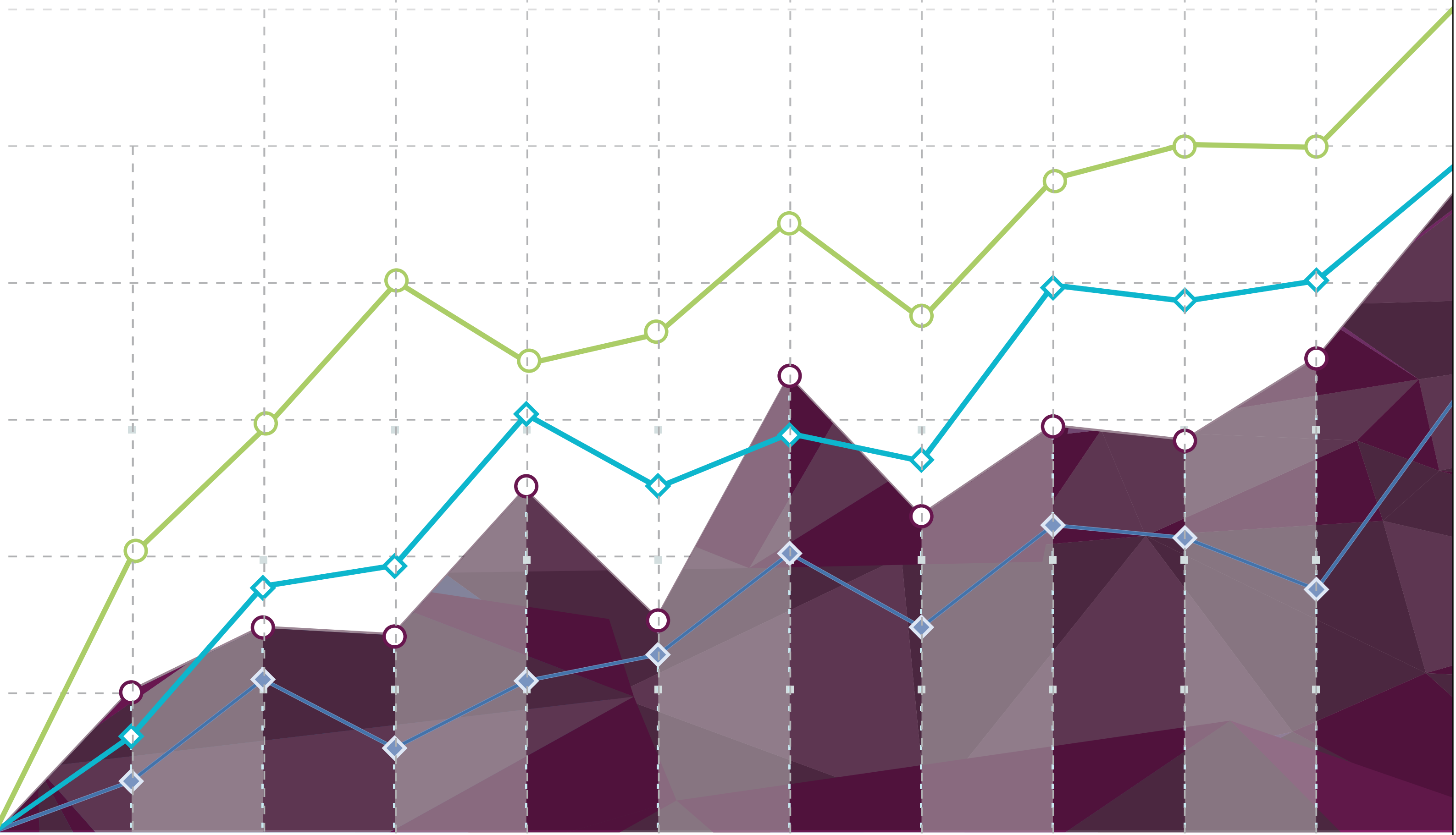
CTIER Handbook:
Technology and Innovation in India
2021



CTIER
CENTRE FOR TECHNOLOGY, INNOVATION AND ECONOMIC RESEARCH

An independent think tank established to inform public thinking on the crucial role of technical capability in economic development

Reviews - CTIER Handbook 2019

"The CTIER Handbook is very useful and relevant as India progresses in increasing its innovation intensity. Technology innovation will be key to India's development and this Handbook is an important addition to catalyse this process."

Nandan Nilekani
Co-founder and Chairman of Infosys and Founding Chairman UIDAI (Aadhaar)

"The CTIER Handbook provides many unique indicators on India's innovation landscape. At Bajaj Auto, we export about 40 percent of our output to over 70 countries. Our success derives from developing products that consumers love worldwide, so innovation is at the heart of what we do. The CTIER Handbook will enable us to benchmark ourselves against global leaders, and will serve as a useful companion in our journey."

Rajiv Bajaj
Managing Director, Bajaj Auto

"Data-driven innovation is the key to India's economic future. By compiling data on R&D related inputs and outcomes in India into an extensive list of indicators, this Handbook provides a good overview of India's technology and innovation sector, appropriately placed in a global context. This is a timely and valuable resource that will be of great use to both government and business leadership as we forge a new path for India in the Fourth Industrial Revolution."

N. Chandrasekaran
Chairman, Tata Sons

Reviews - CTIER Handbook 2019

"The CTIER Handbook is a brilliant compendium of contemporary, comprehensive, and comparative data based evidence of the state of technological innovation in India. It also draws sharp insights into issues that link firm and sector level innovation driven outcomes to macroeconomic outcomes. It is the most definitive reader for all those who wish to understand how innovation and related government policies are tied to economic growth and well being of the people of India."

Pankaj Chandra
Vice Chancellor, Ahmedabad University

"The CTIER handbook is an impressive review of the level, range and types of innovation ongoing in the Indian economy. Previously analyzing this required scouring almost a dozen different data-sources, so brining this together into one document with insightful analysis is a huge step forward – anyone interested in modelling and predicting the growth of the Indian economy should read this."

Nicholas A Bloom
William Eberle Professor of Economics at Stanford University,
Co-Director of the Productivity, Innovation and Entrepreneurship program at the National Bureau of Economic Research.

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Foreword

The Chinese sage Confucious is supposed to have said "May you live in interesting times". Confucius meant this as a curse, and we can see why. We live in very interesting times. An unprecedented health crisis has affected every country this past year, prompting unprecedented action to lock down economies, with devastating consequences. Global economic growth in 2020 is forecast to be minus 5 percent, and in India minus 7.5 percent. Our goal must be to not only recover, but to put in place long run processes to grow rapidly for decades. Innovation typically accounts for over half of long run economic growth. So if we want to grow at rates of 7, 8, 9 and 10 percent year on year, we must gain a deeper understanding of how one builds technical capacity across the economy.

In these last few months, the government has launched a programme to deepen technical capability within Indian industry. Atmanirbhar (AN), or self-reliance, has been supplemented by a production-linked incentive (PLI) scheme. AN-PLI has identified thirteen sectors where supply chains must be deepend. For example, not just mobile phones, but the components that go into them, and not just pharmaceuticals, but the APIs they are made off. It provides firms with a subsidy of Rs 2 trillion over five years, almost one percent of GDP. The government has also continued its policy of increasing protection of Indian industry, with thousands of items seeing increased tariffs over the last four years.

The government emphasises that its objective is not to cut India off from the world, but to build an Indian industry that is stronger, and will integrate more competitively with the world. Will it work? Will Indian industry emerge more competitive and with deeper domestic supply chains and value added? Or will we revert to our 1970s-style economy of an uncompetitive industry sheltering behind high tariffs? Whether we succeed or not will depend on three things.

First, the government needs to adopt a much stronger export-oriented stance. This requires that all tariff protection be limited in time - with a clear and announced road-map for reduction to zero in say five years for the bulk of items. This must be combined with a pro trade policy - with free-trade agreements in place to access our most desired markets on attractive terms. And we need to shed our misplaced preference for a strong rupee - a rupee at Rs 100 to the dollar would completely address the protection of Indian industry without tariffs, and be the greatest export incentive around. The government can go further, and insist that the PLI subsidy requires export commitments, and these export commitments must be met for the subsidy to be paid.

Second, industry needs to have a much more aggressive investment strategy for technology and international markets. In house R&D investment by Indian industry accounts for 0.3 percent of GDP, compared with 1.5 percent for the world. So we must scale our investment in R&D by a factor of five. This CTIER Handbook is full of comparisons with other countries, by industry, to suggest how.

Third, the government needs to understand that investment in public research is not of value if it continues to be made in autonomous state R&D laboratories. This investment has to progressively move to the higher education sector, where most of the world does it. Public research in our higher education sector accounts for 0.05 percent of GDP, compared with 0.4 percent worldwide - so it needs to scale by a factor of eight. The objective is not research output; that is at best a nice bonus. The goal of public research is talent, to develop brilliant students who learn to be good researchers alongside their professors.

The Institute of Chemical Technology in Mumbai, previously the University Department of Chemical technology, has a well-deserved reputation of being our country's premier research-teaching institute. It has produced fine research output for decades, with hundreds of patents, thousands of consulting assignments, and a close connection with industry. But this contribution of its research output pales in comparison with the value it has added through its graduates - which include Mukesh Ambani of Reliance, Madhukar Parikh of Pidilite, Keki Gharda of Gharda Chemicals, Ramesh Mashelkar of NCL/CSIR, Anji Reddy of DRL, Narotam Sekhsaria of Ambuja Cements, and M M Sharma of UDCT (who himself did so much to build UDCT into the powerhouse it is). Thousands of lesser known graduates form the foundation for our successful pharmaceutical and speciality chemical industries. The UDCT story needs to be writ large across sectors and disciplines. We must build talent for India, by moving our public research funding from the state autonomous R&D institutes to higher education.

It is with great pleasure that we release this second CTIER Handbook on Technology and Innovation in India 2021. I would like to record my thanks and appreciation to Janak Nabar and his committed small team at CTIER for doing so much to make good quality data on India's innovation available for us all - and to provide a comparative perspective for many indicators, so we know where we are normal, and where we are not. This 2021 edition is greatly welcome as we rebuild our economy, and set course for decades of rapid growth. Innovation will be at the heart of that process. These Handbooks help us understand how.

Naushad Forbes

Pune, January 2021

Acknowledgements

We are extremely grateful to Rakesh Basant, Pankaj Chandra, Sunil Mani and Anjan Das for their continued support and guidance as members of CTIER's Research Advisory Council. This edition of the Handbook also contains opinion pieces by Rakesh Basant, Pankaj Chandra and Sunil Mani, giving our readers excellent insights on the data presented in the Handbook. The Handbook has benefitted immensely from the generosity of their time and ideas.

This Handbook would not have been possible without the generous funding support of Forbes Marshall and Bajaj Group CSR. We are also thankful for the support we have received from members of Forbes Marshall, especially Bobby Kuriakose, Rajendra Bhide, Digvijay Bhandari, Chhaya Gogate, Pratik Ghosh, Shirley Ignatius, Dharmesh Thaker, Rahul Mahashabde, Jayant Damle, Hemant Zende, Homi Sanjana, Roopali Pathak, Shaleen Radhu, Nitin Kunjir, Prakash Kinage, Navanath More and Pradeep Shelar. At Bajaj Group CSR, we would particularly like to thank Pankaj Ballabh and Shraddha Agrawal.

The entire process of collating and verifying the data presented in the Handbook is challenging at the best of times, especially when there are multiple sources of publicly available data as well as specialised subscription databases involved. Co-ordinating this exercise has been even more challenging during the pandemic. Pankaj Chandra's generosity allowed us access to various databases at Ahmedabad University that helped supplement CTIER's own database subscriptions. Our past interns, Nikhil Krishna, Kartikeya Vashista, Sanket Chhajed, Abhishek Mukherjee assisted the team in compiling much of the state level data presented in this Handbook. We also received valuable support from Anamika Chourasia, Neeraj Singh, Subashree Nag, Deepika Kotecha, Anupam Das, Chirag Mange, Pranav Sharma and Stuti Misra for data on publications, startups and patents.

The CTIER Team would also like to thank Jayesh Parmar, Kamlesh Kakade and Noshir Dadrawala for their support to the Centre. Sameer Karmarkar and Kartiki Jagtap at Satisfice Designs, Pune have greatly helped enhance the layout and design of the Handbook. At various points during the past year, we have been fortunate to benefit from discussions with Abrar Ali Saiyyed, Subash Sasidharan, Dinar Kale and Smita Srinivas.

Lastly we would like to thank our families for their patience and constant encouragement that enabled us to put together this second CTIER Handbook, working remotely across multiple geographies and differing internet speeds.

Swati Joshi, Dipti Singhania, Vaishnavi Dande, Madhurjya Deka and Janak Nabar

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Chapter 1

About the Handbook

Chapter 01

About the Handbook

The CTIER Handbook: Technology and Innovation in India brings together key indicators of India's R&D and innovation ecosystem. The data captured in the Handbook allows for a comparison of India with the global economy, covers indicators on regional innovation systems and encourages a deeper study of industrial R&D and innovation in India. The Handbook is intended for use by policymakers, industry leaders and academics. The purpose of having these indicators in one place is to encourage the reader to draw her own conclusions about India's innovation ecosystem. It also hopes to draw the reader into the debate on the need for greater R&D and innovation in India, its importance for India's economic development, and how this could best be fostered.

The CTIER Handbook Technology and Innovation in India 2021 builds on the set of indicators introduced in the CTIER Handbook Technology and Innovation in India 2019 published two years ago. In this edition of the Handbook, we have invited essay contributions from members of CTIER's Research Advisory Council that can be found in Section 1. The essays expand upon or have used data that appears in Section 2. Furthermore, we have also introduced a few new indicators, used multiple sources of data for some of the indicators to ensure the data is as comprehensive as possible, introduced new data in the Appendix section that some of our readers may find useful, and have tried to address issues concerning data that we felt were problematic. Examples of these new indicators or issues that we have tried to address have been captured in Table 1.2 towards the end of this chapter.

The next section of this chapter discusses the structure of the Handbook followed by the Data and Methodology section.

Structure of the Handbook

The Handbook comprises two main sections – 'Section 1: Technology and Innovation in India: Essays' that has essay contributions from invited authors as well members of the CTIER team and 'Section 2: Technology and Innovation in India: Indicators' that consists of three data chapters. The three chapters in Section 2 cover 'India and the Global Economy', 'Regional Innovation Systems' and 'Industry in India'. The data in Section 2 has been organised to showcase 'input' and 'output' indicators with respect to R&D and innovation in India. Examples of the input and output indicators we have considered can be found in Table 1.1 below.

Table 1.1 | Examples of Input and Output Indicators

Input Indicators	Output Indicators
• R&D expenditure as percent of GDP • Charges for the use of intellectual property (payments) • Foreign Direct Investment • Venture Capital Investment • Researchers per million • Manpower employed in R&D • Policies introduced by state governments • Pupil teacher ratio and gross enrolment ratio in higher education • Number of incubation centres • MNC R&D presence in India	• Publications by country, including share of industry-academia collaborations • Patents, trademarks, copyrights filed domestically and abroad • Patents granted • Share of high technology products in manufactured exports • Number of startups by state

In 'India and the Global Economy', we find that India's R&D spending continues to be dominated by the government sector that accounted for 52 percent of India's total R&D expenditure in 2018. Industry's share of total R&D expenditure was 41 percent in 2018, having edged slightly lower from 44 percent in 2015. The R&D expenditure by major government scientific agencies increased to around USD 7.2 billion in 2018 from USD 5.7 billion in 2015. The Defence Research & Development Organisation (DRDO) continues to be the largest spender on R&D amongst the major government scientific agencies. With respect to global industry, Indian firms remain absent in 5 out of the top 10 global industrial R&D sectors. China has seen a marked increase in the number of firms that make it to the list of the top 2,500 global R&D spenders – in 2019 there were 507 firms from China that were present in this list compared to 326 firms in 2016. The structure of industrial R&D in India has seen two new sectors making an appearance in the top R&D sectors for India, namely food producers and electronic & electrical equipment. With respect to foreign direct investment (FDI) into India, the data captures the amount of FDI received by top sectors in 2018-19 and 2017-18. These top sectors have been identified based on cumulative FDI that has come into these sectors since the year 2000. However, if one simply considers the top 10 sectors that attracted FDI in 2018-19 alone, then the non-conventional energy sector is seen to make it to the top 10 sectors that attracted FDI in 2018-19. India remains one of the top three destinations with respect to Venture Capital (VC) funding globally, having attracted around USD 13.6 billion in VC funding in 2018. While India is one of top countries in terms of global research publications, its rank is seen to improve to number six from number ten when journals from the Web of Science's Emerging Sources Citation Index (ESCI) are taken into consideration. The number of patents granted to India by the USPTO was 5,378, with multinational corporations based in India continuing to account for a large share of these patents.

The 'Regional Innovation Systems' chapter is intended to provide an overview of the innovation systems of India's states. It considers data on various policies that have been introduced by the states to promote innovation in different sectors. In recent years, around 7 states have introduced or are working on electric vehicle policy while around 8 states have introduced an aerospace & defence policy. There is data on firm R&D presence across states taking into consideration firms whose R&D units had been recognised by the Department of Scientific and Industrial Research (DSIR). Some of the other data in the chapter includes FDI by states, funding for startups across states, the number of startups that have been established in 2019, government supported incubators across states as well as data on distribution of top ranked education institutes across states. While Maharashtra has the highest number of industrial R&D units based on the available sample of DSIR recognised units, it is also the top state in terms of funding received for startups as well as the number of new startups that were established in 2019. Tamil Nadu ranks highest for some of the indicators that cover government supported incubators as well as the number of educational institutions in the top 100 institutions in India. Andhra Pradesh and Uttar Pradesh are the top states when it comes to the number of institutes of national importance like the Indian Institutes of Technology (IIT), the National Institutes of Technology (NIT), the Indian Institutes of Science Education & Research (IISER) etc. Given the varying degrees of each state's innovation capabilities and the different challenges they face, this chapter is intended to encourage the study of regional innovation systems by focusing on the innovative capabilities of firms and the institutions around them.

In 'Industry in India', one of the key indicators is the list of the top 100 R&D spenders in India. In 2018-19, Tata Motors Ltd recorded the highest spending on R&D by a firm in India. Tata Motors had also been ranked first in the top spenders list in the CTIER Handbook 2019. The top 100 spenders account for around 80 percent of industrial R&D in India. Siemens, which is ranked 21 in the list of the top 2,500 global R&D spenders, spends more than all of Indian industry on R&D. The chapter also features data on the R&D intensity (R&D expenditure as a percent of sales) of select Indian firms within India's top R&D sectors in comparison with the global average R&D intensity for each of these sectors. With respect to the R&D spending by multinational corporation (MNC) R&D centres, we have estimated this to have totalled around USD 10.5 billion in 2019.

The startup sectors that were among the larger recipients of funding in 2019 included the consumer sector, fintech, retail, and the travel and hospitality tech sector. The sub-sectors that dominated the funding landscape within the consumer sector were B2C e-commerce and logistics tech while payments and alternative lending dominated the fintech sector. The chapter also presents a sectoral breakdown of patents obtained in 2018-19 by Indian industry. The industrial sectors that dominated were pharmaceutical & biotechnology and software & computer services followed by automobile & parts and oil & gas. It is interesting to note that a higher share of patents were granted abroad for the pharmaceutical & biotechnology, software & computer services and the oil & gas sectors, while the automobile & parts sector had a significantly higher share of patents granted by the Indian patent office.

Data and Methodology

The data in the Handbook has largely been collated from secondary sources.

For global indicators, we have used publicly available databases from the World Bank, the World Intellectual Property Office, the United States Patent and Trademark Office, UNESCO Institute for Statistics, Organisation for Economic Co-operation and Development, the US National Science Board and the EU Industrial Investment R&D Scoreboard.

Data pertaining to India were compiled from various reports, publications, websites and databases of Government of India departments and ministries such as the Department of Science and Technology (DST), Department of Scientific and Industrial Research (DSIR), Department for Promotion of Industry and Internal Trade (DPIIT), the Reserve Bank of India (RBI), Ministry of Human Resource Development (MHRD), StartUp India, Invest India, state government department websites and various annual reports published by companies. We have also used third party subscription databases such as Prowess, Web of Science, XLPAT and Tracxn where required.

The data in Chapters 6, 7 and 8 have been presented in the form of charts, tables and maps, along with accompanying text on facts observed in the data. The Handbook also contains certain indicators that have been developed by CTIER – such as the top 100 top industrial R&D spenders in India, the top R&D sectors in India, the number of higher technology R&D centres in different states, number of Indian and global patents by industrial sector based on patents obtained by India's top 100 R&D spenders. For the indicators that have been developed by CTIER, the accompanying text contains a brief description of the methodology used to construct the indicator.

Changes from CTIER Handbook 2019

In the current Handbook, we have introduced new indicators, modified certain indicators, or removed indicators that had been introduced in the previous Handbook. The decision to remove any indicator would have been prompted by the poor quality of the underlying data available at the time of writing the current Handbook. We also highlight instances where we have identified certain anomalies in the original data sources and the steps taken to address these anomalies. The table below captures the changes that have been introduced in the CTIER Handbook: Technology and Innovation in India, 2021.

Table 1.2 | Changes Introduced in Current Handbook

Indicator Number	Indicator Name	Nature of Change
6.11	Country-Wise Comparisons by Share of Publications, Impact, Share of Industry-Academia Collaborations and Share of International Collaborations in Total Publications (2015-19)	The share of international collaborations in total publications has been newly introduced as part of this indicator. It has also been introduced in indicators 6.12, 6.12.1 and 6.13.
6.18	Patent Applications with Indian Patent Office by Sector (2019)	The data in the 2018-19 annual report of The Office of the Controller General of Patents, Designs & Trademarks (CGPDTM), Government of India, for patent applications for a number of sectors were found to be inconsistent with data historically reported for these sectors by the CGPDTM. The data by sectors in indicator 6.18 has been modified to ensure consistency with data reported in previous years Annual Reports.
7.5	State-Wise Number of Incubation Centres	This indicator in the CTIER Handbook 2019 was based on data available on the Startup India website. In the current Handbook, this indicator uses data available from the Department of Biotechnology, the Biotechnology Industry Research Assistance Council (BIRAC), the Ministry of Electronics and Information Technology, the Department of Science and Technology and the Atal Innovation Mission, Niti Aayog. The data has been checked for overlaps with the data on incubators that had been previously available on the Startup India website.
----	Technology Payments by Sector	This indicator had appeared in the CTIER Handbook 2019 as indicator 8.4.1 and had provided a breakdown of technology payments by sector for Indian industry. Although the current Handbook has an indicator on the total technology payments by Indian industry, the indicator on technology payments by sector has not been included in this Handbook due to concerns that the sectoral breakdown would not be accurate in its representation.
---	Import of Capital Goods by Sector	This indicator had appeared in the CTIER Handbook 2019 as indicator 8.5.1 and had provided a breakdown of import of capital goods by sector for Indian industry. Although the current Handbook has an indicator on the total import of capital goods by Indian industry, the indicator on import of capital goods by sector has not been included in this Handbook due to concerns that the sectoral breakdown would not be accurate in its representation.

Indicator Number	Indicator Name	Nature of change
8.8	Sectoral Breakdown of Patents Granted to India's Top 100 Industrial R&D Spenders (2018-19)	This is a newly introduced indicator. The data by sector has been compiled based on patents that had been granted to India's top 100 industrial R&D spenders, both in India and abroad.
8.9	Top Patentees with the Indian Patent Office (2018-19)	For the CTIER Handbook 2019, the data had been available in the annual report of The Office of the Controller General of Patents, Designs & Trademarks, Government of India for the top 5 patentees with the Indian Patent Office. In the current Handbook, the data has been put together using the XLPAT database. The data is based on the first named applicant with the Indian Patent Office.
A.2	Annual Foreign Direct Investment into India by Components	The current handbook provides a more detailed breakdown of FDI equity inflows compared to the CTIER Handbook 2019. The indicator can be found in the Appendix section.
A.3	FDI Equity Inflows into India by Sector - Top 10 Based on 2018-19	This indicator has been included in the Appendix section and highlights the top 10 sectors that attracted FDI in 2018-19. In Chapter 6, the data on FDI inflows in indicator 6.6.1 captures the top 10 sectors based on cumulative FDI flows since the year 2000.
A.6	Country-Wise Comparisons by Share of Publications, Impact, Share of Industry-Academia Collaborations and Share of International Collaborations in Total Publications Including ESCI Journals (2015-19)	The main difference between this indicator which can be found in the Appendix section and indicator 6.11 on publications in Chapter 6, is that indicator A.6 takes into consideration publications that appear in ESCI journals.
A.8	Select Policies Introduced by Union Territories	This indicator has been added to complement indicator 7.1 that captures policies introduced by various states and the National Capital Territory of Delhi.
A.11	India's Import of Capital Goods by Commodity	Indicator A.11 captures total import of capital goods by the public as well as private sector and can be found in the Appendix section. It uses data from the Department of Commerce and the World Integrated Trade Solution (WITS) classification of capital goods. Indicator 8.5 captures data on import of capital goods by industry for a select number of firms.

Section 1

Technology and Innovation in India : Essays

Chapter 02

New Ventures and Manufacturing: the Unfinished Agenda

Pankaj Chandra

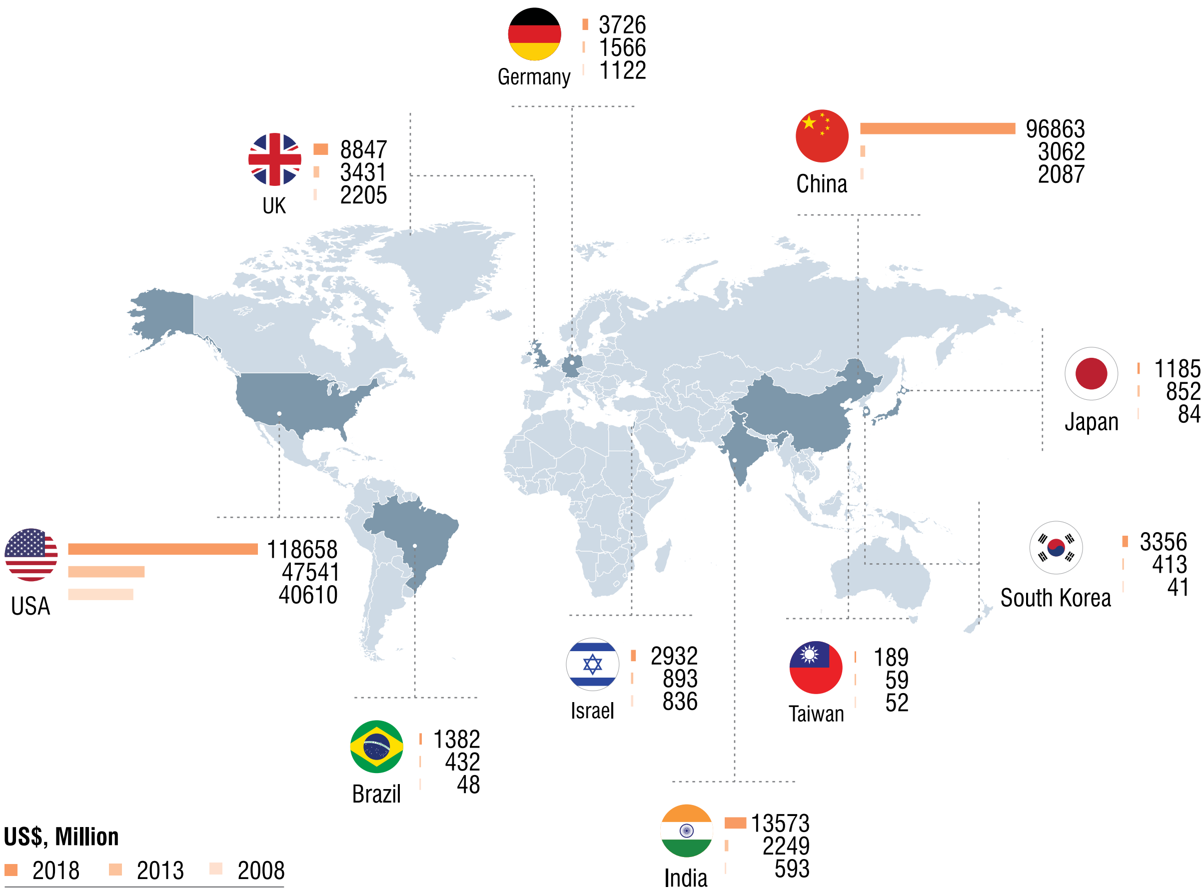
Growth in Indian manufacturing has been stunted. Manufacturing contributed 17.4 percent of Indian GDP in fiscal year 2020 which was slightly higher than its contribution to GDP over the last two decades. Unfortunately, employment in manufacturing increased by "just one percentage point, compared with a five-point increase for the services sector". (Dhawan and Sengupta, 2020) Several emerging countries around the world have doubled their growth in manufacturing during the similar period. With automation and new manufacturing technologies, productivity growth is seen to be coming from such new investments rather than from labour productivity. The worrisome picture is that labour productivity in manufacturing seems to be declining over the last eight years. (Jethmalani, 2019) There is one other fact that needs some attention. In Japan, small and medium enterprises account for 99.7 percent of all enterprises, 70 percent of employees, and more than 50 percent of the amount of value-added (in the manufacturing industry). They are the backbone of the Japanese economy. However, "as per the ASI, an overwhelming 72 percent of the firms in India have 0-49 employees, although the output share of such firms is just 6.9 percent."(Jethmalani, 2019) So how does a nation grow its manufacturing gross value add per worker, how does it increase the involvement of more employees in the manufacturing sector in light of growth in new technologies, and how does it grow its labour productivity?

It is our estimate that if we want to have about 50 medium size companies in manufacturing (with at least INR 250cr turnover), we will need about 5,000 small enterprises to progress towards becoming medium in size. To get 5,000 enterprises to become stable small enterprises, about 50,000 would need to be started. This is a staggering estimate as the mortality rates of Indian manufacturing is high. Interestingly, as many more become medium sized, the number of startups required decreases since most small startups grow as part of subcontracting network and employment opportunity increases. Growing such an ecosystem of interdependent firms has the potential to grow the manufacturing activity especially when capital available for manufacturing is highly irregular. There has been a belief amongst the policy makers in India that if they can convince large producers globally to make India as part of their manufacturing supply chain, it would lead to growth in gross value added as well as employment. While the end result could become true, what they fail to recognize is that large global firms get attracted to a country where the ecosystem of suppliers and skilled manpower exists strongly. This often comes from medium enterprises.

Let us look at how venture investments have been supporting startups in manufacturing in India which is the starting point for building of a sizeable ecosystem of medium enterprises (See Figure 2.1). While India ranks third in terms of venture capital (VC) investments (across all sectors including services) behind US and China, it is an order of magnitude lower than what they have received. VC Investment in India is about 14 percent of what China received and about 11 percent of what was invested in the US. The growth in investment in China has been 31 times as opposed to 3 times in India over a five year period ending in 2018. I hope the policy makers are asking, why?

The author acknowledges able research support by Dipti Singhania in the preparation of this essay.

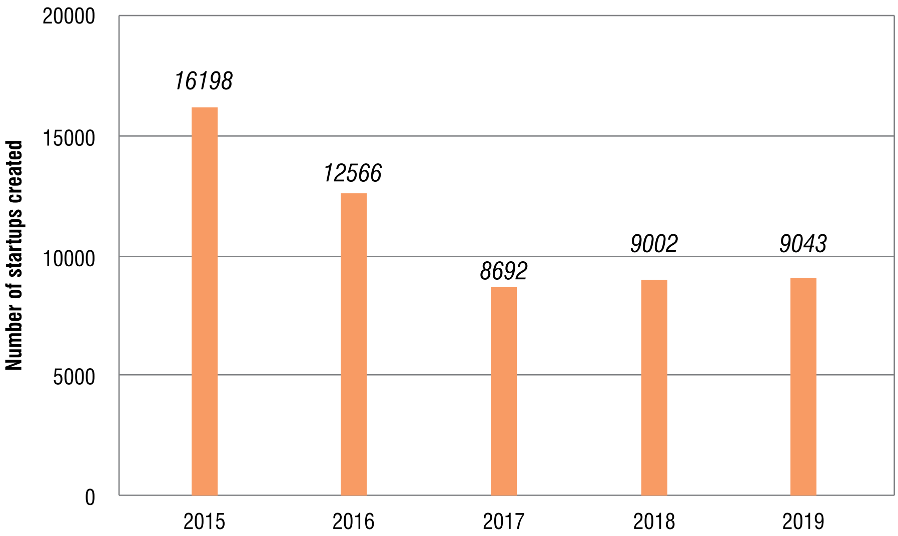
Figure 2.1 | Venture Capital Investment (USD million) in Select Countries



Source: National Science Foundation (NSF), Science & Engineering Indicators 2020, Invention, Knowledge Transfer and Innovation - Global Venture Capital Investment, by financing stage, selected region, country or economy: 2008-18; Tracxn data for India for the years 2013 and 2018, data downloaded on 8 September 2020 from the platform

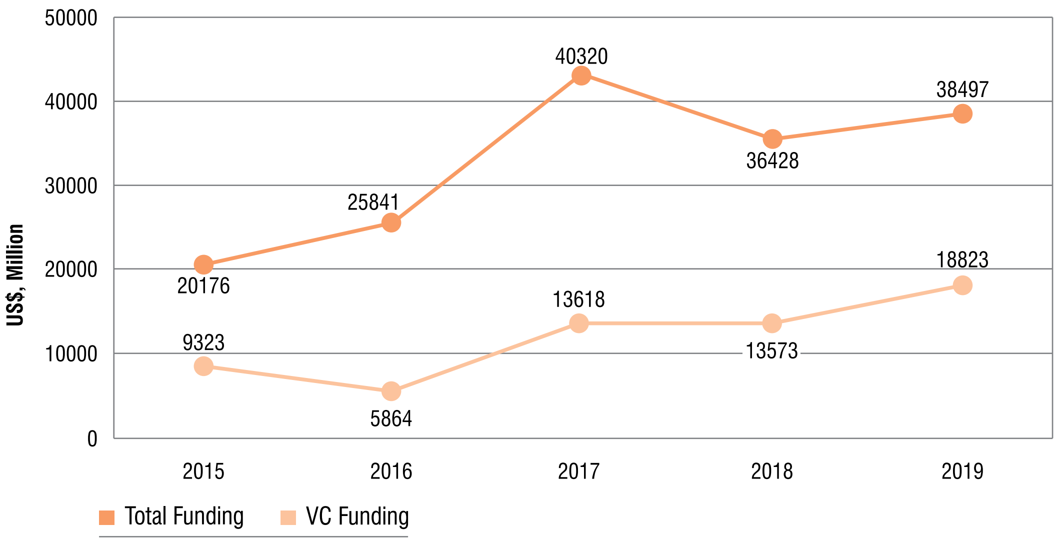
Between 2015 and 2019 (both years included), India created 55,501 startups (See Figure 2.2) and saw a venture capital funding and total funding (VC, PE, Private Equity, Angel and Debt) of USD 61.2 billion and USD 161.3 billion respectively. (See Figure 2.3) This amounts to an average total funding of about US$ 2.9 million per startup. There is an assumption in this figure that all the funding went only to startups created during this period. However, if funding went to startups created earlier (which is highly likely) then the average total funding per startup drops even further. This is indicative of the fact that much of the funding is happening in the tech sector that is not manufacturing oriented as manufacturing requires much higher investments in plant and machinery (and related software). Maharashtra, Karnataka, and National Capital Region (Delhi, Noida and Gurugram) attracts most of the funds and also has the largest number of startups. But there are some interesting anomalies – Tamil Nadu, Gujarat, Rajasthan and Bihar see higher number of new companies registered with the Ministry of Corporate Affairs(compared to other States) but do not receive commensurate investments. Three possible hypotheses that may explain this phenomenon are as follows: one, some of these States are more manufacturing oriented in terms of their economy than others while funders (as mentioned above) are not looking to support new manufacturing ventures and innovations; two, the productivity of Indian manufacturing is not sufficient to support any programme of scaling of operations; and three, since manufacturing requires a broader ecosystem of government and private entities than services in terms of capabilities, it is that much more difficult to get equivalent returns via manufacturing than through a service enterprise in the short run.

Figure 2.2 | Number of Startups Created in India (2015 - 2019)



Source: Tracxn, data downloaded on 8 September 2020 from the platform

Figure 2.3 | Funding for New Startups (USD million) in India (2015 - 2019)



Source: Tracxn, data downloaded on 8 September 2020 from the platform

Data shows that over the last five years (2015-2019), the largest source of funding has been conventional debt (USD 56.7 billion) followed by IPO (USD 32.3 billion). Series A, B, C, and D funding have been around USD 6.7 billion, USD 9.6 billion, USD 9.2 billion, and USD 9 billion respectively. Interestingly, Angel investing has been around USD 0.8 billion. (See Table 2.1) This points towards an inherent weakness in funding manufacturing startups which not only require more funds to set up a production unit but also require higher risk capital than most service and tech ventures. Conventional debt is often conservative as well. Later stage funding, as mentioned above, are largely for scaling and rarely help in developing new products or processes by new ventures.

Table 2.1 | Total Funding for Startups (and New Companies) by Type of Financing

Total Round Amount (US$, Million)	2015	2016	2017	2018	2019
Angel	151	177	178	222	78
Conventional Debt	5535	11469	12494	14544	12677
Venture Debt	453	54	66	102	164
Mezzanine Debt	0	0	0	0	0
Other Debt	578	3130	0	0	0
Grant (prize money)	21	3	8	16	16
PE	1198	996	1187	1620	651
Post IPO	2907	4148	12769	6352	6088
Seed	400	399	408	425	544
Series A	1399	1321	1035	1316	1597
Series B	1402	1167	2014	2004	3001
Series C	1711	752	1472	2605	2618
Series D	1148	1026	1082	1816	3883
Series E	1187	771	313	2328	963
Series F	607	205	1810	877	3090
Series G	560	0	468	750	2394
Series H	150	219	17	1152	150
Series I	760	0	1100	267	104
Series J	0	4	3900	33	479
Unattributed	10	0	0	0	0

Source: Tracxn (Data downloaded on 8 September 2020 from the platform)

It is no surprise then that of all the new companies registered with MCA in 2018-19 (i.e., 1,47,545), only 12.6 percent were in manufacturing. States (and UTs) that are above this average percent are Dadra and Nagar Haveli, Gujarat, Meghalaya, Puducherry, Assam, Punjab, Madhya Pradesh, Chhattisgarh, Manipur, Rajasthan, Uttarakhand, Andhra Pradesh and Maharashtra. In terms of absolute number of new manufacturing companies, the top ten States (UT) were Maharashtra, Delhi, Gujarat, Uttar Pradesh, Karnataka, Tamil Nadu, Telangana, Haryana, West Bengal, and Rajasthan (the States that also attract the maximum investment). The three top areas that saw the largest number of new firms were Metals & Chemicals (and products thereof), Machinery & Equipment, and Food stuff. (See Table 2.2) Textiles was a distant fourth. At an average investment of less than USD 3 million per start-up across both tech and manufacturing sectors, it is not difficult to see why there is low growth in new ventures in manufacturing. Having said that, one encouraging trend is the increasing investment in Logistics and Road Transport Technologies – this is essential in completing the manufacturing ecosystem and ensuring that existing supply chains of manufacturing companies are operating efficiently.

Table 2.2 | New Companies Registered with Ministry of Corporate Affairs (MCA) in 2018-19 by Manufacturing Sectors

Manufacturing Sectors	Number of new companies
Metals & Chemicals, and products thereof	4645
Food stuffs	4225
Machinery & Equipments	4168
Textiles	2097
Paper & Paper products, Publishing, printing and reproduction of recorded media	1521
Others	1513
Leather & products thereof	267
Wood Products	182
Total Manufacturing Companies	**18618**

Source: Ministry of Corporate Affairs (MCA), Government of India, Annual Reports (various years), http://www.mca.gov.in/MinistryV2/incorporatedorclosedduringthemonth.html, Centre for Technology, Innovation and Economic Research (CTIER)

Mint reported in 2019 on a State Bank of India Research study which estimates that India's output per worker will rise to USD 6,414 by 2021 versus USD 16,698 in China. (Jethmalani, 2019) This has been a real challenge in India. Productivity is a function of managerial & technological capabilities, adoption of world class manufacturing practices like lean production systems, product & process innovation, and new technology. While large manufacturers have deployed many of the above, new and small enterprises appear to be in a perpetual bootstrapped mode – waiting to grow before investing in productivity enhancing methods. Two outcomes are common: either they remain in a low productivity state as it prevents them from growing, or when they grow they cannot shed their practices and mindset of the past and they rarely become high gross value add producers. Many of India's manufacturing sectors need massive upgrade in technology and processes. A government policy that incentivises process technology upgrade is essential for attracting orders for higher value add products as well as higher paying customers and consequently, investments. While some sectors like auto & auto-components, machine tools, and pharmaceuticals are ahead of the curve by adopting automation and connected systems, a large majority of Indian firms do not use sharp analytics on their shop floors to make decisions. It is not a surprise that RBI's estimates are that Indian manufacturing's capacity utilization across sectors is around 60-70 percent. (Dhawan and Sengupta, 2020) Indian firms also underinvest in training of their employees in advanced manufacturing and managerial practices. The point being made is simple: if a new venture or a small producer wants to get higher returns, they must have an innovative product, a very competitive and high quality design facility and shop floor (one that solves a variety of complex problems rather than one that tries to produce a simple product in large volumes), vendors who supply raw materials & parts competitively and reliably, highly skilled workforce with contemporary technological understanding, and strong managerial capabilities across the supply chain. Such a facility is attractive to investors and customers alike. New ventures must be job shops that deliver quality through superior engineering skills and process advantage. They are the quintessential problem solvers. There is little systematic effort by engineering associations and government to help firms build such capabilities. Most try to build extensive supply chains around a single or limited product range which is how large firms compete and not startups or new ventures unless they have a very innovative product that is first of its kind with deep consumer potential (e.g., Electric Scooter). Chemicals, for example, a sector where Indian manufacturing is doing reasonably well, comprises of a large number of small firms that have never been able to scale. One has to look at their shop floors to understand why a young and innovative engineer would never like to work there as they don't see any technical or managerial growth at many such places. Technological capabilities fundamentally reside in people and machines. The latter is easily procured but the former needs to be nurtured. Indian startups and small firms don't invest in technological capabilities of their engineers. When compensation is not a competitive advantage of a firm, as is the case of startups and small firms, time and opportunity to take up challenging projects can be a big draw in retaining talented engineers and building deep capabilities in a firm. This approach is missing in Indian firms. Higher productivity is also linked with better organization of shop floors and the accompanying managerial capabilities. Once again, new enterprises rarely pay attention to the same at the start of the journey.

There are four key drivers of change that is taking place around the world – globalization is under stress, technology is challenging the way we do things and live, urbanization is forcing societies to think afresh how cities and services engage with each other, and the climate crisis is making the world think differently about how we consume, produce, and live. There are several implications and opportunities for manufacturing and especially for new ventures. These range from newer products and services, newer markets, changing preferences to new application areas of existing technologies, redefining of risks and uncertainty including phasing out of an entire industry to new compliance requirements, new channels, and new partnerships in a highly polarized world. Most important, it is clear that post-Covid the world of products and services will get re-written. In such volatile and complex times, resilience and agility become very crucial. Firms that can control effectively the exchange of resources and whose consumption of resources remain commensurate with knowledge that it generates and the output that it produces will survive. Interestingly, in the world of biology, as a cell's size increases, its volume increases much faster than its surface area, making it less efficient in the exchange of material and energy. Large firms are at a relative disadvantage at this juncture and in these environments. This is the time for new ventures and small firms as new opportunities for new products and processes emerge. However, it will also require the emergence of a network firm – a collection of small firms that are part of the same product and process ecosystem. Network firms are nimble; they are experts in a process; each requires limited resources; each can build definitive capability and the network builds flexible capabilities and market channels. They need to be curated. This is where policy has failed Indian manufacturing. Indian policy makers are driven by a poor understanding of the dynamics of new manufacturing as well as by the prejudiced view of large manufacturers in the country and outside. They have failed to understand that it is in micro-ecosystems that new and small ventures incubate & survive before they go on to become medium and large firms within the country and outside. Traditional thinking on clusters, industrial estates that are terribly managed, subsidies that don't encourage building of technological capabilities, and bureaucratic & archaic laws surrounding manufacturing (and yes, they have yet to vanish) continue to plague creation of new ventures in manufacturing.

