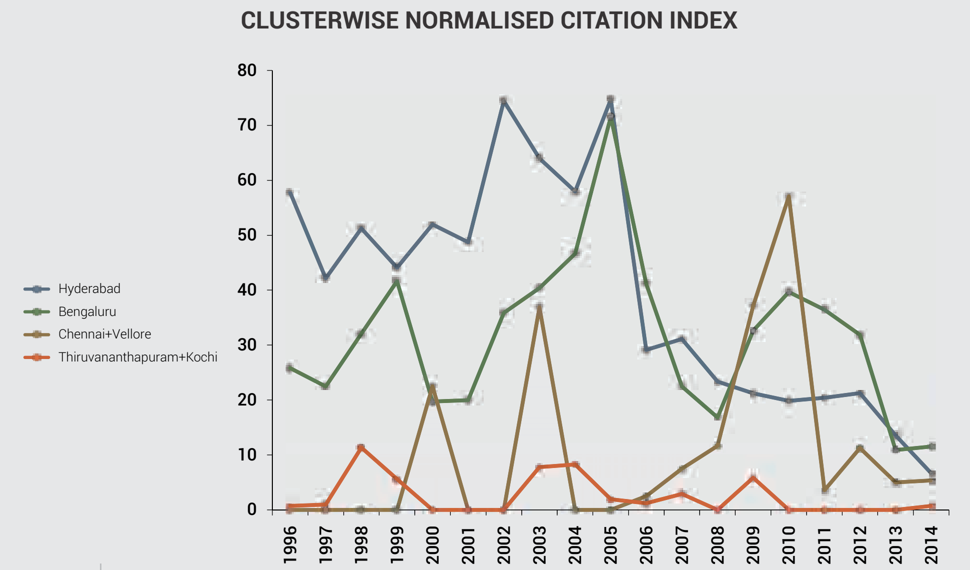


Figure 2.21 | Normalised citation index for select industry publications in the four clusters

CLUSTER	COMPANY	YEAR	TITLE	NO. OF TIMES CITED
HYDERABAD	Dr.Reddy's	2002	Cu(I)-catalyzed three component coupling protocol for the synthesis of quinoline derivatives	132
	Dr.Reddy's	2003	Pd/C mediated synthesis of 2-substituted benzo[b]furans/ nitrobenzo[b]furans in water	74
	Suven Life Sciences	2004	Quantitation of tadalafil in human plasma by liquid chromatography-tandem mass spectrometry with electrospray ionisation	45
	Dr.Reddy's	2004	Anticancer and immunostimulatory compounds from Andrographis paniculata	170
	Divis Labs	2005	A newly synthetic chromium complex - chromium (phenylalanine)(3) improves insulin responsiveness and reduces whole body glucose tolerance	43
	Suven Life Sciences	2005	Liquid chromatography/electrospray ionisation mass spectrometry method for the quantification of valproic acidin human plasma	43
BENGALURU	Strides Arcolab Ltd.	2005	Synthesis, characterisation and antimicrobial activity of some substituted 1,2,3-triazoles	118
	Strides Arcolab Ltd	2006	Synthesis of some pyrazolo[3,4-d]pyrimidine derivatives as potential antimicrobial agents	119
CHENNAI+ VELLORE	Evolva Biotech	2010	Improved vanillin production in baker's yeast through in silico design	56

Table 2.4 | Industry publications causing peaks in normalised citation index

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. Therefore, forward citations indicate that the patent belongs to a popular area with high impact. On an average, less than 30% of patents filed by Indian industries have forward citations and therefore, the average number of citations per patent is low (Figure 2.22). This could probably be the case because Indian industries tend to focus on process patents. Most cities have a comparable percentage of the patents cited. However, with respect to the average number of citations for the cited patents, it is highest in Bengaluru and Hyderabad. Chennai+Vellore comes close to these two cities. Thiruvananthapuram+Kochi has very low number of citations indicating that the companies there are not focused on innovation and research as much as those in the more matured clusters.

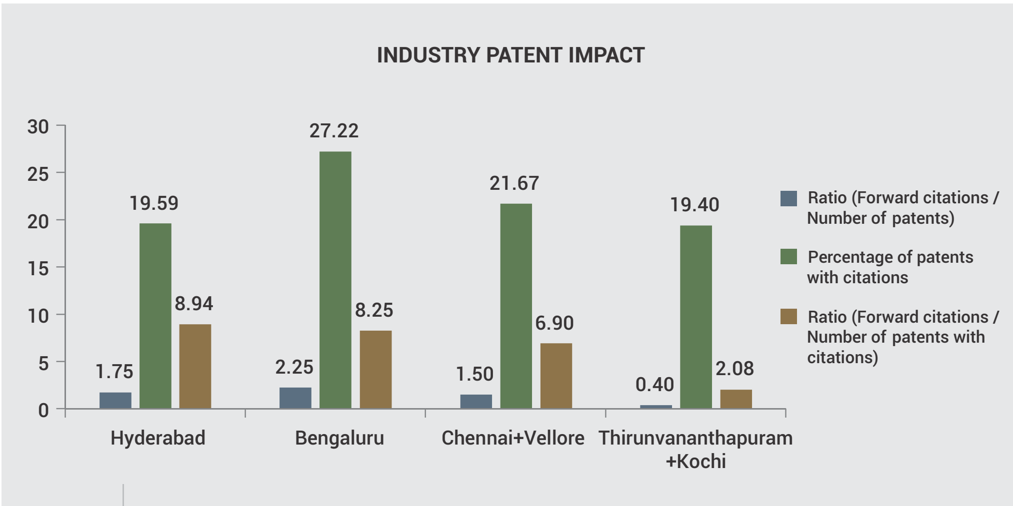


Figure 2.22 | Citations of patents from select industries in the four clusters

Influence of anchors

Large companies in every growing cluster serve as anchors to support innovation. These companies invest in promising start-ups and some of them set-up research centres such as DRILs by Dr Reddy's, Mazumdar Shaw Cancer Centre and Biocon-BMS Research Centre. The study has identified eleven such anchors which generate over billions of rupees (Figure 2.23) in revenue that when partly invested into R&D improves the innovation profile of the cluster.

Most important is the talent pool generated because of the large number of employees trained in world-class setups (Figure 2.23). When such employees move out to start their own ventures, knowledge disseminates. An example of this is the Astra Zeneca Centre of Bengaluru which led to the birth of several start-ups in the City after the centre was shut down.

