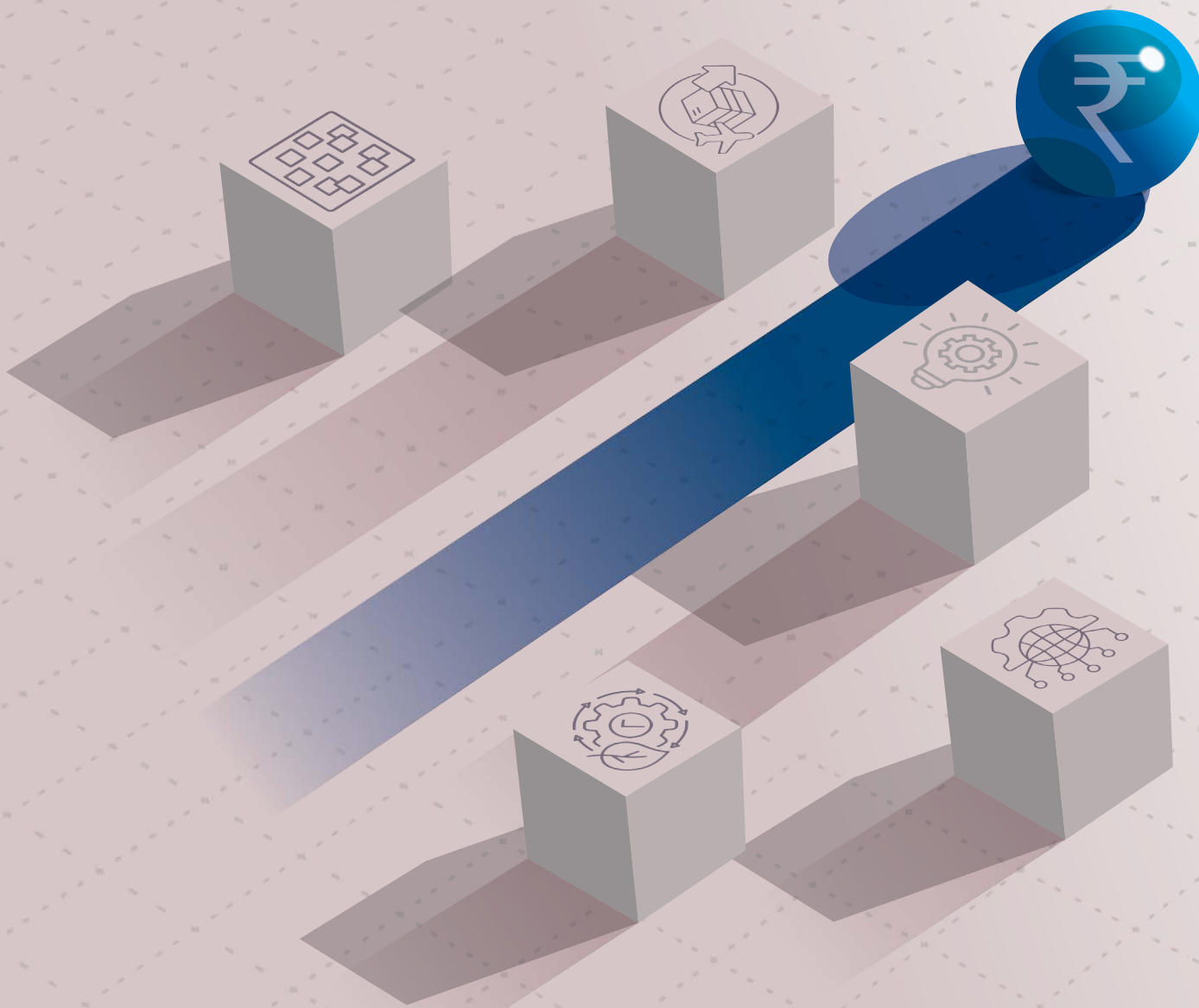


CTIER Innovation Report

Industry in India: Followers or Leaders?



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

Contents

Foreword	4		
Acknowledgements	5		
1. Introduction	6		
Followers or leaders?	9		
2. Industrial R&D in India	14		
The structure of industrial R&D in India differs vastly from the world	15		
Indian firms are profitable but not investing enough of their profits in R&D	17		
Indian firms need to tap more into global markets	17		
Indian firms must gain a better understanding of intellectual property management	19		
Realising India's R&D ambitions	21		
3. Digital Adoption and Innovation in Indian Industry	22		
AI is helping redefine Indian industry's value chain	23		
AR/VR is providing immersive experiences to customers and employees	25		
		IoT is transforming operations and impacting product and service offerings	26
		Nascent adoption of digital twins and other digital technologies	26
		4. Disruptive Trends in Industrial R&D	28
		Boundaries between sectors are blurring	33
		Emerging technologies are disrupting how firms conduct research	35
		Sustainability is a driver in the technologies being developed	36
		5. The R&D Talent Imperative	39
		R&D teams in Indian firms	40
		Global hiring practices	41
		6. What must Indian Industry do?	46
		Sources and notes	49
		About CTIER	52

About the cover

The grid provides the reader a visual aid to understand Indian industry across various parameters. The choice of sphere and cubes signifies the pace of growth and resistance faced on each parameter. The blue sphere is intended to signify that top Indian R&D firms are fairly profitable, and are comparable to their global peers. These profits have not translated into investments that would make Indian industry more competitive on the innovation front. The other five parameters, R&D, adoption of digital technologies across the value chain, exports, use of data and sustainability are represented by cubes, signifying the need for adequate attention lest they remain a drag on the competitiveness of Indian industry.