In conclusion, policies in India around creation and enabling of new ventures and their growth are out of kilter with the changing times and its needs. Unless it becomes extremely easy to setup and close down manufacturing ventures, to become part of a micro-ecosystems that enable growth of new ventures, to find enabling resources for upgrading of technologies and technical capabilities especially for new and small ventures, to deal with government bureaucracy, and to find local talent, it will be difficult to attract extensive venture funding and innovators to manufacturing in India.

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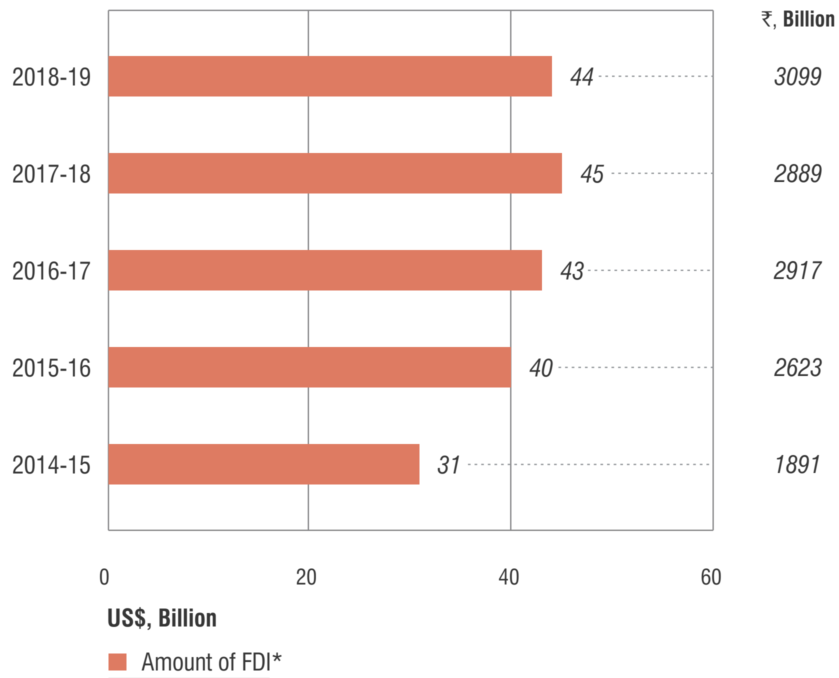
Chapter 03

Foreign Direct Investment and Technological Change in India

Rakesh Basant

Foreign direct investment (FDI) flows into India have increased dramatically in the last two decades. Even during the last five years, the increase in flows has been significant: the FDI inflow in 2018-19 was USD 44 billion as compared to USD 31 billion in 2014-15. (See Figure 3.1)

Figure 3.1 | Annual Foreign Direct Investment Equity Inflows into India (2015 - 2019)



*Does not include reinvested earnings and other capital. This amounted to around 17.6 billion in 2018-19

Source: Department for Promotion of Industry and Internal Trade (DPIIT), Government of India, Quarterly FDI factsheet, June 2019; Center for Technology, Innovation and Economic Research (CTIER)

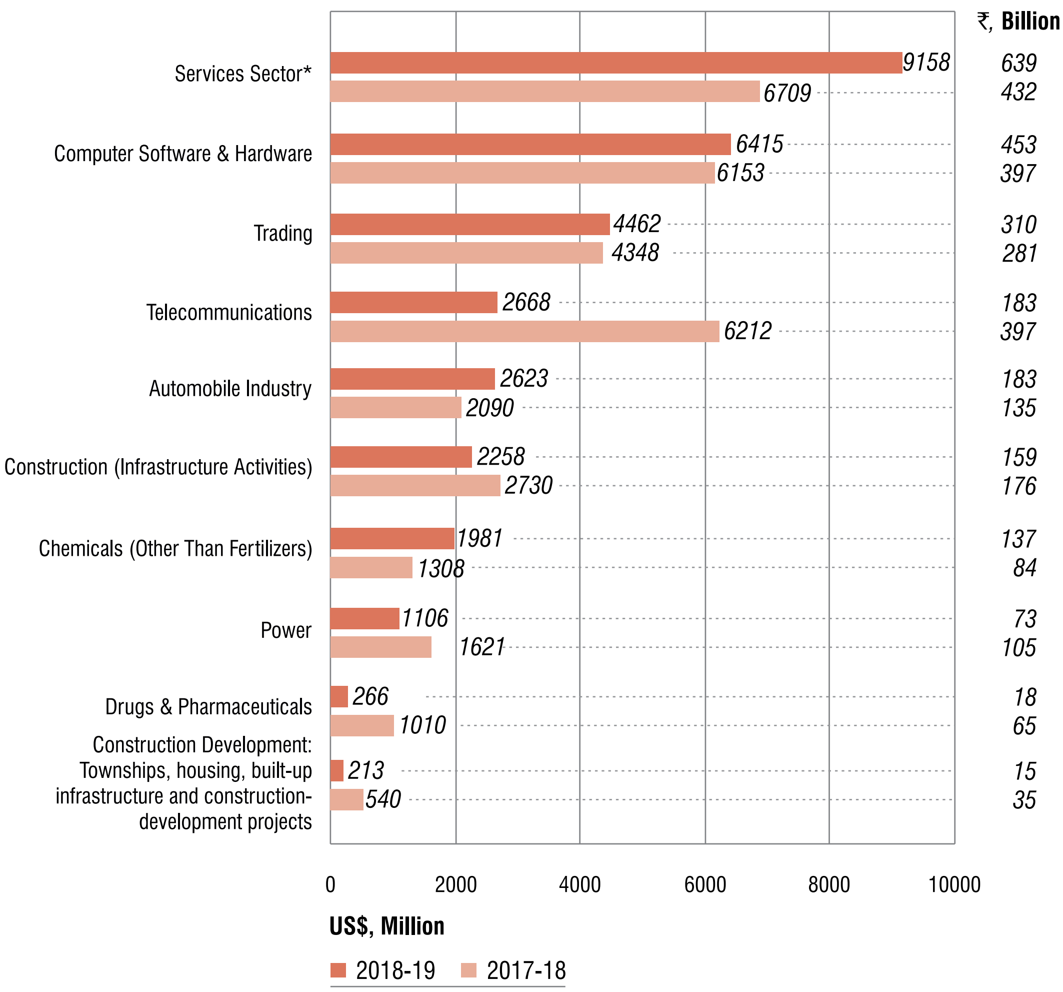
FDI is expected to provide productivity benefits to the host economy through a variety of processes. Entry of multinational corporations (MNCs), typically associated with liberalization of FDI policy, provides an additional source of competition for the host country firms. Such competition effects can drive host country firms to undertake innovation and other productivity enhancing measures to meet the competition. Apart from enhancing competition, the entry of MNCs can also result in flows of new knowledge as the multinational firms bring with them new technology and advanced managerial practices as they begin their operations in the host economy. As host country firms get exposed to this new knowledge, they can learn from it and improve their own technological capabilities. This technology spillover driven process of learning is often referred to as contagion effect. Since FDI affects both competition and contagion conditions in the

This piece leverages data contained in this volume to raise some issues relating to FDI and technological change. The core arguments are essentially based on the analysis undertaken by the authorfor a forthcoming book tentatively titled Innovation and Public Policy – Imperatives for India to be published by Penguin random House. The book provides a review of the literature relevant for the issues raised here. In order to avoid cluttering the text, only those references are cited here which provide additional data that complements the information contained in this volume.

host economy and changes in these conditions have the potential to influence domestic firms' decisions with regard to technology, one needs to understand which activities of MNCs are important for affecting these conditions and how.

One obvious proposition can be that impact of FDI is likely to be more in those sectors wherein the flows have been significant. For example, in 2018-19, the FDI flows were the highest in the service sector, followed by computer software & hardware, trading, telecommunications and the auto-sector (See Figure 3.2, Table 3.1). But FDI flows fluctuate from year to year. In 2017-18, for example, the size of flows was not very different for the services sector, computer hardware & software and telecommunications while in 2018-19, the service sector was significantly ahead of others in attracting FDI. (Table 3.1)

Figure 3.2 | FDI Equity Inflows into India by Sector (2017- 18 and 2018- 19)



		2018-19	2017-18
Total for Top 10 Sectors	US$, Million	31150	32721
	₹, Billion	2170	2107
Grand Total	US$, Million	44366	44857
	₹, Billion	3099	2889

Source: S&T Indicators Tables, Research and Development Statistics 2019-20 available at https://dst.gov.in/sites/default/files/S%26T%20Indicators%20Tables%2C%202019-20.pdf; Department of Science and Technology (DST), Government of India, Research and Development Statistics 2017-18, December 2017; Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) Figures in rupees were converted to dollars using the USD-INR exchange rate of 61.1 calculated as an average for the fiscal year 2014-15, and USD-INR exchange rate of 64.46 calculated as an average for the fiscal year 2017-18 based on data from Federal Reserve Bank of St Louis.
(ii) Total Central Government R&D Expenditure includes R&D Expenditure by Select Major Scientific Agencies and R&D Expenditure by Central Ministries/Departments other than Major Scientific Agencies.
(iii) Total National R&D expenditure for 2014-15 has been updated as per the latest figures released by DST.

Therefore, the cumulative flows of the last few years would provide a better indication of the sectors that have been affected more by MNC entry. In general, contagion effects are contingent on the new technology or knowledge flows that are associated with investment flows. Thus, if the sectors are technology intensive or hi-tech, the chances of MNCs bringing new technology with investment are high; low tech sectors may not obtain such technology flows. As such, many segments within the top 10 sectors in India receiving FDI inflows in recent years are likely to be technology intensive (See Figure 3.2) but a more disaggregated analysis of flows within each sector would be needed to get a clearer picture.

Table 3.1 | FDI Equity Inflows into India by Sector - Top 10 based on 2018-19

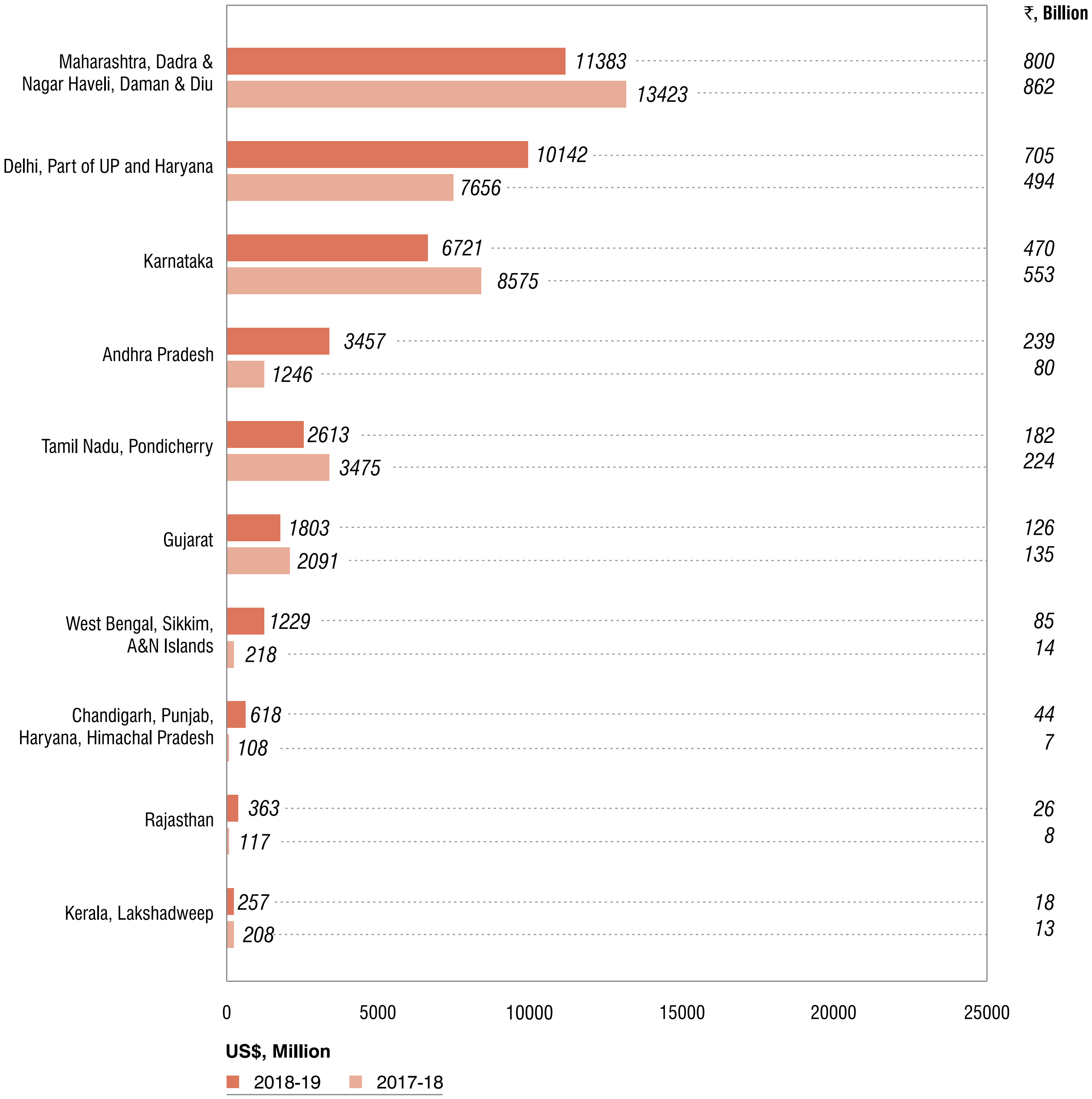
No.	Sector	2017-18 (₹, Billion)	2017-18 (US$, Million)	2018-19 (₹, Billion)	2018-19 (US$, Million)
1	Services Sector*	432	6709	639	9158
2	Computer Software & Hardware	397	6153	453	6415
3	Trading	281	4348	310	4462
4	Telecommunications	397	6212	183	2668
5	Automobile Industry	135	2090	183	2623
6	Construction (Infrastructure Activities)	176	2730	159	2258
7	Chemicals (Other Than Fertilizers)	84	1308	137	1981
8	Non-conventional Energy	78	1204	101	1446
9	Information & Broadcasting (Including Print Media)	41	639	89	1252
10	Power	105	1621	73	1106
	Total for top 10 sectors	2126	33013	2327	33370
	Grand total	2889	44857	3099	44366

*Services sector includes Financial, Banking, Insurance, Non-Financial / Business, Outsourcing, R&D, Courier, Tech. Testing and Analysis

Source: Quarterly FDI factsheet, Department of Industrial Policy and Promotion (DIPP), (various years); Center for Technology, Innovation, and Economic Research (CTIER)

As is the case for sectors, one can argue that the impact of FDI would be more significant in regions where the investment flows are concentrated. This is so because proximity of domestic firms to MNCs also helps in observing firm practices, building linkages and therefore in the overall learning process. In 2018-19 Maharashtra was the top recipient of FDI inflows, followed by the Delhi region and Karnataka. (See Figure 3.3) Once again, annual inflows of FDI may vary across states as is evident from the fact that in 2017-18, Karnataka received more inflows than the Delhi region which was not the case in 2018-19 (See Figure 3.3) Cumulative FDI inflows during a recent period into a region would provide a measure of the potential of contagion and competition effects of MNC entry in various regions as well. If contagion effects are dependent on geographical proximity as is the case in situations when MNC practices need to be observed closely or when knowledge flows take place through local linkages, states with higher FDI may benefit more from such spillovers than others. This will be particularly the case when the knowledge is tacit in nature and difficult to transfer through non-personal market interactions. Competition effects may, however, be more widespread and not restricted to the host state as markets for MNC products are likely to be national. Of course, knowledge spillovers from MNC activity may also cross state borders if they build linkages with entities in other regions and knowledge gets disseminated through other processes like employee turnover.

Figure 3.3 | Foreign Direct Investment into India for Select States (2017- 18 and 2018- 19)



Source: Department for Promotion of Industry and Internal Trade (DPIIT), Government of India, Quarterly FDI factsheet, March 2019; Centre for Technology, Innovation and Economic Research (CTIER)

While estimates of cumulative inflows of FDI in recent (say 3-5) years in a region or an industry provide an indication of the potential impact of MNC entry in a sector or a region, other features of MNC entry may also influence the nature of contagion and competition effects. Typically, Greenfield investments by MNCs are more likely to result in higher competition and contagion effects as compared to brownfield ones or MNC entry through mergers and acquisitions (M&A). This is so because Greenfield investments create new productive capacity that increases market supply and new vintages of technologies are more likely to be brought in if MNCs use this mode of entry. This does not mean that MNCs will not bring in new knowledge if the investments are being made in brownfield projects or entry is taking place through M&A. New knowledge may be necessary to address local competition if competition provided by host country firms and their technological capability is high. The decision to bring in new technology may also vary with type of MNC ownership as foreign firms may worry about their technology getting leaked to local competitors. In general, the potential of such knowledge leakages is low if a MNC is operating through a wholly owned subsidiary as compared to a joint venture or equity alliance as the MNC may have more control over its knowledge in the first case as compared to the latter two. Thus, more knowledge may get transferred to a wholly owned subsidiary due to lower appropriability concerns and JVs or equity alliance may provide more opportunities for the domestic partners to learn, even though learning (spillover) potential may be less, given the lower quantum of knowledge flows.

The available data suggests that share of greenfield investments in FDI into India showed a declining trend after 2000 till about 2013 and M&As were the preferred mode of entry by MNCs during this period. (Rao and Dhar, 2018) There seems to be some movement towards greenfield projects since 2014 and about 40 percent of FDI came through this route during the last six years. (Anand, 2020) While the share of FDI in manufacturing increased in 2000s, a large part of these inflows were through M&A. However, the share of FDI in high-tech manufacturing sectors was only about 27 percent of total FDI in manufacturing during 2003-14 and more than 80 percent has come through the M&A route. The situation has not changed in recent years. (Rao and Dhar, 2018) Moreover, even within manufacturing, often the focus seems to be on assembly of products for sale in the domestic markets with little interest in exports.

The knowledge flows associated with FDI and the resulting learning opportunities are also dependent on the activity in which the MNC is involved. These activities can be quite diverse and include setting up an R&D facility, undertake contract R&D in the host nation, assemble products or set up manufacturing facilities. MNC involvement can also be restricted to marketing and distribution. In all these activities, the contagion effects would depend the nature of linkages that MNCs build with the host nation agents. Typically, a focus only on marketing and distribution is less likely to entail significant knowledge spillovers. Such contagion potential increases with MNCs undertaking manufacturing and R&D activities, although foreign firms may make efforts to reduce leakages of knowledge especially from their R&D activities. Broadly then, MNC participation in 'low-end' activities would typically result in limited knowledge flows to the host country adversely affecting the learning potential of their entry. Very little, however, is known about the linkages the MNCs have built within India in recent years and their involvement in training and other capability building activities is also not known. Given this lack of information, it is difficult to ascertain if knowledge flows through FDI have facilitated capability building among domestic firms.

While the discussion above regarding the potential role of FDI in creating technological change in host countries makes intuitive sense, empirical results on the impact of various characteristics of FDI, have not been always consistent across studies, even among the few that have focused on India. Apart from differences in host country contexts and methodological issues, one of the key reasons for these inconsistent results is the non-availability of appropriate data. As mentioned, information on the nature of linkages (backward, horizontal, forward) is usually not available. Besides, the role of FDI also varies with time and analysis of dynamic relationship between FDI and technological change in the host country is even more complex and data intensive than short-term analyses. But one result that has been consistent across studies in various countries has been that absorptive capacity of the host country firms is critical for benefiting from MNC entry. If the technology gap between the host country firms and the MNC is very high, both the contagion and competition effects work against the host country as its firms are neither able to learn from nor compete with the multinationals. A corollary of this argument is that while MNCs can provide opportunities for transfer of technological information in the host country through their activities, they may not build technological capabilities to understand this information well. Building of such capabilities require local technological efforts. The available data on India suggests that its R&D intensity (R&D expenditure to GDP ratio) is lower than developed nations and many emerging economies like Brazil, Taiwan, South Korea, Israel and China.[1] It has also not seen any significant increase in recent years. Besides, the business enterprises contribute a significantly lower share in India's R&D as compared to other nations. [2]

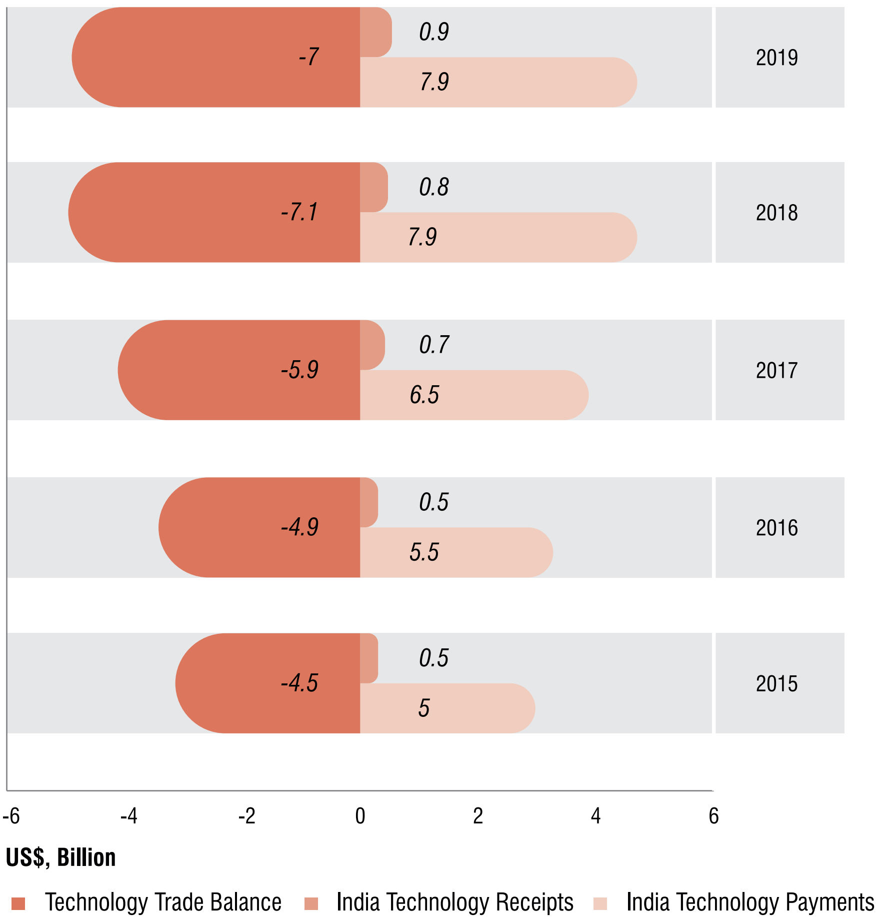
[1] See Indicator 6.1, R&D Expenditure as a Percent of Gross Domestic Product across Select Countries, pg. 50

[2] See Indicator 6.2, Country-wise Comparisons of Share of R&D in National R&D Expenditure by Sector of Performance in 2018 (%), pg. 51

Evidently, enterprises in India are not making enough investments in building local capabilities so that they can benefit from MNC presence and effectively compete with them. It is possible that the Indian corporate sector is trying to build such capabilities through foreign technology imports which have become easier after the onset of the economic reforms. The aggregate data suggests significant increase in such imports in recent years (See Figure 3.4). Overall, however, it is difficult to discern a clear pattern in the strategies followed by the Indian business enterprises to deal with contagion and competition effects unleashed by the entry of MNCs. More research with better data is needed to understand this area better.

While R&D intensity and other technological activity may not be very high in India, there is ample evidence of research capacity which has attracted MNCs to set up R&D centers in India. Such MNC presence has increased significantly in recent years and their R&D investments have been on the rise (See Table 3.2) Usually, MNCs create overseas R&D facilities to adapt their products for local markets, benefit from local research expertise and build global networks of research collaboration. The nature of activity undertaken by the R&D labs in the host country affects the flows of knowledge and the consequent impact on local innovation capabilities. Typically, an adaptation focus might link the work of the MNC lab to local markets and result in local knowledge flows. If the R&D lab is an important component of the MNC's global R&D efforts, the level and complexity of R&D activity may be high but flows of knowledge within the host economy may be low if the

Figure 3.4 | India's Technology Trade Balance (2015 - 2019)



Source: Reserve Bank of India (RBI) Balance of Payment (various years) available at https://rbi.org.in/scripts/SDDS_ViewDetailsaspx?Id=5&IndexTitle=Balance+of+; Centre for Technology, Innovation and Economic Research (CTIER)

Note: Figures reported above are calculated for calendar years. The Reserve Bank of India (RBI), Balance of Payment, captures fiscal year data on Charges for the Use of Intellectual Property (CIP). CIP for the fiscal year 2018-19 was USD 8 billion and for the fiscal year 2019-20 was USD 7.7 billion.

Table 3.2 | Global MNCs having R&D Presence in India

Firms	Total R&D Expenditure (US$, Billion)	Share in Total of Top 2500 (%)
Top 2500 global R&D firms	947	100
Top 100 global R&D firms	497	52
92 global R&D Spenders (in top 100 with presence in India*)	465	49
65 global R&D Spenders (in top 100 with R&D centres in India)	350	37

*in the form of either an R&D Centre or a subsidiary

Source: EU Industrial R&D Investment Scoreboard (2019); Ministry of Corporate Affairs (MCA); Various News reports; Company Websites; Centre for Technology, Innovation and Economic Research (CTIER)

Note: Exchange rate used for calculation is from EU Industrial R&D Investment Scoreboard (2019) as on 31st December 2018; 1 EUR = 1.15 USD

R&D activity is only integrated with the core R&D efforts of the parent company with no local linkages.

Some evidence suggests that till recently the projects performed in these R&D centers in India were small and of short duration, focusing on the labour intensive tasks relating to the MNC's global R&D needs. The linkages of these centers with local entities were limited and they mainly sought support from the global business units of the MNC. (Basant and Mani, 2012) Consequently, knowledge spillovers for the local economy may have been rather limited due to the limited interaction with local entities. Recent developments, however, suggest that the centers in India are not only used for its low cost of operations but also for developing technologies for markets like India. (Nabar, 2018) It is not yet known if this shift in the market orientation of the research undertaken by the MNC R&D centers has resulted in changes in the nature of their domestic linkages. Limited evidence that is available does not suggest that such a shift has taken place. (Mani, 2020) Besides, no information is available on the circulation of R&D personnel from these centers to other enterprises.

Overall, it is very difficult to assess the impact of MNC activity on technological change in India. Till recently, MNCs have not entered in high-tech areas in any significant manner, nor have they been very active in creating state of the art green-field projects. One can argue, therefore, that the opportunities to learn through contagion effects, have been somewhat limited. The competition effects of MNC entry, however, are likely to be high. The ability of domestic firms to respond to this competition through innovation is unknown but no significant increase in R&D efforts suggests that the response of domestic firms to MNC competition is not built around enhancing research capacity through own research efforts. Since most studies show that good absorptive capacities of domestic firms and of the regions where MNCs are located are preconditions for benefits to accrue from competition and contagion effects, lack of such efforts does not augur well.

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Chapter 04

High Technology Manufacturing in India

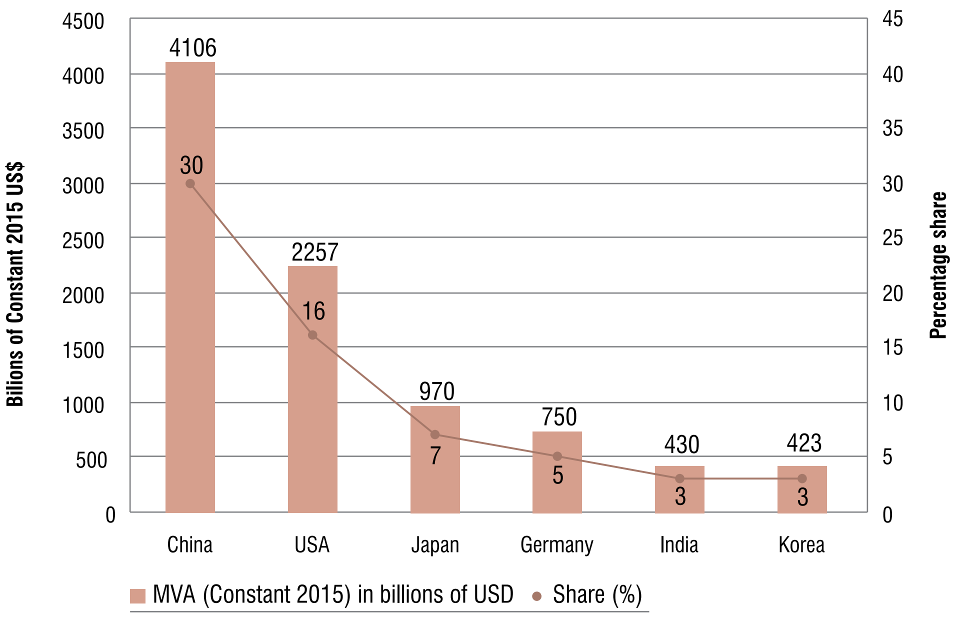
Sunil Mani

India is one of the largest but late industrializing countries in the world. From around 2006 or so, the country has been striving to industrialize through the manufacturing route as growth driven by the manufacturing sector has several long-lasting economic benefits. First of all the manufacturing sector has much more linkages with the other two sectors of the economy, namely the primary and tertiary sectors. Second, most of the innovations that are used in the primary and tertiary sectors emanate from the manufacturing sector. For these reasons and more countries across the world including that of India are on a conscious drive to increase the size and technical content of its manufacturing sector. The manufacturing sector in turn consists of several disparate industries. One way of grouping them is in terms of their respective employment content and another way is to group them according to their technical content. Although the manufacturing sector in most developing countries is supposed to be dominated by labour-intensive or low technology industries, the current emphasis is on growing the share of high technology industries. This emphasis on high technology manufacturing is for three specific reasons at least. First, high technology industries have very high levels of productivity, both capital and labour. So even if their share is small, their contribution to the GDP of the country is expected to be much larger. Second, high technology industries have much better linkages with downstream and upstream industries as most high technology manufactured products are based on an assembly of components. So, their multiplier effects on growth in the region where they are located are supposed to be much higher. Third, world trade in manufactured products is dominated by high technology products (Mani, 2004, Lall, (1998)) and if a country wants to increase its share of exports, it must encourage the production of high technology manufactures. Given the capital-intensive nature of production, use of very often-proprietary technology, high failure rates etc., the role of the state in high technology products is very well accepted. Even in advanced countries such as the USA or Japan, where the market is perceived to be more efficient in the allocation of resources, high technology production has been supported through concerted state intervention. For instance, the role of the state in the SEMATECH project in the USA or the VLSI one in Japan is now very well accepted as the main reason for the supremacy of both the USA and Japan in semiconductor production. Having successfully achieved its original target, the programme is now moving towards the development of other high technology industries such as biomedicine, cybersecurity and alternative energy. The specific way in which the state intervenes in the development of high technology industries can vary in terms of its content. There are at least three ways in which the state intervenes. The first mode is a direct one in which the state establishes a state-owned enterprise (SOE) which then manufactures the high technology product. The second mode is for the state to establish a public R&D programme either exclusively or in partnership with the market, develop the high technology and then transfer it to production enterprises whether owned by the state or the private sector. The third mode is for the state to craft the ecosystem for high technology production by having explicit policies and instruments for this to be developed by both public and private sector enterprises. Most industrializing countries such as India have used all the three modes. Modes 1 and 2 were very popular in the pre liberalization phase while Mode 3 is the preferred one in the post-liberalisation phase characterised by paring down of state intervention in economic activities

The growing importance of high technology manufacturing

In 2015, India emerged as the fifth largest manufacturer in the world defined in terms' her share in world Manufacturing Value Added (MVA) (See Figure 4.1). The small size of India's manufacturing sector can be inferred from the fact that in terms of her share in World MVA, India's manufacturing sector is only as big as that of Korea's and only about 10 percent of China's. Even within her GDP, according to the latest estimates for 2018-19 by the CSO, the share of the manufacturing sector in overall GDP works out to about 18.1 percent (Central Statistical Organization, 2020). The government is pursuing a strategy for increasing both the share of manufacturing and an improvement of its technology content through several high-profile strategies the most recent version of it is the "Make in India" strategy announced in 2014. The recently announced Atmanirbhar package further seeks to increase both the size and content of her manufacturing sector.

Table 4.1 | Manufacturing Value Added of India in Comparison with Other Leading Countries, 2019 (Constant 2015 in Billions of USD)



Source: Extracted from UNIDO INDSTAT 2 2020, ISIC Revision 3 database, https://stat.unido.org/database/INDSTAT%202%202020,%20ISIC%20Revision%203 (accessed on October 27, 2020)

For quite some time, and precisely since the start of the current millennium, India has been trying to shore up its small manufacturing sector both in terms of its size and in terms of its technological content. There are two visible manifestations of this "growing high technology manufacturing industry' strategy. First, several policy statements about specific high technology manufacturing sectors have been enunciated. Examples of this are the Aerospace manufacturing (contained in the civil aviation), Automotive, Biotechnology, Chemical, Electronics and telecommunications, Pharmaceutical, Semiconductor policies announced from time to time during the period. Second is the growing importance of high technology products in both the gross value added and exports of the manufacturing sector.

The growing importance of high technology products in India's manufacturing value-added

It is interesting to note that high technology manufactures account for about 55 percent of gross value added of the manufacturing sector. Unfortunately, lack of availability of consistently disaggregated data for earlier periods are not available and so one cannot track how much of an improvement in the high technology intensity of domestic manufacturing has taken place. Further our way of defining the high technology sector does fully correspond to the OECD definition. and so we do not foresee any overestimation of high-tech output. This means that India's manufacturing sector has a high share of technology-intensive industries such as chemicals in general, pharmaceuticals, automotive and machinery and equipment in general. In terms of ranking within the high technology sector, automotive and pharmaceuticals are the top two sectors. India is already well known the world over for its pharmaceutical industry which is very often referred to as the pharmacy of the developing world. Given the ongoing pandemic, India has a very important role to play both in terms of vaccine development and manufacturing and also in generic versions of therapeutic drugs. She has already a reputation as a hub for making compact cars and stands a good chance for becoming a hub for the manufacture of Electric Vehicles (EVs).

Table 4.1 | Share of High Technology Products in Total Manufactured Products (Values are in Rs in Crores; Based on Gross Value Added in Constant 2011-12 Price)

	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Manufacture of transport equipment	147452	134846	165994	217971	233723	244065	263000
Manufacture of pharmaceutical; medicinal chemicals and botanical products	81284	93090	98406	110119	131359	134332	144163
Manufacture of optical and electronics products n.e.c	7146	6784	7846	11528	12013	13156	14395
Manufacture of machinery and equipment n.e.c	115054	97404	107335	113922	138626	159962	169864
Manufacture of electronic component, consumer electronics, magnetic and optical media	15341	17255	16125	15165	18238	16021	18289
Manufacture of electrical equipment	52646	51948	50636	53286	51552	76170	81593
Manufacture of computer, electronic & optical products	31679	37164	33107	45208	51678	50957	55328
Manufacture of computer and peripheral equipment	4441	7980	4823	6033	6471	7215	7556
Manufacture of communication equipment	4751	5145	4312	12482	14956	14566	15088
Manufacture of coke & refined petroleum products	142618	150254	218515	253450	231418	230452	211743
Manufacture of chemical and chemical products except pharmaceuticals, medicinal and botanical products	116682	112375	115005	119330	122965	124171	142679
Total High Tech	719094	714245	822104	958494	1012999	1071067	1123698
Total Gross Value Added	**1288919**	**1346108**	**1468900**	**1643539**	**1803931**	**1928554**	**2042267**
Share of High Tech (in %)	55.8	53	56	58.3	56.1	55.5	55

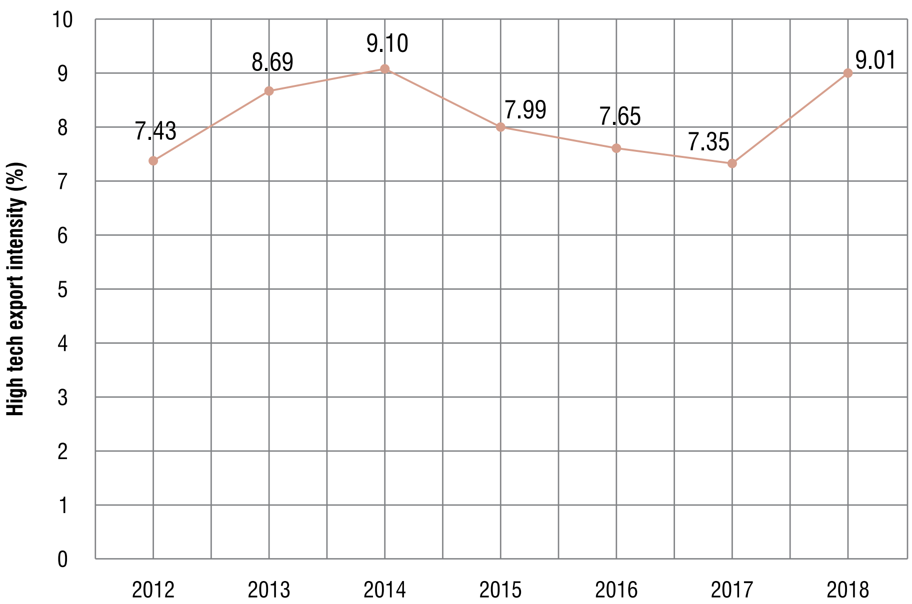
Source: Central Statistical Organization (2020)

However, most of the high technology products are targeted at the domestic market and as we can see from the next section that India's high technology intensity (high tech exports measured as a percentage of manufactured exports) although doubled itself over time is still less much less compared to other high technology promoting countries such as that of China.

The growing importance of high technology products in India's manufactured exports

As a late industrializing country, deficient in both disembodied technology and management and organizational skills, India's export basket was to a large extent dominated by labour-intensive manufacturers such a cotton textile, ready-made garments, gems and jewellery and leather and leather manufactures. However, India's export basket has slowly undergone a qualitative change with more high technology products taking a discernible position in it. The high technology product intensity has been increasing over the years and in 2018 stood at around 9 percent of all manufactured exports (See Figure 4.2). In value terms, it has been growing at a rate of 17 percent per annum during this period. The growing importance of high technology production is evident even in Indian patenting abroad as almost the entire patents granted to Indian inventors at the USPTO, during the same period is in high technology areas such as pharmaceuticals and the computer-implemented inventions (Mani, 2020).

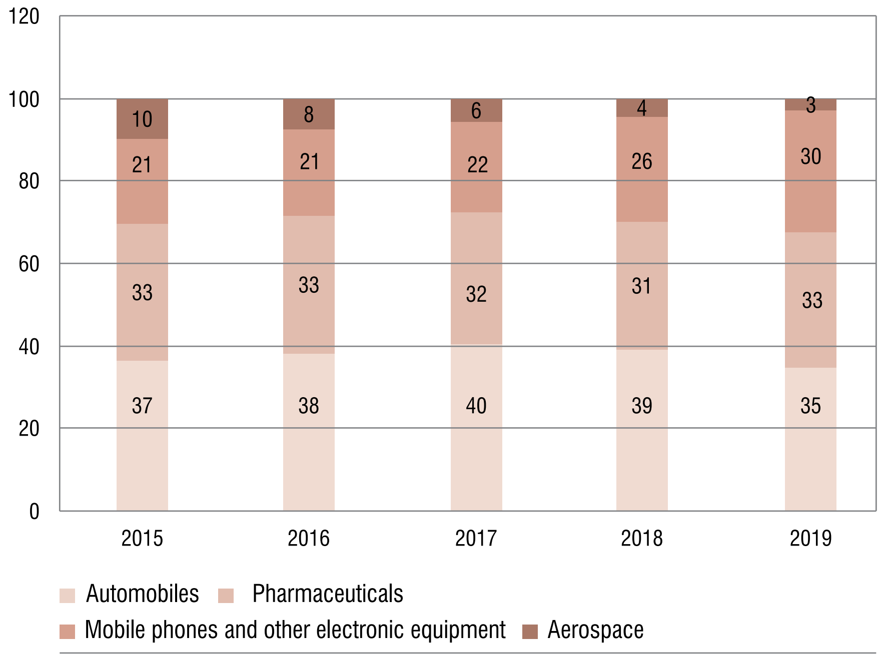
Figure 4.2 | **Increasing High technology export intensity, 2012-2019**



Source: World Bank (2020)

High technology exports from India are driven by four items, namely automobiles, pharmaceuticals, mobile phones and other electronic equipment and parts and aerospace (See Figure 4.3). Of these four, exports of three of them have been increasing (although there is a decline in aerospace exports since 2015). Exports of mobile phones have been steadily declining. However, India has a consistently positive trade balance in only three of them namely aerospace, automobiles and pharmaceuticals, while it has a growing negative trade balance in mobile phones. This is a bit counter-intuitive as India had a long strategy of developing local technological capability in telecommunications equipment where a considerable amount of state investments in manufacturing and R&D were done. Further with a total subscriber strength of nearly 1 billion telephone subscribers and growing India has one of the largest markets in the world for telecommunications equipment but it has virtually no serious manufacturer of telecom equipment, but only assemblers of equipment based on imported components. It was seen that gross value added to the gross value of output ratio is very low in the case of this industry (Mani, 2020).

Figure 4.3 | Exports of high technology products- disaggregated from 2015 through 2019



Source: ITC Trade Map-International Trade Statistics, http://www.trademap.org/tradestat/Product_SelCountry_TS.aspx?nvpm=1|699||||TOTAL|||2|1|1|2|2|1|1|1| (accessed on October 27, 2020)).

Of these four industries, only the success achieved in the pharmaceutical industry has merited any detailed attention. Although there are some studies available on the automobile and telecommunications equipment industries, there are, practically, no studies on the aerospace industry in the country. While the role played by the policy on patents in explaining the growth of India's pharmaceutical industry has been debated, the role of public policies in shaping the growth trajectory of the other three high technology industries has hardly attracted any attention in the scholarly literature. In fact, in India, there has been an erroneous tendency to equate high technology with luxury consumption goods which are hardly suited for the bulk of the consumers with very low purchasing power. But as recent events and discussions have shown rather conclusively that each of these four high technologies has made a perceptible difference to the living conditions of an average Indian citizen. For instance, having a successful and innovative generics drug industry has made many lifesaving drugs at affordable prices and especially in times of the current coronavirus pandemic, having one of the cheapest telecommunications services and indeed equipment (although much of the latter is imported) has increased the affordability of telecommunication services and reduced the rural-urban digital divide by a significant amount. Likewise having a successful aerospace industry has increased communications services and have increased the diffusion of telemedicine and education in unreachable physical locations. This has again become very relevant in times of the current pandemic where almost the entire school and higher education is now conducted online. Further, having a domestic automobile industry has increased both the movement of passengers and goods across large tracts of the country. In other words, the growth of high technology industries has gone towards improving the quality of life of an Indian citizen.