About 80 different classes of products and services are generated from these anchor companies, as seen in Table 2.5.

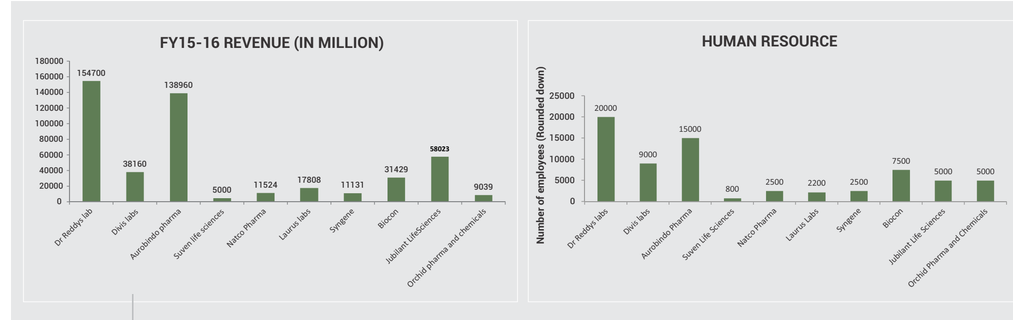


Figure 2.23 | Revenue (FY 2015-16) and Human Resources of anchor companies in four clusters

Products / Services of anchor companies in the clusters		
• Anabolic Steroid	• Antiretroviral	• Drugs for Overactive Bladder
• Analgesic	• Antispasmodic	• Genome Data Analysis
• Anti-Cholinergic	• Antithrombotics	• Glargine
• Anti-Emetic	• Antivirals	• Heavy Metal Chelator
• Anti-Fungal	• Anxiolytics	• Hematinics
• Anti-Hypercholestrolemia	• Bronchodilator	• Hydroxycinnamic
• Anti-Migrane	• Calcimimetic	• Hyperphosphataemia
• Anti-Ulcer	• Carotenoids	• Immnunomodulator
• Anti-Alzheimers	• Cephalosporins	• Immunosupressant
• Antiarrhythmic	• Clinical Trial Intelligence	• Itolizumab
• Antibacterials	• CNS Agents	• Lispro & Aspart
• Anti-Cancer	• Commercial Products	• mAb Biosimilars
• Anticonvulsants / Antiepileptics	• Cough Suppressant	• Metabolic Disorders
• Antidepressants / Antipsychotics	• Curcuminoids	• Muscle Relaxant
• Antidiabetics	• Custom Curation Services (Biology, Chemistry and Clinical Trial)	• New Drug Delivery Systems
• Antidiarrheals	• Diabetes Drugs	• Pain Management
• Antiglaucoma	• Diuretics	• Patient Monitoring, Computer Tomography, Diagnostic ECG etc.
• Antihistaminics, Antiasthamatics	• Drugs for Memory Impairments with Aging	• Pediatrics
• Antihyperlipoproteinemics	• Drugs for Cardiovascular Disease	• Peptide Biosimilars
• Antihyperparathyroid	• Drugs for Feeding Disorders	• Pharma IT Services
• Antihypertensives	• Entry Inhibitors	• Polyphenols
• Anti-Infective	• Erectile Dysfunction Drugs	• Pulmonary Arterial Hypertension
• Anti-Inflammatory	• Eugeroics	• Rh-Insulin
• Antineoplastic	• Flavonoids	• Target Intelligence and Analytics
• Antiobesity	• Drugs for Chronic Constipation	• Urinary Incontinence Drugs
• Antiosteoporotics	• Drugs for Hyper Uracemia	• Vitamins
• Antiparkinsonian		
• Antipsoriatic/ Antiacne		

Table 2.5 | Products / Services of anchor companies in the clusters

2.2.3 Supporting ecosystem

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

Bengaluru, Hyderabad and Chennai are well-developed clusters with good support structure for innovation (Figure 2.24). Also, the corresponding states have start-up policies specifically focused on improving the overall hygiene factors that attract enterprise.

In case of Thiruvananthapuram, while the number of government organisations, science parks and business associations are present in good numbers, many of them are not fully functional or are not focused on life sciences. In addition, in Thiruvananthapuram+Kochi, Information technology (IT) companies seem to be incentivised due to the promise of quicker turnaround, lower capital expenditure and much larger scope of employment.

IP firms are more in Bengaluru, as it is the major hub for innovation. Law firms are more in Chennai because it is the oldest legal administrative hub in south India with the Indian patent office also situated at Chennai.

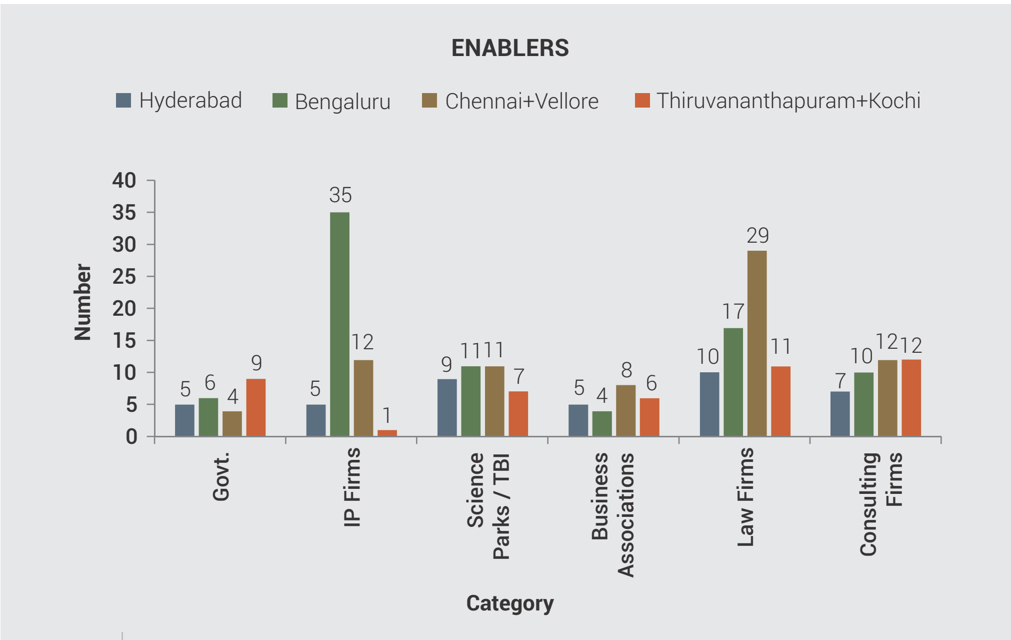


Figure 2.24 | Distribution of various start-up enablers in the clusters under study

Chemical suppliers are large in number in Hyderabad, directly correlatable to the large presence of pharmaceutical companies (Figure 2.25).

Chemical suppliers and lab / medical equipment suppliers are present in almost evenly in both Bengaluru and Chennai.

Kerala, in general, has less number of suppliers in both categories but the number of medical suppliers is proportionately higher due to well-established medical centres such as Amrita Institute and SCTIMST.

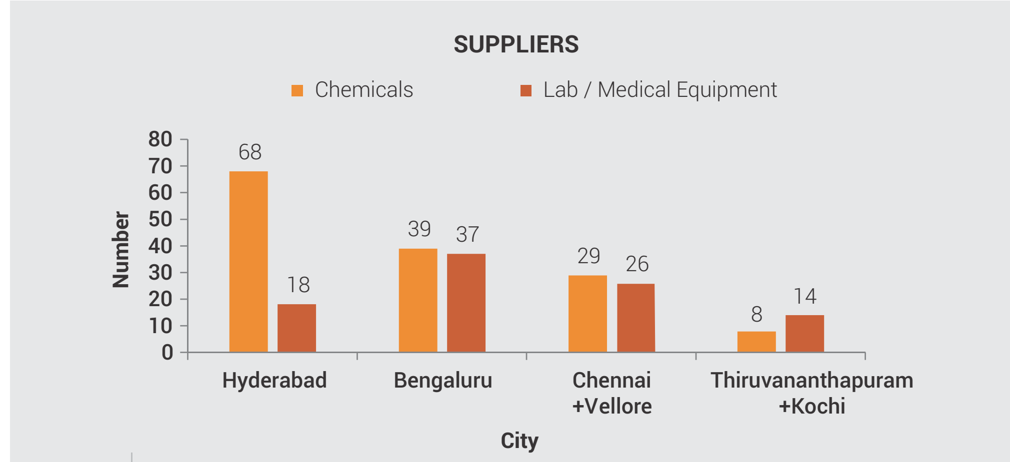


Figure 2.25 | Distribution of chemical and lab / medical suppliers in the four clusters under study

2.2.3.2 Funding support

Funding is considered the fuel on which a business runs. 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 of 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. It is not surprising that as per Tracxn data, the pharma generics sector raised the maximum amount (nearly 40%) out of the total funds raised by 101 ventures across India (Figure 2.26). The next major sector that attracted funding was CRAMS / CRO / API. Other areas such as Medical Devices and Healthcare IT have also been able to garner around 12% and 9% funding respectively. Bioinformatics and Biosimilars have also started getting popular.

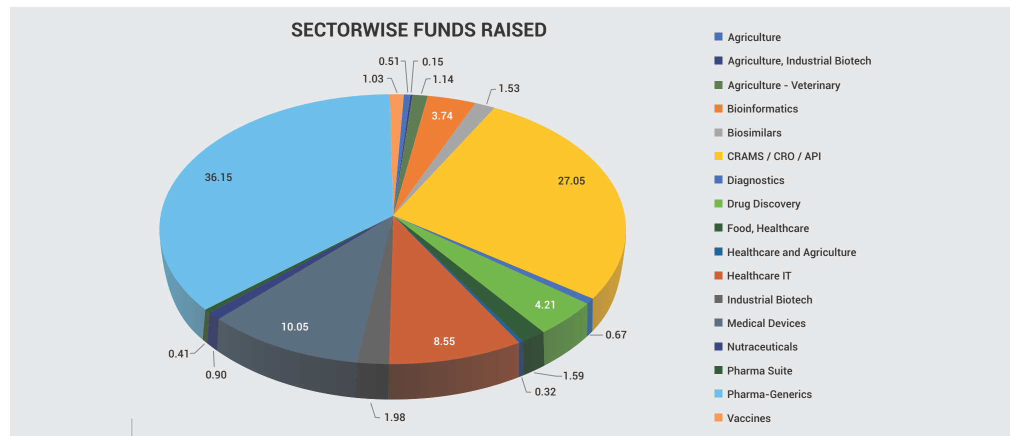


Figure 2.26 | Funding raised by life sciences start-ups in India

Citywise analysis on funding patterns

As observed in Tracxn data, 101 resident life sciences companies in only 18 cities in the Country raised private funding . Out of these, Bengaluru reported the highest number of funded companies (Figure 2.27). However, the quantum of funds raised by companies based out of Hyderabad was much higher (Figure 2.28).

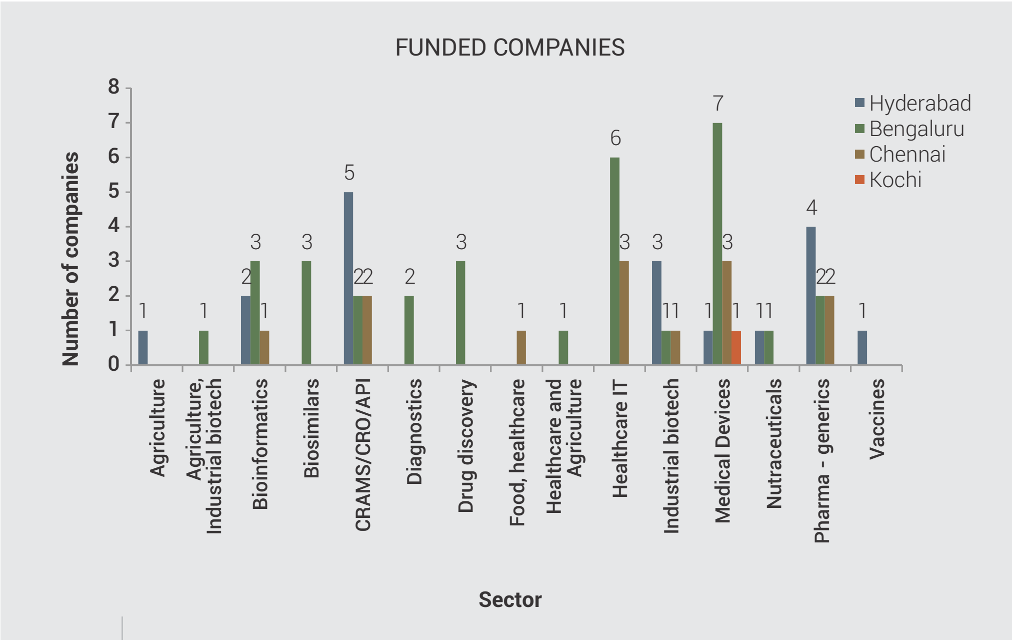


Figure 2.27 | Number of companies in the 4 clusters by sectors that have raised private fund (based on Tracxn data)