[1] See the OECD definition at https://wayback.archive-it.org/5902/20150701011436/http://www.nsf.gov/statistics/seind93/chap6/doc/6s193.htm (Accessed on October 26, 2020)

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Chapter 05

Learnings from India's COVID-19 Response and Furthering Medical Device Innovation

Janak Nabar

The learnings gleaned from the response of India's research and manufacturing ecosystem to the health crisis offer an opportunity to push for greater technology deepening in India's healthcare sector and develop an industrial and innovation policy for greater medical device innovation in India. Some of the other learnings include but are not limited to: the economic distress caused by a strict nationwide lockdown that was imposed in late March 2020, the handling of the migrant worker crisis, the sharp decline of 23.9 percent y-o-y in GDP in 1Q2021 followed by another contraction in GDP in 2Q2021, and the response to the various stimulus measures announced by the government and the Reserve Bank of India to support the economy. At the time of writing, there were over 1,40,000 COVID related deaths officially accounted for in India. According to news reports, a report by the Parliamentary Standing Committee on Health & Family Welfare titled 'The Outbreak of Pandemic COVID-19 and its management', has highlighted among other things, the poor health infrastructure in India, the lack of sufficient testing, poor contact tracing early on in the crisis, concerns about the reliability of testing kits, and the risks faced by vulnerable non-COVID patients especially women and children. Investment in India's healthcare infrastructure is a clear priority, and the budget for FY2022 is expected to see a significant increase in healthcare spending. At the same time, a structured approach to technology deepening in the healthcare sector, with a focus on medical device innovation has the potential to contribute towards sustaining India's economic recovery going forward. This article seeks to document the mission mode response that brought about several partnerships between industry, academia and government, the country's ability to focus on therapeutic drugs and plan for a vaccine, and the structure of India's industrial R&D as well as investments in public research that aided the response. While there were steps that had already been taken towards developing the medical devices sector in India prior to WHO's declaration of the pandemic, much more needs to be done to develop a successful industrial and innovation policy for this sector.

The mission mode response

The mission mode response by several public research laboratories, higher education institutions like the IITs, Indian industry and startups in the face of global supply chain disruptions and rising cases in India is laudable. Within a few months, starting March 2020, there was a significant ramp up in domestic production of ventilators, personal protective equipment (PPE) kits, testing kits, masks etc. According to news reports, the number of PPE kit manufacturers increased from around 20 in February 2020 to over 600 manufacturers by June 2020, whereas the number of ventilator manufacturers increased from around 8 in February 2020 to over 50 manufacturers by June 2020. News reports also mentioned that various components and parts for ventilators too were increasingly manufactured in India over this period. There were many instances of startups from the IITs tying up with larger manufacturing firms or government facilities, partnerships that were forged between government entities and private players, and between smaller firms and larger firms to increase production of ventilators, PPE kits, testing kits and alcohol-based sanitizers. By end June 2020, manufacturers appeared to be exploring the possibility of exporting some of these essential items. Research laboratories and manufacturers were able to reduce the cost of the reverse transcription polymerase chain reaction (RT-PCR) test kits, which in turn also saw state governments gradually lower the price caps on test kits to one-fourth of what the test kits cost early on in the pandemic. While the government had constituted empowered groups to plan and implement the response to COVID-19, including one for medical equipment, the role and importance of industry associations in the response must also be acknowledged. Industry associations were able to coordinate for example between garment manufacturers and auto manufacturers for scaling up production of PPE kits, or link startups and smaller firms to larger auto manufacturers for the production of ventilators. While the coming together of industry, academia and government in mission mode is indeed commendable, the partnerships were nevertheless forced by circumstances. It is unclear whether many of these partnerships will continue in the post pandemic world. The auto manufacturers for example very likely began to return to their main line of business as the economy started to come out of the lockdowns that had been imposed. It is also unclear whether several of these ventilators or PPE kits that were produced as an emergency response met the necessary quality standards for export, for them to have transitioned into a sustained business opportunity.

Planning for a vaccine and therapeutic drugs

India has over the years demonstrated its technological capabilities when it comes to vaccines and therapeutic drugs. Manufacturers like the Serum Institute of India are known globally for their high quality and low cost vaccines. With respect to a vaccine for COVID-19, the Serum Institute has a tie up with the Oxford Vaccine Group to manufacture the 'Covishield' vaccine in India. In the case of therapeutic drugs for the treatment of COVID, there were six Indian pharmaceutical firms that began manufacturing Remdesivir in India under a license agreement with Gilead Sciences. Remdesivir had been granted an Emergency Use Authorization by the USFDA in May 2020. Although the WHO has only recently issued a conditional recommendation against the use of Remdesivir in the treatment of hospitalised patients, early on in the pandemic this drug had been considered a potentially effective antiviral drug for the treatment of COVID-19 patients. India must capitalize on its competitive position in the pharmaceutical industry and ensure that it is able to scale up production of the COVID-19 vaccine as well as generic versions of therapeutic drugs used for the treatment of COVID-19. This would not only require a focus on domestic policy and regulatory support for local manufacturing, but also enhanced global co-operation to ensure that the vaccines and therapeutic drugs are available at an affordable cost to many in the developing world. An important step that India took towards this was the joint proposal it made along with South Africa in early October 2020 to the WTO, requesting for a waiver on intellectual property agreements related to vaccines, tests and treatments for COVID-19. The proposal however has been facing opposition from the EU and the US.

In recent months, there has also been increased planning for the eventual procurement and distribution of the vaccine for COVID-19. The planning has involved identifying and mapping cold chain facilities across India. For the purposes of administering the COVID-19 vaccine, the Indian government plans to utilise the infrastructure that is part of its universal immunisation programme that is used to vaccinate children across the country against diseases like polio and measles. However, large investments in cold chain facilities with significant participation from the private sector would be required to successfully administer the COVID-19 vaccine to a large section of India's 1.4 billion population. According to news reports, there are presently around 29,000 cold chain facilities across India that could cater to around 60 million doses, with two doses potentially required per person. Investment in the infrastructure and logistics required to administer the COVID-19 vaccine will result in increased demand for items like glass vials, dry ice as well as commercial trucks that would need to be fitted with special cold storage units. In the long run, the increase in cold storage and transportation facilities also has the potential to benefit the agriculture sector.

India's industrial and public R&D and the COVID response

India's investment in R&D as a share of GDP at 0.7 percent has consistently remained low for several decades. The expenditure on R&D by Indian industry at USD 6.7 billion in 2019 is especially low, and accounts for just over 40 percent of the country's expenditure on R&D. Nevertheless, despite the low level of industrial R&D, we posit that it was the structure of India's industrial R&D seen in Table 5.1, and its industrial base that allowed for the mission mode partnerships to emerge early on in the crisis.

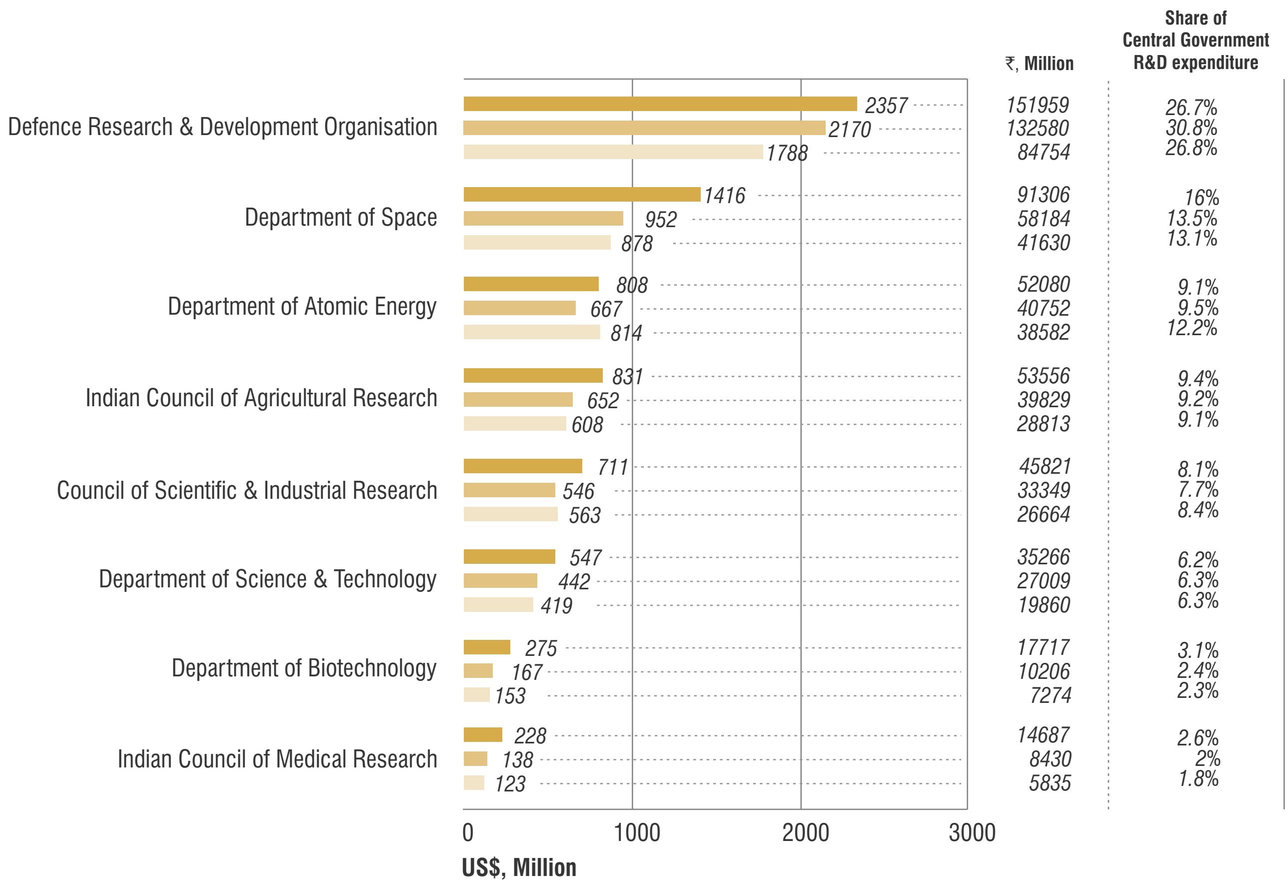
Table 5.1 | Structure of India's Industrial R&D

Sector (India)	Share of Sector R&D in total R&D (%)
Pharmaceuticals & Biotechnology	34
Automobiles & Parts	27.1
Oil & Gas	9.1
Aerospace & Defence	6.3
Software & Computer Services	5.9
Industrial Engineering	5.2
Chemicals	4
Industrial Metals & Mining	1.8
Food Producers	1.5
Electronic & Electrical Equipment	1.4

Source: Prowess, data downloaded on 30 September 2020 from the platform; ACE Equity, data downloaded on 7 July 2020 from the platform; Annual Reports (2018-19) of Indian companies; Ahmedabad University; Centre for Technology, Innovation and Economic Research (CTIER)

As highlighted above, sectors such as pharmaceuticals & biotechnology and the automobile & parts that were at the forefront of the response and account for around 60 percent of industrial R&D in India. The software & computer services sector that accounts for around 6 percent of industrial R&D spending has also been involved in the development of diagnostic healthcare technologies using artificial intelligence for the detection of COVID-19. India's public funded R&D institutions too have been at the forefront of the pandemic response. Public expenditure on healthcare R&D as a share of total expenditure on R&D by the central government was just 5.7 percent in 2017-18, taking into account the combined spending by the Indian Council of Medical Research (ICMR) and the Department of Biotechnology (DBT) in Figure 5.1.

Figure 5.1 | Public healthcare R&D expenditure by ICMR and DBT was 5.7 percent of Central Government R&D expenditure in 2017-18



Source: S&T Indicators Tables, Research and Development Statistics 2019-20 available at https://dst.gov.in/sites/default/files/S%26T%20Indicators%20 Tables%2C%202019-20.pdf; Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) Figures in rupees were converted to dollars using the USD-INR exchange rate of 47.4 calculated as an average for the fiscal year 2009-10 and the USD-INR exchange rate of 61.1 calculated as an average for the fiscal year 2014-15, and USD-INR exchange rate of 64.46 calculated as an average for the fiscal year 2017-18 based on data from Federal Reserve Bank of St Louis

(ii) Total Central Government R&D Expenditure includes R&D Expenditure by Select Major Scientific Agencies and R&D Expenditure by Central Ministries/Departments other than Major Scientific Agencies. Total Central Government R&D expenditure was USD 8830 million in 2017-18 and USD 7053 million in 2014-15.

(iii) Total National R&D expenditure for 2014-15 has been updated as per the latest figures released by DST

However, the pandemic also saw labs from the Defence Research and Development Organisation (DRDO), the Indian Space Research Organisation (ISRO) and the Indian Railways also joining the government's health research efforts. Thus, the share of public expenditure on healthcare R&D would have necessarily seen an increase in the current financial year. While the pandemic may have necessitated the ad hoc involvement of ISRO and the Railways, the Indian government should sustain the increased spending on healthcare R&D through ICMR and DBT going forward. Expenditure of around USD 1.6 billion on healthcare research, would increase the share of healthcare R&D to 20 percent of the central government's overall expenditure on R&D, bringing the share closer to that of countries like the US and the UK.

Designing policies for technology deepening to aid in India's economic recovery

The country's economic policies should be designed in a way that would allow for greater technology deepening in sectors where India does have a presence on the global stage and allow for technology diversification into sectors like electronics where the country's absence is clearly visible. A structured approach to technology deepening and diversification would contribute towards sustaining India's economic recovery going forward. As can be seen in Table 5.2 below, while India has 13 firms present in the pharmaceuticals & biotechnology sector when it comes to top global R&D firms and sectors, it has no presence in the healthcare equipment & services sector. India also currently imports around 80 percent of its medical device needs, with medical device imports having been around USD 6 billion in FY2019-20. Developing a smart specialisation strategy around medical devices would allow India to build on its competitive strength in the pharmaceuticals & biotechnology sector and ensure greater technology deepening in the healthcare sector. India has a tremendous opportunity to provide its citizens and the rest of the world with access to high quality and affordable healthcare equipment.

Table 5.2 | Sector-wise Global Industrial R&D Expenditure and Country-wise Number of Firms - India's Opportunity is in Healthcare Equipment & Services

Sector	R&D expenditure (US$, Millions)	Total Number of Firms	Number of Firms									
			Select Advanced Economies				Select Emerging/Asian Economies					
			USA	UK	Germany	Japan	Brazil	China	India	Israel	South Korea	Taiwan
Pharmaceuticals & Biotechnology	176892	429	221	26	9	28	0	44	13	4	7	1
Technology Hardware & Equipment	147000	250	89	7	4	22	0	48	0	3	8	45
Automobiles & Parts	146961	150	22	4	15	33	0	36	7	0	8	4
Software & Computer Services	135367	285	150	14	5	7	1	61	4	7	3	3
Electronic & Electrical Equipment	73781	227	44	5	9	39	0	67	0	1	7	24
Industrial Engineering	34418	188	34	4	22	36	1	38	1	0	3	0
Chemicals	25695	128	28	3	10	34	1	25	1	0	6	1
General Industrials	23487	82	16	4	8	16	0	17	0	1	8	2
Aerospace & Defence	23227	50	17	6	1	0	1	6	0	2	3	0
Health Care Equipment & Services	19048	86	48	6	8	8	0	6	0	0	0	0
Top 3 sectors	470853	829	332	37	28	83	0	128	20	7	23	50
Top 10 sectors	805876	1875	669	79	91	223	4	348	26	18	53	80
Total (2500)	946938	2500	769	127	130	318	6	507	32	22	70	89

Source: EU Industrial R&D Investment Scoreboard (2019); Centre for Technology, Innovation and Economic Research (CTIER)

Note: Figures in euros were converted to dollars using the EUR-USD exchange rate of 1.15 as at 31 December 2018 and as mentioned in the EU Industrial R&D Investment Scoreboard

There are some positive steps that have already been taken towards developing India's medical device sector. The sector currently allows for 100 percent foreign direct investment in new ventures through the automatic route. In February 2020, the Ministry of Health and Family Welfare issued notifications through The Gazette of India that all medical devices would be regulated under the Drugs and Cosmetics Act, 1940 beginning 1 April 2020. The new Medical Devices (Amendment) Rules, 2020 builds on the Medical Devices Rules, 2017, and also specifies that all newly notified devices, whether manufactured in India or imported, would need to be registered with the Central Drugs Standard Control Organisation (CDSCO) within a specified time frame. The announcement in February signalled a move towards a unified regulator to ensure that medical devices meet certain regulatory and quality standards. In her FY2021 budget speech, Finance Minister Nirmala Sitharaman had announced a scheme for the electronics sector, and had said that 'with suitable modifications' the electronics scheme could be adapted to manufacture medical devices. In the current tough fiscal environment that India finds itself in, where the central government's fiscal deficit is expected to widen significantly given its COVID related spending, focusing resources on medical devices would perhaps be a more prudent way to grow the electronics sector too.

Much more however needs to be done to develop a successful industrial and innovation policy around medical devices that complements the steps that have already been taken. For instance, although the FY2021 budget speech mentioned setting up technology clusters that would have test beds and small scale manufacturing facilities, there would need to be dedicated facilities that cater to medical device manufacturers. Device manufacturers have often lamented the lack of sufficient testing and test bed facilities, as well as the lack of access to existing testing facilities especially for smaller firms and startups. Providing access to testing facilities at some of the top public universities would provide much needed support to startups in this sector. Ensuring sufficient funding support at critical stages of the development of devices would be important, and the role industry associations would be essential here in connecting smaller innovative firms with larger firms. The support from larger firms and the government could be in various forms that include guidance as well as financial support, be it towards filing of patents for example or when devices require FDA, CE and other regulatory approvals. Certain policies would need to be revisited. The government may need to consider removing or lowering import duties on electronics components – the duties are often a barrier to lowering the cost of innovative devices. The government may also need to revisit the health cess on the import of medical devices announced in the FY2021 budget. Apart from making technology imports that India could benefit from more expensive, it is unclear whether having a cess like this will actually promote the manufacturing of quality innovative devices in India. The training of public officials would need to be an essential component of this strategy around medical devices, especially with respect to public procurement. Ensuring that those framing procurement rules are able to focus on the functionality of the devices rather than specific parts without compromising on the quality and standards of a device, would spur greater innovation in this sector. Lastly, both the government as well as industry associations would need to work together to create a brand around India's medical device innovations and take these innovations overseas.

In conclusion

Policy makers should build on the learnings from the mission mode response that saw industry, academia and government come together to tackle the COVID-19 crisis. India needs a smart specialisation strategy around medical devices to build on its competitive strengths in the pharmaceutical & biotechnology and software & computer services industry. Re-thinking economic policy with technology at its core, one that pushes for technology deepening and diversification in a sequenced manner will help sustain India's economic recovery.

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Section 2

Technology and Innovation in India : Indicators

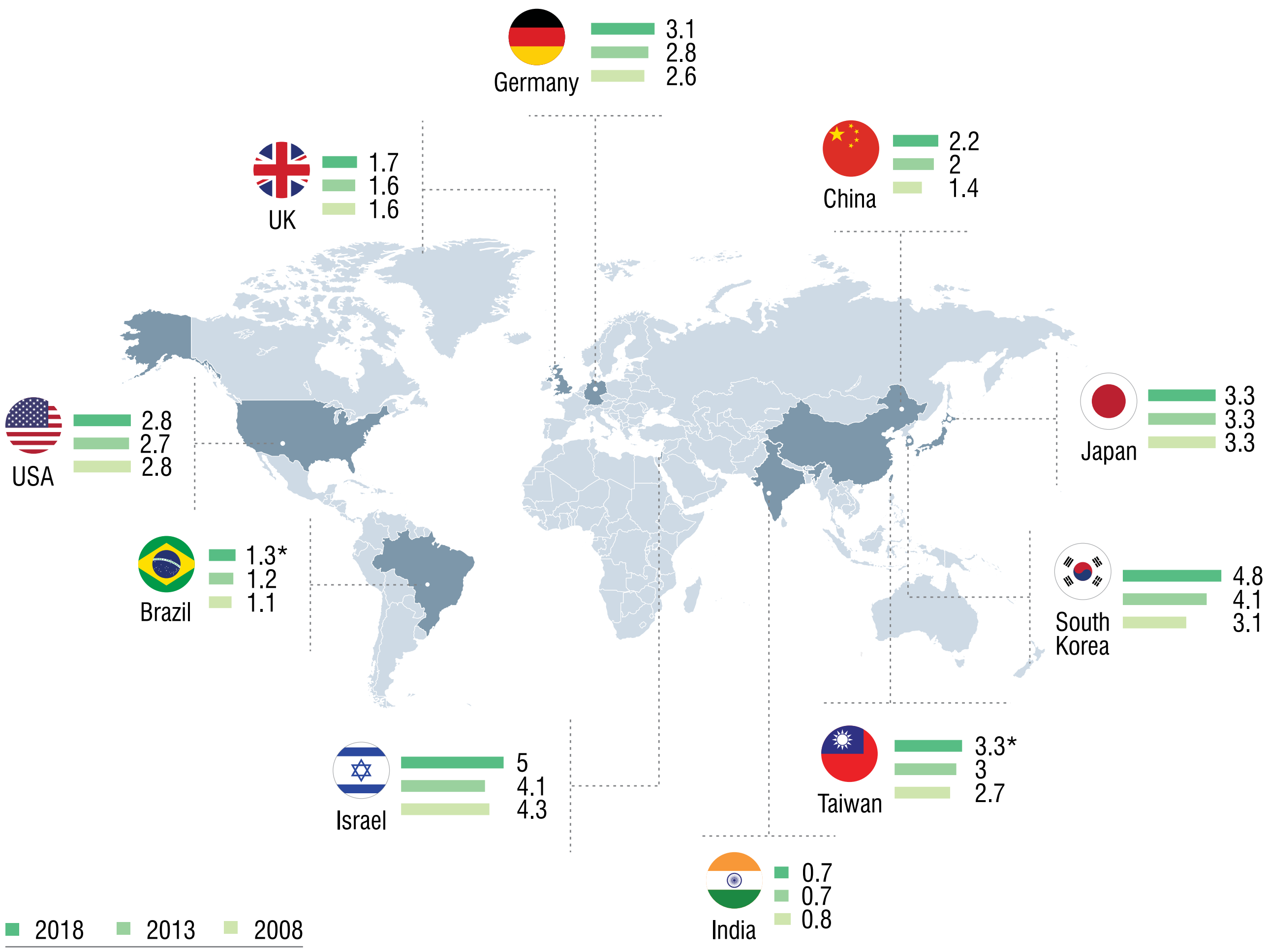
Chapter 6

India and the Global Economy

This chapter looks at the comparison of India with select countries on input and output indicators with respect to R&D and innovation outlined below. The select countries are a combination of advanced economies and emerging economies to allow the reader to view India's position relative to both. Where possible, we have also delved deeper into data that pertains to India.

Number	Indicator
6.1	R&D Expenditure as a Percent of Gross Domestic Product across Select Countries
6.2	Country-wise Comparisons of Share of R&D in National R&D Expenditure by Sector of Performance in 2018 (%)
6.2.1	Share of India's R&D Expenditure by Sector of Performance
6.3	R&D Expenditure by Select Key Scientific Agencies under Government of India
6.4	Sector-wise Global Industrial R&D Expenditure and Country-wise Number of Firms (2019)
6.4.1	Comparison of the Structure of Global and Indian Industrial R&D (Sector Share of Total Industrial R&D Spending)
6.5	Payments and Receipts for Intellectual Property (2019)
6.5.1	India's Technology Trade Balance (2015 - 2019)
6.6	Annual Foreign Direct Investment (FDI) Equity Inflows into India (2015 - 2019)
6.6.1	Foreign Direct Investment into India by Sector (2017- 18 and 2018- 19)
6.7	Venture Capital Investment in Select Countries
6.7.1	Funding for New Startups in India (2015 - 2019)
6.7.2	Number of Startups Created in India (2015 - 2019)
6.8	Country-wise Comparisons for Full Time Researchers per Million (2018)
6.9	Country-wise Comparisons of Global Science and Engineering (S&E) PhDs
6.9.1	Degrees Awarded in S&E Degree Programmes in India (2018)
6.9.2	Enrolment in S&E Degree Programmes in India (2018)
6.10	Persons Employed (full time equivalent) as Researchers by R&D Establishments in India
6.11	Country-wise Comparisons by Share of Publications, Impact, Share of Industry-Academia Collaborations and Share of International Collaborations in Total Publications (2015 - 2019)
6.12	Country-wise Comparison by Share of Publications, Impact, Share of Industry-Academia Collaborations and Share of International Collaborations by Top Subject Categories (2015 - 2019)
6.12.1	India's Top Areas of Cumulative Publications (2015 - 2019) - Impact, Industry-Academia Collaborations, International Collaborations and Comparisons with Global Averages
6.13	Ranking of Institutions in India by Number of Publications (2015 - 2019)
6.14	Country-wise Comparisons for Patent Applications Filed Abroad
6.15	Country-wise Comparisons for Patent Applications with Respective Domestic Patent Offices (2018)
6.16	Applications for Patents, Industrial Design and Trademarks from India (2014 - 2018)
6.17	Patent Applications with Indian Patent Office by Residents and Non-Residents (2014 - 2018)
6.18	Patent Applications with Indian Patent Office by Sector (2019)
6.19	Patents Granted by the United States Patent and Trademark Office (USPTO) to Select Countries
6.20	Country-wise Comparisons for Patents Granted by Respective Domestic Patent Offices (2018)
6.21	Patents Granted by the Indian Patent Office to Residents and Non-Residents (2014 - 2018)
6.22	High Technology Exports as Share of Manufactured Exports for Select Countries

6.1 | R&D Expenditure as a Percent of Gross Domestic Product across Select Countries



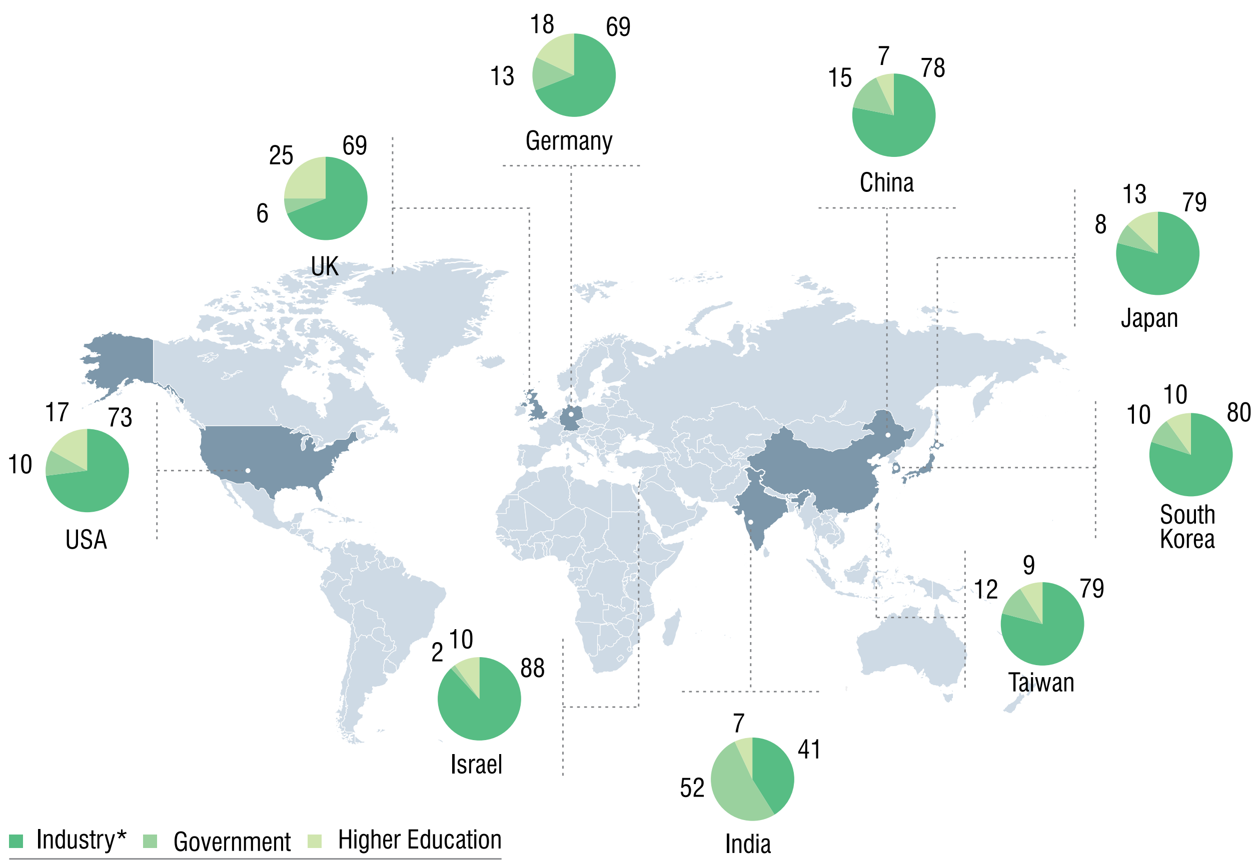
*Data reported for Brazil and Taiwan is for 2017

Source: UNESCO Institute of Statistics (various years), UNESCO Institute for Statistics, available at http://data.uis.unesco.org/; Department of Science and Technology (DST), Research and Development Statistics at a Glance 2019-20 available at https://dst.gov.in/news/research-development-statistics-glance-2019-20 for data on India; Taiwan Statistical Data Book (2019) for data on Taiwan; Centre for Technology, Innovation and Economic Research (CTIER)

India's R&D expenditure as a percent of Gross Domestic Product (GDP) was 0.7 percent in 2018. It has remained in the range of 0.6 percent and 0.9 percent for over three decades.[1] Countries that have seen a noticeable increase in their expenditure on R&D as a percent of GDP since 2008 include South Korea, Taiwan, China and Germany while it has remained relatively stable for countries like the US, UK and Japan in 2018 compared to 2008. Israel and South Korea continue to remain among the top spenders on R&D as a percent of GDP.

[1] India's National Innovation System: Transformed or Half-formed? Forbes N (2016)

6.2 | Country-wise Comparisons of Share of R&D in National R&D Expenditure by Sector of Performance in 2018 (%)



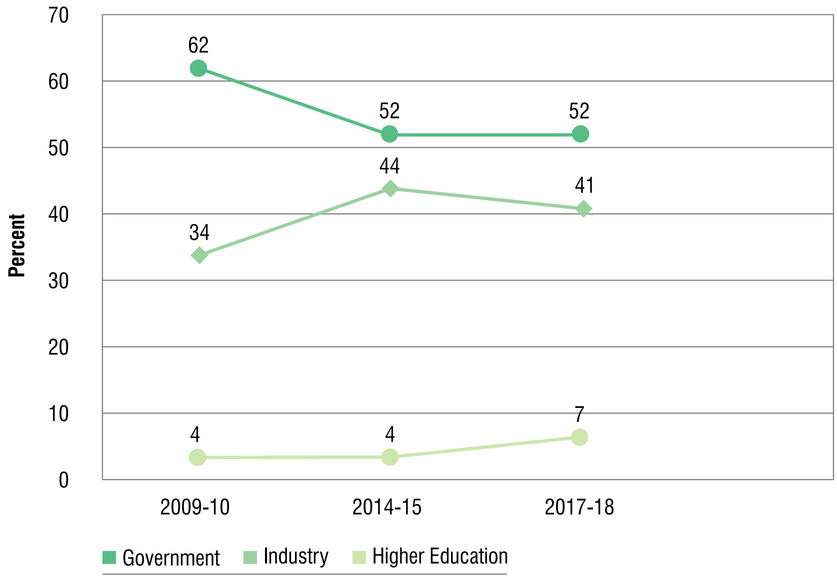
*UNESCO uses the term business enterprises

Source: UNESCO Institute of Statistics (2018), UNESCO Institute for Statistics, available at: http://data.uis.unesco.org/; Department of Science and Technology (DST), Research and Development Statistics at a Glance 2019-20 available at https://dst.gov.in/news/research-development-statistics-glance-2019-20 for data on India; Taiwan Statistical Data Book (2019) for data on Taiwan; Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) Higher Education includes Higher Education sector and Private Non-Profit sector
(ii) Data not available for Brazil
(iii) Taiwan data is for 2017

For the select countries in our sample, R&D spending is dominated by Industry. Israel's industry accounted for 88 percent of spending on national R&D in 2018, whereas the share of spending by industry in other countries, excluding India, ranged between 69 percent to 80 percent. In India, R&D spending continues to be dominated by the government sector and accounted for 52 percent of national R&D spending in 2018, whereas spending by industry (that includes private sector and public sector business enterprises) accounted for 41 percent. The share of spending in the higher education sector varied between 7 percent to 26 percent. India's share of spending on R&D in the higher education sector was 7 percent in 2018, comparable to that of China.

6.2.1 | Share of India's R&D Expenditure by Sector of Performance

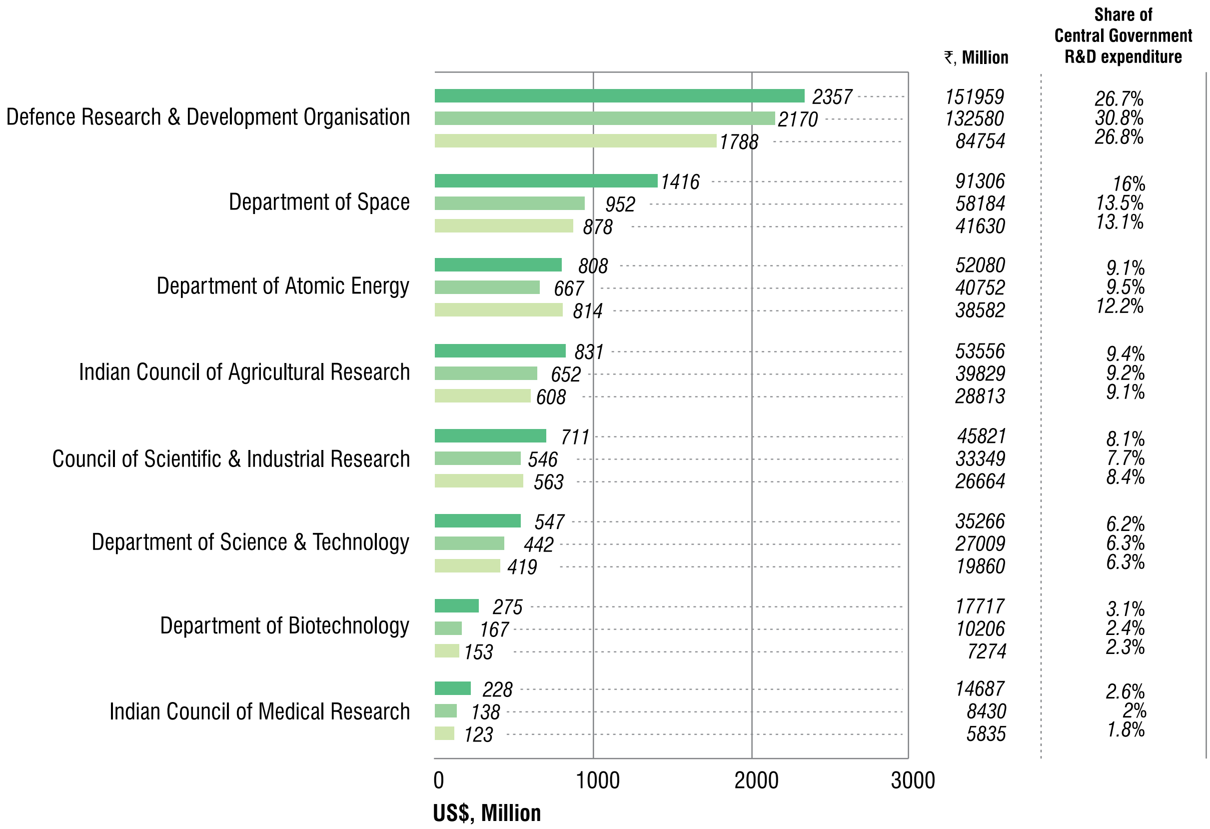


Source: Department of Science and Technology (DST), Research and Development Statistics at a Glance 2019-20 available at https://dst.gov.in/sites/default/files/R%26D%20Statistics%20at%20a%20Glance%202019-20.pdf; Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) Government Sector includes Centre and State expenditure on research and development
(ii) Industry includes private and public sector industries and Scientific and Industrial Research Organisation (SIRO)

R&D spending in India is still dominated by the government sector, and accounted for 52 percent of the total R&D expenditure in 2018. The share of R&D spending by industry was 41 percent in 2018 compared to 44 percent in 2015, whereas the share of R&D spending in the higher education sector increased to 7 percent in 2018 compared to 4 percent in 2015. In 2009-10, the share of R&D spending by the government sector had been 62 percent while the share of R&D spending by industry had been 34 percent. The data reported for 2009-10 and 2014-15 had been captured in the CTIER Handbook: Technology and Innovation in India 2019, and reflected the data from DST as available at the time.

6.3 | R&D Expenditure by Select Key Scientific Agencies under Government of India



		Total for Select Key Scientific Agencies	Total Central Government R&D expenditure	Total National R&D expenditure
2017-18	**US$, Million**	7173	8830	17658
	₹, Million	462391	569200	1138250
2014-15	**US$, Million**	5734	7053	14316
	₹, Million	350338	430949	874734
2009-10	**US$, Million**	5346	6682	11190
	₹, Million	253412	316705	530413

Source: S&T Indicators Tables, Research and Development Statistics 2019-20 available at https://dst.gov.in/sites/default/files/S%26T%20Indicators%20 Tables%2C%202019-20.pdf; Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) Figures in rupees were converted to dollars using the USD-INR exchange rate of 47.4 calculated as an average for the fiscal year 2009-10 and the USD-INR exchange rate of 61.1 calculated as an average for the fiscal year 2014-15, and USD-INR exchange rate of 64.46 calculated as an average for the fiscal year 2017-18 based on data from Federal Reserve Bank of St Louis

(ii) Total Central Government R&D Expenditure includes R&D Expenditure by Select Major Scientific Agencies and R&D Expenditure by Central Ministries/Departments other than Major Scientific Agencies

(iii) Total National R&D expenditure for 2014-15 has been updated as per the latest figures released by DST

R&D expenditure by major scientific agencies increased to USD 7.2 billion in 2018 from USD 5.7 billion in 2015. The largest increases in 2018 compared to 2015, were seen for the Department of Biotechnology and the Indian Council of Medical Research followed by the Department of Space (DoS). The Defence Research & Development Organisation (DRDO) continues to be the largest spender on R&D. The scientific agencies listed above accounted for 81 percent of total central government R&D expenditure and 41 percent of national R&D expenditure in 2015 and 2018. Strategic R&D investments by the DRDO, the DoS and the Department of Atomic Energy accounted for 52 percent of total central government expenditure on R&D in 2018, compared to 54 percent in 2015. The data reported for 2009-10 and 2014-15 had been captured in the CTIER Handbook: Technology and Innovation in India 2019, and reflected the data from DST as available at the time.

6.4 | Sector-wise Global Industrial R&D Expenditure and Country-wise Number of Firms (2019)

Sector	R&D expenditure (US$, Millions)	Total Number of Firms	Number of Firms									
			Select Advanced Economies				Select Emerging/Asian Economies					
			USA	UK	Germany	Japan	Brazil	China	India	Israel	South Korea	Taiwan
Pharmaceuticals & Biotechnology	176892	429	221	26	9	28	0	44	13	4	7	1
Technology Hardware & Equipment	147000	250	89	7	4	22	0	48	0	3	8	45
Automobiles & Parts	146961	150	22	4	15	33	0	36	7	0	8	4
Software & Computer Services	135367	285	150	14	5	7	1	61	4	7	3	3
Electronic & Electrical Equipment	73781	227	44	5	9	39	0	67	0	1	7	24
Industrial Engineering	34418	188	34	4	22	36	1	38	1	0	3	0
Chemicals	25695	128	28	3	10	34	1	25	1	0	6	1
General Industrials	23487	82	16	4	8	16	0	17	0	1	8	2
Aerospace & Defence	23227	50	17	6	1	0	1	6	0	2	3	0
Health Care Equipment & Services	19048	86	48	6	8	8	0	6	0	0	0	0
Top 3 sectors	470853	829	332	37	28	83	0	128	20	7	23	50
Top 10 sectors	805876	1875	669	79	91	223	4	348	26	18	53	80
Total (2500)	946938	2500	769	127	130	318	6	507	32	22	70	89

Source: EU Industrial R&D Investment Scoreboard (2019); Centre for Technology, Innovation and Economic Research (CTIER)

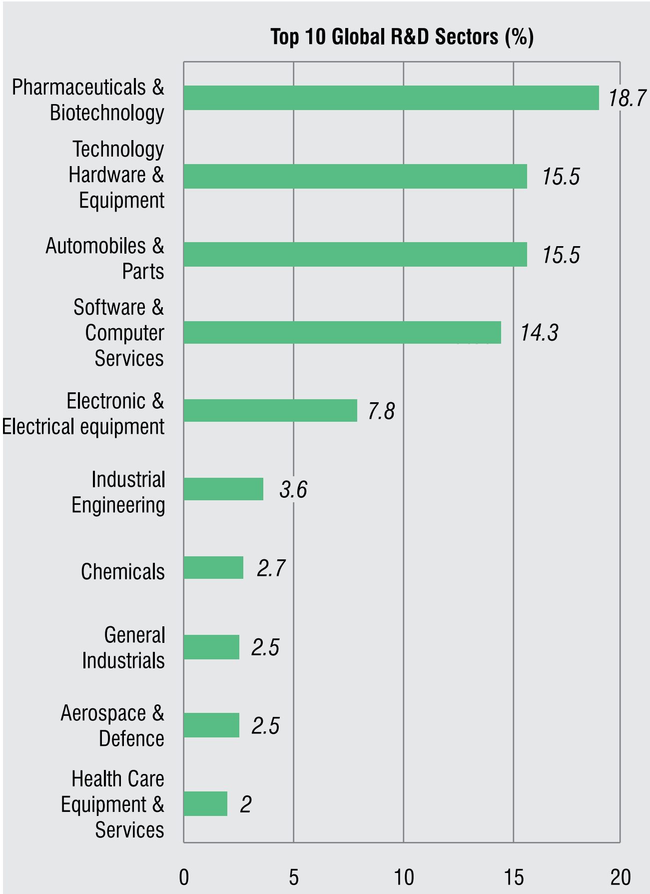
Note: Figures in euros were converted to dollars using the EUR-USD exchange rate of 1.15 as at 31 December 2018 and as mentioned in the EU Industrial R&D Investment Scoreboard

India had 32 firms in the list of top 2,500 global R&D spenders compared to 25 in 2016.[2] Of these there were 26 firms present in the top 10 sectors. There are 13 firms in the pharmaceutical & biotechnology sector, 7 in the automobiles & parts sector, 4 in software & computer services sector, and 1 each in the industrial engineering and chemicals sector. Indian firms remain absent in 5 out of the top 10 global industrial R&D sectors.

There has been a marked increase in the number of firms from China in the top 2,500 global R&D spenders list in 2019 compared to 2016. In 2019, the top R&D spenders list had 507 firms from China compared to 326 in 2016. The top 10 global sectors had 348 firms from China compared to 242 in 2016, with significant increases in the number of firms seen in sectors like software & computer services, electronic & electrical equipment, pharmaceuticals & biotechnology, chemicals and technology & hardware equipment.