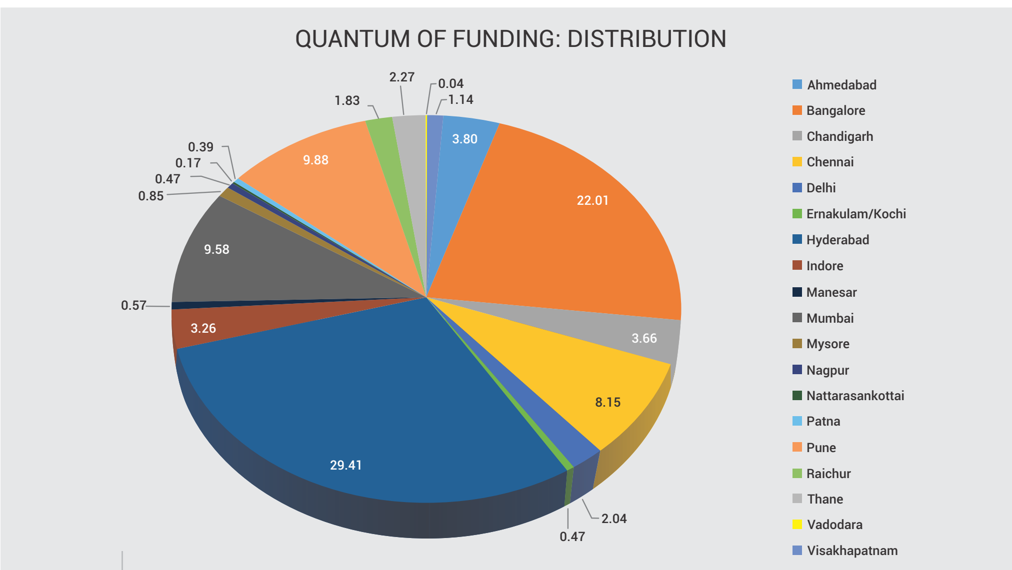


Figure 2.28 | Distribution in terms of quantum of funding raised by life sciences companies across various cities in India

Hyderabad is also known to be the Indian Pharmaceuticals capital. As of 2010, the city manufactured one third of India's bulk drugs and 16% of biotechnology products. CRAMS/CRO/API and Pharma generics are the major sectors. As mentioned earlier, the establishment of Indian Drugs and Pharmaceuticals Limited (IDPL), a public sector undertaking, in 1961 was followed over the decades by many national and global companies opening manufacturing and research facilities in the city. Dr. Reddy's Laboratories played a seminal role in building the pharma cluster around Hyderabad by establishing an innovation culture among its employees, encouraging spin offs, imparting high quality training, setting up a translational research centre - Dr. Reddy's Institute of Life Sciences, supporting research at LVPEI and several other activities that made Hyderabad a vibrant biopharma cluster.

Bengaluru is one of the most hi-tech entrepreneurial cities in India. It has the highest number of venture-funded life sciences companies, largely in healthcare IT and medical devices. These sectors do not require as much funding as pharma and also have shorter gestation periods which correlates well with Hyderabad receiving a greater quantum of funding. Bengaluru contributed to a major proportion of India's IT exports. This was probably the reason for a strong healthcare IT sector in Bengaluru.

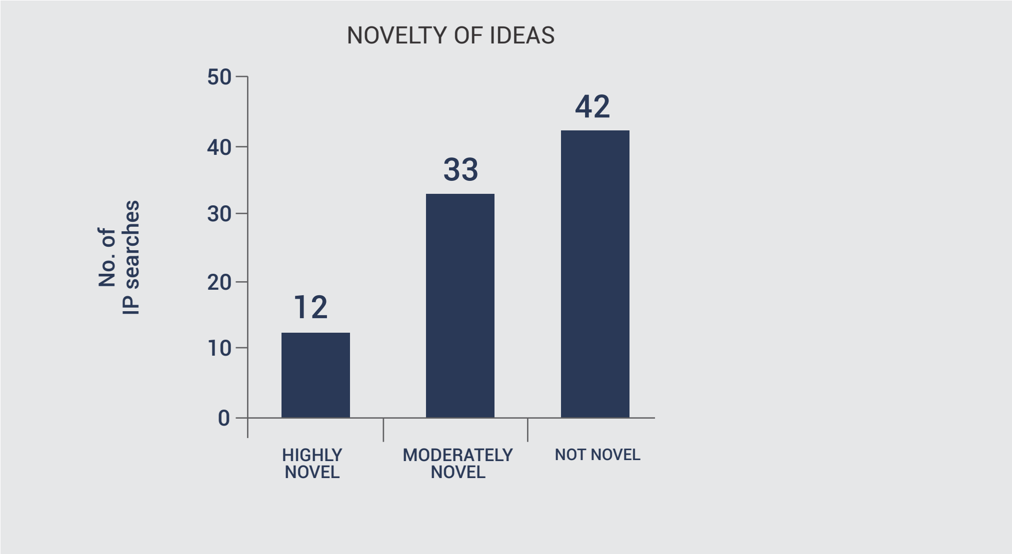
Chennai displayed similar trends as Bengaluru with healthcare IT and medical devices start-ups receiving most funding. Chennai has been the major hub of economic activities for several decades. Medical tourism is a source of the city's economy accompanied by the presence of automobile and manufacturing industry which has laid the foundation for the medical devices sector in Chennai.

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. An analysis of this showed that the maximum interest in IP services was among individuals who wish to start a venture, and start-ups (Figure 2.26). The interest levels in availing IP services and also awareness varied among institutions. National level institutes with in-house Technology Transfer Offices or IP cells mostly sought help in technology transfer services, while universities and colleges needed help with IP awareness among faculty and students and patentability search. Interest levels in most institutions were found to be tepid even with incentives such as highly subsidized or free services.

Data from 87 IP search services provided by BRIC showed that 48% of the patentability search queries were not novel pointing to poor awareness about prior art and existing competition. 14% technologies were found to be truly novel indicating that Indian innovators are working on low hanging fruits and not exploring disruptive technology.



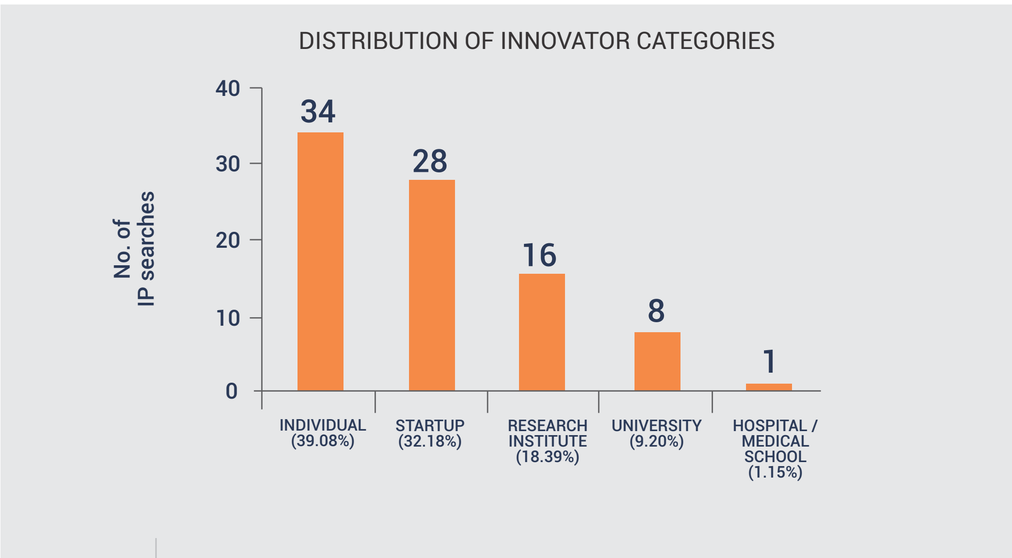


Figure 2.29 | Experiences of BRIC around IP culture in the ecosystem

2.3 Key findings from KOL survey

To understand an ecosystem, its is imperative to analyse ground realities which 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 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 Advantages in various south Indian clusters

Hyderabad came out as a moderately well-developed cluster with features and incubation support similar to Bengaluru although highly skewed towards the pharma sector. The support from both these state governments for start-up policies and establishment of state-supported incubation are an added advantage.

Bengaluru appeared to be the most mature cluster with a conducive start-up environment as felt by those who strategically chose Bengaluru for their operations as well as several others based elsewhere in southern India. Presence of strong clinical community and support from institutions like St. Johns Medical College was a huge value addition for companies looking to partner for clinical validation. 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. Finally, several entrepreneurs preferred Bengaluru because of its pleasant weather, cosmopolitan nature and diversity of job opportunities across a wide range of sectors.

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. Chennai also instituted the Golden Jubilee Women's Biotech Park which was pointed out by several women entrepreneurs as a mark of a friendly, gender sensitive and supportive innovation environment.

Thiruvananthapuram and Kochi were together found to be an emerging 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.

Figure 2.30 is a comparative table of attributes indicating the quality of the innovation ecosystems in the four clusters compiled from KOL interviews. The degree of satisfaction for each attribute has been captured qualitatively through the ubiquitous smiley - two smileys indicating very good, one smiley for satisfactory / okay and blank indicating a gap / need for improvement.

Innovation Indicators	Bengaluru	Chennai+ Vellore	Hyderabad	Thiruvananthapuram + Kochi
Strong research institutes	☺☺	☺☺	☺☺	☺
Business schools	☺		☺	
Clinical community for large animal and biocompatibility studies				☺☺
Strong clinical community	☺☺	☺☺	☺	☺
Presence of investors	☺☺	☺	☺	
Community investments			☺	
Good presence of industries in all areas of biotech	☺			
Mature markets and customers	☺			
Strong manufacturing sector		☺☺		
Pharma industry		☺	☺☺	
Strength of IT sector	☺☺	☺	☺	☺
Vibrant start-up community	☺☺	☺	☺	
Networking forums	☺☺	☺	☺	
Job availability in diverse streams	☺☺		☺	
Talent pool	☺	☺	☺	
Mentors with global experience	☺☺			
Legal and CA community	☺☺	☺☺	☺☺	
Incubation	☺☺	☺	☺☺	
Infrastructure		☺	☺	
Support for women entrepreneurs		☺		
Supplier and vendor base	☺	☺	☺	
Government support	☺☺	☺	☺☺	☺
Weather	☺☺			

Figure 2.30 | Advantages in various south Indian clusters as pointed out by Key Opinion Leaders

2.3.2 Key challenges

The challenges / issues expressed by various stakeholders in the four clusters were analysed (Figure 2.31). Start-ups and large companies constitute industries that have several problems in common but many were found to be specific to the age and size of company and therefore 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.

Duty and taxation also adversely affect several innovative projects. Minimum alternative tax of 18% was mentioned as a severe impediment especially in the life sciences sector since most companies have large gestation periods and survival of R&D projects is purely through grants and revenues from the services arms. While this has been addressed in Startup India policy where companies incorporated after April 2016 and notified for innovative capacity are exempt from this, it does not apply retrospectively. High import duties of 30% on raw materials as opposed to less than 10% on finished goods was pointed out as one of the major hurdles for Indian innovators against their competitors from countries such as China and South Korea. Ophthalmology products are exempt from such duties and hence extending this to several other key areas would help several entrepreneurs flourish. In addition, antidumping duties on imported goods in these areas would benefit notified start-ups towards following competitive pricing for their technologies.

Vendor base for engineering prototypes / manufacturing was a problem faced by SMEs and start-ups.

Goods and Services Tax (GST) and its implications on start-ups

The GST bill that will be implemented from April 2017 aims to unify all indirect taxes. This is expected to benefit all businesses and favour start-ups.

1. The ease of starting a business in India by rationalising taxes through GST is expected to encourage entrepreneurs to enter into the manufacturing and industrial sector. Currently, several registrations such as VAT registration, CST registration, import / export registration are required to avail duty benefits. This will be eliminated on implementation of GST.
2. The significant aspect of GST is that this tax will be levied only on the final destination or on consumption of goods or services based on the value added (addition of value would be the taxable event) . This helps to eliminate economic distortions in taxation amongst the states and helps in the free movement of goods.
3. GST also seeks to reduce the discretion exercised by the assessing authority to ensure a more transparent taxation system. This is expected to provide better opportunities for new businesses.
4. The tax is levied only on finished product movement and not at every stage of production or distribution, thus removing the complexity of taxation.
5. Individuals are expected to benefit from reduced prices due to GST resulting in increased consumption and its ripple effect on the economy.