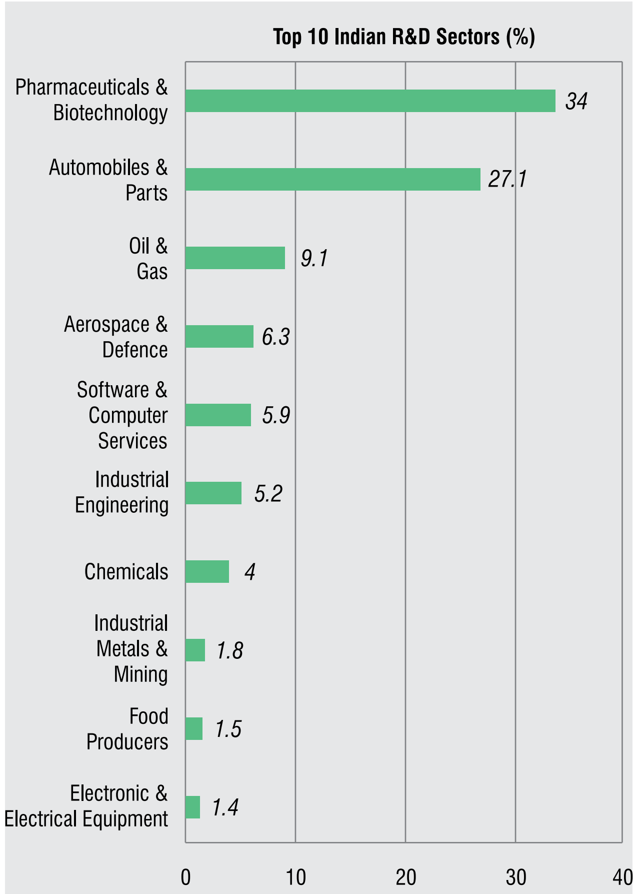
[2] CTIER Handbook: Technology and Innovation in India 2019

6.4.1 | Comparison of the Structure of Global and Indian Industrial R&D (Sector Share of Total Industrial R&D Spending)



Source: EU Industrial R&D Investment Scoreboard (2019); Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) Total for the top 2500 companies according to EU Industrial R&D Investment Scoreboard (2019) for the year was USD 947 billion
(ii) Figures in euros were converted to dollars using the EUR-USD exchange rate of 1.15 as at 31 December 2018 and as mentioned in the EU Industrial R&D Investment Scoreboard



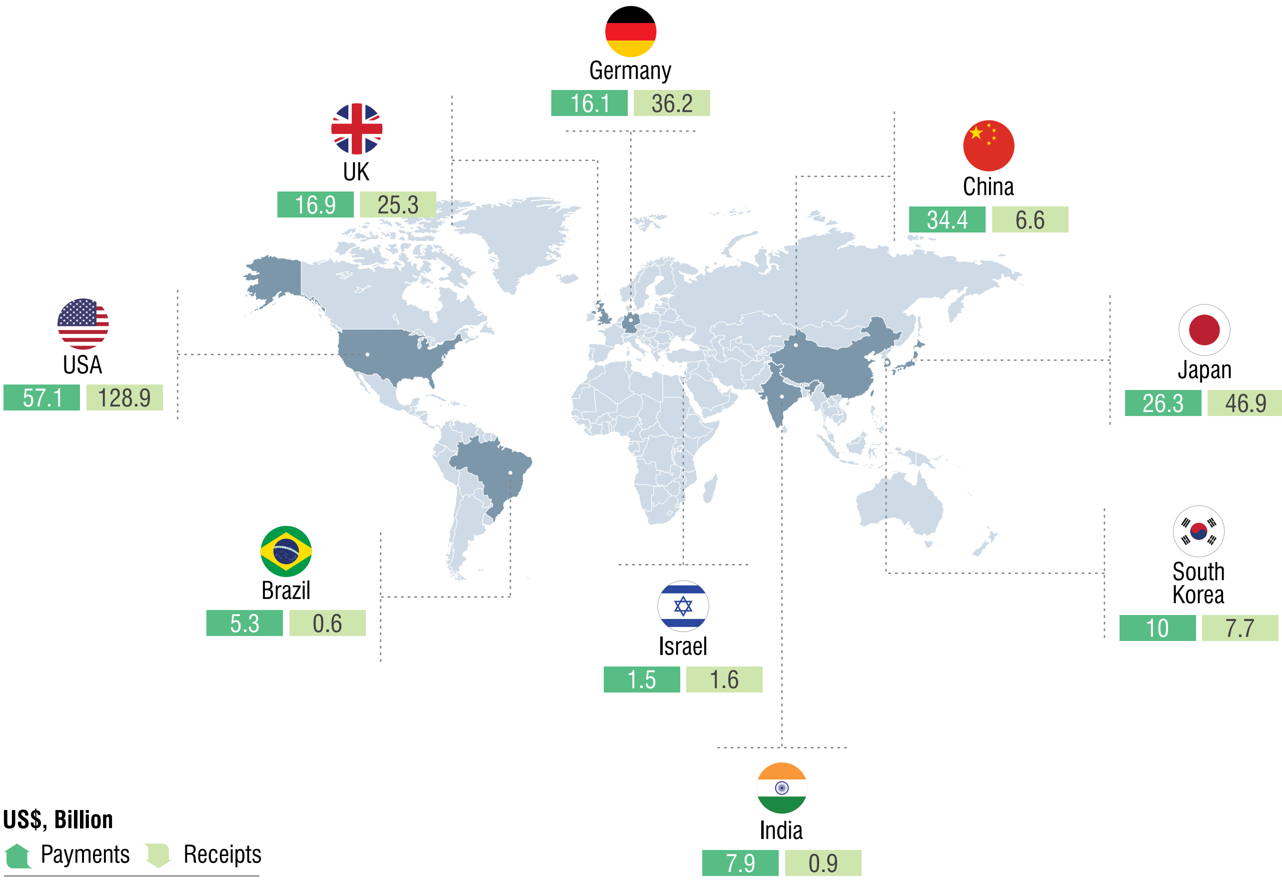
Source: Prowess, data downloaded on 30 September 2020 from the platform; ACE Equity, data downloaded on 7 July 2020 from the platform; Annual Reports (2018-19) of Indian companies; Ahmedabad University; Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) Total for the sample selected for the year was USD 5980 million (INR 418 billion). This sample of top 310 R&D spending firms represented 90% of total industrial R&D spending in 2018-19
(ii) Figures in rupees were converted to dollars using the USD-INR exchange rate of 69.92 calculated as an average for the fiscal year 2018-19 based on data from Federal Reserve Bank of St Louis

India's industrial R&D is dominated by the pharmaceutical & biotechnology and automobiles & parts sectors. These top two sectors contribute to more than 60 percent of the total industrial R&D spending in India. Other major sectors contributing to industrial R&D in India include oil & gas, aerospace & defence and software & computer services. Global industrial R&D on the other hand is dominated by pharmaceutical & biotechnology, technology hardware & equipment, automobiles & parts, software & computer services and electronic & electrical equipment. The structure of India's industrial R&D has 7 sectors in common with the top global sectors of industrial R&D. Top global sectors such as technology hardware & equipment, general industrials and healthcare equipment & services are absent from India's top industrial R&D sectors. In 2016[3], India's top industrial R&D sectors included electricity and general industrials. Two new sectors, food producers and electronic & electrical equipment, have made an appearance in the top 10 R&D sectors for India having replaced electricity and general industrials.

[3] CTIER Handbook: Technology and Innovation in India 2019

6.5 | Payments and Receipts for Intellectual Property (2019)

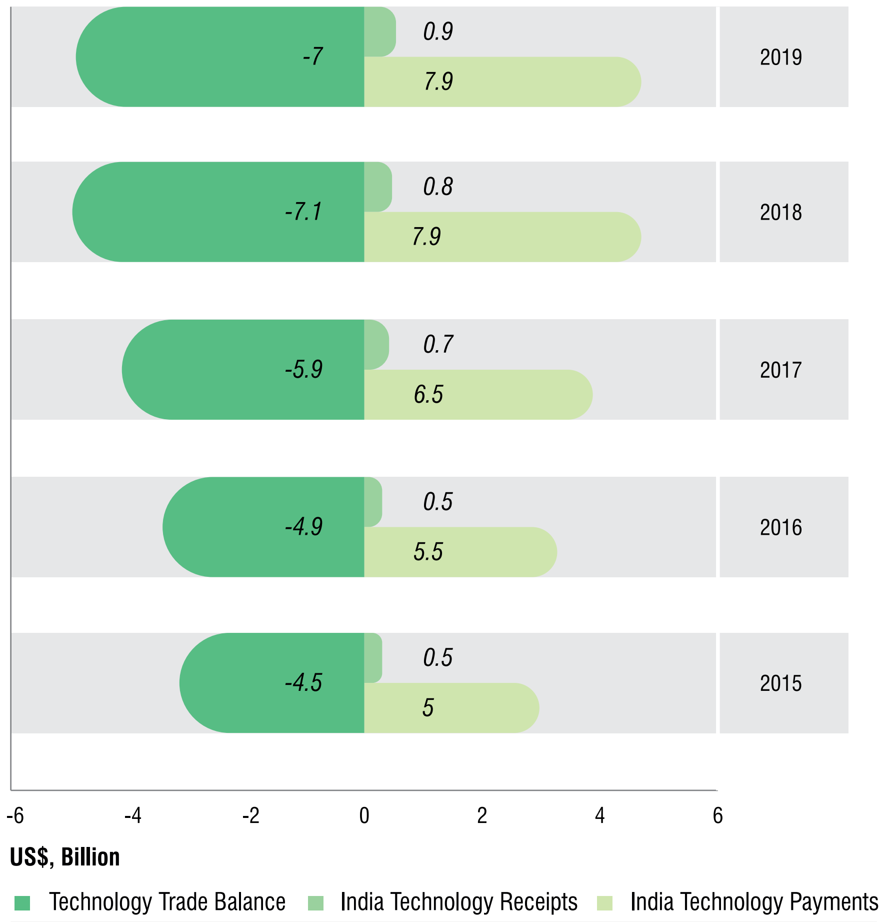


Source: Reserve Bank of India (RBI), Balance of Payment (various years) available at https://rbi.org.in/scripts/SDDS_ViewDetails.aspx?Id=5&IndexTitle=Balance+of+ for data on India; World Development Indicators (2019), Indicators, available at http://data.worldbank.org/ for data on Brazil, China, Germany, Israel, Japan, South Korea, UK and USA; Centre for Technology, Innovation and Economic Research (CTIER)

The select advanced economies in the sample under consideration had a positive technology trade balance in 2019. While the technology trade surplus has increased for Japan, Germany and the UK, the technology trade surplus for the US has narrowed in 2019 compared to 2015. India and China's technology trade deficit continued to widen in 2019 compared to 2015, with China's technology trade deficit coming in at USD 28 billion followed by India's deficit at USD 7 billion.

The data for 2015 for our sample of countries can be found in the Appendix (Table A.1).

6.5.1 | India's Technology Trade Balance (2015 - 2019)

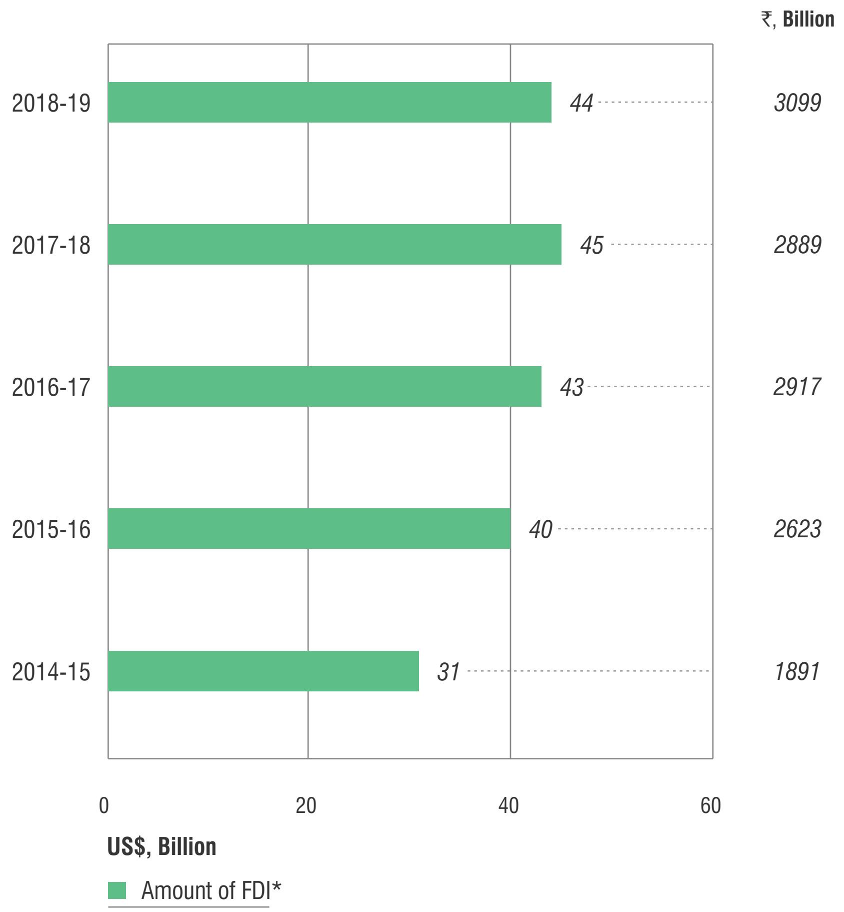


Source: Reserve Bank of India (RBI) Balance of Payment (various years) available at https://rbi.org.in/scripts/SDDS_ViewDetails.aspx?Id=5&IndexTitle=Balance+of+; Centre for Technology, Innovation and Economic Research (CTIER)

Note: Figures reported above are calculated for calendar years. The Reserve Bank of India (RBI), Balance of Payment, captures fiscal year data on Charges for the Use of Intellectual Property (CIP). CIP for the fiscal year 2018-19 was USD 8 billion and for the fiscal year 2019-20 was USD 7.7 billion.

India's payments for the use of intellectual property had seen an increasing trend between 2015 and 2018. In 2019, the payments for the use of intellectual property came in at USD 7.9 billion, unchanged from the previous year. The technology receipts on the other hand had seen marginal increases each year between 2015 and 2019. India's technology trade deficit was USD 7 billion in 2019.

6.6 | Annual Foreign Direct Investment Equity Inflows into India (2015 - 2019)

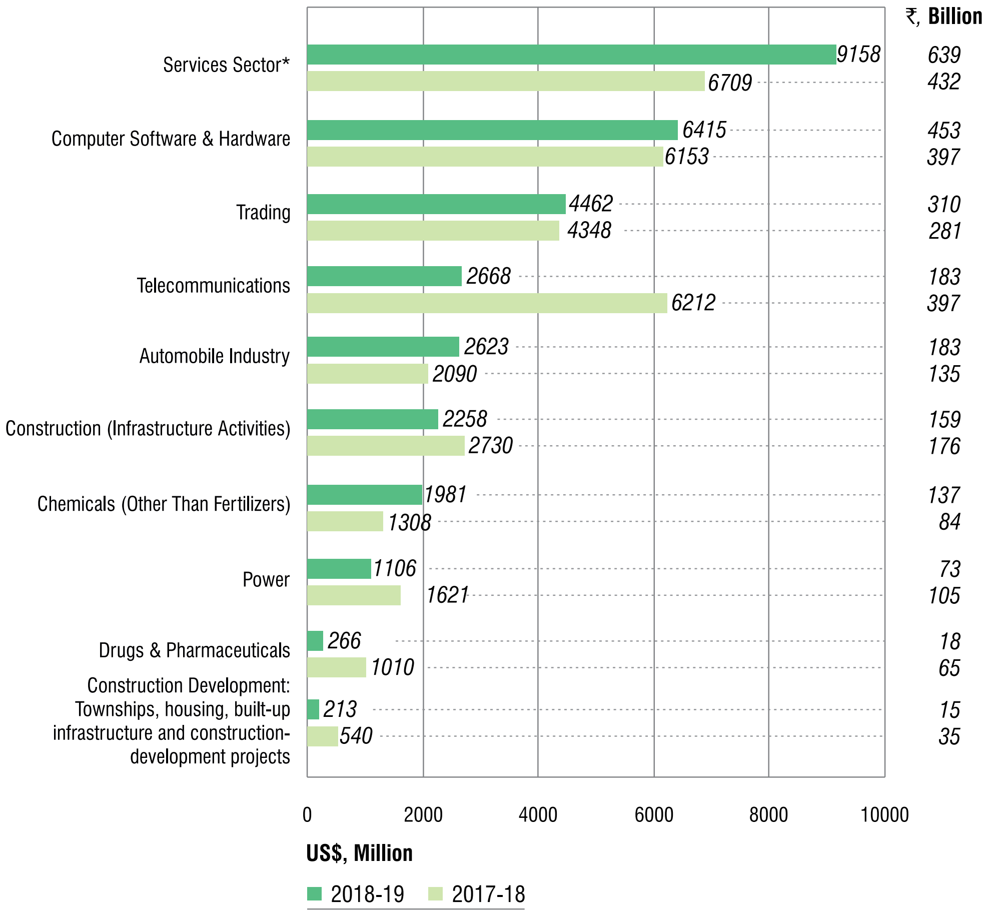


*Does not include reinvested earnings and other capital. This amounted to around 17.6 billion in 2018-19

Source: Department for Promotion of Industry and Internal Trade (DPIIT), Government of India, Quarterly FDI factsheet, June 2019; Center for Technology, Innovation and Economic Research (CTIER)

The Foreign Direct Investment (FDI) equity inflows in 2018-19 amounted to USD 44 billion, as reported by Department for Promotion of Industry and Internal Trade (DPIIT). The equity inflows reported above include FDI received through the Foreign Investment Promotion Board (FIPB) route, RBI's automatic route and acquisition of shares route. The FDI received in 2018-19 was slightly lower than the amount received in 2017-18. The amount received as FDI through reinvested earnings, equity capital of unincorporated bodies and other capital amounted to USD 17.6 billion in 2018-19. The various components of FDI as reported by the RBI can be found in the Appendix (Table A.2).

6.6.1 | FDI Equity Inflows into India by Sector (2017- 18 and 2018- 19)



		2018-19	2017-18
Total for Top 10 Sectors	US$, Million	31150	32721
	₹, Billion	2170	2107
Grand Total	US$, Million	44366	44857
	₹, Billion	3099	2889

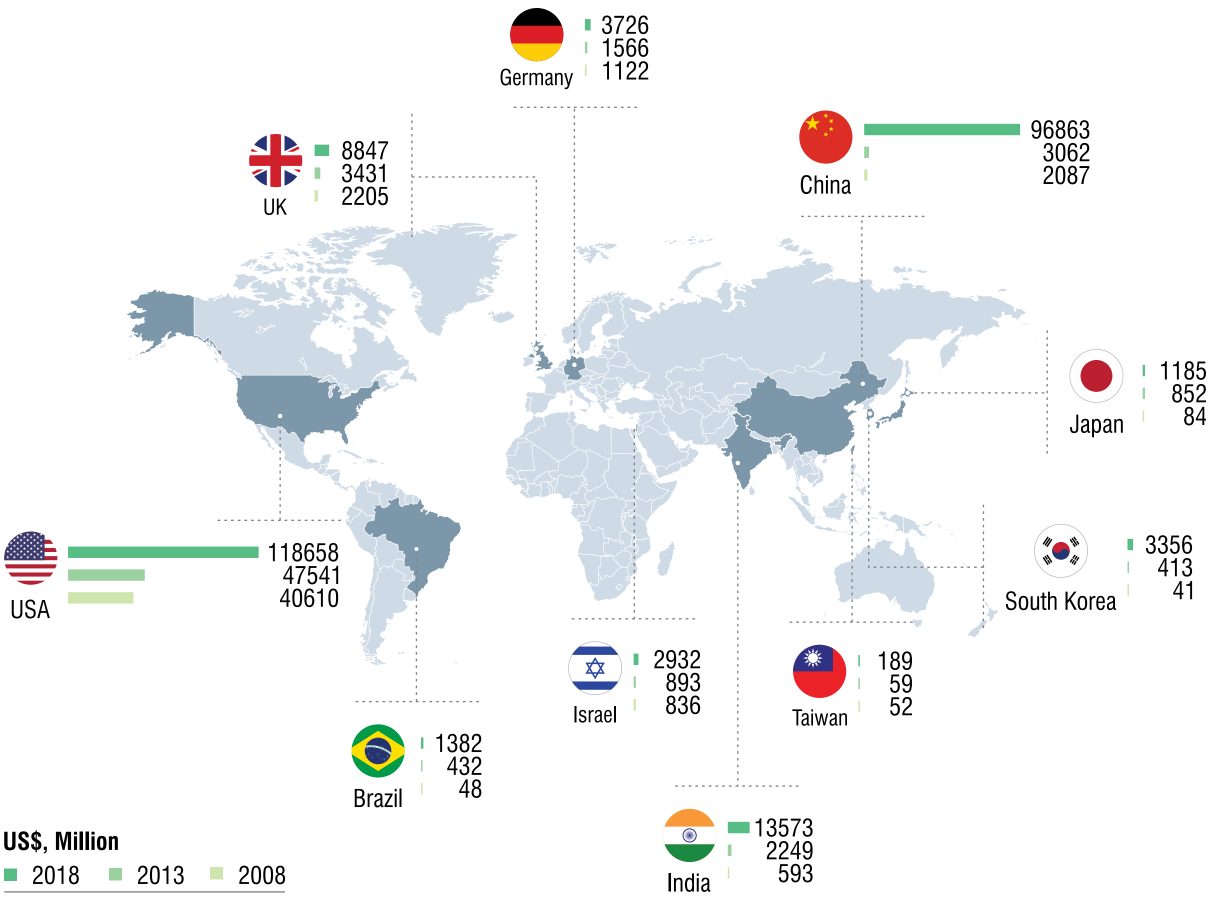
*Services sector includes Financial, Banking, Insurance, Non-Financial / Business, Outsourcing, R&D, Courier, Tech. Testing and Analysis

Source: Quarterly FDI factsheet, Department for Promotion of Industry and Internal Trade (DPIIT), (March 2019); Centre for Technology, Innovation, and Economic Research (CTIER)

FDI equity inflows excluding reinvested earnings etc. came in at USD 44 billion in 2018-19. The figure above captures FDI inflows for ten sectors in 2018-19 and 2017-18. These ten sectors have attracted the highest amount of FDI (on a cumulative basis for each sector) since the year 2000. If we simply considered the top ten sectors that attracted FDI in 2018-19, non-conventional energy with USD 1.4 billion and information & broadcasting (including print media) with USD 1.3 billion were seen to rank above the power sector. The figure for the top 10 sectors that attracted FDI in 2018-19 alone can be found in the Appendix (Table A.3).

In 2018-19, the services sector was the highest recipient of FDI inflows at USD 9.2 billion, followed by computer software & hardware at USD 6.4 billion. The telecommunications sector attracted just USD 2.7 billion in 2018-19 after having seen inflows of USD 6.2 billion in the previous year.

6.7 | Venture Capital Investment (USD million) in Select Countries

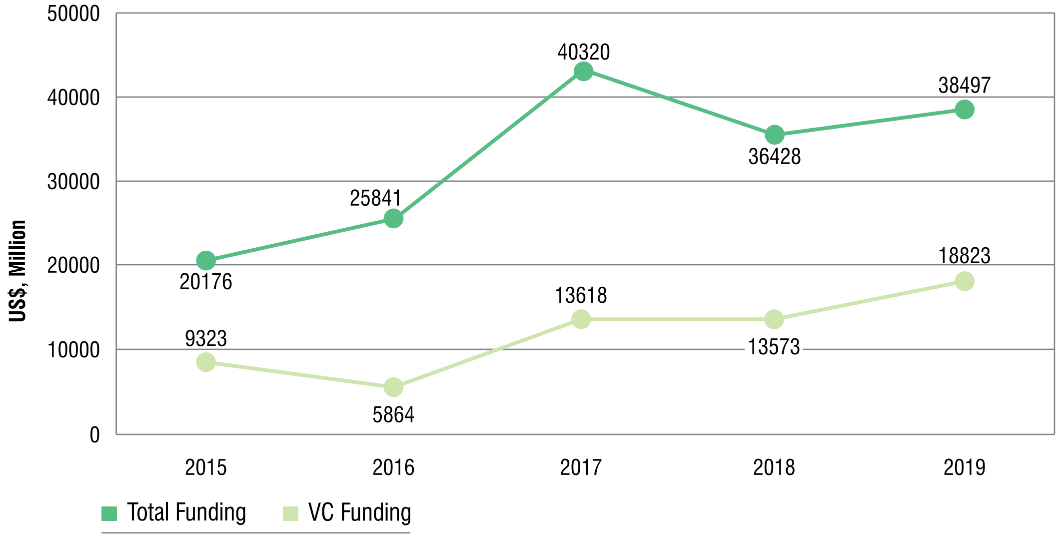


Source: National Science Foundation (NSF), Science & Engineering Indicators 2020, Invention, Knowledge Transfer and Innovation - Global Venture Capital Investment, by financing stage, selected region, country or economy: 2008-18; Tracxn data for India for the years 2013 and 2018, data downloaded on 8 September 2020 from the platform

The US and China are the top two destinations for Venture Capital (VC) funding globally. In 2018, the US recorded VC funding of USD 119 billion followed by China that saw VC funding of USD 97 billion. India was one of the top destinations for VC funding after the US and China, and saw total VC funding of USD 13.6 billion in 2018.

Apart from India, the latest available global data is as of 2018. We have used NSF data for all the countries in our sample, except for India where data for 2013 and 2018 is from Tracxn. For the purpose of global comparison, we have reported data for India in the table above as of 2018. The data on India's VC funding in 2019 is also available on Tracxn and is reported in the next indicator.

6.7.1 | Funding for New Startups (USD million) in India (2015 - 2019)



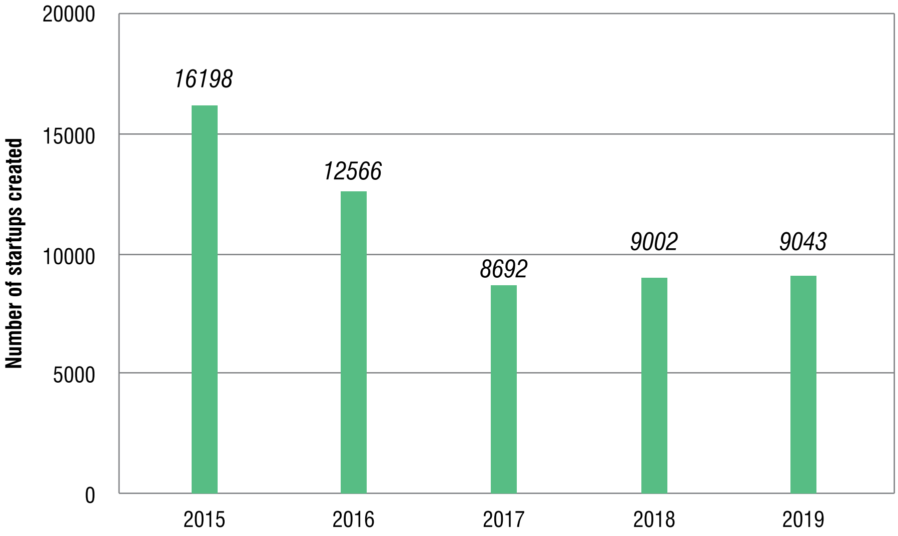
Source: Tracxn (various years), data downloaded on 8 September 2020 from the platform

Note: Total Funding includes Venture Capital, Private Equity, Angel, Debt

Total funding for startups (and new companies) in India was USD 38 billion in 2019 compared to USD 20 billion in 2015. The total funding saw a sharp increase in 2017 when it peaked at USD 40.3 billion. In 2019, the total funding for startups (and new companies) was mainly driven by VC funding and conventional debt financing. VC funding accounted for around 49 percent of total funding while conventional debt accounted for 33 percent. The share of VC funding in total funding had seen a drop in 2016, and has steadily risen since.

The details of the breakup of funding into categories like seed funding, various series rounds, etc. can be found in theAppendix (Table A.4). The data on VC funding captured above is from the Tracxn platform and includes funding for technology and offline startups (and new companies). The Appendix (Table A.5) provides a comparison of the VC funding data for India as reported by NSF as well as Tracxn.

6.7.2 | Number of Startups Created in India (2015 - 2019)



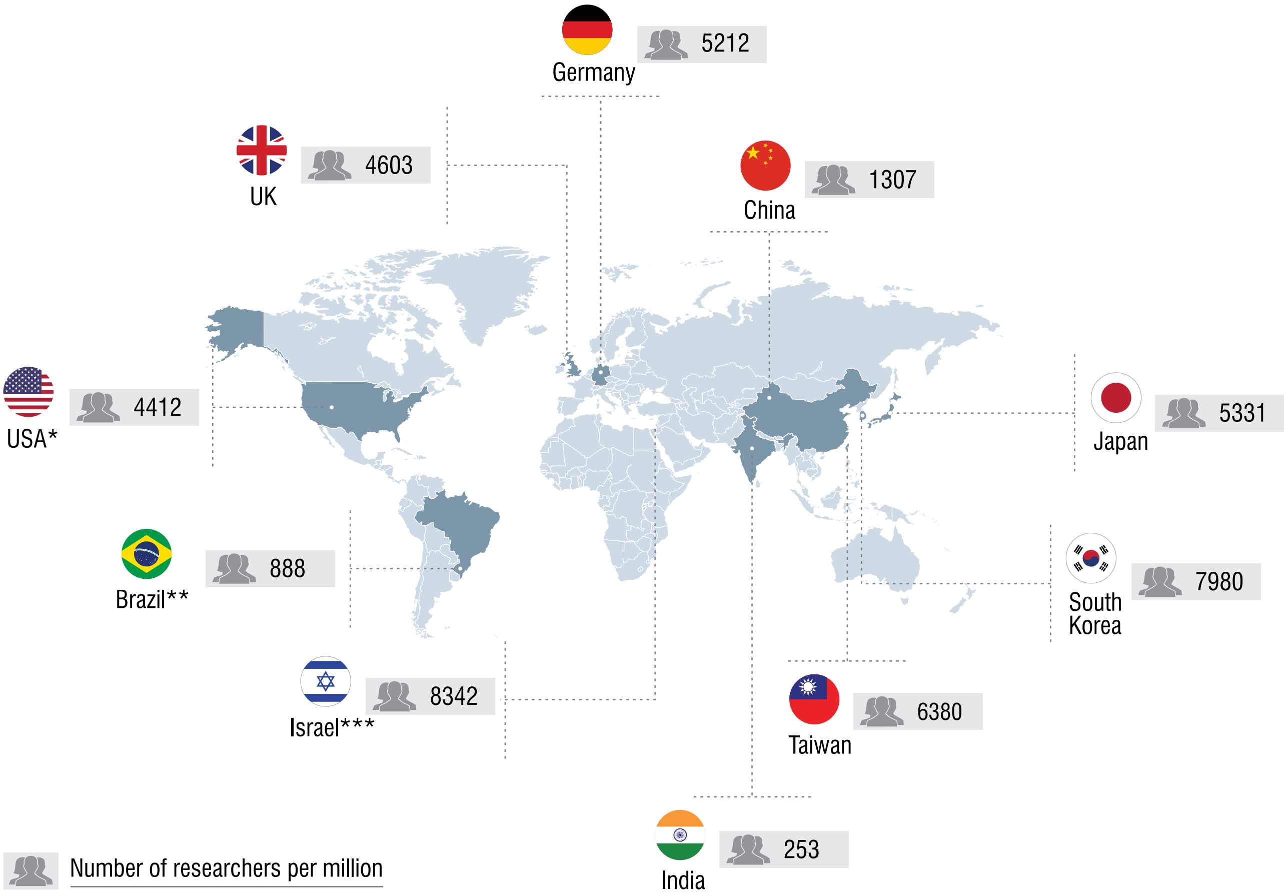
Source: Tracxn, data downloaded on 8 September 2020 from the platform

There were 9,043 startups (and new companies) including offline startups created in India in 2019. This was marginally higher than that reported for 2018 and well below the number seen in 2015. The reported startup data (as of September 2020) is subject to change based on when new startups founded in a particular year are identified. For instance, the number of startups (and new companies) including offline startups previously reported were 13,104 and 7,876 in 2015 and 2016[4] respectively, compared to 16,198 and 12,566 as can be seen in the chart above. The numbers may also vary depending on the source of the data on startups. Entities that conform to the definition of a startup[5] and have been recognised by the Department for Promotion of Industry and Internal Trade (DPIIT) can be found on the Startup India website.

[4] CTIER Handbook: Technology and Innovation in India 2019

[5] See Glossary (B.22)

6.8 | Country-wise Comparisons for Full Time Researchers per Million (2018)

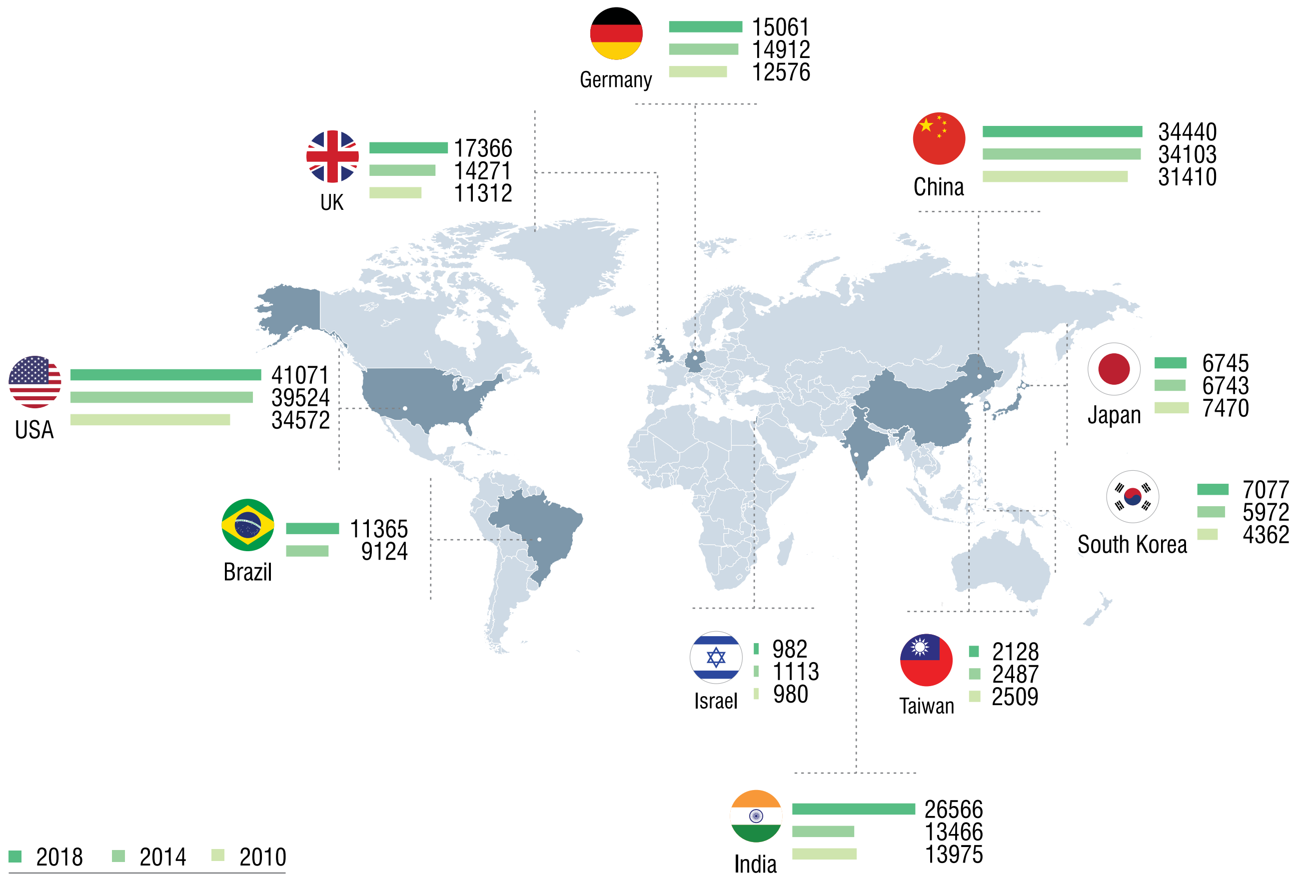


*Latest data available for 2017
**Latest data available for 2014
***Latest data available for 2012

Source: UNESCO Institute of Statistics (2018), UNESCO Institute for Statistics, available at http://data.uis.unesco.org/ for data on Brazil, China, Germany, India, Israel, Japan, South Korea, UK and USA; Taiwan Statistical Data Book (2019) for data on Taiwan; Centre for Technology, Innovation and Economic Research (CTIER)

In 2018, India had 253 full-time researchers per million compared to 1,307 researchers per million in China. India's number of researchers per million is significantly below that of all the other select economies. Israel had the highest number of researchers per million at 8,342 based on the latest available data from 2012. This was followed by South Korea which had 7,980 researchers per million.

6.9 | Country-wise Comparison of Global Science and Engineering (S&E) PhDs



Source: National Science Foundation (NSF), Science & Engineering Indicators 2020, Higher Education in Science and Engineering, S&E doctoral degrees by selected region, country, or economy and field: 2000–16, available at https://ncses.nsf.gov/pubs/nsb20197/; OECD Statistics (2018), Graduates by field, available at https://stats.oecd.org/Index.aspx; Ministry of Human Resource Development, Department of Higher Education, All India Survey on Higher Development (AISHE) Report (various years)

Note: (i) Data for 2010 for Brazil not available
(ii) Data reported as 2018 for China is as of 2015 and for Taiwan is as of 2016 based on NSF data
(iii) Data reported for 2018 for US, UK, Germany, Brazil, Israel, South Korea is based on OECD Statistics (2018)

In 2018, the US had 41,071 S&E PhDs followed by China that had 34,440 S&E PhDs. India's S&E PhDs at 26,566 in 2018 was the third highest among the select economies in the table above. Since 2010, India has seen a near two fold increase in the number of S&E PhDs. India's share of S&E PhDs in total PhDs was 65 percent in 2018, comparable to that in China and Israel and significantly higher than that for Japan and South Korea.

The data for India is based on the PhD numbers reported in the annual reports of the All India Survey of Higher Education (AISHE). The categories considered from the AISHE reports include Science, Engineering & Technology and IT & Computer, Agriculture, Veterinary & Animal Sciences, Social Science, Fisheries Science and Marine Science/ Oceanography. These categories are in line with those used by NSF from the International Standard Classification of Education (ISCED) 2011 to define S&E subject categories.

The NSF includes the following categories when considering S&E PhDs - physical and biological sciences and mathematics and statistics, computer sciences, agricultural sciences, engineering, and social and behavioural sciences.

For all other countries, the data has been taken from the NSF Science & Engineering Indicators, 2020 and OECD Statistics (2018).

6.9.1 | Degrees Awarded in S&E Degree Programmes in India (2018)

Field	Degrees Awarded in S&E				
	PhD	Postgraduate	Undergraduate	M.Phil	Total
Natural Science	10023	230833	1054155	7558	1302569
Agriculture, Fisheries, Marine, Veterinary & Animal Sciences	5186	13840	49121	32	68179
Engineering & Technology	7659	145233	991604	2024	1146520
Medical Science	1606	48246	226234	87	276173
Social Science	3698	275807	180507	3013	463025
Non S&E	12641	786105	3973094	13073	4784913
Grand Total	40813	1500064	6474715	25787	8041379

Source: Ministry of Human Resource Development, Department of Higher Education, All India Survey on Higher Education (AISHE) Report 2018-19 available at http://aishe.nic.in/aishe/reports

Note: Engineering &Technology also includes degrees awarded in IT & Computer

As seen in the previous indicator, and using the NSF definition of S&E, the number of S&E PhDs awarded in India in 2018 stood at 26,566 and accounted for 65 percent of the total PhDs awarded. The S&E PhDs awarded were largely dominated by the natural sciences at 10,023 followed by engineering & technology at 7,659.

S&E postgraduate[6] degrees, excluding the degrees awarded in medical science, accounted for 44 percent of the total number of postgraduate degrees awarded in 2018. The S&E postgraduate degrees were dominated by social science at 2,75,807 followed by natural science at 2,30,833.

The S&E undergraduate degrees, excluding the degrees awarded in medical science, accounted for 35 percent of the total number of undergraduate degrees awarded in 2018. For the undergraduate S&E degrees awarded, degrees awarded in natural science were the highest at 10,54,155 followed by engineering & technology at 9,91,604.

In the computation of S&E PhDs, postgraduate and undergraduate degrees, the degrees awarded in medical science have been excluded here to ensure consistency with the NSF definition of S&E for the purpose of international comparability.

[6] Programme after Graduation and generally having the duration of 2/3 years in General/Professional courses (AISHE)

6.9.2 | Enrolment in S&E Degree Programmes in India (2018)

Field	Enrolment in S&E Degree Programmes				
	PhD	Postgraduate	Undergraduate	M.Phil	Total
Natural Science	44702	587592	4713301	7321	5352916
Agriculture, Fisheries, Marine, Veterinary & Animal Sciences	8112	33458	275037	92	316699
Engineering & Technology	44734	379236	4599515	1209	5024694
Medical Science	7473	159250	1196758	369	1363850
Social Science	16698	715743	905315	6376	1644132
Non S&E	47451	2100007	16906825	15325	19069608
Grand Total	169170	3975286	28596751	30692	32771899

Source: Ministry of Human Resource Development, Department of Higher Education, All India Survey on Higher Education (AISHE) Report 2018-19 available at http://aishe.nic.in/aishe/reports

Note: Engineering & Technology also includes degrees awarded in IT & Computer

The table above reports the data on enrolment in S&E PhD, postgraduate and undergraduate programmes. The number of S&E PhD enrolments, using the NSF definition of S&E, stood at 1,14,246 and accounted for 68 percent of total PhDs enrolled in 2019. The S&E PhDs enrolments are largely dominated by engineering & technology at 44,734 and natural sciences at 44,702.

S&E postgraduate degree enrolments, excluding enrolments in the medical science programme, accounted for 43 percent of the total number of postgraduate enrolments, compared to 37 percent in 2015.[7] Social science had the highest number of enrolments at 7,15,743 followed by natural sciences at 5,87,592 and engineering & technology 3,79,236.

S&E undergraduate enrolments, excluding enrolments in the medical science programme, accounted for 37 percent of the total number of enrolments in undergraduate programmes. Natural science dominates at 47,13,301 followed by engineering & technology at 45,99,515 and social science at 9,05,315.

Here too, in the computation of enrolment in S&E PhDs, postgraduate and undergraduate programmes, the enrolments in the medical science programmes have been excluded to ensure consistency with the NSF definition of S&E for the purpose of international comparability.

[7] CTIER Handbook: Technology and Innovation in India 2019

6.10 | Persons Employed (full-time equivalent) as Researchers by R&D Establishments in India

Name of Establishment	2010			2015			2018		
	Researchers	Total Staff*	Researchers as share of total (%)	Researchers	Total Staff*	Researchers as share of total (%)	Researchers	Total Staff*	Researchers as share of total (%)
A. Institutional Sector									
Major scientific agencies	57331	138179	41.5	54331	135179	40.2	53891	122165	44.1
Central government ministries/ departments	10030	50070	20	10030	50070	20	8790	30429	28.9
State governments	20544	80949	25.4	21450	78172	27.4	16376	48794	33.6
Total institutional sector (A)	87905	269198	32.7	85811	263421	32.6	79057	201388	39.3
B. Higher Education Sector (B)**	22100	22100	-	113074	113074	-	124702	124702	-
C. Industrial Sector									
Public sector including joint sector	10701	16180	66.1	10400	15879	65.5	9291	12035	77.2
Private sector	63971	110984	57.6	64446	111459	57.8	107003	155489	68.8
SIRO ***	8142	22664	35.9	9263	24386	38	21765	59355	36.7
Private + SIRO	72113	133648	54	73709	135845	54.3	128768	214844	59.9
Total industrial sector (C)	82814	149828	55.3	84109	151724	55.4	138059	226879	60.9
Total (A+B+C)	192819	441126	43.7	282994	528219	53.6	341818	552969	61.8

*Total Staff includes manpower engaged in R&D, auxiliary and administrative activities
**Data on manpower engaged in auxiliary and administrative activities is unavailable for the higher education sector.
***Scientific and Industrial Research Organization

Source: Department of Science and Technology (DST), Government of India, S&T Indicators Tables, Research and Development Statistics 2019-20 available at https://dst.gov.in/sites/default/files/S%26T%20Indicators%20Tables%2C%202019-20.pdf; Research and Development Statistics 2017-18; Research and Development Statistics 2011-12; Centre for Technology, Innovation and Economic Research (CTIER)

The table above considers manpower at R&D establishments in India, and includes manpower engaged in R&D, auxiliary and administrative activities as reported by the Department of Science & Technology (DST). The number of employees engaged in R&D activities as a share of total manpower has increased to 62 percent in 2018 from 54 percent in 2015. This appears to have been driven significantly by an increase in the number of employees engaged in R&D activities in the private sector and in scientific and industrial research organisations (SIROs). The private sector and SIROs saw a combined increase in the number of researchers by 75 percent in 2018 compared to 2015. The number of researchers in the higher education sector increased by around 10 percent in 2018 compared to 2015, while the major scientific agencies, central government ministries/departments, state governments and public sector enterprises saw a decline in the number of researchers in 2018 compared to 2015.