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. Local vendors with smaller manufacturing factories were usually approached by entrepreneurs. While most of these vendors possessed good skills, they lacked design capabilities or creativity to be able to manufacture from drawings or explanation. Start-ups were often found to import the initial prototype from elsewhere and then needed several iterations to obtain a desired quality product. Although it served as a work-around, these problems could pose serious issues in the establishment of strong long-term manufacturing capabilities in the Country.

Indian academia seemed to lack awareness of industry needs and often appeared to be out-of-sync 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 severe lack of capabilities in the other. A more detailed discussion on issues with collaboration have been taken up in the subsequent section.

	Industry		Academia	Enablers
	Startups	SMEs / Large Companies		
Funding	☹☹	☹		
Sales / Marketing expertise	☹			
Compliances	☹☹	☹☹	☹☹	☹☹
Duty and taxation	☹☹	☹☹		☹
Vendor base	☹			☹
Innovation talent	☹	☹	☹☹	☹
Awareness on commercialisation, IP & regulations	☹		☹☹	
Perception of working with other stakeholders	☹	☹	☹☹	
Collaboration with other stakeholders	☹		☹☹	☹

Figure 2.31 | Summary of issues pointed out by various stakeholders

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, five likely causes were identified. For each hurdle, KOLs were asked to select from the five probable causes which they felt were important. Figure 2.32 gives a glimpse of what % 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.

Several institutes were found to have restriction on sabbaticals and rules in permitting students from starting their ventures. Over 60% KOLs felt such attitude and archaic rules in academic institutions were important bottlenecks that needed reforms to enable a conducive innovation ecosystem in academia.

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.

Most of Indian academia was still caught up in the proverbial 'publish or perish' mode and other activities such as industry collaborations and spin-offs were not encouraged. This reflected in the absence of criteria like translational prospects of research or sourcing funds from alternate routes in faculty performance metrics.

Industries and start-ups opined that the pace of work in Indian academia was often slow because of lack of motivation to quickly commercialise a technology with only relevant experiments. 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 do not take their technology 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.

2.3.3.2 Intellectual property rights

Protecting technologies from infringement or copying through filing of patents was recognised by academia as important. Awareness and ability to protect IP was not evidenced beyond top tier institutes. About 40% of the KOLs said that prohibitive costs in obtaining Patent Cooperation Treaty (PCT) filings, budget cuts and competitive funding landscape made patenting take a back seat especially in academic institutes because of lack of clarity in valuation of patents and their ability to provide reasonable return on investments. However, with increasing early stage funding, seed grants and funding schemes specifically for filing patents, these problems are expected to diminish over time.

In addition, University Grants Commission (UGC) norms mandates publications for graduating students which often interferes with timelines of filing.

Procedural delays and lack of trained manpower to manage patent cells / TTOs caused technologies to become obsolete or lose their relevance with industry.

2.3.3.3 Regulatory hurdles

One of the biggest obstacles that made several entrepreneurs hit a wall was regulatory hurdles.

One of the biggest challenges as pointed out by nearly 40% KOLs was the lack of comprehensive guidelines or bodies to certify Indian technologies. Healthcare, pharma and biotech sector are governed by the Drugs and Cosmetics Act of 1940 that has caused a lot of uncertainty in the applicable rules.

Lack of standards in many areas leading to the adoption of EU (European Union) or US-FDA (United States Food and Drug Administration) standards had its own share of problems.

At CDSCO, whose manpower primarily has a pharma background, people have impeded the understanding within the regulator of new emerging technologies such as synthetic biology, biosimilars, CRISPR and medical technologies leading to slowness in the process of regulatory 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.

The Indian regulators were often also branded to be less transparent leading to lack of faith by several innovators to pursue the entrepreneurial route. Large companies have the wherewithal to address this issue.

Restrictions on biodiversity, adoption of GM (Genetically Modified) crops were mentioned as topics where the societal conversations had not adequately taken place and a very minor vocal group of advocacy groups have dominated the narrative.

Nearly 20% KOLs felt that regulatory clearances during setting up the company was a hurdle. These processes are however getting increasingly streamlined and will hopefully not be a problem in the future. About 30% KOLs mentioned duties and taxation as an issue. As discussed earlier, introduction of GST is expected to address this problem.

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.

Lack of funding in development phase for start-ups and a limited number of players in angel and early stage VC rounds were pointed out by 40% and 50% of KOLs respectively as a reflection of a broken ecosystem. About 20% KOLs felt lack of synergy between government and institutional funding is an added impediment in incentivising the life sciences sector in comparison to other areas such as IT or E-commerce.

Several hurdles and long gestation periods have not yet brought in enough confidence among private investors to fund heavily in life sciences sector. The culture of PhDs or second generation entrepreneurs turning into venture capitalists was felt necessary, especially in ascertaining the prospects and risks involved in these investments.

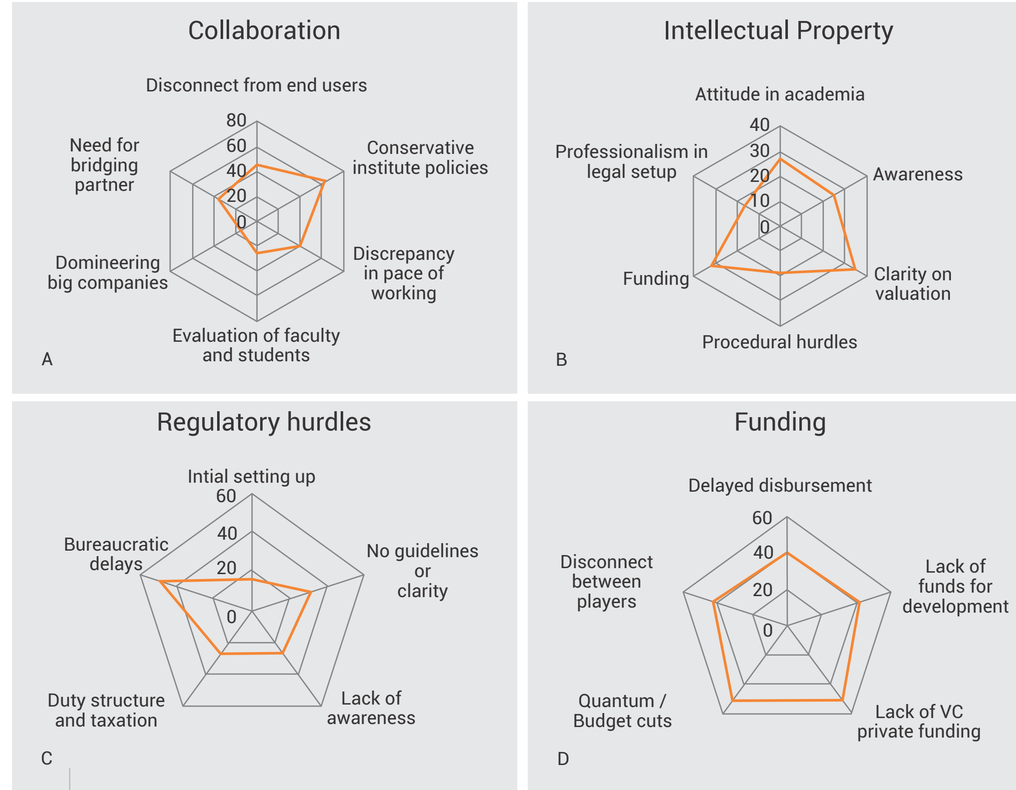


Figure 2.32 | Major hurdles discussed by KOLs - Percentage of KOLs pointing out various issues in collaboration (A) intellectual property rights (B) regulatory hurdles (C) and funding (D) are represented

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 (Figure 2.33).

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. Establishment of BIRAC with innovation funding schemes for industry at various stages of growth was a move in the right direction. Larger investment ticket sizes from government funding would be possible only if the budgets of DBT, the Department of Science and Technology (DST), Council for Scientific and Industrial Research (CSIR), ICMR, Department of Electronics and Information Technology (DeitY) and other science and technology led departments were increased and a higher percentage of India's GDP was invested in R&D activities.

Larger funding for government schemes encouraging industry-academia collaboration like those by BIRAC and DeitY would lead to more active knowledge flow within the ecosystem.

Department of Scientific and Industrial Research (DSIR) recognition to new start-ups without physical assets and operational track record and to incubators / bodies promoting start-ups would have a huge bearing on the ability of start-ups to attract funding.

Revisions in the bankruptcy law was requested. This has already been addressed by the Insolvency and Bankruptcy Code, 2016 passed in May 2016.

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.

Figure 2.33 | Various levels of solutions or expectations from KOLs to improve innovation ecosystem

2.3.4.2 State level policy changes

Matters related to infrastructure, education, local taxes are state matters and therefore, state level policies also need to be aligned with the national level incentives.

First and foremost was establishing single window clearances for company establishment, sales tax and VAT registrations and clearances from the pollution control board. State level taxes and labour laws also need to be aligned to the state's focus on incentivising the biotech sector. State level start-up policies of the governments of Kerala, Telangana and Karnataka reflect the proactive role played by the states in promoting start-ups.

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.

Several KOLs pointed out that a big challenge in availability of good creative talent was linked to the education system. While there are central boards of education, many students graduate through schools that adhere to state decided syllabus. The current education system was primarily dependent on rote learning which in the long run impedes the creativity and problem solving capabilities of students. Revision in teaching methods would be the first step towards talent generation.

2.3.4.3 Stakeholder level changes

With the government incentivising start-ups through various schemes, it was also the responsibility of the individual players 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. Establishment of LARTA like bodies would be crucial in knowledge dissemination to new age entrepreneurs and academic spin-offs as a one stop solution for myriad issues faced by them. Such bodies could be part of public private partnerships.

Academic institutions have a huge role in improving the state of education. While syllabus is a state matter, offering elective courses, mandating industry internships or short-term courses on business fundamentals is a decision for individual institutes to make. This would be particularly useful in generating industry-ready talent.

Individual companies could start acceleration centres either in partnership with incubators or by themselves. This trend is increasingly gaining popularity. This would help in nurturing entrepreneurs at an early stage and aligning industry-start-up-academia goals.

Since funding was scarce, it would be important that individual institutions and companies accessing government grants use equipment procured responsibly. Redundancy in equipment leads to insufficient use and on the whole reduces productivity. Lastly, veterinary colleges should also consider establishing Technology Business Incubators to be able to conduct large animal studies and trials.

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 is affected by several stakeholders and the type of interactions amongst them. In Figure 3.1, a colour coding 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.

The present study focused on the underlying dynamics of four clusters spread across south India - viz Bengaluru, Hyderabad, Chennai and Thiruvananthapuram. Through this report, we have shown the inherent strengths and existing gaps in each of these clusters including the nature of interactions amongst the four stakeholders. Two of the four clusters, Hyderabad and Bengaluru that the report focused on, 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 is rapidly growing as a biopharma cluster and is leveraging its lessons from being the automotive hub of the Country while Thiruvananthapuram is still a nascent hub that shows potential for future growth.

Through a combinatorial approach of primary, secondary data and interviews with KOL, the present study has teased apart the underlying tendencies of the four 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 B2G or B2C. B2G models work well for public heath related and low cost technologies. However, when higher value products are involved, going through a tendering process could often be cumbersome for start-ups. With the Government encouraging entrepreneurship, further support in the last mile of public procurement would further add to the success of translation of innovation. B2C models are often difficult for entrepreneurs considering the sales, distribution and marketing costs.

India has over 100 Technology Business Incubators (TBIs) and incubation facilities and the Government has played a significant role in providing support for initial establishment of several bio-incubation centres in the four 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 to entrepreneurs and SMEs, but also facilitate networking and cross-talk 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. Incubators need to improve the quality of mentoring support. This is a challenge given the fact that the ecosystem in each of these clusters is young, with limited supply of mentors. On the funding front, grant support in India is very positive which now enables several people to receive funding at the crucial stage of taking an idea to the proof-of-concept - the first hurdle in the productisation value chain. While there are a few instances of follow-on funding programmes by the Government, the present study found that there is a case for initiating several other follow-on funding programmes which would help start-ups to transition to the next level. Also, there is a need for synergy between institutional funding and government grants so that deserving start-ups do not become victims of the so called "valley of death."

While launch of several schemes by the Government has created a conducive environment for entrepreneurs, lack of regulatory transparency, standards and guidelines would pose a huge obstacle in the coming years. This lack of clarity also creates an unfriendly environment for early stage investors to fund start-ups.