The total number of full-time equivalent researchers in India was 3,41,818 in 2018 and as seen in Indicator 6.8, the number of full-time researchers per million population remains low compared to many countries. The data on manpower engaged in auxiliary and administrative activities is unavailable for the higher education sector. The data reported for employees engaged in R&D activities in 2010 and 2015 had been captured in the CTIER Handbook: Technology and Innovation in India 2019 based on DST data available at the time.

6.11 | Country-wise Comparisons by Share of Publications, Impact, Share of Industry-Academia Collaborations and Share of International Collaborations in Total Publications (2015 - 2019)

Country		Global Rank	Share in Global Publication Output (%)	Category Normalized Citation Impact	Share of Industry-Academia Collaborations (%)	Share of International Collaborations (%)
Select Advanced Economies	USA	1	26	1.3	3.4	32.5
	UK	3	7.7	1.4	3.8	51.6
	Germany	5	6.2	1.3	4.9	51.9
	Japan	6	4.4	0.9	4.5	29.5
Select Emerging Economies	Brazil	14	2.3	0.9	1.5	36.8
	China	2	16.6	1.1	1.7	24.1
	India	10	4	0.8	0.9	21.9
	Israel	29	0.8	1.4	3	49.2
	South Korea	13	2.8	1	3.7	29

Source: InCites (based on data from Web of Science), data downloaded from the platform on 9 October 2020; Centre for Technology, Innovation and Economic Research (CTIER)

Note: Data is based on cumulative publications by each country (2015-2019)

With respect to global publication output, India ranked tenth with 5,54,818 publications or 4 percent of the cumulative global publication for the years 2015 to 2019.[8] India's publication output during the period 2015 - 2019 was higher than the publication output of other emerging economies like Brazil, Israel and South Korea.

The impact of these global publications is measured using the Category Normalized Citation Impact (CNCI) devised by the data analytics software 'InCites'. CNCI gauges the quality of publications by assigning a higher weightage to highly cited papers. India has the lowest CNCI score among the select countries in the table above.

In terms of industry-academia (I-A) collaborations, India has the lowest share of I-A collaborations among the select economies. India's share of I-A collaborations is 0.9 percent of its total publications. Germany has the highest share of I-A collaborations at 4.9 percent followed by Japan at 4.4 percent. The I-A figures are calculated by dividing publications that have at least one industry co-author by the total number of publications. Within the sample of select countries, India also has the lowest share of international collaborations at 21.9 percent.

If one includes publication output between 2015 and 2019 that appears in journals that are part of the Emerging Sources Citation Index (ESCI)[9], India's rank in global publication output is seen to improve significantly to sixth position. The country-wise comparisons of publication output when ESCI journals are included can be found in Appendix (A.6).

[8] Values are based on cumulative publication output from 2015-19. Five year cumulative values have been considered to account for the lag between the year a paper is published and when it starts being cited.

[9] Journals included in the Emerging Sources Citation Index (ESCI) cover all disciplines and range from international and broad scope publications to those that provide deeper regional and specialty area coverage. These journals are part of the Web of Science Core Collection™, and have been selected by experts from Clarivate for their editorial rigor and best practice at a journal level.

6.12 | Country-wise Comparison by Share of Publications, Impact, Share of Industry-Academia Collaborations and Share of International Collaborations by Top Subject Categories (2015 - 2019)

Rank	Sector	Output Indicators	Global Average	Select Advanced Economies				Select Emerging Economies				
				USA	UK	Germany	Japan	Brazil	China	India	Israel	South Korea
1.	Electrical & Electronic Engineering	Share in Global Publication Output (%)	-	16.8	4.6	4.6	5.3	1.7	26.9	8.7	0.6	3.9
		Category Normalized Citation Impact	1	1.6	1.5	1.2	0.8	0.8	1	0.7	1.4	1
		Industry-Academia Collaborations (%)	4.1	8.6	5.9	9.6	8.8	2.2	3.4	1.1	7.7	8.5
		International Collaborations (%)	20	38.8	61.3	42.6	23.7	33	23	11.6	45.3	24.3
2.	Multidisciplinary Materials Science	Share in Global Publication Output (%)	-	16.8	4.4	6.5	5.4	1.5	35.4	6.8	0.6	6.1
		Category Normalized Citation Impact	1	1.4	1.2	1.1	0.9	0.6	1.2	0.9	1.2	1
		Industry-Academia Collaborations (%)	2.3	3.9	4.1	3.7	5.5	1.2	1.7	0.4	2.3	5.2
		International Collaborations (%)	26	51.8	69.4	61.7	42.5	42.1	24.9	23.8	59.1	32.8
3.	Multidisciplinary Chemistry	Share in Global Publication Output (%)	-	28.9	4.4	5.9	5	1.3	26.2	5.5	0.6	5.2
		Category Normalized Citation Impact	1	1	1.5	1.3	1	0.8	1.5	0.7	1.1	0.9
		Industry-Academia Collaborations (%)	1.6	2.4	5.5	3.6	3.4	1.1	1	0.4	1.5	2.5
		International Collaborations (%)	20.9	26.9	61.2	55.8	33.3	36.9	24.4	25.3	53.9	29.1
4.	Oncology	Share in Global Publication Output (%)	-	33.9	6.6	7	7.3	1.2	18.2	1.9	0.9	3.4
		Category Normalized Citation Impact	1	1.6	2.1	1.7	1.3	1.8	0.9	0.7	2.5	2.2
		Industry-Academia Collaborations (%)	3	6.8	11.7	12.1	6.7	7.8	1.1	2.3	11	10.4
		International Collaborations (%)	18	31.8	57	50.4	19.4	44.2	16.9	24.3	61	27.5
5.	Applied Physics	Share in Global Publication Output (%)	-	17.6	4.5	7.6	8	1.1	27.7	6.6	0.7	5.9
		Category Normalized Citation Impact	1	1.3	1.2	1.1	0.9	0.7	1.3	0.8	1	0.9
		Industry-Academia Collaborations (%)	2.7	4.6	3.9	4	7	1.9	1.6	0.7	3.1	5.9
		International Collaborations (%)	24.9	47.9	68.6	59.4	32.5	50.2	25.7	21.6	56.8	30.6

Rank	Sector	Output Indicators	Global Average	Select Advanced Economies				Select Emerging Economies				
				USA	UK	Germany	Japan	Brazil	China	India	Israel	South Korea
6.	Biochemistry & Molecular Biology	Share in Global Publication Output (%)	-	30.1	6.7	7.2	6	2.6	18	4.2	1	3.6
		Category Normalized Citation Impact	1	1.3	1.5	1.3	0.9	0.8	1	0.8	1.4	0.8
		Industry-Academia Collaborations (%)	1.4	2.4	3.9	3.3	2.9	0.7	0.5	0.5	1.7	1
		International Collaborations (%)	24.9	38.4	64.3	58.6	31.7	39	25	27.6	55.9	29.6
7.	Physical Chemistry	Share in Global Publication Output (%)	-	18.9	4.9	7.3	6	1.9	33.1	6.5	0.8	4.7
		Category Normalized Citation Impact	1	1.2	1	0.9	0.9	0.6	1.4	0.7	1	1.2
		Industry-Academia Collaborations (%)	2	3.3	3.8	3.3	2.9	1.1	1.5	0.5	1.3	4.3
		International Collaborations (%)	28.6	50	68.6	63	31.7	42.8	27.1	27.3	57.9	38.8
8.	Environmental Sciences	Share in Global Publication Output (%)	-	20.6	6.6	5.7	6	3	26.1	4.5	0.5	2.9
		Category Normalized Citation Impact	1	1.2	1.4	1.3	0.9	0.9	1.2	0.9	1.1	1
		Industry-Academia Collaborations (%)	1.1	2.3	2.4	2.5	2.9	1	1	0.3	0.7	1.8
		International Collaborations (%)	29.4	49.8	71.1	66.6	31.7	42.5	30	27.2	59.4	38.7
9.	Neurosciences	Share in Global Publication Output (%)	-	36.7	9.6	9.1	5.5	2.5	9.1	1.7	1.2	2.3
		Category Normalized Citation Impact	1	1.3	1.5	1.3	0.8	0.9	1	0.7	1.1	1
		Industry-Academia Collaborations (%)	1.7	2.8	4.9	5.1	3.8	0.8	0.7	1	2.6	1.6
		International Collaborations (%)	25.3	35	63.4	57.6	26.5	43.3	31.9	22.9	53.1	27.7
10.	Computer Science, Theory & Methods	Share in Global Publication Output (%)	-	18.9	5.5	5.8	4.3	1.8	22.1	9.5	1	2.4
		Category Normalized Citation Impact	1	1.8	1.4	1.2	0.7	0.7	1.1	0.6	1.3	1
		Industry-Academia Collaborations (%)	3.6	10.1	5.8	6	5.6	1.8	3.6	1.2	9.3	5.3
		International Collaborations (%)	20.5	37	57.6	43	26.3	34.5	21.7	11.8	54.8	27.8

Source: InCites (based on data from Web of Science), data downloaded from the platform on 9 October 2020; Centre for Technology, Innovation and Economic Research (CTIER)

Note: Data is based on cumulative publications by each country (2015 - 2019)

In the table, we have considered the top 10 subject categories by cumulative global publication output between 2015 and 2019. By subject category, electrical & electronic engineering has the highest number of global publications. India with 8.7 percent of the total global output in this category continues[10] to be the third largest contributor to electrical & electronic engineering publications after China and USA. For other top subject categories like multidisciplinary materials science and computer science, theory & methods, India is the third largest contributor ranking above advanced economies like the UK, Germany and Japan. As seen in indicator 6.11, India's share of publications in total global publications is 4 percent. In the top 10 subject categories apart from oncology and neurosciences, India's share of publications is greater than 4 percent. However the impact of India's publications in each of these sectors as measured by the CNCI score is below the global average for each of the top 10 subject categories. India's CNCI score for the top subject categories ranges between 0.6 to 0.9.

India's I-A collaborations as a share of its total publication output as mentioned in indicator 6.11 was 0.9 percent. For top subject categories like electrical & electronic engineering, computer science, theory & methods, neurosciences and oncology, India's share of I-A collaborations was above 0.9 percent. When it comes to the share of international collaborations, India's share of international collaborations was low in subjects like electrical & electronic engineering and computer science, theory & methods, and well below its average share of international collaborations of 21.9 percent as captured in indicator 6.11 for its total publication output.

[10] CTIER Handbook: Technology and Innovation in India 2019

6.12.1 | India's Top Areas of Cumulative Publications (2015 - 2019) - Impact, Industry-Academia Collaborations, International Collaborations and Comparisons with Global Averages

Rank	Top areas of Indian publication	Indian publications	Indian Share of World publications (%)	Category Normalized Citation Impact		Industry-Academia Collaborations (%)		International Collaborations (%)	
				World	India	World	India	World	India
1	Electrical & Electronic Engineering	88403	8.7	1	0.7	4.1	1.1	20	11.6
2	Multidisciplinary Materials Science	44102	6.8	1	0.9	2.3	0.4	26	23.9
3	Computer Science, Theory & Methods	32849	9.5	1	0.6	3.6	1.2	20.5	11.8
4	Telecommunications	32456	11.4	1	0.8	4.5	0.9	22.5	10.3
5	Applied Physics	30038	6.6	1	0.8	2.6	0.7	24.9	21.6
6	Multidisciplinary Chemistry	28241	5.5	1	0.7	1.6	0.4	20.9	25.3
7	Computer Science, Artificial Intelligence	24776	8.9	1	0.5	3.2	1	21	12.6
8	Physical Chemistry	23208	6.5	1	0.7	2	0.5	28.5	27.3
9	Energy & Fuels	19095	6.3	1	0.8	3.4	0.8	22.2	17.8
10	Computer Science, Information Systems	18981	6.8	1	0.8	3.7	1.4	23.3	15.9

Source: InCites (based on data from Web of Science), data downloaded from the platform on 9 October 2020; Centre for Technology, Innovation and Economic Research (CTIER)

Note: Cumulative publication output for India during the period 2015 to 2019 was 554818.

India's total cumulative publication output during the period 2015 to 2019 was 5,54,818. By subject category electrical & electronic engineering has the highest share with 88,403 publications or 16 percent of India's total publication output during the period under consideration. This is followed by multidisciplinary materials science with 44,102 publications or 8 percent of India's total publication output. India's top areas of publication output has six subject categories in common with the top 10 global areas of publication output.

Both the CNCI score and the share of I-A collaborations for each of India's top subject categories by publication output are below the respective global averages for these categories. The share of international collaborations for the top subject categories for India, apart from multidisciplinary chemistry, are also below the global averages for these categories.

6.13 | Ranking of Institutions in India by Number of Publications (2015 - 2019)

Rank	Name	Number of Publications	Category Normalized Citation Impact	Industry Collaborations (%)	International Collaborations (%)
1	Council of Scientific & Industrial Research (CSIR) - India	32665	0.9	0.4	20.3
2	Indian Council of Agricultural Research (ICAR)	15105	0.6	0.1	12.8
3	Indian Institute of Science (IISc) - Bangalore	12754	1	2.3	30.3
4	Department of Science & Technology (India)	12073	1	0.4	32.6
5	Indian Institute of Technology (IIT) - Kharagpur	11514	0.9	0.9	21.7
6	Indian Institute of Technology (IIT) - Bombay	11108	1	1.6	30
7	Indian Institute of Technology (IIT) - Madras	10753	1	1.4	28.1
8	Indian Institute of Technology (IIT) - Delhi	10357	0.9	1.4	21.6
9	All India Institute of Medical Sciences (AIIMS) New Delhi	9610	1.1	0.8	16.9
10	Vellore Institute of Technology	8738	1	0.5	22
11	University of Delhi	8449	1.1	0.4	29.2
12	Bhabha Atomic Research Center (BARC)	8301	0.9	0.3	26
13	Indian Institute of Technology (IIT) - Roorkee	7967	1	0.4	20.5
14	Indian Institute of Technology (IIT) - Kanpur	7535	0.9	1.7	25.6
15	Jadavpur University	7324	0.8	0.3	18.7

Highest Rank   Lowest Rank

Source: InCites (based on data from Web of Science), data downloaded from the platform on 9 October 2020; Centre for Technology, Innovation and Economic Research (CTIER)

Note: Data is based on cumulative publication by each institution (2015 - 2019)

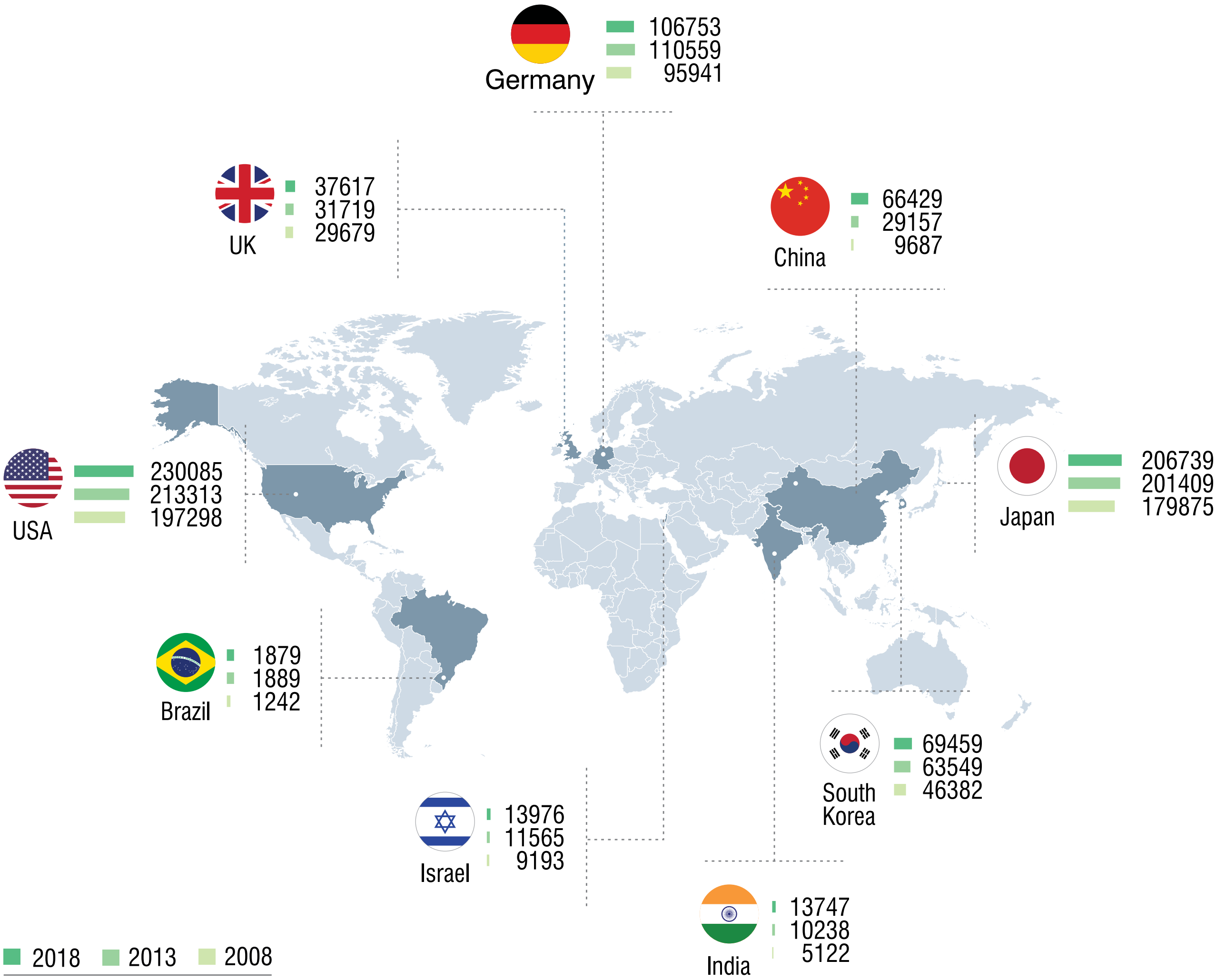
The table above ranks the top 15 Indian institutions based on cumulative publication output for the years 2015 to 2019. The Council of Scientific & Industrial Research (CSIR) is ranked first in terms of publication output, followed by the Indian Council of Agricultural Research (ICAR). The Vellore Institute of Technology is the only private institution that features in this list of the top 15 institutions.

In terms of impact as measured by the CNCI score, AIIMS-Delhi and University of Delhi are the top institutions with a CNCI score of 1.1.

With respect to I-A collaborations as a share of publications, the Indian Institute of Science (IISc) Bangalore has the highest share at 2.3 percent, followed by IIT Kanpur and IIT Bombay with 1.7 percent and 1.6 percent respectively.

In terms of international collaborations as a share of publications, the Department of Science and Technology has the highest share at 32.6 percent, followed by the Indian Institute of Science (IISc) Bangalore and IIT-Bombay with 30.3 percent and 30 percent respectively.

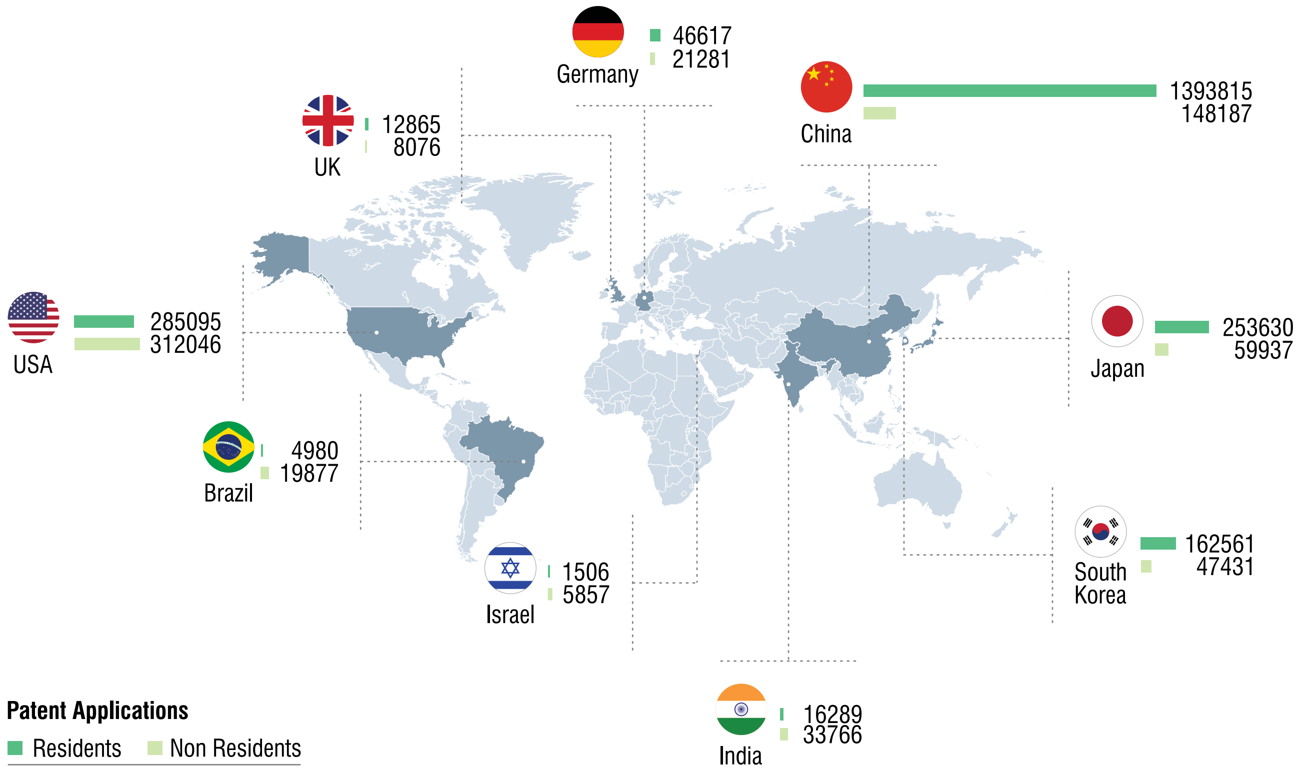
6.14 | Country-wise Comparisons for Patent Applications Filed Abroad



Source: World Intellectual Property Organization (WIPO) IP Statistics Data Center, available at https://www3.wipo.int/ipstats/index.htm?tab=patent

India's patent applications filed abroad increased to 13,747 in 2018 from 5,122 in 2008. China on the other hand saw a jump in patent applications filed abroad to 66,429 in 2018 from 29,157 in 2013, and recorded the strongest growth in patents filed abroad amongst the select countries. In absolute numbers, USA and Japan continue to dominate the number of patent applications filed abroad, followed by Germany. China appears to be closing in on South Korea, while India's numbers are comparable to those of Israel. The UK saw its growth in patent applications filed abroad for the period 2013 to 2018 pick up relative to the preceding five year period. The growth in patent applications filed abroad was subdued for Japan and negative for Germany in the period 2013 to 2018 compared to the growth observed for the period 2008 to 2013.

6.15 | Country-wise Comparisons for Patent Applications with Respective Domestic Patent Offices (2018)

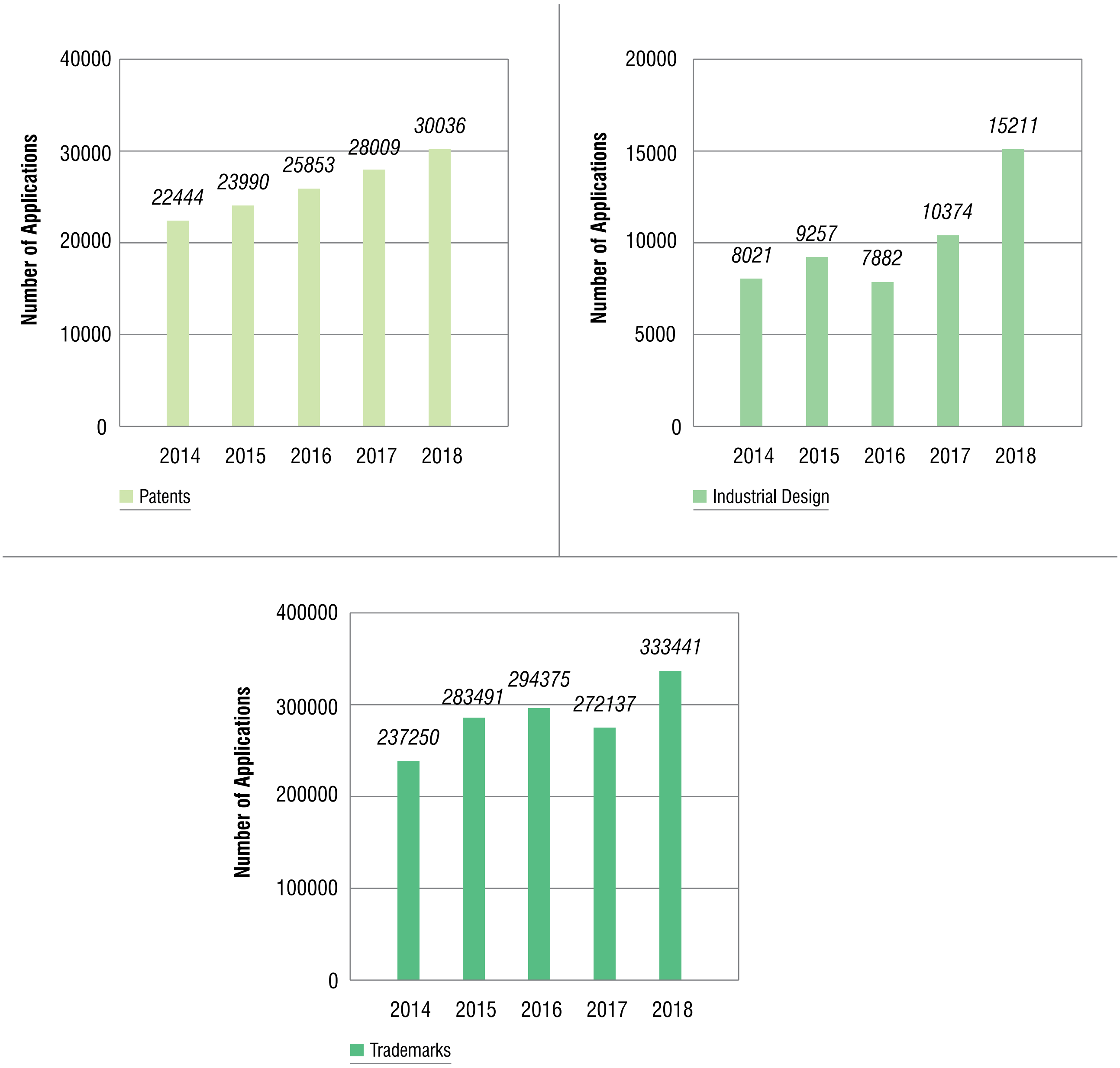


Source: World Intellectual Property Organization (WIPO) IP Statistics Data Center, available at https://www3.wipo.int/ipstats/index.htm?tab=patent

Note: (i) Resident includes domestic filings
(ii) Non-resident includes filings coming in from overseas

Non-resident patent applications with the Indian Patent Office were higher than the resident patent applications in 2018. The number of non-resident patent applications was close to 34,000, while the number of resident patent applications was over 16,000. For a majority of the select countries, resident patent applications were higher than non-resident patent applications in 2018. China's resident patent applications continued to significantly outnumber the non-resident patent applications in 2018.

6.16 | Applications for Patents, Industrial Design and Trademarks from India (2014 - 2018)

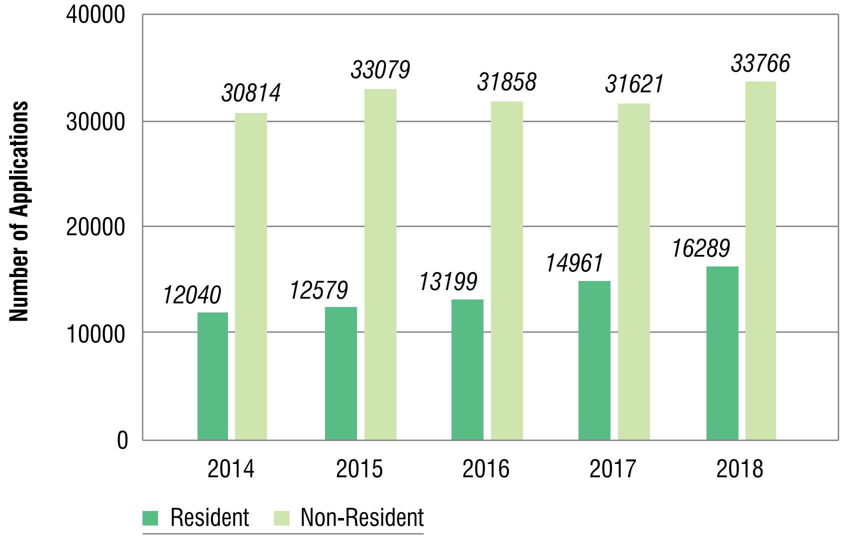


Source: World Intellectual Property Organization (WIPO) IP Statistics Data Center, available at https://www3.wipo.int/ipstats/index.htm?tab=patent

Note: Intellectual Property filings include resident and abroad

The patent applications in the figure above include filings by residents with the Indian Patent Office and filings with patent offices abroad. There has been a steady increase in India's patent applications between 2014 to 2018. The applications for industrial design has seen a sharp increase in recent years after having experienced a drop in 2016. The applications for trademarks saw a jump in 2018 after having seen a drop in 2017.

6.17 | Patent Applications with Indian Patent Office by Residents and Non-Residents (2014 - 2018)

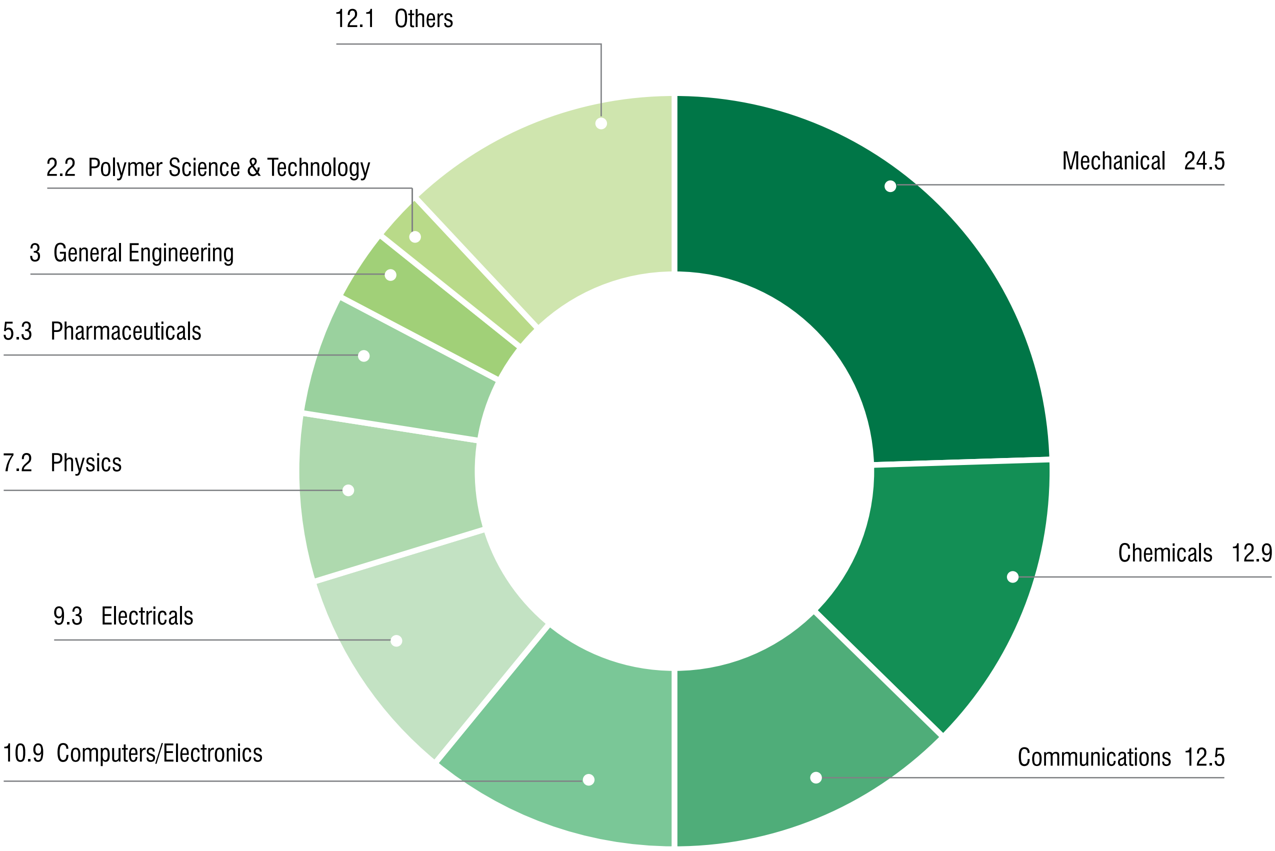


Source: World Intellectual Property Organization (WIPO) IP Statistics Data Center, available at https://www3.wipo.int/ipstats/index.htm?tab=patent

Note: (i) Resident includes domestic filings
(ii) Non-resident includes filings coming in from overseas

The number of non-resident patent applications with the Indian Patent Office has consistently been higher than the number of resident patent applications. Non-resident patent applications picked up in 2018 to 33,766 after having slowed in the previous two years. Resident patent applications have seen a steady increase between 2014 and 2018. The share of resident patent applications in total patent applications with the Indian Patent Office has increased to 33 percent in 2018 from 28 percent in 2014.

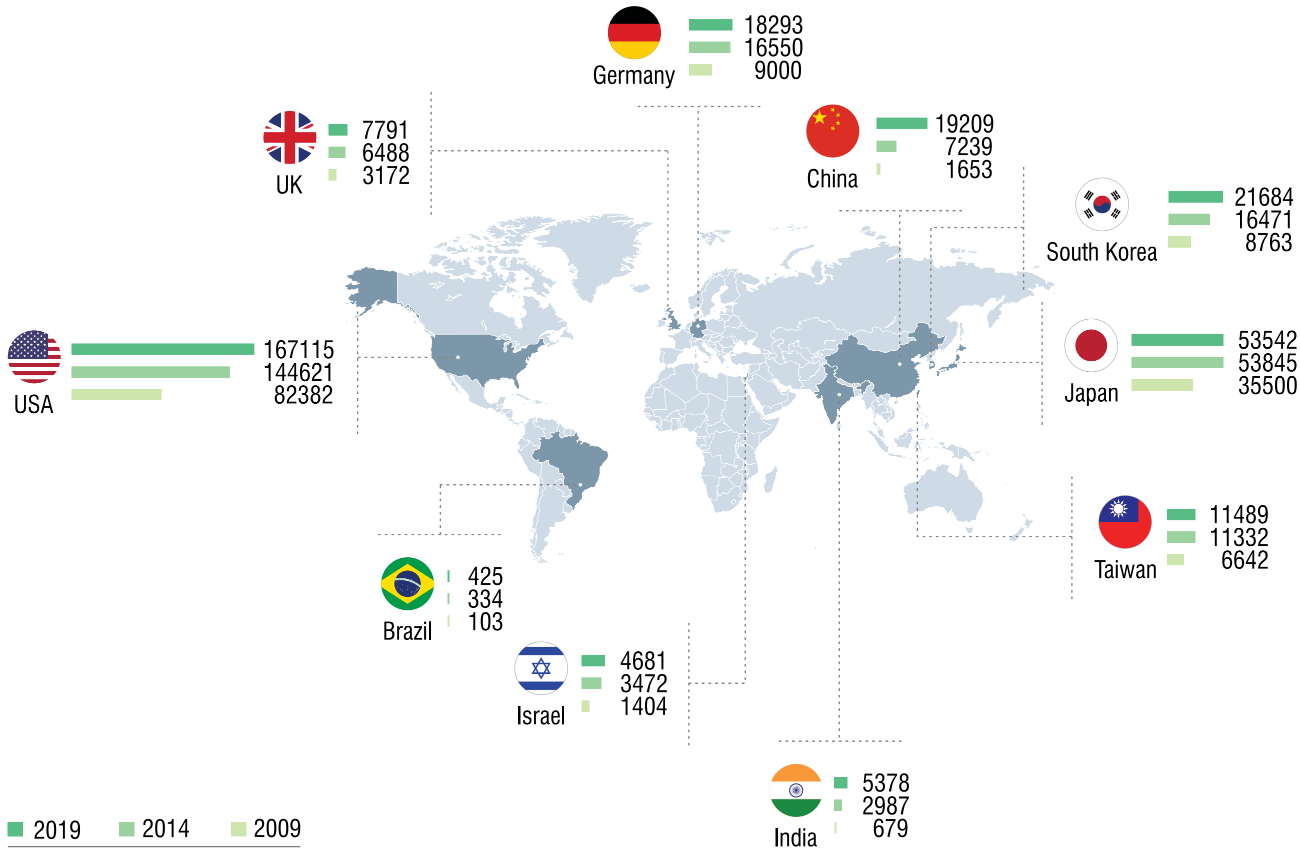
6.18 | Applications with Indian Patent Office by Sector (2019)



Source: The Office of the Controller General of Patents, Designs & Trademarks, Government of India, Annual Report 2018-19; Centre for Technology, Innovation and Economic Research (CTIER)

In 2019, patent applications by field of technology were largely concentrated in sectors such as Mechanical, Chemical, Communication and Computer/ Electronics that accounted for over 60 percent of the total patent applications filed in India.

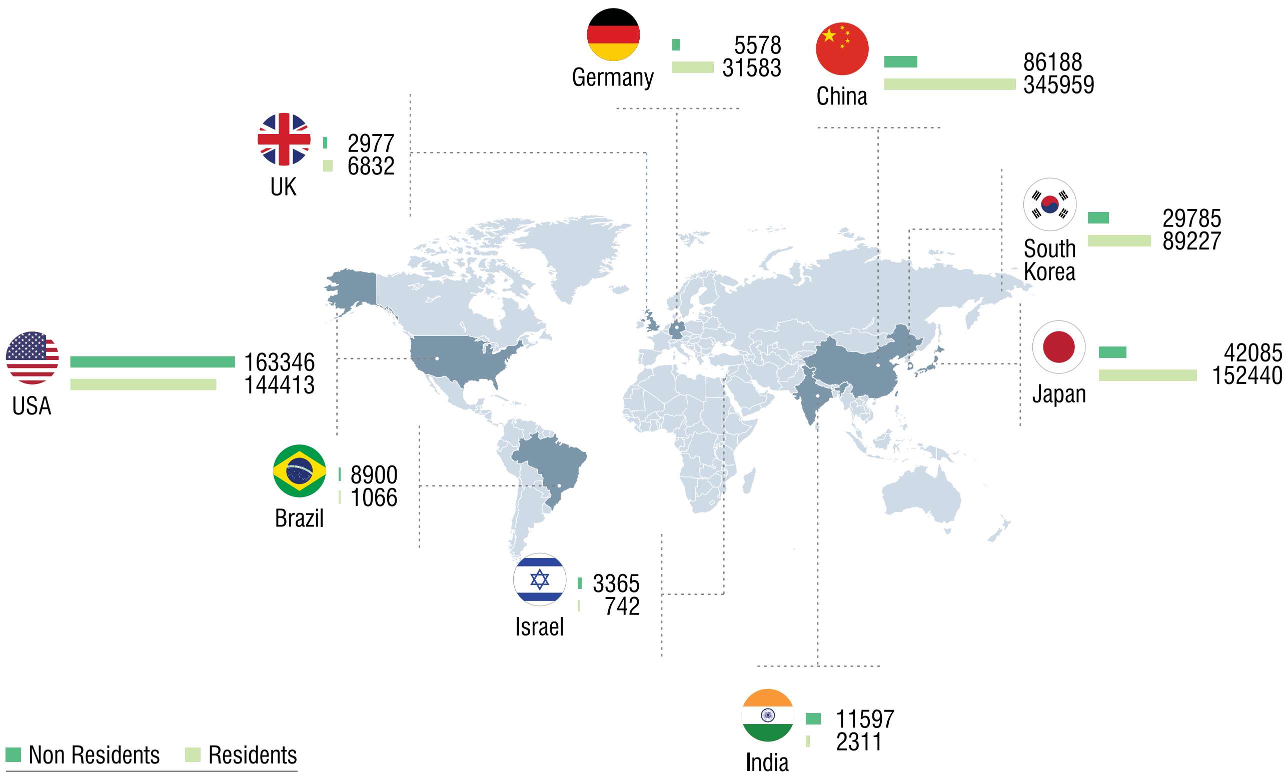
6.19 | Patents Granted by the United States Patent and Trademark Office (USPTO) to Select Countries



Source: USPTO, Patent Counts By Country, State, and Year - Utility Patents December (2019) (https://www.uspto.gov/web/offices/ac/ido/oeip/taf/all_tech.htm#PartA1_1a); Centre for Technology, Innovation and Economic Research (CTIER)

Patents granted by the USPTO to applicants from India increased to 5,378 in 2019 from 679 in 2009. Multinational corporations (MNCs) based in India have continued to be a major driver of the increase in patents granted to India and accounted for over 70 percent of the total patents that were granted to India in 2019. The list of the top Indian and top MNC patentees present in India can be found in Indicator 8.10. Data on the number of patents granted abroad for our sample of countries can be found in Appendix (Table A.7).

6.20 | Country-wise Comparisons for Patents Granted by Respective Domestic Patent Offices (2018)

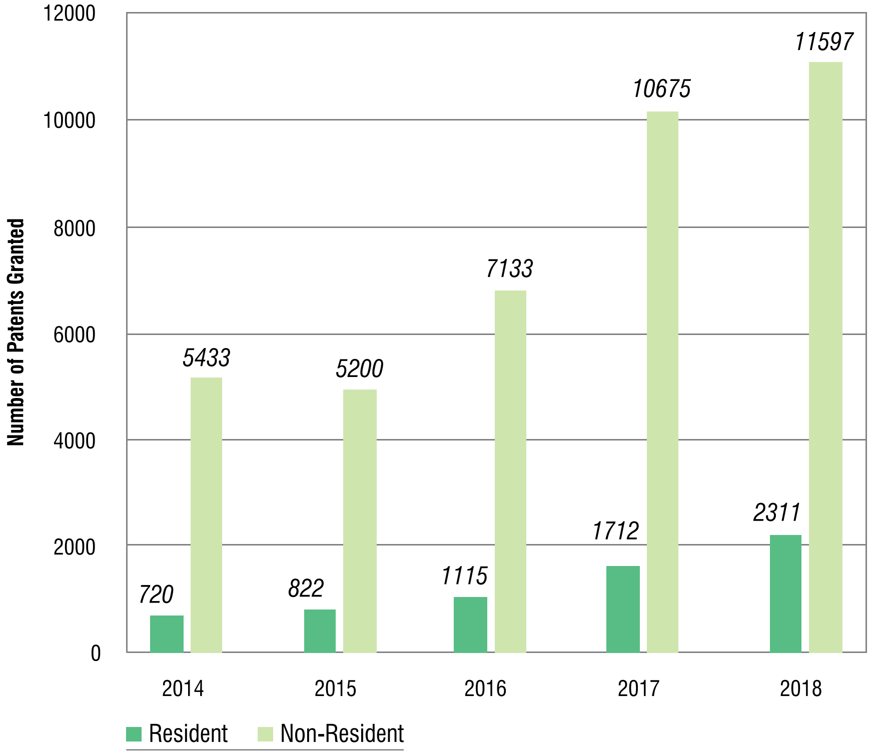


Source: World Intellectual Property Organization (WIPO) IP Statistics Data Center, available at https://www3.wipo.int/ipstats/index.htm?tab=patent

Note: (i) Resident includes domestic filings
(ii) Non-resident includes filings coming in from overseas

The number of patents granted by the Indian Patent Office to resident applicants was 2,311 in 2018, while the number granted to non-resident applicants was 11,597. In a majority of the countries in our sample, the number of patents granted by their respective patent offices was higher for residents compared to non-resident applicants. In Germany, the number of residents who were granted patents was six times the number of non-residents, while in China and Japan this was around four times.