Academia plays a crucial role in any innovation ecosystem. There has been a 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.' Basic research and translational research are intertwined and need significant funding to attract talent such that there is a critical mass of well-trained innovators in the future. There is an urgent need to create a vibrant ecosystem in the innovation capacity of Indian academia to especially encourage translation of academic research into products and processes that benefit the society. Faculty-led entrepreneurship has taken roots in at least three of the clusters that this report studied (Bengaluru, Hyderabad and Chennai) and is growing. This needs further policy impetus and changes in academic policies especially in assessment frameworks for promotion of faculty such that the faculty who wish to combine research with entrepreneurship are not disadvantaged. There is a noticeable trend of establishment of new private universities in southern India. Some of the private universities are transforming themselves from 'teaching only' institutions to combine research components. This is a positive trend. It will be important to find policy instruments that can help private universities to transition from only teaching universities to research universities.

Overall, reforms could be classified into short-term and long-term; short-term involves immediate fixing of gaps in support, procurement and funding obstacles; long-term involves reforms in education, research and regulations that are crucial in creating a culturally suitable environment for innovation and entrepreneurship.

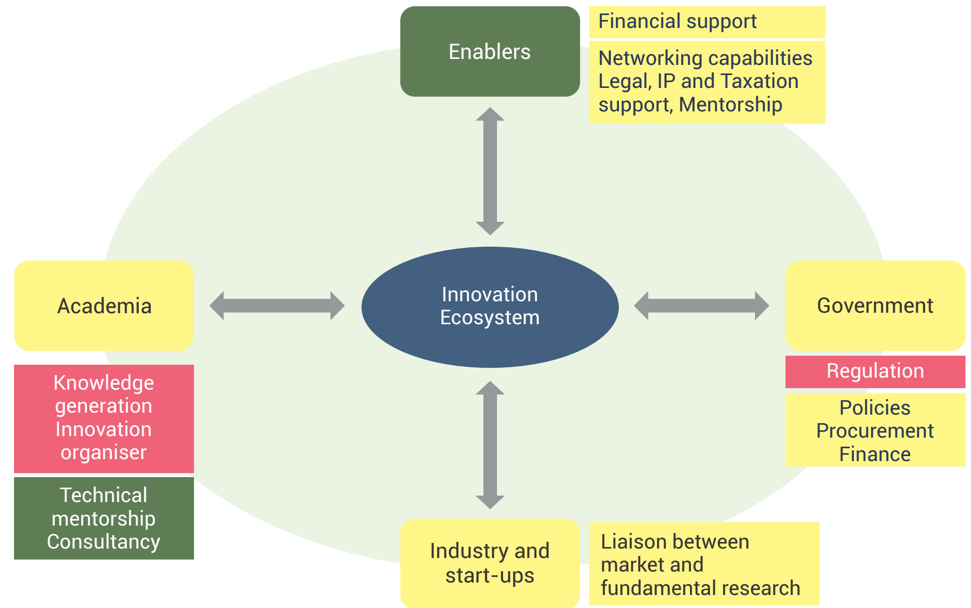


Figure 3.1 | Current status of the Indian innovation ecosystem - Green, Yellow and Red boxes indicate vibrant, intermediary and poor status respectively

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 in south India, will play a critical role for achieving the stretched target. However, there exist 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 to provide the following recommendations:

1. Knowledge generation

Ensuring quality and relevance:

- Making it mandatory to include parameters such as H index for appraisals and promotions. Tenure track positions to be awarded on review after few years.
- Encouraging sabbaticals to explore new frontiers and stay up-to-date with emerging applications.

- Incentivising younger faculty: Reducing number of years of service to qualify for sabbaticals. Promotions and incentives to be given for faculty who manage to succeed and return back to academia.
- Institutions with good publishing records could be selected for targeted translational programmes, primarily to promote truly interdisciplinary collaborations. Such collaborations could look beyond publications and include co-development of products.
- Bringing in the culture of translational research in academia and research institutions through sensitisation and awareness programmes and creating a vibrant, conducive ecosystem.
- Change in academic policy to include a performance matrix that takes into account entrepreneurial achievements, IP, technology licensing for faculty promotion.
- Capacity building of promising private institutions through increased funding for research.
- Connecting private academic institutions with public institutions for joint innovation research.
- Greater emphasis on academia-industry collaborations especially in the realm of product development.

2. Regulations and regulatory bodies

- Improving the human resource capacity of the regulatory agencies, especially provision for wider backgrounds of regulators rather than purely pharma graduates. PhDs / industry experience in various streams of science and engineering would enable better guidelines, clearances and due diligence.
- Policy changes in public procurement of innovative products, greater transparency in public procurement.
- Greater fiscal and tax credits to support innovation-driven R&D in industry. Special tax provisions / incentives in VC / Angel investments for R&D core companies in defined focus areas. These could be adapted from Israel, Singapore or New Zealand.
- Antidumping duties on imported goods in specific focus areas would benefit DIPP recognised start-ups towards competitive pricing of their technologies.

3. Capacity building in enabling ecosystems:

- Training programmes for individuals in Technology Transfer Offices (TTOs) in academic institutes to be able to market technologies and negotiate for reasonable valuations.
- Setting up regional professionally managed TTOs to help institutes that cannot run their own TTOs effectively.
- One on one networking forums especially for entrepreneurs, through incubators. Although this is implicit, certain number of unique value added interactions should be mandated.
- Presence of active clinical advisors in incubators to help improve connect with clinical requirements and enable easier acceptance when clinicians are end users.

- Setting up Technology Business Incubators in veterinary institutes for conducting large animal studies and trials.
- Incubators, science parks to be supplemented with pilot scale plants and packaging facilities to accelerate manufacturing capabilities of start-ups.
- Setting up LARTA like bodies as one-stop solution for start-up queries under a public private partnership.
- Establishing more institutes for technical training to strengthen vendor base with possible global collaborations.

4. Funding

- Need for follow-on funding: To initiate greater number of follow-on funding schemes through public agencies as well as through PPP models.
- Large ticket size grants: There is a need for larger quantum of grants especially beyond the proof of concept stage for high risk product development. This could be both in areas of national priority and in high global opportunity segments.
- Sensitizing angel and VC funders on intricacies of life science product development and need for more events connecting start-ups to private funders.
- 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 start-ups. The information could be used by VCs to encourage investment in technology heavy start-ups.
- Policies on engaging the diaspora would be advantageous in the long run not only in monetary terms but also in transfer of technological knowhow.

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BIRAC is a Section 8 (not for profit) company setup by the Department of Biotechnology (DBT), GoI 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 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 16 years of operations, IKP has supported over 220 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.