6.21 | Patents Granted by the Indian Patent Office to Residents and Non-Residents (2014 - 2018)

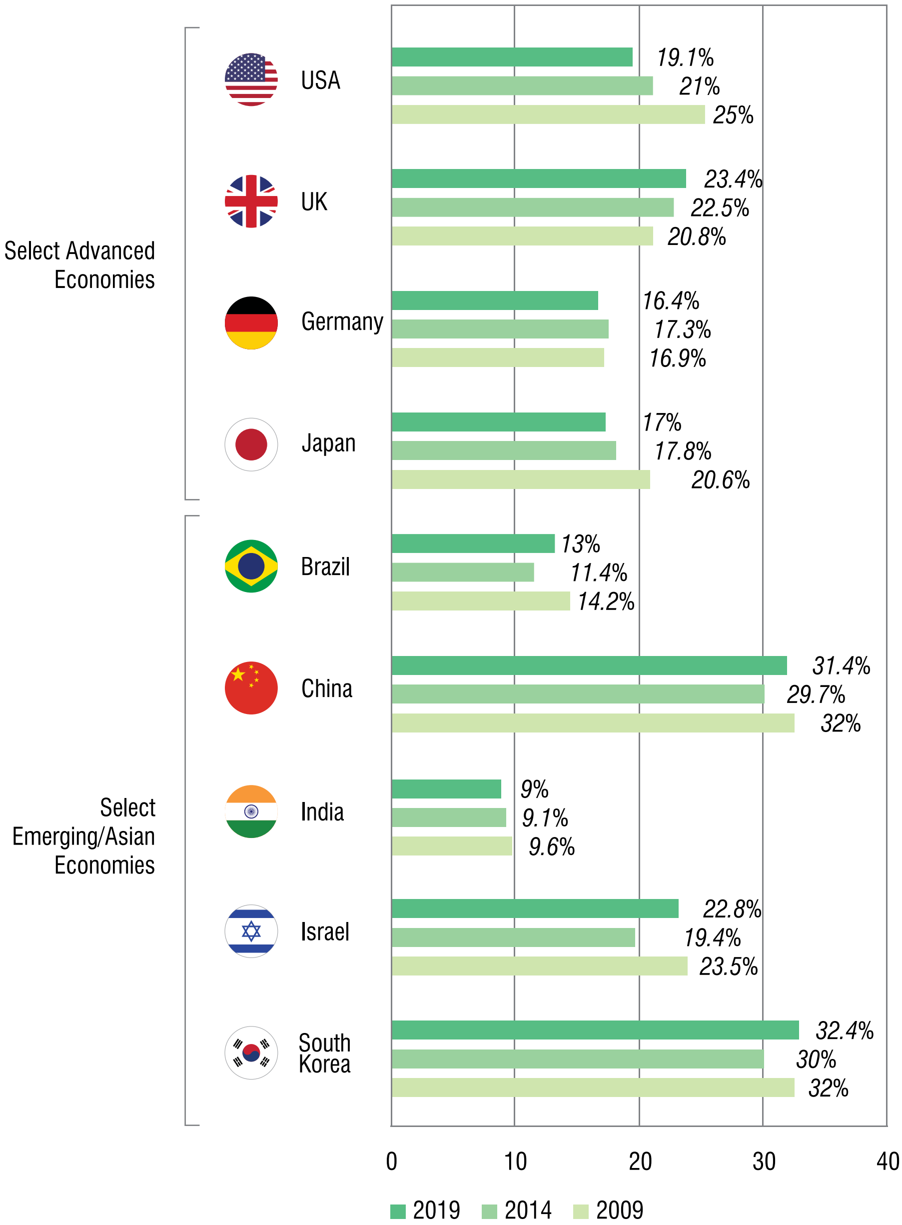


Source: World Intellectual Property Organization (WIPO) IP Statistics Data Center, available at https://www3.wipo.int/ipstats/index.htm?tab=patent

Note: (i) Resident includes domestic filings
(ii) Non-resident includes filings coming in from overseas

The number of patents granted by the Indian Patent Office to non-residents was substantially higher than the patents granted to residents in 2018. The gap between the patents granted to non-residents and the patents granted to residents has been steadily widening in recent years. Nevertheless, while the yearly growth rate in the number of patents granted to residents has been strong since 2016, the yearly growth rate in the number of patents granted to non-residents was strong in 2016 and 2017 slowed in 2018.

6.22 | High Technology Exports as Share of Manufactured Exports for Select Countries



Source: World Development Indicators (various years), Indicators, available at http://data.worldbank.org/; Centre for Technology, Innovation and Economic Research (CTIER)

India's share of high technology exports in manufactured exports was 9 percent in 2019 compared to 9.6 percent in 2009. In comparison to the other advanced and emerging economies, India continues to have the lowest share of high technology exports in manufactured exports. For the advanced economies, the share reported for the UK was above 20 percent in 2019, while for the emerging economies like China and South Korea, the share of high technology exports in manufactured exports was over 30 percent for in 2019.

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Chapter 7

Regional Innovation Systems

This chapter is intended to provide an overview of the innovation systems of India's states. The work on regional innovation systems has become increasingly prominent, and focuses on the innovative capacity of firms and the institutions around them. The reader should be aware that these are however, still newly developing ecosystems and data availability and reliability will evolve over time to allow for better analysis.

Number	Indicator
7.1	Select Policies Introduced by States
7.2	State-wise Distribution of Industrial R&D Centres
7.2.1	State-wise Distribution of Select Higher Technology and Knowledge Intensive R&D Centres
7.3	Foreign Direct Investment into India for Select States (2017- 18 and 2018- 19)
7.4	Funding for Startups in Top Indian States (2019)
7.4.1	State-wise Distribution of Startups (and New Companies) (2019)
7.5	State-wise Number of Incubation Centres
7.6	State-wise Gross Enrolment Ratio in Higher Education (2018- 19)
7.7	State-wise Pupil Teacher Ratio in Higher Education (2018- 19)
7.8	State-wise Number of Institutes in Top 100 under the National Institute Rankings Framework (2019)
7.9	State-wise Number of Institutes of National Importance (2019)
7.10	Patent Applications Filed from Select States with Indian Patent Office

Chapter 07

Regional Innovation Systems

7.1 | Select Policies Introduced by States

State	Biotech Policy	Industrial Policy	IT, ITeS, ICT, Electronics, ESDM Policy	MSME Policy	Start-Up Policy
Andhra Pradesh	2015-20	2015-20	IT (2014-2020), Electronics (2014-2020)	2015-20	2014-20
Arunachal Pradesh	-	2008	-	-	-
Assam	2018-22	2019	IT and Electronics (2017)	-	2017
Bihar	-	2016	ICT (2011)	-	2017
Chattisgarh*	-	2019-24	Electronics, IT and ITeS (2014-19)	-	2016
Delhi	-	2010-21	-	-	2019
Goa	-	2014	IT (2018)	-	2017
Gujarat	2016-21	2015	IT (2016-21)	-	2016-21
Haryana	-	2015	IT& ESDM (2017), ICT (2017)	2019	2017
Himachal Pradesh	2014	2019	IT, ITeS & ESDM (2019)	-	2016
Jammu and Kashmir**	-	2017	-	-	-
Jharkhand	-	2016	ESDM (2016), IT & ITeS (2016)	-	2016-21
Karnataka	2017-22	2014-19	Electronics (2011), ICT (2011)	-	2015-20
Kerala	2003	2018	IT (2017)	-	2014
Madhya Pradesh	2003	2018	IT, ITeS & ESDM (2016)	-	2016
Maharashtra	2001	2019	Electronics (2016), IT & ITeS (2015)	-	2018
Manipur	-	2017	IT (2015)	-	2016
Meghalaya	-	2016	-	-	2018 (Draft)
Mizoram	-	2012	-	-	2019
Nagaland	-	2000	IT (2011)	-	2019
Odisha	2018	2016	ICT (2014)	2016	2018
Punjab	-	2018	-	-	2018
Rajasthan	2015	2019	IT & ITeS (2015)	2015	2015
Sikkim	-	-	-	-	-
Tamil Nadu	2014	2014	ICT (2018)	2016-17	2018-23
Telangana	2015-20	2016	Electronics (2016), ICT (2016)	-	2016
Tripura	-	2017	IT & ITeS (2017)	-	2019
Uttar Pradesh	2014	2017	IT (2017-22), Electronics (2017)	2017	2017-22
Uttarakhand	2018-23	2015	IT (2018), ICT and Electronics (2016-25)	2015	2018
West Bengal	-	2013	IT and Electronics (2018)	2013-18	2016-21

*Year of the Biotechnology policy for Chattisgarh could not be verified
**The data reported is for the state of Jammu and Kashmir which was reorganised into the Union territory of Ladakh and Union territory of Jammu and Kashmir from October 2019

Source: Startup India Hub, available at: https://www.startupindia.gov.in/; Invest India, available at: https://www.investindia.gov.in/; Various State Government Websites; Centre for Technology, Innovation and Economic Research (CTIER)

As seen in the table above, most states have an industrial policy, an IT policy and a startup policy. Around 6 states have also introduced separate electronics policies, while in some states the electronics policy has been combined with the IT policy.

With respect to renewable energy policies, several states have introduced a solar policy. Over the past few years, around 7 states have also either introduced or are working on an

Renewable Energy Policy	Automobile & Auto-components	Electric Vehicle Policy	Aerospace & Defence
Solar (2018), Wind (2015), & Wind-Solar hybrid power (2018)	2015-20	-	2015-20
-	-	-	-
Solar (2017), small Hydro (2007)	-	-	-
Solar (2017), Biomass & Bagasse (2017), small Hydro (2017)	-	-	-
Solar (2017)	2012	-	-
Solar (2016)	-	2018-23	-
Solar (2017)	-	-	-
Reuse of treated waste water (2017), Hydel Policy (2016), Solar (2019), Waste to Energy (2016), Wind Power (2016)	-	-	2016
Solar (2016)	-	-	-
Hydro (2018), Solar (2016)	-	-	-
Solar (2013), small Hydro (2017)	-	-	-
Solar (2015)	2016	-	-
Solar (2014), Wind (2014), small Hydro (2014), Biomass (2014)	-	2017	2013-2023
Solar (2013), small Hydro (2012)	-	2018 (Draft)	-
Solar (2012), Wind (2013), Biomass (2011), small Hydro (2011)	-	2019 (Draft)	2014
Solar (2015), Waste to Energy (2015), Bagasse (2015), Wind (2015), Biomass (2015)	-	2018	2018
Solar (2014)	-	-	-
-	-	-	-
Solar (2017)	-	-	-
-	-	-	-
Solar (2016), Wind (2016), Small Hydro (2016), Biomass (2016), Waste to Energy (2016)	-	-	2018
Solar (2012), Hydel (2012), Biomass (2012), Wind (2012), Waste to Energy (2012)	-	-	-
Solar (2019), Wind and Hybrid (2019), Biomass (2010)	-	-	-
-	-	-	-
Solar (2019)	2014	2019	2019
Solar (2015)	-	-	-
-	-	-	-
Solar (2017), BioEnergy (2018)	-	2019	2018
Pirul and Other Biomass (2018), Solar (2013)	-	-	-
Solar (2012), Wind (2012), Biomass (2012), Waste to Energy (2012), Mini and small hydro (2012)	-	-	-

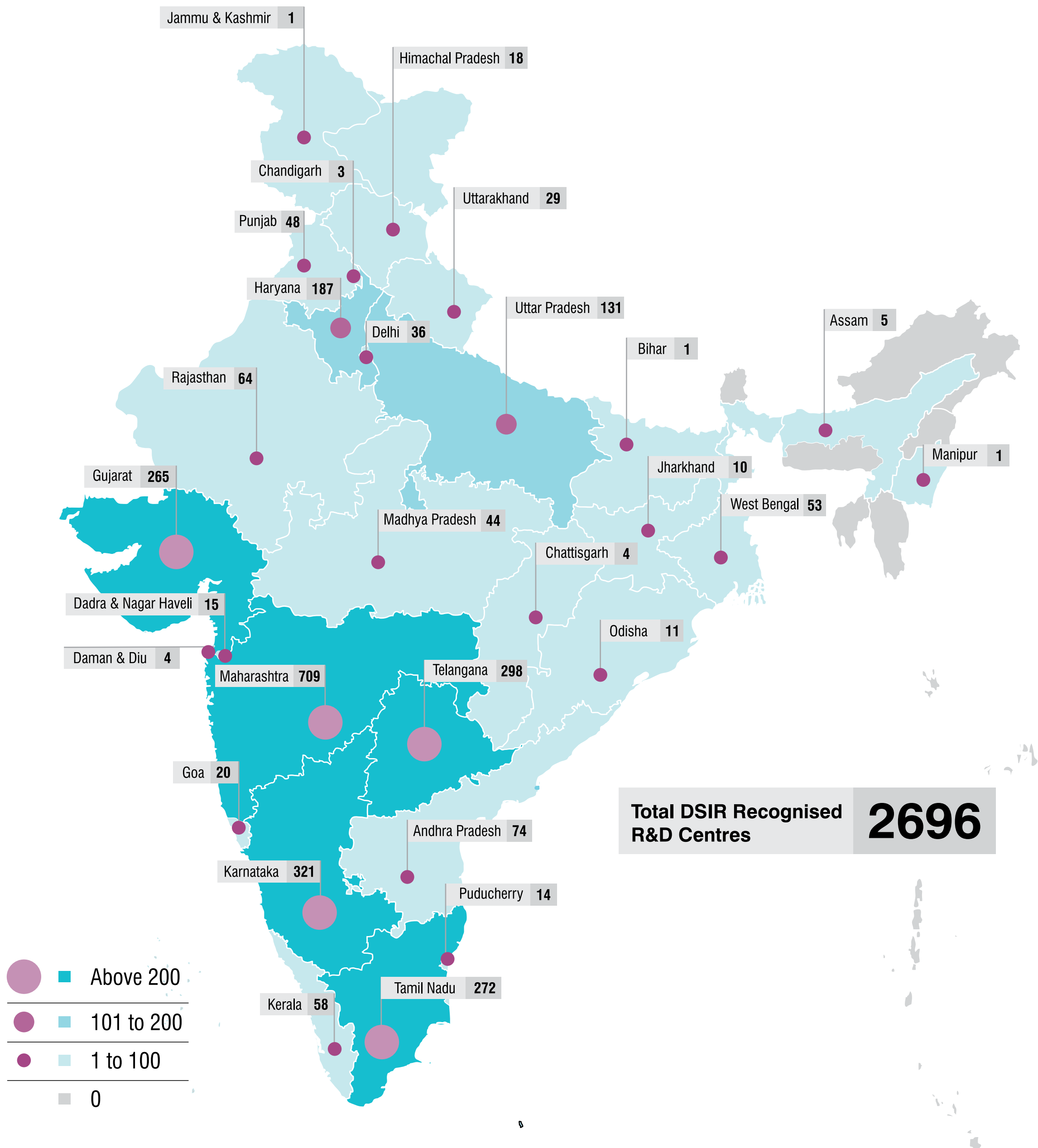
electric vehicle policy.

Among the higher technology policies, there are around 15 states that have a Biotech policy while around 8 states have also introduced an aerospace & defence policy.

While the policies for National Capital Territory of Delhi have been captured in the table above, policies for other union territories can be found in the Appendix (A.8).

The data on state policies has been collated from individual state government websites, Invest India and the Startup India websites.

7.2 | State-wise Distribution of Industrial R&D Centres



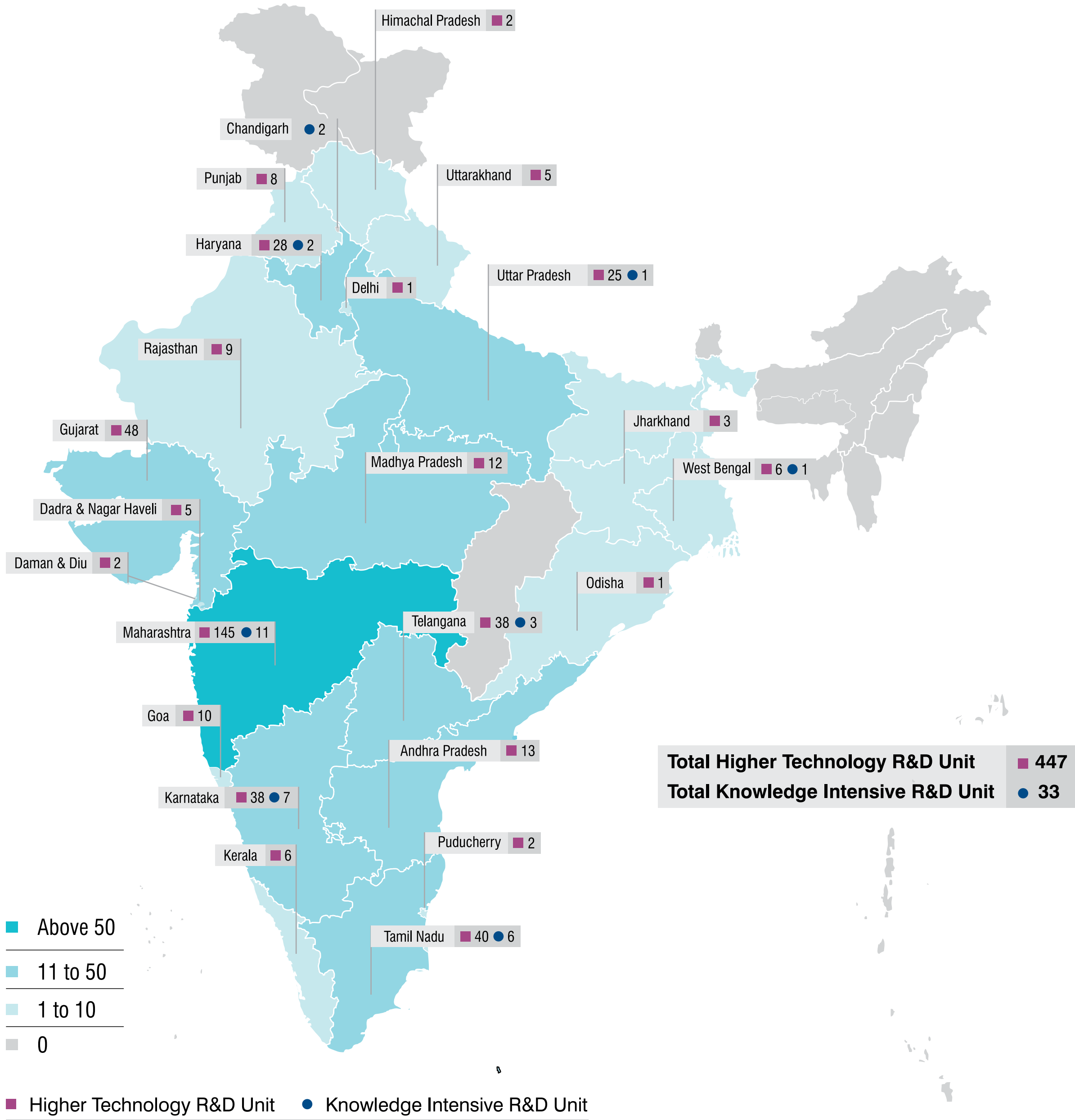
Source: Department of Scientific and Industrial Research (DSIR), Government of India, Directory of In-house R&D Units (various years); Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) Telangana was formed in the year 2014. Prior to 2014, data for Telangana was covered under Andhra Pradesh
(ii) The data reported is for the state of Jammu and Kashmir which was reorganised into the Union territory of Ladakh and Union territory of Jammu and Kashmir from October 2019

The table above considers the in-house R&D units of 2,069 firms that had been recognised by the Department of Scientific and Industrial Research (DSIR). The directories of in-house R&D units released in 2016 and 2017 published the locations of one or more registered in-house R&D units of these 2,069 firms. There were 327 firms that had multiple R&D units across different states in India. The state-wise locations of 2,696 R&D units were identified and have been captured in the figure above.

Maharashtra had 709 R&D units, the highest number amongst all states, and accounted for 26 percent of the total DSIR recognised R&D Units. Some of the other top locations for the DSIR recognised R&D Units were Karnataka, Telangana, Tamil Nadu and Gujarat.

7.2.1 | State-wise Distribution of Select Higher Technology and Knowledge Intensive R&D Centres



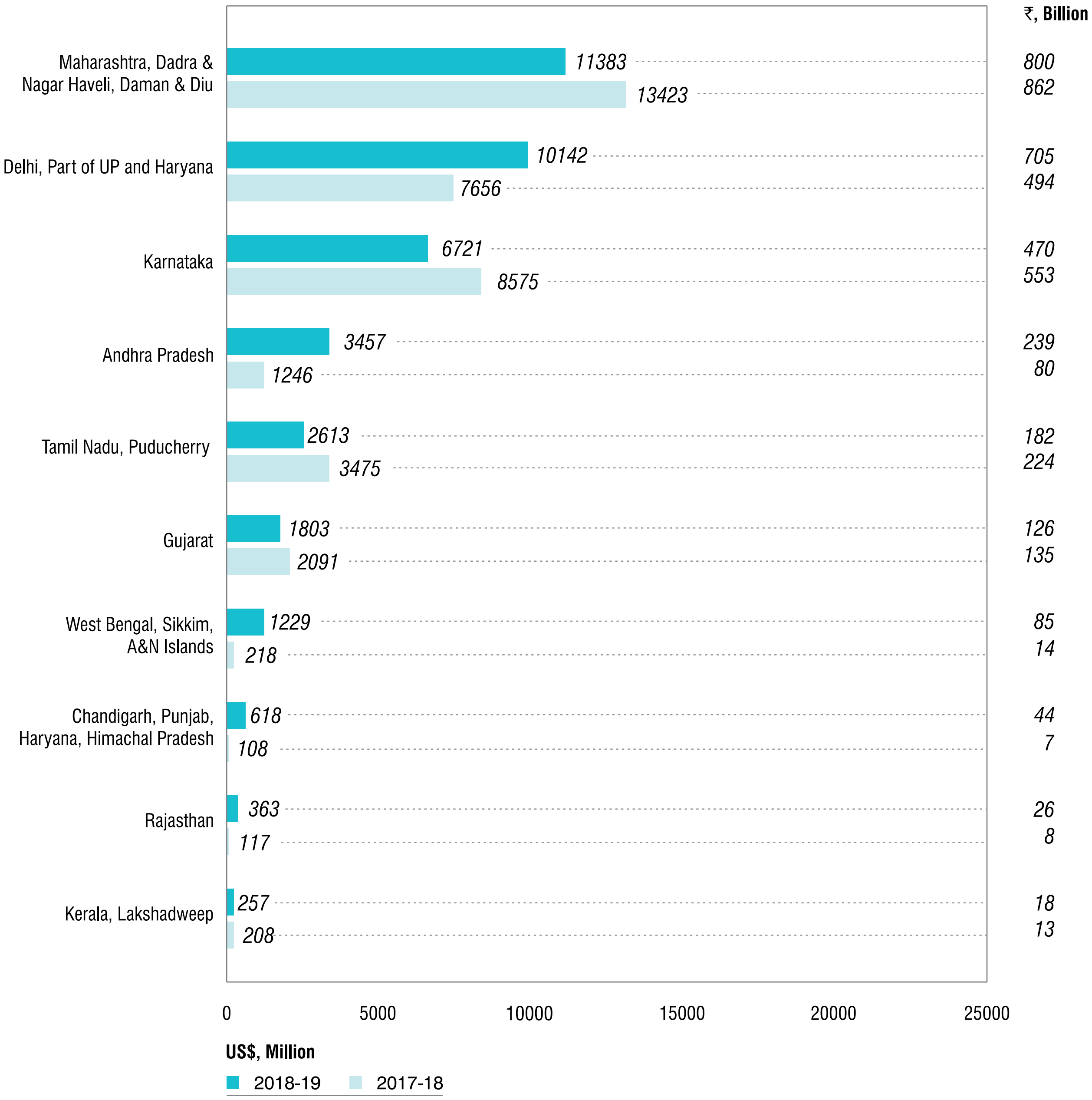
Source: Department of Scientific and Industrial Research (DSIR), Government of India, Directory of In-house R&D Units (various years); Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) 212 firms from our list of top R&D spenders were identified as higher technology and knowledge intensive R&D firms on the basis of ISIC Rev 4 and mapped to the Directory of In-house recognized R&D Units.
(ii) Telangana was formed in the year 2014. Prior to 2014, data for Telangana was covered under Andhra Pradesh
(iii) The data reported is for the state of Jammu and Kashmir which was reorganised into the Union territory of Ladakh and Union territory of Jammu and Kashmir from October 2019

The R&D units of 212 firms identified as Higher Technology and Knowledge Intensive have been considered in the figure above. These 212 firms are from a sample of 352 firms that account for around 90 percent of the total industrial R&D in India. The Higher Technology and Knowledge Intensive definitions are based on the International Standard Industrial Classification (ISIC) Rev 4.[1] As seen above, Maharashtra has the highest number of Higher Technology and Knowledge Intensive R&D units at 145 and 11 respectively.

[1] See glossary (B.6)

7.3 | Foreign Direct Investment into India for Select States (2017- 18 and 2018- 19)



Source: Department for Promotion of Industry and Internal Trade (DPIIT), Government of India, Quarterly FDI factsheet, March 2019; Centre for Technology, Innovation and Economic Research (CTIER)

In 2018-19, Maharashtra[2] was the top recipient of FDI inflows totalling USD 11.3 billion, followed by Delhi[3] that received USD 10 billion. Most states including Maharashtra, Karnataka, Tamil Nadu[4] and Gujarat saw decrease in FDI inflows in 2018-19 compared to the previous year whereas Delhi, Andhra Pradesh and West Bengal[5] are few of the states that saw an increase in FDI inflows.

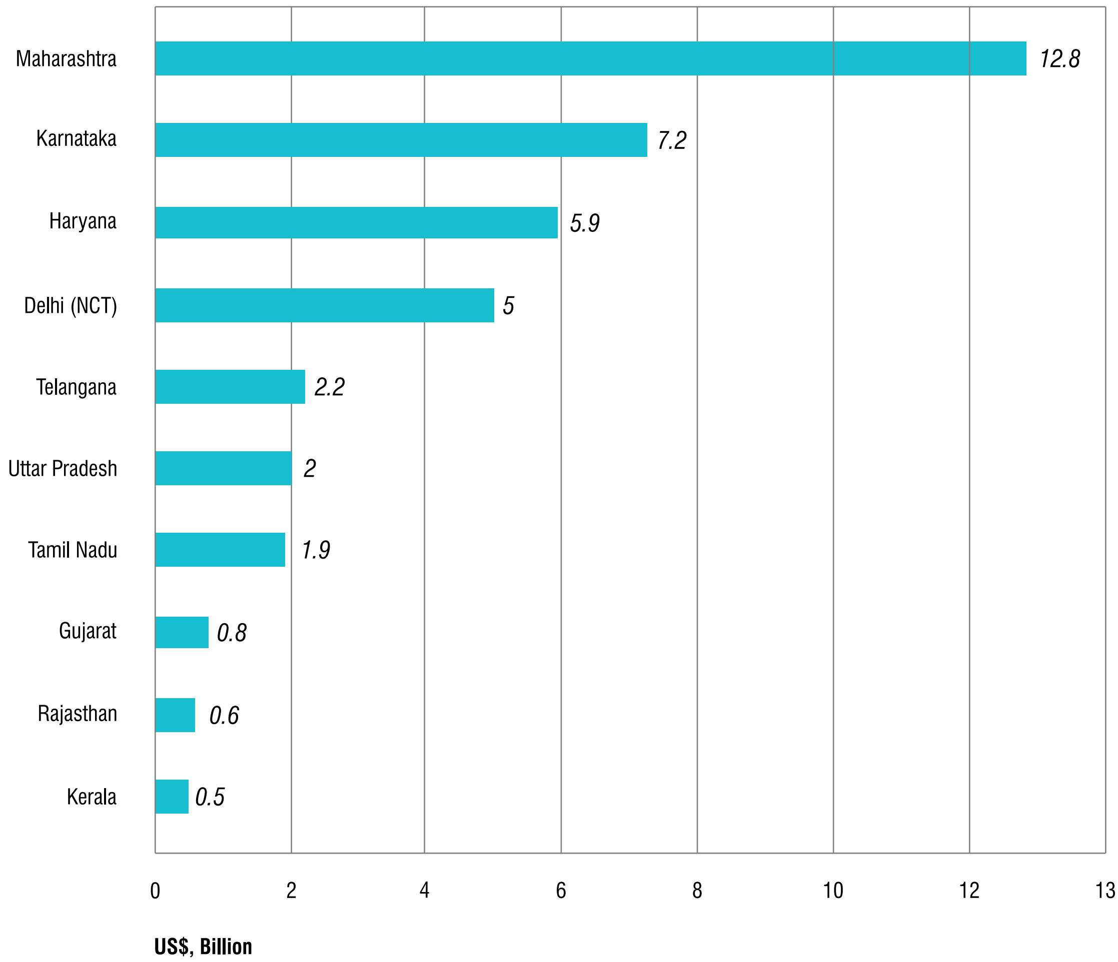
[2] Includes Dadra & Nagar Haveli and Daman & Diu

[3] Includes part of Uttar Pradesh and Haryana

[4] Includes Pondicherry

[5] Includes Sikkim and Andaman & Nicobar Islands

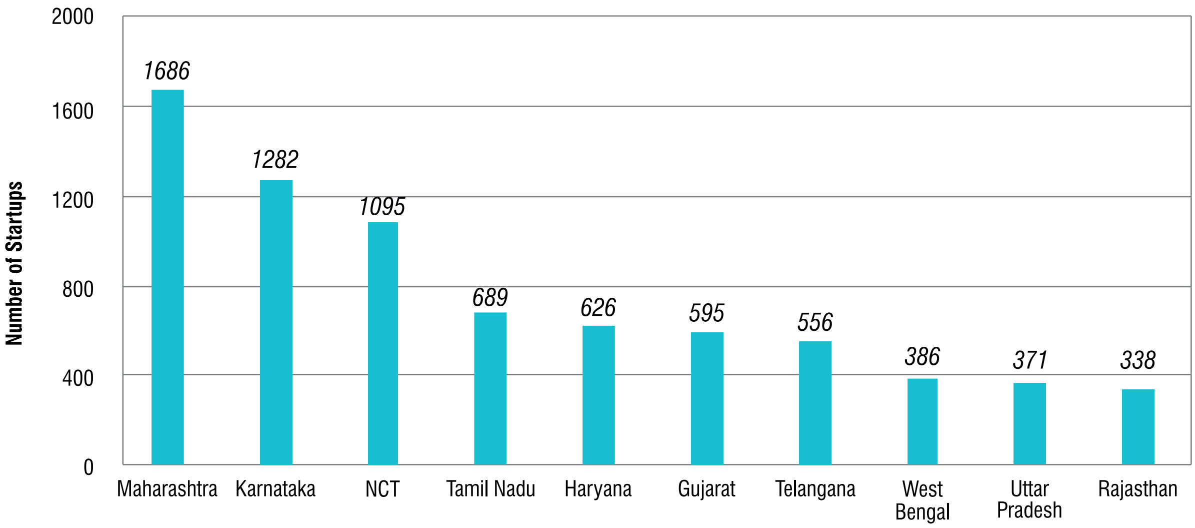
7.4 | Funding for Startups in Top Indian States (2019)



Source: Tracxn, data downloaded on 8 September 2020 from the platform; Center for Technology, Innovation and Economic Research (CTIER)

In 2019, Maharashtra attracted the most funding for startups (and new companies), amounting to USD 12.8 billion. This was followed by Karnataka that received USD 7.2 billion and Haryana received USD 5.9 billion. The National Capital Territory (NCT) followed in fourth place at USD 5 billion. The funding mentioned here includes angel investments, conventional debt, venture debt, private equity, seed funding and various series rounds as provided by Tracxn. The Tracxn data considered here includes funding for technology and offline startups (and new companies).

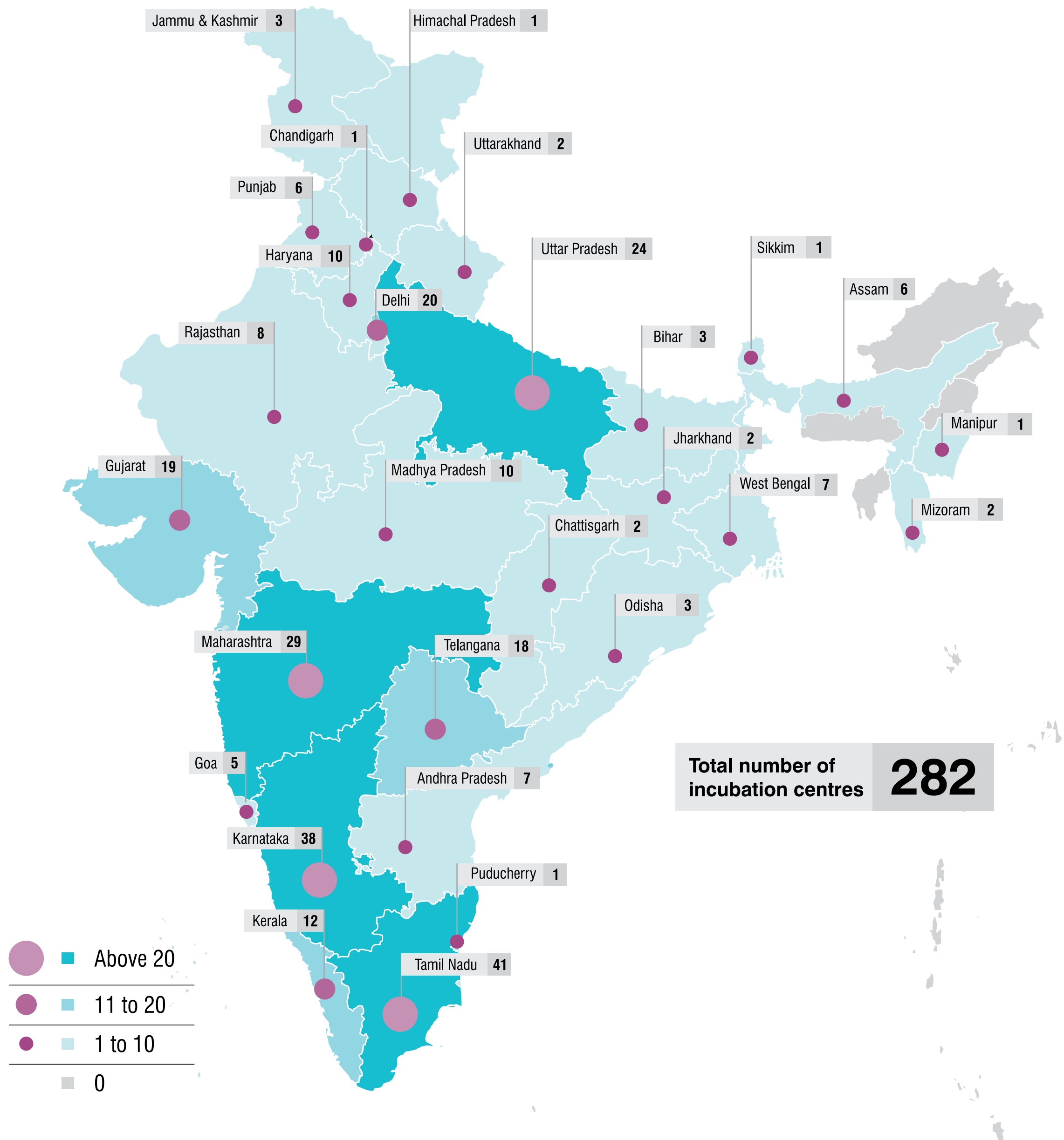
7.4.1 | State-wise Distribution of Startups (and New Companies) (2019)



Source: Tracxn, data downloaded on 8 September 2020 from the platform

In 2019, Maharashtra saw 1,686 startups being established, followed by Karnataka that saw 1,282 new startups (and new companies). The National Capital Territory (NCT) came in third with 1,095 startups, while Tamil Nadu was fourth with 689 startups. Although the NCT and Tamil Nadu saw more startups (and new companies) being established in 2019 compared to Haryana, the amount of total funding received by startups in Haryana as seen in the previous indicator was higher than the amounts received by the NCT and Tamil Nadu. Data on the state-wise number of new companies registered with the Ministry of Corporate Affairs (MCA) in 2019 can be found in the Appendix (Table A.9).

7.5 | State-wise Number of Incubation Centres

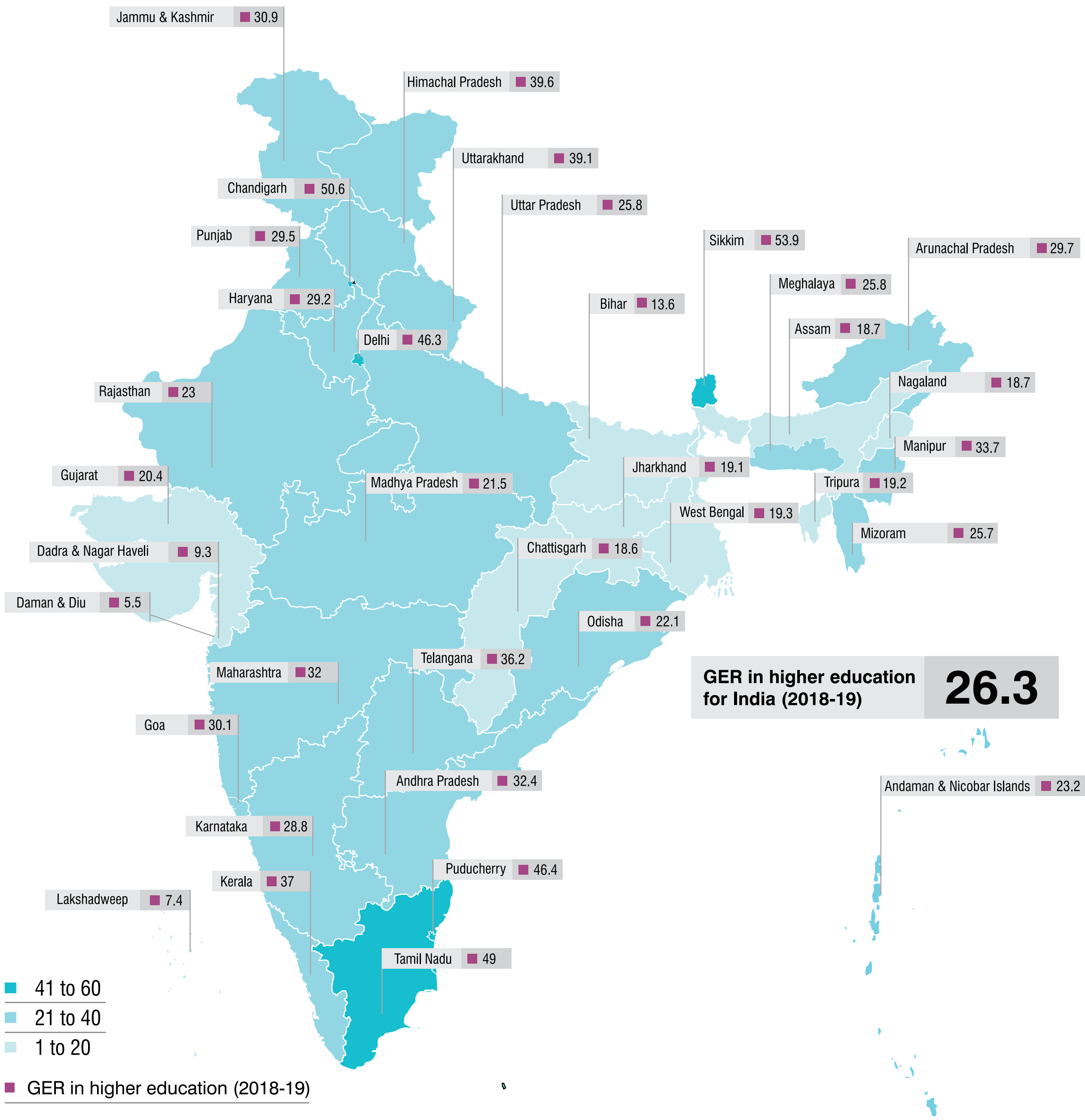


Source: Technology Business Incubator (TBI), National Science and Technology Entrepreneurship Development, Department of Science and Technology available at http://www.nstedb.com/institutional/tbi-list.htm; Knowledge Bank, Agnii, Government of India available at https://www.agnii.gov.in/learning?-from=blog&id=5; Technology Incubation and Development of Entrepreneurs (TIDE), Ministry of Electronics and Information Technology available at https://meity.gov.in/content/technology-incubation-and-development-entrepreneurs; Selected Atal Incubation Centres, Atal Innovation Mission, NITI Aayog available at https://aim.gov.in/selected-atal.php; Biotech Parks and Incubators, Department of Biotechnology available at http://dbtindia.gov.in/schemes-programmes/translational-industrial-development-programmes/biotech-parks-incubators; Bioincubators Nurturing Entrepreneurship for Scaling Technologies, BIRAC, Department of Biotechnology available at https://birac.nic.in/bionest.php; Centre for Technology, Innovation and Economic Research (CTIER)

Note: The data reported is for the state of Jammu and Kashmir which was reorganised into the Union territory of Ladakh and Union territory of Jammu and Kashmir from October 2019

We have identified a total of 282 incubators, of which 205 are supported by various government entities like the Department of Science and Technology (DST), the Ministry of Electronics and Information Technology (MeitY), the Atal Innovation Mission (AIM) and the Department of Biotechnology (DBT). Tamil Nadu has the highest number (41) followed by Karnataka (38). There are 178 incubators located at academic institutions (see Appendix table A.10). Tamil Nadu has the highest number of incubators located at academic institutions at 36, followed by Uttar Pradesh that has 16.

7.6 | State-wise Gross Enrolment Ratio in Higher Education (2018- 19)



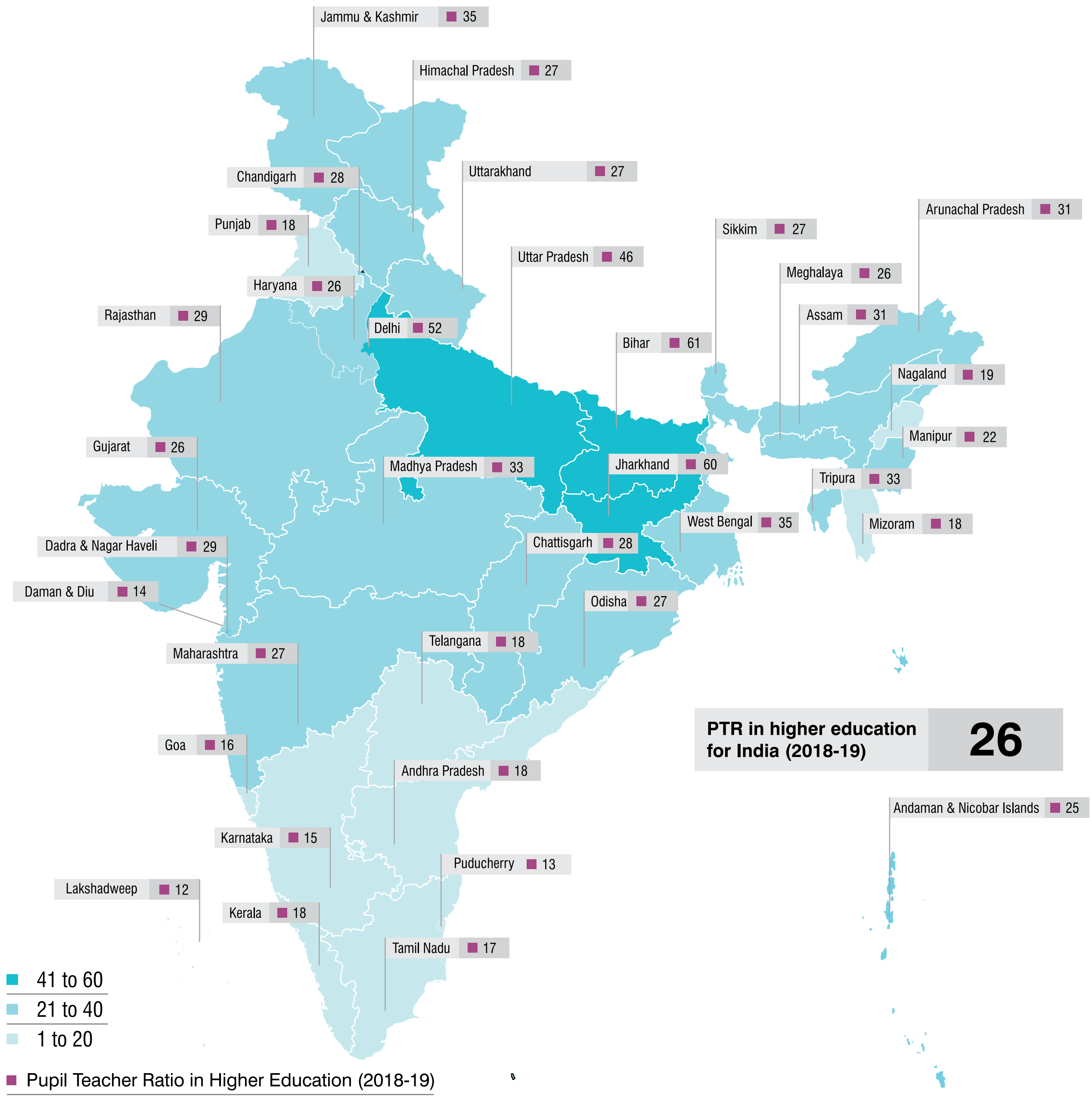
Source: Ministry of Human Resource Development, Department of Higher Education, All India Survey on Higher Education (AISHE) 2018-19

Note: The data reported is for the state of Jammu and Kashmir which was reorganised into the Union territory of Ladakh and Union territory of Jammu and Kashmir from October 2019

The national average Gross Enrollment Ratio (GER) in higher education has increased to 26.3 percent in 2018-19 compared to 24.5 percent in 2015-16.[6] The GER varies significantly across States/Union Territories, ranging from 5.5 percent in Daman & Diu to 53.9 percent in Sikkim. States that have a relatively higher GER include Chandigarh (50.6 percent), Tamil Nadu (49 percent), Puducherry (46.4 percent), and Delhi (46.3 percent) while those states with relatively lower GERs include Bihar (13.6 percent), Chattisgarh (18.6 percent), and Assam & Nagaland (both 18.7 percent). GER captures the percentage of people between the ages 18-23 enrolled in universities, colleges, or other higher education institutes.

[6] CTIER Handbook: Technology and Innovation in India 2019

7.7 | State-wise Pupil-Teacher Ratio in Higher Education (2018- 19)

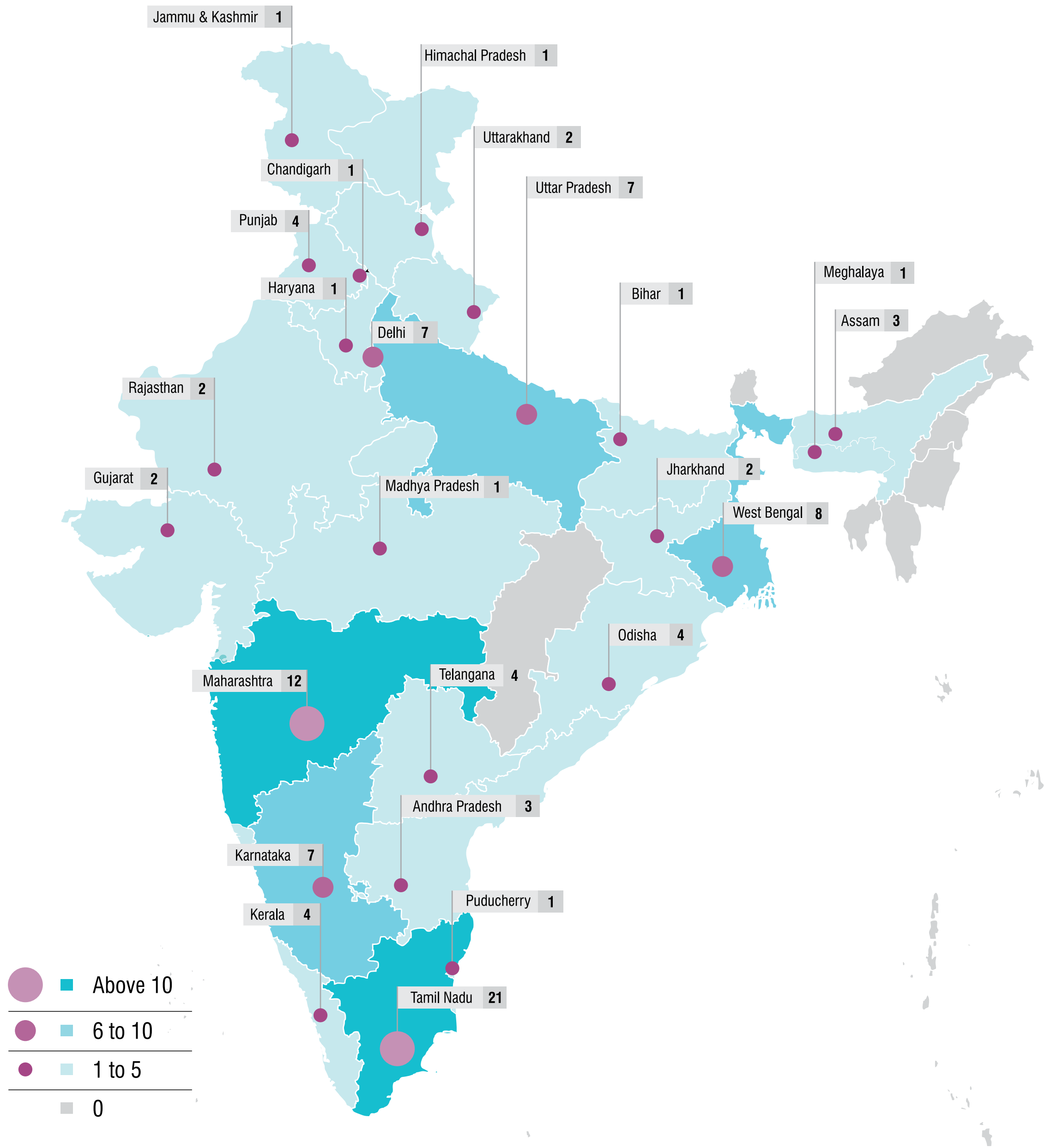


Source: Ministry of Human Resource Development, Department of Higher Education, All India Survey on Higher Education (AISHE) Report 2018-19

Note: The data reported is for the state of Jammu and Kashmir which was reorganised into the Union territory of Ladakh and Union territory of Jammu and Kashmir from October 2019

The Pupil-Teacher Ratio (PTR) in Higher Education reported above has considered the Pupil-Teacher Ratio for both 'regular & the distant mode of education' and enrolment in all types of institutions (University, Colleges, and Stand-alone Institution). The PTR at the all India level was 26 for the year 2018-19, and ranged from 12 in Lakshadweep to 61 in Bihar. States and Union Territories with very low PTR were Lakshadweep, Puducherry and Karnataka while states with a very high PTR were Bihar, Jharkhand, and Delhi.

7.8 | State-wise Number of Institutes in Top 100 under the National Institute Ranking Framework (2019)

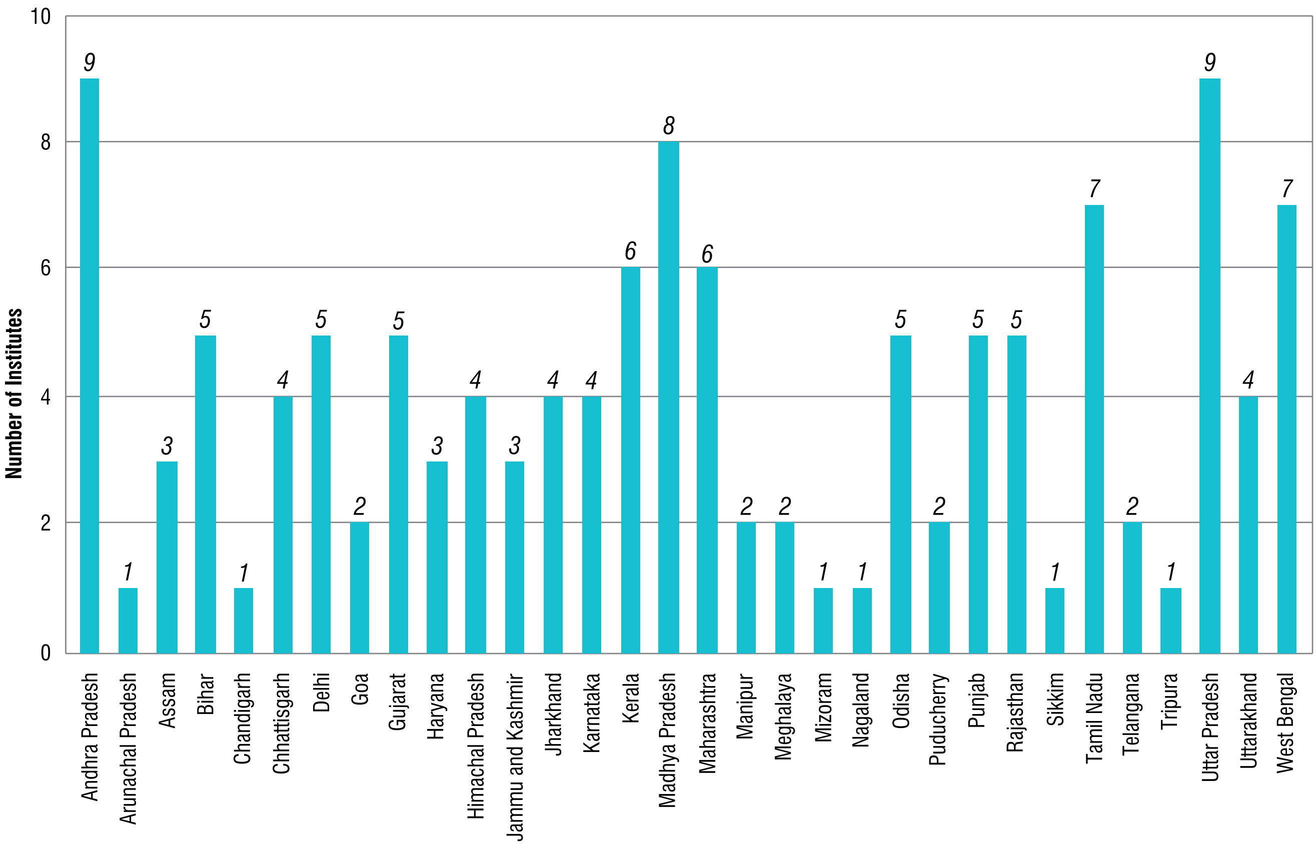


Source: Ministry of Human Resource Development (MHRD), National Institutional Ranking Framework (2019) available at https://www.nirfindia.org/2019/OverallRanking.html

Note: The data reported is for the state of Jammu and Kashmir which was reorganised into the Union territory of Ladakh and Union territory of Jammu and Kashmir from October 2019

The figure above considers the top 100 ranked universities and institutes in India according to the National Institute Ranking Framework (NIRF), and their distribution across states. NIRF outlines a methodology to rank institutions across the country on the basis of parameters which broadly cover "Teaching, Learning and Resources," "Research and Professional Practices," "Graduation Outcomes," "Outreach and Inclusivity," and "Perception". Tamil Nadu has the highest number of educational institutes ranked in the top 100 with 21 institutes followed by Maharashtra and West Bengal with 12 and 8 institutes respectively. A total of 24 states have at least one institute ranked in the top 100.

7.9 | State-wise Number of Institutes of National Importance (2019)



Source: Ministry of Human Resource Development, Department of Higher Education, All India Survey on Higher Education (AISHE) Report 2018-19

Note: (i) Institutes of National Importance (INI) are premier public higher education institutions in India established by an act of parliament
(ii) The data reported is for the state of Jammu and Kashmir which was reorganised into the Union territory of Ladakh and Union territory of Jammu and Kashmir from October 2019

According to the AISHE Report 2018-19, there were 127 Institutes of national importance (INI) in the country as published by the Ministry of Human Resource Development (MHRD). The institutes of national importance have been established by an Act of Parliament. These include the various Indian Institutes of Technology (IIT)[7], National Institutes of Technology (NIT)[8], Indian Institutes of Information Technology (IIIT)[9], Indian Institutes of Science Education & Research (IISER)[10], All India Institutes of Medical Sciences (AIIMS)[11] and the Schools of Planning and Architecture[12], among others. Andhra Pradesh and Uttar Pradesh each have 9 INIs, the highest number of INIs in any state. In 2018-19 there were 26 institutes that were granted the status of INI.

[7] Government of India. "The Institute of Technology Act, 1961"

[8] Government of India. "The National Institutes of Technology Act, 2007"

[9] Government of India. "The Indian Institutes of Information Technology (Public-Private Partnership) Act"

[10] Government of India. "The National Institutes of Technology (Amendment) Act, 2012

[11] Government of India. "All India Institute of Medical Sciences Act, 1956"

[12] Government of India. "The School of Planning and Architecture Bill, 2014"

7.10 | Patent Applications Filed from Select States with Indian Patent Office

No.	State/UT	Number of Patent Applications Filed				
		2014-15	2015-16	2016-17	2017-18	2018-19
1	Maharashtra	3267	3699	3595	3820	4257
2	Tamil Nadu	1423	1756	2018	2742	2391
3	Karnataka	2134	2020	1815	2022	2185
4	Delhi	1131	1154	1075	1434	1322
5	Telangana	462	795	805	999	1045
6	Uttar Pradesh	665	655	637	721	972
7	Gujarat	585	529	633	712	868
8	Punjab	97	192	207	247	661
9	West Bengal	406	454	480	538	529
10	Haryana	343	395	444	449	520
11	Andhra Pradesh	563	275	278	276	323
12	Rajasthan	149	150	181	190	305
13	Kerala	263	280	276	312	277
14	Madhya Pradesh	101	159	141	191	195
15	Himachal Pradesh	18	55	40	110	193
	Total for top 15	11607	12568	12625	14763	16043
	Total for all States	12071	13066	13219	15550	17005

Source: The Office of the Controller General of Patents, Designs & Trademarks, Government of India, Annual Reports (various years); Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) Telangana was formed in the year 2014. Prior to 2014, data for Telangana was covered under Andhra Pradesh
(ii) Ranking of States done based on 2018-19 filings
(iii) Patents applications filed are the sum of ordinary, convention and national phase applications

The 15 states in the table above accounted for close to 95 percent of the total number of patent applications filed with the Indian Patent Office in 2018-19. The states of Maharashtra, Tamil Nadu, Karnataka and Delhi accounted for around 60 percent of the total patent applications in 2018-19. A majority of the states have seen an increase in patent applications in recent years. The state of Telangana was formed in 2014 and prior to 2014, the data for Telangana was captured under the data for Andhra Pradesh. Andhra Pradesh saw a subsequent drop in patent applications and have remained steady around the 275 level since 2015-16.

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Chapter 8

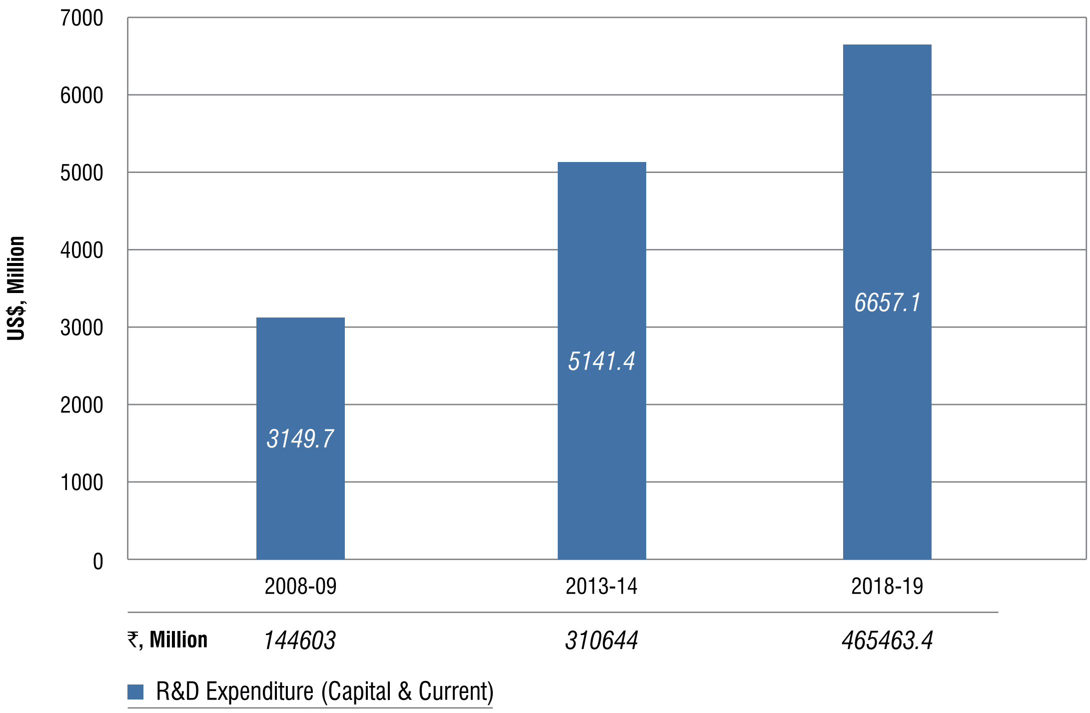
Industry in India

This chapter features some unique data for India, never available before, such as the list of the top 100 R&D spenders in India. We have also included some introductory data on startups and expect to add newer indicators in forthcoming editions.

Number	Indicator
8.1	Total Industrial R&D Expenditure in India
8.2	CTIER's Top 100 Industrial R&D Spenders in India (2018- 19)
8.3	Comparison of Select Indian Firms' R&D Intensity with Respective Sector Global Average R&D Intensity
8.4	Total Foreign Exchange Spending on Technology Payments
8.5	Import of Capital Goods by Indian Industry
8.6	Global MNCs having R&D Presence in India
8.7	Startup Sectors Attracting Funding in India
8.8	Sectoral Breakdown of Patents Granted to India's Top 100 Industrial R&D Spenders (2019)
8.9	Top Patentees with the Indian Patent Office (2018- 19)
8.10	Top Patentees with the United States Patent and Trademark Office (USPTO) (2019)

Chapter 08 Industry in India

8.1 | Total Industrial R&D Expenditure in India



Source: Annual Reports (2018-19) of Indian companies; Prowess, data downloaded on 30 September 2020 from the platform; ACE Equity, data downloaded on 7 July 2020 from the platform; Ahmedabad University; Centre for Technology, Innovation and Economic Research (CTIER)

Note: Figures in rupees are converted to dollars using the USD-INR exchange rate of 45.91 calculated as an average for the fiscal year 2008-09, the USD-INR exchange rate of 60.42 calculated as an average for the fiscal year 2013-14 and the USD-INR exchange rate of 69.92 calculated as an average for the fiscal year 2018-19 according to Federal Reserve Bank of St Louis

India's industrial R&D expenditure in 2019 was USD 6657.1 million. The R&D expenditure captured above considers capital and current account expenditure on R&D reported by firms in their annual reports. The current account component of R&D expenditure represents around 75 percent of total industrial R&D spending in India.

Although industrial R&D expenditure in India for 2019 has more than doubled since 2009, it remains low by global standards. For instance, Siemens[1] which is ranked 21 in the list of top 2,500 global R&D spenders[2], spends slightly more than all of Indian industry on R&D, while Alphabet, the top global R&D spender, spends more than three times that of all of Indian industry.

1 Siemens reported USD 6795 million as R&D Expenditure for the year 2018-19 in the EU Industrial R&D Investment Scoreboard (2019)

2 EU Industrial R&D Investment Scoreboard (2019)

8.2 | CTIER's Top 100 Industrial R&D Spenders in India (2018- 19)

Rank	Company Name	Sector	R&D Spending (₹, Million)	R&D Spending (US$, Million)	Share in Total Top 100 R&D Spending (%)
1	Tata Motors Ltd.	Automobiles & Parts	29652.5	426.6	8.1
2	Mahindra & Mahindra Ltd.	Automobiles & Parts	26419.4	380.1	7.2
3	Reliance Industries Ltd.	Oil & Gas	23770	342	6.5
4	Lupin Ltd.	Pharmaceuticals & Biotechnology	15828.4	227.7	4.3
5	Hindustan Aeronautics Ltd.	Aerospace & Defence	14644	210.7	4
6	Dr. Reddy'S Laboratories Ltd.	Pharmaceuticals & Biotechnology	11994	172.6	3.3
7	Cipla Ltd.	Pharmaceuticals & Biotechnology	10693.1	153.8	2.9
8	Sun Pharmaceutical Inds. Ltd.	Pharmaceuticals & Biotechnology	9620.8	138.4	2.6
9	Bharat Electronics Ltd.	Aerospace & Defence	8866.6	127.6	2.4
10	Bharat Heavy Electricals Ltd.	Industrial Engineering	8196.9	117.9	2.2
11	Mylan Laboratories Ltd.	Pharmaceuticals & Biotechnology	7710.6	110.9	2.1
12	Aurobindo Pharma Ltd.	Pharmaceuticals & Biotechnology	7537	108.4	2.1
13	Cadila Healthcare Ltd.	Pharmaceuticals & Biotechnology	7482	107.6	2
14	Maruti Suzuki India Ltd.	Automobiles & Parts	7128	102.5	1.9
15	Ashok Leyland Ltd.	Automobiles & Parts	6581.3	94.7	1.8
16	Hero Motocorp Ltd.	Automobiles & Parts	5497.1	79.1	1.5
17	Alembic Pharmaceuticals Ltd.	Pharmaceuticals & Biotechnology	5127.7	73.8	1.4
18	Oil & Natural Gas Corpn. Ltd.	Oil & Gas	5011.9	72.1	1.4
19	V E Commercial Vehicles Ltd.	Automobiles & Parts	4909.1	70.6	1.3
20	Intas Pharmaceuticals Ltd.	Pharmaceuticals & Biotechnology	4644.2	66.8	1.3
21	Bajaj Auto Ltd.	Automobiles & Parts	4563.5	65.7	1.2
22	Glenmark Pharmaceuticals Ltd.	Pharmaceuticals & Biotechnology	4536.9	65.3	1.2
23	Infosys Ltd.	Software & Computer Services	4510	64.9	1.2
24	Indian Oil Corpn. Ltd.	Oil & Gas	4373.4	62.9	1.2
25	Torrent Pharmaceuticals Ltd.	Pharmaceuticals & Biotechnology	3980.8	57.3	1.1
26	Wipro Ltd.	Software & Computer Services	3942	56.7	1.1
27	Alkem Laboratories Ltd.	Pharmaceuticals & Biotechnology	3867.3	55.6	1.1
28	Sun Pharma Advanced Research Co. Ltd.	Pharmaceuticals & Biotechnology	3682.5	53	1
29	Eicher Motors Ltd.	Automobiles & Parts	3549.4	51.1	1
30	Steel Authority Of India Ltd.	Industrial Metals & Mining	3198.6	46	0.9
31	Bosch Ltd.	Automobiles & Parts	3091	44.5	0.8
32	T V S Motor Co. Ltd.	Automobiles & Parts	3074.9	44.2	0.8
33	Tata Consultancy Services Ltd.	Software & Computer Services	3050	43.9	0.8
34	Edgeverve Systems Ltd.	Software & Computer Services	2895.3	41.7	0.8
35	Macleods Pharmaceuticals Ltd.	Pharmaceuticals & Biotechnology	2792.3	40.2	0.8
36	Oracle Financial Services Software Ltd.	Software & Computer Services	2601.3	37.4	0.7
37	Hindustan Petroleum Corpn. Ltd.	Oil & Gas	2538.5	36.5	0.7
38	Ajanta Pharma Ltd.	Pharmaceuticals & Biotechnology	2421.5	34.8	0.7
39	Eugia Pharma Specialities Ltd.	Pharmaceuticals & Biotechnology	2419.3	34.8	0.7
40	Abbott Healthcare Pvt. Ltd.	Pharmaceuticals & Biotechnology	2351.5	33.8	0.6
41	H C L Technologies Ltd.	Software & Computer Services	2290	32.9	0.6
42	Daimler India Commercial Vehicles Pvt Ltd.	Automobiles & Parts	2216	31.9	0.6
43	Apollo Tyres Ltd.	Automobiles & Parts	2193.7	31.6	0.6
44	Larsen & Toubro Ltd.	Construction and Materials	2167	31.2	0.6
45	Biocon Ltd.	Pharmaceuticals & Biotechnology	2166	31.2	0.6
46	Tata Steel Ltd.	Industrial Metals & Mining	2157.9	31	0.6
47	U P L Ltd.	Chemicals	2153	31	0.6
48	Force Motors Ltd.	Automobiles & Parts	2044.1	29.4	0.6
49	Natco Pharma Ltd.	Pharmaceuticals & Biotechnology	1976	28.4	0.5
50	Brahmos Aerospace Pvt. Ltd.	Aerospace & Defence	1930.8	27.8	0.5

Source: Annual Reports (2018-19) of Indian companies; Prowess, data downloaded on 30 September 2020 from the platform; ACE Equity, data downloaded on 7 July 2020 from the platform; Ahmedabad University; Centre for Technology, Innovation and Economic Research (CTIER)

51	Unichem Laboratories Ltd.	Pharmaceuticals & Biotechnology	1808.9	26	0.5
52	Suzlon Energy Ltd.	Electricity	1742.1	25.1	0.5
53	I T C Ltd.	General Industrials	1727.1	24.8	0.5
54	Wockhardt Ltd.	Pharmaceuticals & Biotechnology	1723.3	24.8	0.5
55	Encube Ethicals Pvt Ltd.	Pharmaceuticals & Biotechnology	1663.1	23.9	0.5
56	Laurus Labs Ltd.	Pharmaceuticals & Biotechnology	1659	23.9	0.5
57	Emcure Pharmaceuticals Ltd.	Pharmaceuticals & Biotechnology	1647.5	23.7	0.5
58	Strides Pharma Science Ltd.	Pharmaceuticals & Biotechnology	1423.7	20.5	0.4
59	Serum Institute of India Pvt. Ltd.	Pharmaceuticals & Biotechnology	1420	20.4	0.4
60	Grasim Industries Ltd.	General Industrials	1368	19.7	0.4
61	Fresenius Kabi Oncology Ltd.	Pharmaceuticals & Biotechnology	1346.8	19.4	0.4
62	Escorts Ltd.	Industrial Engineering	1345.4	19.4	0.4
63	Landis + Gyr Ltd.	Electronic & Electrical Equipment	1326.4	19.1	0.4
64	U S V Pvt. Ltd.	Pharmaceuticals & Biotechnology	1271.9	18.3	0.3
65	Micro Labs Ltd.	Pharmaceuticals & Biotechnology	1222.7	17.6	0.3
66	Jubilant Generics Ltd.	Pharmaceuticals & Biotechnology	1196	17.2	0.3
67	Tejas Networks Ltd.	Technology Hardware & Equipment	1188.7	17.1	0.3
68	Renault Nissan Technology & Business Centre India Pvt. Ltd.	Automobiles & Parts	1134.3	16.3	0.3
69	M R F Ltd.	Automobiles & Parts	1113	16	0.3
70	Mankind Pharma Ltd.	Pharmaceuticals & Biotechnology	1103.2	15.9	0.3
71	Sutherland Global Services Pvt. Ltd.	Software & Computer Services	1100	15.8	0.3
72	S R F Ltd.	Chemicals	1044	15	0.3
73	Secure Meters Ltd.	Electronic & Electrical Equipment	1036.7	14.9	0.3
74	Cummins Technologies India Pvt. Ltd.	Industrial Engineering	1033.6	14.9	0.3
75	Brakes India Pvt. Ltd.	Automobiles & Parts	1023.8	14.7	0.3
76	Solara Active Pharma Sciences Ltd.	Pharmaceuticals & Biotechnology	1015.1	14.6	0.3
77	Bharat Petroleum Corpn. Ltd.	Oil & Gas	1007.2	14.5	0.3
78	Mahindra Electric Mobility Ltd.	Automobiles & Parts	991.8	14.3	0.3
79	Hetero Labs Ltd.	Pharmaceuticals & Biotechnology	979.5	14.1	0.3
80	Gland Pharma Ltd.	Pharmaceuticals & Biotechnology	965.8	13.9	0.3
81	Aricent Technologies (Holdings) Ltd.	Software & Computer Services	949	13.7	0.3
82	Kirloskar Oil Engines Ltd.	Industrial Engineering	922.8	13.3	0.3
83	PAR Formulations Pvt Ltd.	Pharmaceuticals & Biotechnology	918.2	13.2	0.3
84	Deccan Fine Chemicals (India) Pvt. Ltd.	Chemicals	917.4	13.2	0.3
85	Asian Paints Ltd.	Chemicals	915.2	13.2	0.3
86	Minda Industries Ltd.	Automobiles & Parts	914.7	13.2	0.3
87	Ceat Ltd.	Automobiles & Parts	907.6	13.1	0.2
88	Intellect Design Arena Ltd.	Software & Computer Services	905.1	13	0.2
89	Ipca Laboratories Ltd.	Pharmaceuticals & Biotechnology	893.5	12.9	0.2
90	Saint-Gobain India Pvt. Ltd.	Construction and Materials	887.3	12.8	0.2
91	C N H Industrial (India) Pvt. Ltd.	Industrial Engineering	880.4	12.7	0.2
92	Syngenta India Ltd.	Chemicals	863.3	12.4	0.2
93	Oil India Ltd.	Oil & Gas	861.9	12.4	0.2
94	Mazagon Dock Shipbuilders Ltd.	Aerospace & Defence	854	12.3	0.2
95	Havells India Ltd.	Electronic & Electrical Equipment	794.3	11.4	0.2
96	Venco Research & Breeding Farm Pvt. Ltd.	Food Producers	761	10.9	0.2
97	J K Tyre & Inds. Ltd.	Automobiles & Parts	755.3	10.9	0.2
98	Kansai Nerolac Paints Ltd.	Chemicals	741	10.7	0.2
99	P I Industries Ltd.	Chemicals	738	10.6	0.2
100	B E M L Ltd.	Industrial Engineering	707.2	10.2	0.2

Note: Figures in rupees were converted to dollars using the USD-INR exchange rate of 69.51 as at 31 December 2018 and based on exchange rates mentioned in the EU Industrial R&D Investment Scoreboard (2019)

8.3 | Comparison of Select Indian Firms' R&D Intensity with Respective Sector Global Average R&D Intensity

Sector	Company	R&D Intensity	Top 2500 Global Average R&D Intensity
Pharmaceuticals & Biotechnology	Lupin Ltd.	13.9	15.9
	Dr. Reddy'S Laboratories Ltd.	11.3	
	Cipla Ltd.	8.6	
	Sun Pharmaceutical Inds. Ltd.	9.3	
	Mylan Laboratories Ltd.	7.0	
Automobiles & Parts	Tata Motors Ltd.	4.3	4.7
	Mahindra & Mahindra Ltd.	4.9	
	Maruti Suzuki India Ltd.	0.8	
	Ashok Leyland Ltd.	2.3	
	Hero Motocorp Ltd.	1.6	
Oil & Gas	Reliance Industries Ltd.	0.6	0.3
	Oil & Natural Gas Corpn. Ltd.	0.5	
	Indian Oil Corpn. Ltd.	0.1	
	Hindustan Petroleum Corpn. Ltd.	0.1	
	Bharat Petroleum Corpn. Ltd.	0.03	
Aerospace & Defence	Hindustan Aeronautics Ltd.	7.4	4
	Bharat Electronics Ltd.	7.3	
	Brahmos Aerospace Pvt. Ltd.	8.0	
	Mazagon Dock Shipbuilders Ltd.	1.8	
Software & Computer Services	Infosys Ltd.	0.6	10.8
	Wipro Ltd.	0.8	
	Tata Consultancy Services Ltd.	0.2	
	Edgeverve Systems Ltd.	11.4	
	Oracle Financial Services Software Ltd.	7.3	

Source: Annual Reports (2018-19) of Indian companies; Prowess, data downloaded on 30 September 2020 from platform; EU Industrial R&D Investment Scoreboard (2019); Centre for Technology, Innovation and Economic Research (CTIER)

The top 10 industrial R&D sectors in India, as captured in Indicator 6.4.1, have been considered above. The table compares the R&D intensities (R&D expenditure as a percent of sales) for top Indian R&D spenders in each sector with the respective global average R&D intensity. Food producers and electronic & electrical equipment now feature in the top 10 industrial R&D sectors in India and have replaced electricity and general industrials that were present in the top 10 R&D sectors in 2016.[3]

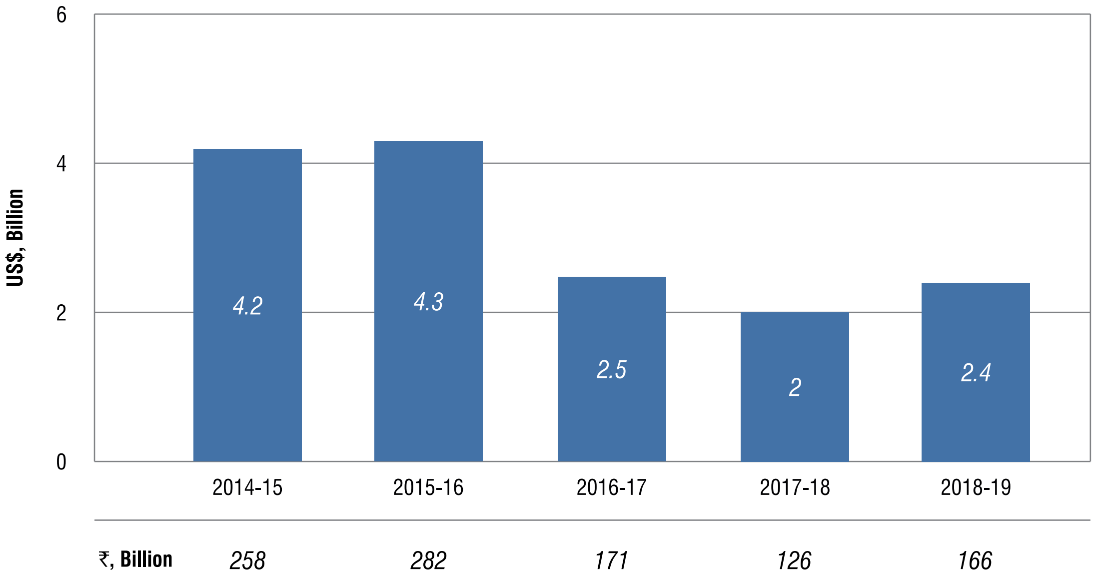
[3] CTIER Handbook: Technology and Innovation in India 2019

Sector	Company	R&D Intensity	Top 2500 Global Average R&D Intensity
Industrial Engineering	Bharat Heavy Electricals Ltd.	2.7	3.2
	Escorts Ltd.	2.2	
	Cummins Technologies India Pvt. Ltd.	2.2	
	Kirloskar Oil Engines Ltd.	2.9	
	C N H Industrial (India) Pvt. Ltd.	2.7	
Chemicals	U P L Ltd.	2.5	2.4
	S R F Ltd.	1.6	
	Deccan Fine Chemicals (India) Pvt. Ltd.	3.4	
	Asian Paints Ltd.	0.6	
	Syngenta India Ltd.	3.0	
Industrial Metals & Mining	Steel Authority Of India Ltd.	0.5	1.1
	Tata Steel Ltd.	0.3	
	J S W Steel Ltd.	0.06	
Food Producers	Venco Research & Breeding Farm Pvt. Ltd.	8.9	1.5
	Sungro Seeds Pvt. Ltd.	10.8	
	Glaxosmithkline Consumer Healthcare Ltd.	1.0	
	Nunhems India Pvt. Ltd.	11.5	
Electronic & Electrical Equipment	Landis + Gyr Ltd.	31.4	5
	Secure Meters Ltd.	6.8	
	Havells India Ltd.	0.8	
	C G Power & Indl. Solutions Ltd.	0.9	
	Electronics Corporation Of India Ltd.	1.8	

Lupin, Tata Motors, Mahindra & Mahindra, Reliance Industries, Hindustan Aeronautics Limited (HAL) and Bharat Electronics feature among the top 10 R&D spenders in India. These companies have R&D intensities that are close to or in some cases even well above the global average R&D intensities for their respective sectors.

Some of the other top Indian firms such as Dr Reddy's, Cipla, Maruti Suzuki India and JSW Steel have R&D intensities below the global average R&D intensity for their respective sectors. Top Indian software services firms such as TCS and Infosys have R&D intensities significantly lower than the global average R&D intensity for the software & computer services sector. This is because the global software & computer services sector tends to be dominated by software product firms such as Alphabet, Microsoft and Facebook that have higher R&D intensities.

8.4 | Total Foreign Exchange Spending on Technology Payments by Select Indian Firms



Source: Prowess, data downloaded on 5 November 2020 from the platform; ACE Equity, data downloaded on 5 November 2020 from the platform; Ahmedabad University; Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) 1726 firms have reported foreign exchange spending on technology payments at least once in the five years 2014-15 to 2018-19
(ii) Total excludes firms engaged in mining, quarrying or extraction
(iii) Figures in rupees are converted to dollars using the USD-INR exchange rate of 61.13 calculated as an average for the fiscal year 2014-15, the USD-INR exchange rate of 65.42 calculated as an average for the fiscal year 2015-16, the USD-INR exchange rate of 67.03 calculated as an average for the fiscal year 2016-17, the USD-INR exchange rate of 64.46 calculated as an average for the fiscal year 2017-18 and the USD-INR exchange rate of 69.92 calculated as an average for the fiscal year 2018-19 according to Federal Reserve Bank of St Louis

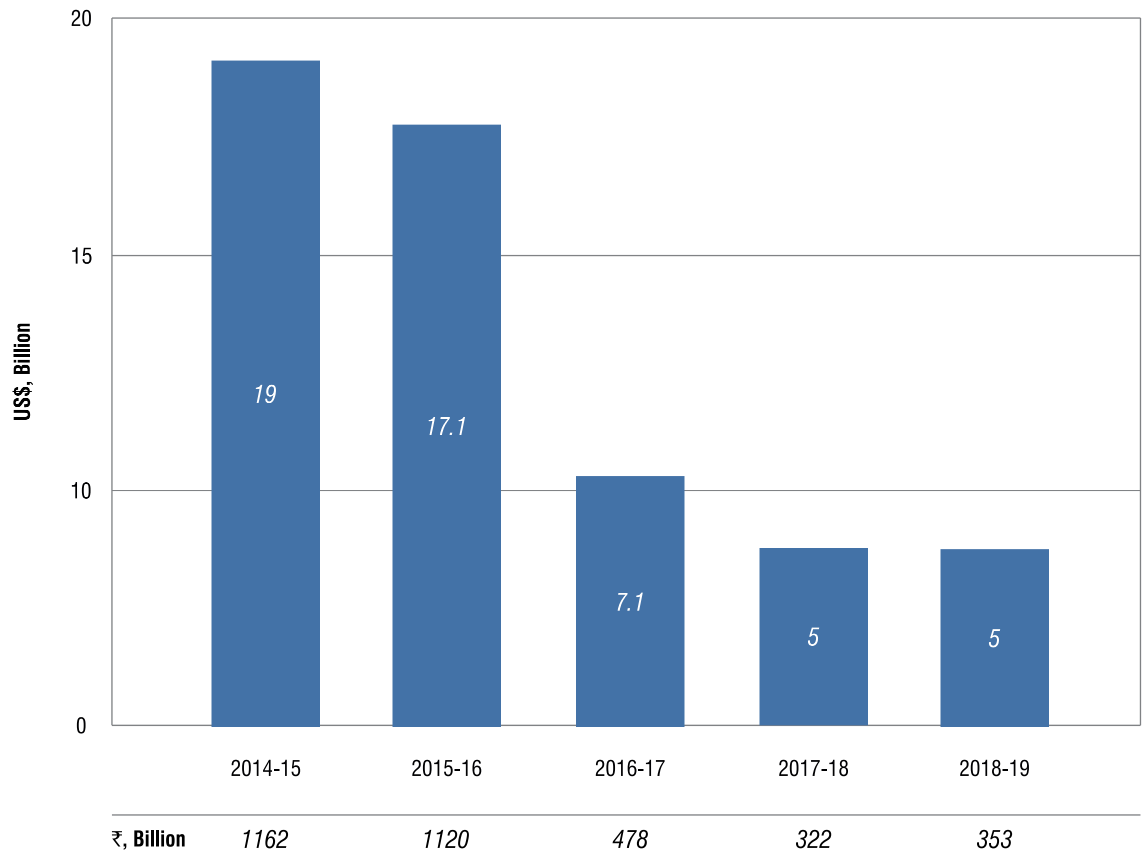
Based on firm level data[4] available for industry, the figure above shows a steady drop for technology payments (that includes royalty and technical fees)[5] between 2014-15 and 2018-19. India's total technology payments on the other hand as reported by the RBI has seen a steady increase over the same period.[6] While there has been a drop in the number of firms over the five years for whom technology payments data is available, it is unclear whether the divergence between the industry level data and the aggregate data has been entirely due to unavailability of firm level data. Currently, a breakdown of RBI's technology payments data by industry is unavailable. Furthermore, it is also difficult to discern from the aggregate level data how much of the payments were towards patented technologies by higher technology or knowledge intensive firms and how much of it may have been towards payments for copyrights and trademarks.

[4] As reported by Prowess and ACE Equity

[5] Also known as 'disembodied technology'

[6] See Indicator 6.5.1

8.5 | Import of Capital Goods by Select Indian Firms



Source: Prowess, data downloaded on 19 October 2020 from the platform; ACE Equity, data downloaded on 19 October 2020 from the platform; Ahmedabad University; Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) 6266 firms have reported foreign embodied technology spending at least once in the five years 2014-15 to 2018-19
(ii) Figures in rupees are converted to dollars using the USD-INR exchange rate of 61.13 calculated as an average for the fiscal year 2014-15, the USD-INR exchange rate of 65.42 calculated as an average for the fiscal year 2015-16, the USD-INR exchange rate of 67.03 calculated as an average for the fiscal year 2016-17, the USD-INR exchange rate of 64.46 calculated as an average for the fiscal year 2017-18 and the USD-INR exchange rate of 69.92 calculated as an average for the fiscal year 2018-19 according to Federal Reserve Bank of St Louis

India's total import of capital goods in 2018-19 was USD 76.5 billion. The commodity-wise breakdown can be found in the Appendix (A.11). The figure above reports data available for 6266 firms for whom import of capital goods has been captured[7] at least once between 2014-15 and 2018-19. The import of capital goods for these firms has been slowing with a sharp drop having been seen in 2016-17 compared to the previous year. There has also been a steady drop in the number of firms over the five years under consideration for whom data on import of capital goods is available.

[7] As reported by Prowess and ACE Equity

8.6 | Global MNCs having R&D Presence in India

Firms	Total R&D Expenditure (US$, Billion)	Share in Total of Top 2500 (%)
Top 2500 global R&D firms	947	100
Top 100 global R&D firms	497	52
92 global R&D Spenders (in top 100 with presence in India*)	465	49
65 global R&D Spenders (in top 100 with R&D centres in India)	350	37

*in the form of either an R&D Centre or a subsidiary

Source: EU Industrial R&D Investment Scoreboard (2019); Ministry of Corporate Affairs (MCA); Various News reports; Company Websites; Centre for Technology, Innovation and Economic Research (CTIER)

Note: Exchange rate used for calculation is from EU Industrial R&D Investment Scoreboard (2019) as on 31st December 2018; 1 EUR = 1.15 USD

The presence of MNC R&D centres in the country has increased from 981 in 2010 to 1,250 in 2019.[8] Although comprehensive data on R&D spending by Multinational Corporation (MNC) R&D centres in India is not available, the Department of Science and Technology (DST) reported the spending of 146 foreign private sector R&D units in India as amounting to USD 945 million[9] in 2017-18.[10] We have estimated MNC R&D expenditure in India through its R&D centres to be around USD 10.5 billion in 2019. This compares to our previous estimate of around USD 8.4 billion in 2016.[11]

We have considered the top 100 global R&D spenders from the list of the top 2,500[12], to arrive at an estimate of the MNC R&D spending in India in 2019. The total R&D expenditure by the top 100 R&D spenders was USD 497 billion that accounted for more than 50 percent of the total R&D expenditure of the top 2,500 global R&D spenders in 2019. Of the top 100 R&D spenders, we were able to verify the presence of 92 MNCs in India, either through a subsidiary or as having a R&D centre in India. Using the Ministry of Corporate Affairs (MCA) database, individual company websites and news reports, we were able to identify the presence of R&D centres in India for 65 of the top 100 global R&D spenders. These 65 MNCs had a total expenditure on R&D amounting to USD 350 billion globally in 2019. Assuming that these 65 firms spend around 3 percent of their global R&D expenditure in India, we arrived at a conservative estimate of at least USD 10.5 billion of R&D expenditure by these firms in the country. Our estimate of USD 10.5 billion for MNC R&D activity in India would possibly be at the lower end of what global MNC R&D centres possibly spend on R&D in India.

[8] India is an R&D hub for MNCs. Will global protectionism play spoilsport? Rishikesha T Krishnan available at https://www.foundingfuel.com/article/india-is-an-rd-hub-for-mncs-will-global-protectionism-play-spoilsport/

[9] Figures in rupees were converted to dollars using the USD-INR exchange rate of 64.46 calculated as an average for the fiscal year 2017-18 based on data from Federal Reserve Bank of St Louis.

[10] S&T Indicators Tables, Research and Development Statistics 2019-20

[11] CTIER Handbook: Technology and Innovation in India 2019

[12] EU Industrial R&D Investment Scoreboard (2019)

8.7 | Startup Sectors Attracting Funding in India

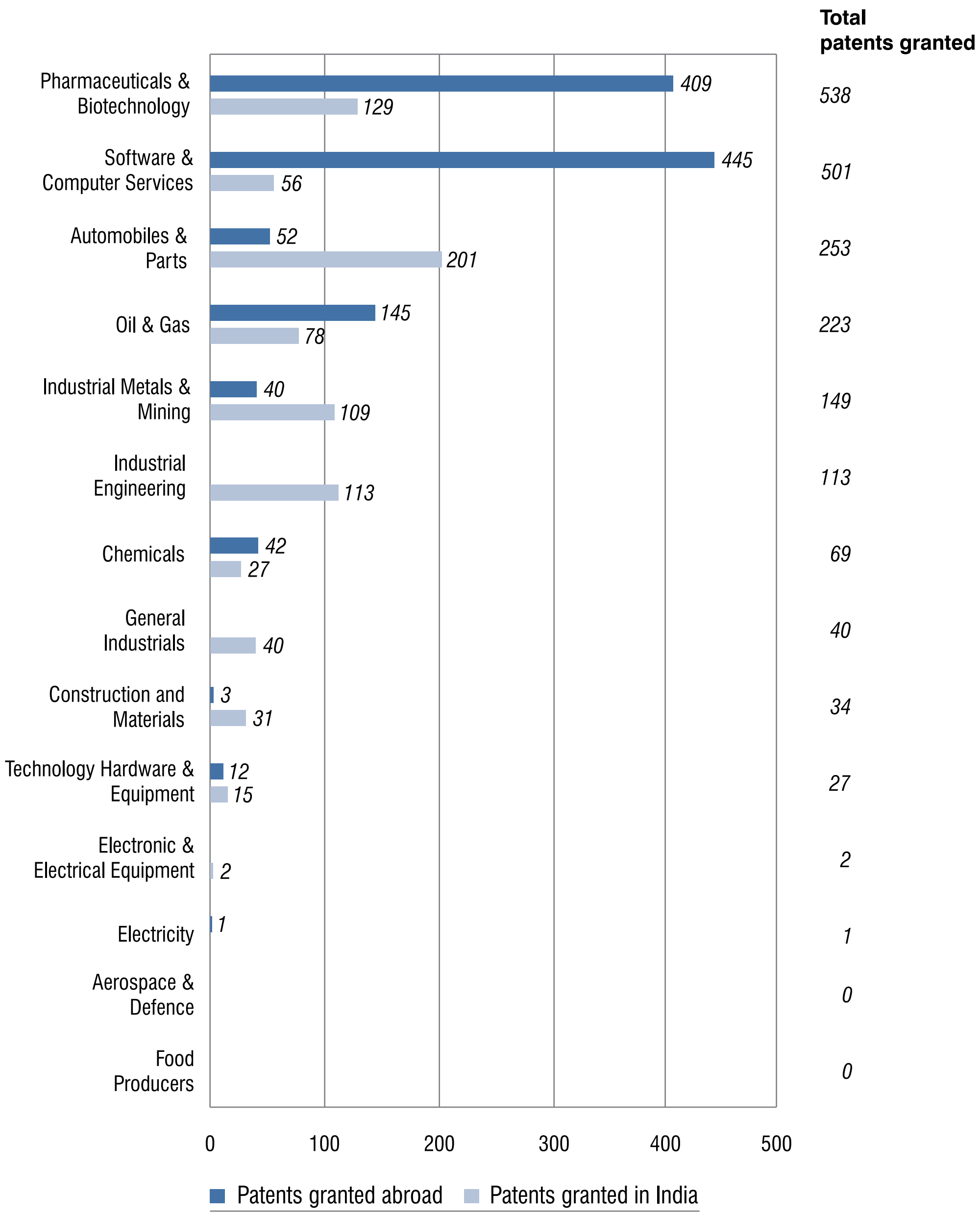
Sector	Total Funding Amount (US$, Million)				
	2015	2016	2017	2018	2019
Consumer	5955	2854	8889	7383	10426
FinTech	1456	656	2747	1717	3986
Retail	3146	1382	4966	2464	3444
Travel and Hospitality Tech	1444	533	1966	1629	3106
Enterprise Applications	1131	663	951	1476	2205
Auto Tech	1333	403	1732	819	2020
Food Tech	539	337	303	2476	1357
Real Estate and Construction Tech	111	206	380	1232	1212
HealthTech	403	220	416	643	978
Gig Economy	1323	257	1702	1534	837
Environment Tech	40	56	33	173	548

Source: Tracxn, data downloaded on 8 September 2020 from the platform

Note: Excludes Debt, Grant and post IPO rounds

According to data from Tracxn, sectors such as consumer, fintech, retail and travel and hospitality tech were among the larger recipients of funding for startups (and new companies), excluding offline companies, in 2019. Sub-sectors like B2C e-commerce and logistics tech dominated the funding landscape for the consumer sector while payments and alternative lending dominated the fintech sector. The retail sector saw B2B e-commerce as a key recipient of funding while online travel and road transport tech were the key sub-sectors for travel and hospitality tech. The online travel and road transport tech sub-sectors also cut across and contributed to the funding received in the consumer sector. The data on funding for sub-sectors can be found in the Appendix (Table A.12).

8.8 | Sectoral Breakdown of Patents Granted to India's Top 100 Industrial R&D Spenders (2019)



Source: XLPAT, data downloaded on 3 November 2020; Centre for Technology, Innovation and Economic Research (CTIER)

The figure above considers the patents granted to India's top 100 R&D spenders, both in India and abroad. There were a total of 1,950 patents granted to India's top R&D spenders in 2018-19. When firm level patent data is aggregated to obtain the number of patents by sector, the sectors that dominate are pharmaceutical & biotechnology and software & computer services. These sectors are followed by automobile & parts and oil & gas. A higher share of patents were granted abroad for the pharmaceutical & biotechnology, software & computer services and the oil & gas sectors, while the automobile & parts sector has a significantly higher share of patents granted by the Indian Patent Office. The aerospace & defence sector, one of the top contributors to India's industrial R&D spending, did not obtain any patents in 2018-19.

8.9 | Top Patentees with the Indian Patent Office (2018- 19)

Top 10 Non Resident Patentees with the Indian Patent Office (2018- 19)

No.	Name of Organisation	Patents Granted
1	Qualcomm Incorporated	416
2	BASF	222
3	Ericsson	179
4	Koninklijke Philips Electronics N.V.	128
5	Siemens	118
6	Huawei Technologies	117
7	Honda Motor Company	109
8	Microsoft Technology Licensing LLC	89
9	General Electric Company	85
10	LG Electronics	82
	Total	**1545**

Source: XLPAT, data downloaded on 26 October 2020; Centre for Technology, Innovation and Economic Research (CTIER)

Note: If a patent was granted to multiple entities or applicants, only the first-named applicant was considered

The table above shows the top 10 non resident patentees with respect to the patents granted by the Indian Patent Office (IPO) in 2018-19. Qualcomm was the largest non-resident patent holder followed by BASF.

Top 10 Indian Resident Patentees with the Indian Patent Office (2018- 19)

No.	Name of Organisation	Patents Granted
1	Council of Scientific & Industrial Research	174
2	Bharat Heavy Electricals Limited	106
3	Indian Institute of Technology	90
4	Tata Motors Limited	88
5	Defence Research & Development Organization	82
6	Tata Steel Limited	71
7	Hindustan Unilever Limited	66
8	TVS Motor Company Limited	65
9	Tata Consultancy Services	50
10	ITC Limited	38
	Total	**830**

Source: XLPAT, data downloaded on 26 October 2020; Centre for Technology, Innovation and Economic Research (CTIER)

Note: If a patent was granted to multiple entities or applicants, only the first-named applicant was considered

The top 10 resident patentees with the Indian Patent Office are captured in the table above. The top patent holder was the Council of Scientific & Industrial Research (CSIR) followed by Bharat Heavy Electricals Limited.

8.10 | Top Patentees with the United States Patent and Trademark Office (USPTO) (2019)

Top Multinational Corporation Patentees (Residents in India) with the United States Patent and Trademark Office (USPTO) (2019)

No.	Name of Organisation	Patents Granted
1	International Business Machines Corporation	589
2	Samsung Electronics Co. Ltd	180
3	Texas Instruments Incorporated	152
4	Honeywell International Inc.	150
5	Adobe Inc.	136
6	Qualcomm Incorporated	122
7	Intel Corporation	115
8	Juniper Networks Inc.	102
9	Hewlett Packard Enterprise Development LP	99
10	Dell Products L.P.	92

Source: XLPAT, 5 October 2020; Centre for Technology, Innovation and Economic Research (CTIER)

The top 10 multinational corporation patentees with the United States Patent and Trademark Office (USPTO) and based in India are largely from sectors such as technology hardware & equipment and software & computer services.

Top 10 Indian (Resident in India) Patentees with the United States Patent and Trademark Office (USPTO) (2019)

No.	Company/Institution Name	Patents Granted
1	Tata Consultancy Services Limited	131
2	Wipro Limited	130
3	Council of Scientific & Industrial Research	82
4	Indian Oil Corporation Limited	23
5	Reliance Industries Limited	22
6	Infosys Limited	18
7	Cognizant Technology Solutions India Pvt. Ltd	17
8	Sun Pharmaceutical Industries Limited	15
9	Cipla Limited	13
10	Indian Institute of Technology Bombay	12

Source: XLPAT, 5 October 2020; Centre for Technology, Innovation and Economic Research (CTIER)

The top 10 Indian patentees with the USPTO comprised firms that have a presence in industrial sectors such as software & computer services, oil & gas and pharmaceuticals & biotechnology. In 2015, the list of top 10 Indian patentees with the USPTO was dominated by the pharmaceuticals & biotechnology sector.[13]

[13] CTIER Handbook: Technology and Innovation in India 2019

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XLPAT (various years). Data downloaded with assistance from XLPAT analyst, data downloaded on 5 October, 26 October and 3 November 2020 from the platform. This is a subscription based database

Section 3

Appendix

Appendix A

Data from Alternate Sources

Table A.1 | Country Comparison of Charges for Use of Intellectual Property (2015)

	Country	Payments (US$, Billion)	Receipts (US$, Billion)
Select Advanced Economies	US	40.6	124.8
	UK	12.9	20.7
	Germany	10.1	24.1
	Japan	17	36.5
Select Emerging/Asian Economies	Brazil	5.3	0.6
	China	22	1.1
	India	5	0.5
	Israel	1.1	1.1
	South Korea	10.1	6.6

Source: Reserve Bank of India (RBI), Balance of Payment (various years) available at https://rbi.org.in/scripts/SDDS_ViewDetails.aspx?Id=5&IndexTitle=Balance+of+ for data on India; World Development Indicators (2015), Indicators, available at http://data.worldbank.org/ for data on Brazil, China, Germany, Japan, South Korea, UK and USA; Centre for Technology, Innovation and Economic Research (CTIER)

Note: (i) Payments for IP here means ''Charges for the use of intellectual property, payments (BoP, current US$)'' in WDI, World Bank.
(ii) Payments for IP here means "Charges for the use of intellectual property, receipts (BoP, current US$)" in WDI, World Bank

Table A.2 | Annual Foreign Direct Investment into India by Components

Year	Equity Inflows				Reinvested earnings	Other capital	Gross Inflows/Gross Investments
	Government (SIA/FIPB)	RBI	Acquisition of shares	Equity capital of unincorporated bodies			
2014-15	2219	22530	6185	952	8983	3423	44291
2015-16	3574	32494	3933	1111	10413	4034	55559
2016-17	5900	30417	7161	1223	12343	3176	60220
2017-18	7797	29569	7491	664	12542	2911	60974
2018-19	2429	36315	5622	689	13672	3274	62001

Source: RBI Bulletin (various years) available at https://www.rbi.org.in/Scripts/BS_ViewBulletin.aspx; Centre for Technology, Innovation and Economic Research (CTIER)

Table A.3 | FDI Equity Inflows into India by Sector - Top 10 Based on 2018-19

No.	Sector	2017-18 (₹, Billion)	2017-18 (US$, Million)	2018-19 (₹, Billion)	2018-19 (US$, Million)
1	Services Sector*	432	6709	639	9158
2	Computer Software & Hardware	397	6153	453	6415
3	Trading	281	4348	310	4462
4	Telecommunications	397	6212	183	2668
5	Automobile Industry	135	2090	183	2623
6	Construction (Infrastructure Activities)	176	2730	159	2258
7	Chemicals (Other Than Fertilizers)	84	1308	137	1981
8	Non-conventional Energy	78	1204	101	1446
9	Information & Broadcasting (Including Print Media)	41	639	89	1252
10	Power	105	1621	73	1106
	Total for top 10 sectors	2126	33013	2327	33370
	Grand total	2889	44857	3099	44366

*Services sector includes Financial, Banking, Insurance, Non-Financial / Business, Outsourcing, R&D, Courier, Tech. Testing and Analysis
Source: Quarterly FDI factsheet, Department for Promotion of Industry and Internal Trade (DPIIT), (various years); Centre for Technology, Innovation, and Economic Research (CTIER)

Table A.4 | Total Funding for Startups (and New Companies) by Type of Financing

Total Round Amount (US$, Million)	2015	2016	2017	2018	2019
Angel	151	177	178	222	78
Conventional Debt	5535	11469	12494	14544	12677
Venture Debt	453	54	66	102	164
Mezzanine Debt	0	0	0	0	0
Other Debt	578	3130	0	0	0
Grant (prize money)	21	3	8	16	16
PE	1198	996	1187	1620	651
Post IPO	2907	4148	12769	6352	6088
Seed	400	399	408	425	544
Series A	1399	1321	1035	1316	1597
Series B	1402	1167	2014	2004	3001
Series C	1711	752	1472	2605	2618
Series D	1148	1026	1082	1816	3883
Series E	1187	771	313	2328	963
Series F	607	205	1810	877	3090
Series G	560	0	468	750	2394
Series H	150	219	17	1152	150
Series I	760	0	1100	267	104
Series J	0	4	3900	33	479
Unattributed	10	0	0	0	0

Source: Tracxn (Data downloaded on 8 September 2020 from the platform)

Table A.5 | Venture Capital Funding by Source of Data

	2015	2016	2017	2018	2019
Tracxn	9323	5864	13618	13573	18823
NSF	8038	3382	10477	5834	-

Source: S&E Indicators Report 2020, National Science Foundation; Tracxn (Data downloaded on 9 September 2020 from the platform)

Table A.6 | Country-wise Comparisons by Share of Publications, Impact, Share of Industry-Academia Collaborations and Share of International Collaborations in Total Publications including ESCI Journals (2015-19)

	Country	Global Rank	Share in Global Publication Output (%)	Category Normalized Citation Impact	Share of Industry-Academia Collaborations (%)	Share of International Collaborations (%)
Select Advanced Economies	USA	1	24.9	1.3	3.3	31.6
	UK	3	7.5	1.4	3.5	49.9
	Germany	5	5.9	1.3	4.7	50.6
	Japan	7	4.2	0.9	4.4	28.8
Select Emerging Economies	Brazil	14	2.5	0.8	1.3	32.2
	China	2	15.3	1.1	1.7	24
	India	6	4.3	0.8	0.8	19.8
	Israel	33	0.8	1.4	2.9	48
	South Korea	13	2.8	1	3.5	28

Source: InCites (based on data from Web of Science), data downloaded from the platform on 9 October 2020; Centre for Technology, Innovation and Economic Research (CTIER)

Note: Data is based on cumulative publications by each country (2015 - 2019)

Table A.7 | Country Comparisons for Patents Granted Abroad

	Country	2009	2014	2018
Select Advanced Economies	US	75764	110036	144669
	UK	10777	16505	19610
	Germany	43205	59413	69973
	Japan	91089	119270	131628
Select Emerging/Asian Economies	Brazil	391	940	910
	China	3109	13665	31346
	India	1461	4292	6039
	Israel	2722	5256	6740
	South Korea	21675	30100	42685

Source: World Intellectual Property Organization (WIPO) IP Statistics Data Center, available at https://www3.wipo.int/ipstats/index.htm?tab=patent

Table A.8 | Select Policies Introduced by Union Territories

Union Territory	Industrial Policy	IT, ITeS, ICT, Electronics, ESDM Policy	Startup Policy	Renewable Energy Policy
Andaman and Nicobar Islands	-	IT and ITeS (2009 Draft)	2018	-
Chandigarh*	2015	ICT (2011), IT and Electronics (2013)	-	-
Dadra & Nagar Haveli**	2018	-	-	2018
Lakshadweep	-	-	-	-
Puducherry	2016	IT (2017-22)	2019	Solar (2015)

*Year of the Biotechnology policy for Chandigarh could not be verified.
**Industrial Policy for Dadra & Nagar Haveli is a combined policy for the UTs of Daman & Diu and Dadra & Nagar Haveli.
Source: Startup India Hub, available at: https://www.startupindia.gov.in/; Invest India, available at: https://www.investindia.gov.in/; Various State Government Websites; Centre for Technology, Innovation and Economic Research (CTIER)

Table A.9 | New Companies Registered with the Ministry of Corporate Affairs (MCA)

State	2018-19	2017-18
Andaman & Nicobar	42	55
Andhra Pradesh	3056	2797
Arunachal Pradesh	40	42
Assam	797	679
Bihar	4044	3734
Chandigarh	592	571
Chattisgarh	754	620
Dadra & Nagar Haveli	38	41
Daman and Diu	25	29
Delhi	18973	20031
Goa	478	471
Gujarat	7871	7906
Haryana	6493	5693
Himachal Pradesh	488	444
Jammu & Kashmir	579	501
Jharkhand	1642	1489
Karnataka	12794	12288
Kerala	5572	4969
Lakshadweep	4	1
Madhya Pradesh	3133	2926
Maharashtra	30253	29761
Manipur	199	140
Meghalaya	34	36
Mizoram	22	16
Nagaland	31	24
Orissa	2262	1908
Pondicherry	143	139
Punjab	1776	1698
Rajasthan	4331	4089
Sikkim	2	6
Tamil Nadu	9098	8695
Telangana	9419	8585
Tripura	107	52
Uttar Pradesh	13662	12324
Uttarakhand	1182	1072
West Bengal	7601	7177

Source: Ministry of Corporate Affairs (MCA), Government of India, available at http://www.mca.gov.in/MinistryV2/incorporatedorclosedduringthemonth.html, Centre for Technology, Innovation and Economic Research (CTIER)

Table A.10 | State-wise Number of Incubation Centres

State	No. of Incubation Centres in State	No. of Incubators at Academic Institutions
Andhra Pradesh	7	4
Assam	6	5
Bihar	3	1
Chandigarh	1	1
Chhattisgarh	2	0
Delhi	20	13
Goa	5	3
Gujarat	19	14
Haryana	10	3
Himachal Pradesh	1	1
Jammu & Kashmir	3	2
Jharkhand	2	1
Karnataka	38	15
Kerala	12	6
Madhya Pradesh	10	5
Maharashtra	29	13
Mizoram	2	2
Manipur	1	0
Odisha	3	3
Puducherry	1	1
Punjab	6	6
Rajasthan	8	7
Sikkim	1	1
Tamil Nadu	41	36
Telangana	18	12
Uttar Pradesh	24	16
Uttarakhand	2	2
West Bengal	7	5
Total	**282**	**178**

Source: Technology Business Incubator (TBI), National Science and Technology Entrepreneurship Development, Department of Science and Technology available at http://www.nstedb.com/institutional/tbi-list.htm; Knowledge Bank, Agnii, Government of India available at https://www.agnii.gov.in/learning?from=blog&id=5; Technology Incubation and Development of Entrepreneurs (TIDE), Ministry of Electronics and Information Technology available at https://meity.gov.in/content/technology-incubation-and-development-entrepreneurs; Selected Atal Incubation Centres, Atal Innovation Mission, NITI Aayog available at https://aim.gov.in/selected-atal.php; Biotech Parks and Incubators, Department of Biotechnology available at http://dbtindia.gov.in/schemes-programmes/translational-industrial-development-programmes/biotech-parks-incubators; Bioincubators Nurturing Entrepreneurship for Scaling Technologies, BIRAC, Department of Biotechnology available at https://birac.nic.in/bionest.php; Centre for Technology, Innovation and Economic Research (CTIER)

Table A.11 | India's Import of Capital Goods by Commodity

HS Code	Product Name	US$, Billion				
		2014-15	2015-16	2016-17	2017-18	2018-19
84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof	25.3	26	25.3	29.7	34.7
85	Electrical machinery and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers,and parts	10.6	12.5	13.9	16.2	16.9
87	Vehicles other than railway or tramway rolling stock, and parts and accessories thereof	3.8	4	3.7	4.6	4.7
88	Aircraft, spacecraft, and parts thereof	2.9	3.1	6.3	6.4	7.1
89	Ships, boats and floating structures	3.5	3.6	4.8	3.8	4.8
90	Optical, photographic cinematographic measuring, checking precision, medical or surgical inst. and apparatus parts and accessories thereof	5.7	5.8	5.9	6.8	7.5
	Others	0.6	0.7	0.6	0.7	0.9
	Total	**52.3**	**55.6**	**60.5**	**68.2**	**76.5**

Source: Import - Commodity-wise, Export Import Data Bank, Department of Commerce, Government of India available at https://commerce-app.gov.in/eidb; World Integrated Trade Solution (WITS) available at https://wits.worldbank.org/Product-Metadata.aspx?lang=en; Centre for Technology, Innovation and Economic Research (CTIER)

Table A.12 | Funding for Indian Technology Startups for Select Sectors

Total Funding (US$, Million)*	2015	2016	2017	2018	2019
B2C E-Commerce	3095	1668	2567	4972	5551
Payments	1220	266	1615	694	2392
Online Travel	307	445	432	1300	1851
Logistics Tech	718	367	351	2166	1317
Road Transport Tech	1160	129	1540	416	1271
B2B E-Commerce	45	154	253	437	997
Alternative Lending	137	296	261	562	724
Electric Vehicles	15	37	20	157	476

*Excludes Debt, Grant and post IPO rounds
Source: Tracxn (Data downloaded on 18 September 2020 from the platform); Centre for Technology, Innovation and Economic Research (CTIER)

Table A.13 | Exchange Rates

Indicator Name	Indicator Number	Exchange Rate used for converting to USD	Period	Source
R&D Expenditure by Select Key Scientific Agencies under Government of India	3.3	1 USD = 47.4 INR	April 1 2009 to March 31 2010	Federal Reserve Bank St.Louis
		1 USD = 61.1 INR	April 1 2014 to March 31 2015	
		1 USD = 64.5 INR	April 1 2017 to March 31 2018	
Sector-wise Global Industrial R&D Expenditure and Country-wise Number of Firms (2019)	3.4	1 EUR = 1.15 USD	31 December 2018	EU Industrial R&D Investment Scoreboard
Total Industrial R&D Expenditure in India	5.1	1 USD = 45.91 INR	April 1 2008 to March 31 2009	Federal Reserve Bank St.Louis
		1 USD = 60.42 INR	April 1 2013 to March 31 2014	
		1 USD = 69.92 INR	April 1 2018 to March 31 2019	
CTIER's Top 100 Industrial R&D spenders in India (2018-19)	5.2	1 USD = 69.51 INR	31 December 2018	EU Industrial R&D Investment Scoreboard
Total Foreign Exchange Spending on Technology Payments	5.4	1 USD = 61.13 INR	April 1 2014 to March 31 2015	Federal Reserve Bank St.Louis
		1 USD = 65.42 INR	April 1 2015 to March 31 2016	
		1 USD = 67.03 INR	April 1 2016 to March 31 2017	
		1 USD = 64.46 INR	April 1 2017 to March 31 2018	
		1 USD = 69.92 INR	April 1 2018 to March 31 2019	
Import of Capital Goods by Indian Industry	5.5	1 USD = 61.13 INR	April 1 2014 to March 31 2015	Federal Reserve Bank St.Louis
		1 USD = 65.42 INR	April 1 2015 to March 31 2016	
		1 USD = 67.03 INR	April 1 2016 to March 31 2017	
		1 USD = 64.46 INR	April 1 2017 to March 31 2018	
		1 USD = 69.92 INR	April 1 2018 to March 31 2019	
Global MNCs having R&D presence in India	5.6	1 EUR = 1.15 USD	31 December 2018	EU Industrial R&D Investment Scoreboard

Appendix B

Glossary

Serial No.	Term	Definition
B.1	Category Normalized Citation Impact (CNCI)	The Category Normalized Citation Impact (CNCI) of a document is calculated by dividing the actual count of citing items by the expected citation rate for documents with the same document type, year of publication and subject area. When a document is assigned to more than one subject area, an average of the ratios of the actual to expected citations is used. The CNCI of a set of documents, for example, the collected works of an individual, institution or country, is the average of the CNCI values for all the documents in the set. For a single paper that is only assigned to one subject area, this can be represented as: NCI = c/ eftd, where: e = the expected citation rate or baseline, c = Times Cited, f = the field or subject area, t = year, d = document type. For a single paper that is assigned to multiple subjects, the CNCI can be represented as the average of the ratios for of actual to expected citations for each subject area. And for a group of papers, the CNCI value is the average of the values for each of the papers. A CNCI value of one represents performance at par with world average, values above one are considered above average and values below one are considered below average. A CNCI value of two is considered twice world average.
B.2	Charges for the use of intellectual property, Payments	Charges for the use of intellectual property are payments and receipts between residents and nonresidents for the authorized use of proprietary rights (such as patents, trademarks, copyrights, industrial processes and designs including trade secrets, and franchises) and for the use, through licensing agreements, of produced originals or prototypes (such as copyrights on books and manuscripts, computer software, cinematographic works, and sound recordings) and related rights (such as for live performances and television, cable, or satellite broadcast). Data are in current U.S. dollars.
B.3	Foreign Direct Investment	Foreign Investment means any investment made by a person resident outside India on a repatriable basis in capital instruments of an Indian company or to the capital of an Limited Liability Partnership (LLP). Foreign Direct Investment (FDI) is the investment through capital instruments by a person resident outside India (a) in an unlisted Indian company; or (b) in 10 percent or more of the post issue paid-up equity capital on a fully diluted basis of a listed Indian company. There are two routes under which foreign investment can be made: automatic and government. Under the automatic route, foreign Investment is allowed under the automatic route without prior approval of the Government or the Reserve Bank of India, in all activities/ sectors as specified in the Regulation 16 of Foreign Exchange Management Act, 1999 (FEMA) 20 (R). And for the government route, foreign investment in activities not covered under the automatic route requires prior approval of the Government.
B.4	Full-time equivalent (FTE) of R&D personnel	The Full-time equivalent (FTE) of R&D personnel is defined as the ratio of working hours actually spent on R&D during a specific reference period (usually a calendar year) divided by the total number of hours conventionally worked in the same period by an individual or by a group.
B.5	Gross Enrolment Ratio in Higher Education	Students enrolled in higher education as a percentage of population between 18-23 years of age.
B.6	High and Medium High Technology (HMT) (Also referred to as Higher Technology)	The OECD definition for High and Medium high technology (HMT) manufacturing is defined in ISIC Rev.4 as Chemicals and chemical products (Division 20), Pharmaceutical products (21), Computer, electronic and optical products (26), Electrical equipment (27), Machinery and equipment n.e.c. (28), Motor vehicles, trailers and semi-trailers (29) and Other transport equipment (30)

	Source	Link	Indicator Numbers
	Clarivate Analytics, InCites Indicators Handbook		6.11, 6.12, 6.12.1, 6.13
	World Bank, World Development Indicators	http://databank.worldbank.org/data/metadataglossary/all/series	6.5, 6.5.1, 8.4
	Reserve Bank of India	https://www.rbi.org.in/scripts/FAQView.aspx?Id=26	6.6, 6.6.1, 7.3
	UNESCO Institute for Statistics	http://data.uis.unesco.org/	6.8, 6.10
	All India Survey on Higher Education (2018-19), Ministry of Human Resource Development	http://aishe.nic.in/aishe/viewDocument.action?documentId=262	7.6
	OECD	https://doi.org/10.1787/5jlv73sqqp8r-en.	7.1, 7.2, 7.2.1

Serial No.	Term	Definition	
B.7	High technology Exports	High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery. The original high-tech products classification is based on SITC Rev. 3 and is taken from Table 4 of Annex 2 of the 1997 working paper of Thomas Hatzichronouglou, OECD.	
B.8	Industry - Academia Collaborations	An industry collaborative publication is one that lists its organization type as “corporate” for one or more of the co-author’s affiliations. The % of Industry Collaborations is the number of industry collaborative publications for an entity (as described above) divided by the total number of documents for the same entity represented as a percentage.	
B.9	Industry Classification Benchmark	The Industry Classification Benchmark (ICB) is a detailed and comprehensive structure for sector and industry analysis, facilitating the comparison of companies across four levels and across national boundaries. The classification system allocates companies to the subsector whose definition closely describes the nature of its business as determined by the source of its revenue or the source of the majority of its revenue, and the appropriate sector, supersector and industry classification automatically results.	
B.10	Institute of National Importance (INI)	An Institution established by Act of Parliament and declared as Institution of National Importance such as All Indian Institute of Technology (IIT), National Institute of Technology (NIT).	
B.11	Knowledge Intensive(KI)	The OECD definition for Knowledge Intensive (KI) sectors is defined in ISIC Rev.4 as Publishing activities (58), IT and other information services (62-63) and Scientific research and development (72)	
B.12	National Industrial Classification	National Industrial Classification 2008 (NIC-2008) is a revised version of NIC-2004. The 38th session of the UN Statistical Commission recommend that countries should make an effort either to adopt national versions of the ISIC, Revision 4, or to adjust their national classifications in such a way that data can be presented according to the categories of the ISIC, 10 Revision 4. Specifically, countries should be able to report data at the two-digit (division) level of the Classification without a loss of information; that is, national classifications should be fully compatible with this level of the ISIC, or it should be possible to arrange them.	
B.13	National Institute Rankings Framework	The National Institutional Ranking Framework (NIRF) was approved by the MHRD and launched by Honourable Minister of Human Resource Development on 29th September 2015. This framework outlines a methodology to rank institutions across the country. The methodology draws from the overall recommendations broad understanding arrived at by a Core Committee set up by MHRD, to identify the broad parameters for ranking various universities and institutions. The parameters broadly cover “Teaching, Learning and Resources,” “Research and Professional Practices,” “Graduation Outcomes,” “Outreach and Inclusivity,” and “Perception”.	
B.14	Non Resident Patents	The terms “non-resident” and “abroad” both relate to filings in a foreign office. However, we use the term “non-resident” for statistics by office, while use the term “abroad” for statistics by origin. In other words, when an office receives an application filed by a foreigner, it’s a non-resident filing for that office. By contrast, when an applicant files an application at a foreign office, it’s a filing abroad from the applicant’s origin.	

	Source	Link	Indicator Numbers
	World Bank, World Development Indicators	http://databank.worldbank.org/data/metadataglossary/all/series	6.22
	Clarivate Analytics, InCites Indicators Handbook		6.11, 6.12, 6.12.1, 6.13
	FTSE Russell	https://research.ftserussell.com/products/downloads/Glossary.pdf	6.4, 6.4.1, 8.2, 8.3, 8.8
	All India Survey on Higher Education (2018-19), Ministry of Human Resource Development	http://aishe.nic.in/aishe/viewDocument.action?documentId=262	7.9
	OECD	https://doi.org/10.1787/5jlv73sqqp8r-en.	7.1, 7.2, 7.2.1
	Ministry of Statistics and Programme Implementation, National Industrial Classification (2008)	http://mospi.nic.in/classification/national-industrial-classification	
	National Institute Ranking Framework (NIRF) Rankings (2019)	https://www.nirfindia.org/OverallRanking.html	7.8
	WIPO	http://www.wipo.int/ipstats/en/help/	6.15, 6.16, 6.17, 6.20, 6.21, 8.9

Serial No.	Term	Definition
B.15	Patents	A patent is an exclusive right granted for an invention, which is a product or a process that provides, in general, a new way of doing something, or offers a new technical solution to a problem. To get a patent, technical information about the invention must be disclosed to the public in a patent application.
B.16	Pupil Teacher Ratio in Higher Education	The ratio of students in a particular academic institution to the teachers/ instructors employed at that institution. Takes into account all institutions - university, colleges and stand-alone institutions in both regular and distant mode.
B.17	R&D intensity	R&D intensity is the ratio between R&D investment and net sales of a given company or group of companies. At the aggregate level, R&D intensity is calculated only by those companies for which data exist for both R&D and net sales in the specified year. The calculation of R&D intensity in the Scoreboard is different from than in official statistics, e.g. BES-R&D, where R&D intensity is based on value added instead of net sales.
B.18	Research & Development Expenditure	Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge.
B.19	Researchers per million inhabitants	Number of professionals engaged in the conception or creation of new knowledge (who conduct research and improve or develop concepts, theories, models, techniques instrumentation, software or operational methods) during a given year expressed as a proportion of a population of one million.
B.20	Resident Patents	The term “resident” is used for filings made by applicants at their home office. The home office can be a national office and/or a regional office. The resident figures by origin may thus correspond to the sum of filings made at a national and a regional office.
B.21	Science & Engineering (S&E) PhDs	S&E PhDs, as defined by the NSF, includes Physical and Biological Sciences and Mathematics and Statistics, Computer Sciences, Agricultural Sciences, Engineering, and Social and Behavioural Sciences. S&E subjects considered by OECD are based on the ISCED 2011 classification and include Social sciences, journalism and information, Natural sciences, mathematics and statistics, Information and Communication Technologies, Engineering, manufacturing and construction, Agriculture, forestry, fisheries and veterinary.
B.22	Startup	Startup means an entity, incorporated or registered in India: a) Upto a period of ten years from the date of incorporation/ registration, if it is incorporated as a private limited company (as defined in the Companies Act, 2013) or registered as a partnership firm (registered under section 59 of the Partnership Act, 1932) or a limited liability partnership (under the Limited Liability Partnership Act, 2008) in India. b) Turnover of the entity for any of the financial years since incorporation/ registration has not exceeded one hundred crore rupees. c) Entity is working towards innovation, development or improvement of products or processes or services, or if it is a scalable business model with a high potential of employment generation or wealth creation. Provided that an entity formed by splitting up or reconstruction of an existing business shall not be considered a ‘Startup’.

	Source	Link	Indicator Numbers
	WIPO	http://www.wipo.int/patents/en/	6.15, 6.16, 6.17, 6.18, 6.19, 6.20, 6.21, 7.10, 8.8, 8.9, 8.10
	All India Survey on Higher Education (2018-19), Ministry of Human Resource Development	http://aishe.nic.in/aishe/viewDocument.action?documentId=262	7.7
	The 2019 EU Industrial R&D Scoreboard	https://iri.jrc.ec.europa.eu/scoreboard/2019-eu-industrial-rd-investment-scoreboard	8.3
	OECD, Frascati Manual 2015	https://www.oecd.org/sti/frascati-manual-2015-9789264239012-en.htm	6.1, 6.2, 6.2.1, 6.3, 6.4, 6.4.1, 8.1, 8.2, 8.3
	UNESCO Institute for Statistics	http://data.uis.unesco.org/	6.8
	WIPO	http://www.wipo.int/ipstats/en/help/	6.15, 6.16, 6.17, 6.20, 6.21, 8.9, 8.10
	NSF, OECD	https://ncses.nsf.gov/pubs/nsb20197/data#supplemental-tables https://stats.oecd.org/Index.aspx?DataSetCode=EDU_GRAD_FIELD#	6.9, 6.9.1, 6.9.2
	Department for Promotion of Industry and Internal Trade, G.S.R. notification 127 (E)	https://www.startupindia.gov.in/content/dam/invest-india/Templates/public/198117.pdf	6.7.1, 6.7.2, 7.4, 7.4.1, 8.7

About CTIER

The Centre for Technology, Innovation and Economic Research (CTIER) is working to raise the level of debate and awareness amongst policy makers, industry and researchers in India about the essential role of technical capability in economic development, and how it is best fostered. The Centre is committed to improving the quality of India's R&D and innovation data, assessing the impact of policy measures introduced to promote R&D and identify ways to create systemic change in India's R&D and innovation system. We aim to inform policy making on the back of high quality empirical economic research, as well as impact higher education in India.

Our Team

Dr. Naushad Forbes

Dr. Naushad Forbes is the Co - Chairman of Forbes Marshall, India›s leading Steam Engineering and Control Instrumentation firm. He is Chairman, Centre for Technology, Innovation and Economic Research (CTIER), Ananta Aspen Centre and Bharatiya Yuva Shakti Trust (BYST).

Forbes Marshall's deep process knowledge helps their customers save energy, improve product quality, increase process efficiency, and run a clean and safe factory. Forbes Marshall has consistently ranked amongst India's Great Places to Work.

Naushad was an occasional Lecturer and Consulting Professor at Stanford University from 1987 to 2004 where he developed courses on Technology in Newly Industrializing Countries. He received his Bachelors, Masters and PhD Degrees from Stanford.

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Farhad is Co-Chairman of Forbes Marshall. He has been at Forbes Marshall since 1982. Previously, he was a member of the R&D technical staff of Hewlett-Packard Company in Palo Alto, California. He is presently Chairman and Board member of Family Business Network - International (FBN-I), an association of 3500 family businesses from 65 countries with 17,000 individual members. He is also currently Chairman of the CII National Committee on Affirmative Action, and is a past Chairman of CII western region and a past Chairman of the CII-FBN India chapter. He is a past member of the Advisory Council of the Graduate School of Business at Stanford University, and a member of the Advisory Board of the MSx Program (formerly known as the Sloan Program) at Stanford University's Graduate School of Business.

He received his B.S. in 1977 and his M.S. in 1979 in Electrical Engineering from Stanford University. He received his M.S. in Management in 1991 from the Sloan Master's Program at the Graduate School of Business at Stanford University.

Janak Nabar

Janak is CEO of the Centre for Technology, Innovation and Economic Research (CTIER), and has been leading CTIER's research efforts. Janak is a member of the CII National Committee on Technology and the Expert Group on Technology. He has been part of working groups constituted by NITI Aayog to rank national R&D laboratories and develop the India Innovation Index. More recently, he was a member of the drafting committees for the Science, Technology and Innovation Policy 2020.

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Professor Chandra was a member of the Government of India Committee on Rejuvenation of Higher Education (Yashpal Committee) that relooked at the Indian Higher Education system as well as the Committee on the Autonomy of Central Institutions. He was also a member of the Telecom Regulatory Authority of India (TRAI).

Professor Chandra's research and teaching interests include Manufacturing Management, Supply Chain Coordination, Building Technological Capabilities, Higher Education Policy, and Hi-tech Entrepreneurship. His recent book titled 'Building Universities that Matter' studies issues of Governance, Change and Institution Building in Indian Universities. He serves on the board of several firms and institutions.

Prof. Rakesh Basant

Dr. Rakesh Basant is a professor of Economics at the Indian Institute of Management, Ahmedabad. He has taught at universities abroad and worked as a consultant to several international organizations.

Prof. Basant's current teaching and research interests focus on firm strategy, innovation, intellectual property rights, entrepreneurial business models, public policy & regulation. His recent research has focused on capability building processes in industrial clusters, Foreign Direct Investment in R&D, innovation-internationalization linkages, competition policy, inter-organizational linkages for technology development (especially academia-industry relationships), incubation models in higher education institutions, emerging entrepreneurial patterns and eco-system in India, strategic and policy aspects of intellectual property rights, linkages between public policy and technological change, economics of strategy, the small scale sector in India and policy issues in higher education.

His sectoral focus of the research in the aforementioned areas has been on Pharmaceutical, IT, Electronics and Auto-component industries. He was also a member of the Indian Prime Minister's High-Level Committee (also known as Sachar Committee) that wrote a report on the Social, Economic and Educational Conditions of Muslims in India. In continuation of this work, a part of his current research focuses on issues relating to Muslims, especially affirmative action in higher education.

Prof. Sunil Mani

Dr. Sunil Mani is Director and NITI Aayog Chair Professor at the Centre for Development Studies, Trivandrum, Kerala, India. Earlier he has been a visiting professor at the National Graduate Institute for Policy Studies, Tokyo, Japan, Bocconi University, Milan, Italy, the University of Toulouse-Jean Jaurès, Toulouse, France and the Indian Institute of Management Calcutta, Kolkata, India and has also worked at the United Nations University- MERIT, Maastricht, The Netherlands as a researcher and head of graduate studies.

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Prof. Mani is specialized in the economics and policy studies of innovation and one of his most recent publications include a book with Professor Richard Nelson of Columbia University, TRIPS Compliance, National Patent Regimes and Innovation, Evidence and Experience from Developing Countries, Cheltenham, UK and Northampton, Mass, USA., 2013.