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Foreword

Innovation largely happens in firms. Firms invest in R&D. The returns on investment in R&D is visible in the growth trajectories of firms. Korean and Chinese firms have often used their demanding buyers overseas for technology that made them world competitive. By way of comparison, many of our large Indian firms are just as profitable as their international peers; they just invest little in R&D.

Where do the next big opportunities for Indian industry lie? The global industrial R&D landscape is changing. Funding cuts in the United States, widespread pressure on immigration and shifting geopolitical priorities provide Indian firms with an opportunity to become more competitive and attract Indian talent back.

What stops Indian firms from investing in house R&D? Are Indian firms followers or leaders? This inaugural edition of the CTIER Innovation Report seeks to provide an understanding of where top Indian R&D firms stand relative to their global peers across a number of indicators such as profitability, R&D intensity, exports and patents. We seek to understand how firms are adopting digital technologies across the value chain, including the use of AI. We highlight the opportunities and risks that firms face as a result of blurring industry boundaries. We identify key technologies being worked on for a more sustainable future. And we point to the lessons that the hiring practices of global R&D firms offer Indian firms, both in terms of diversity of roles and diversity in talent.

The potential of our firms to lead in technology is real. I hope the report offers valuable insights for industry leaders considering areas where Indian industry can lead and how we can become more competitive through an increased focus on R&D, digital adoption across the value chain and nurturing multidisciplinary R&D teams.

Naushad Forbes

Chairman CTIER, Co-Chairman Forbes Marshall, Past President CII

Pune, July 2025

Acknowledgements

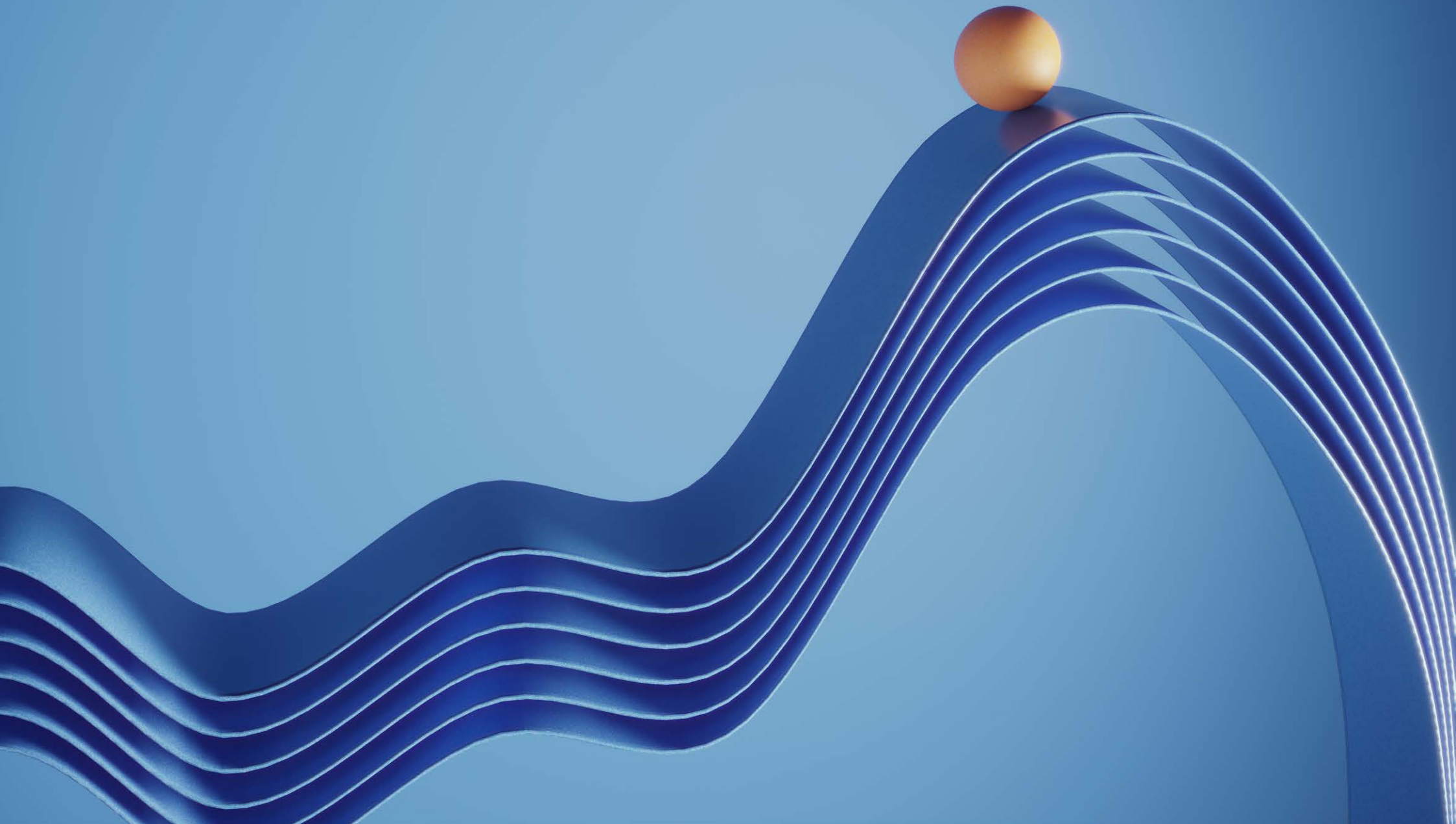
The CTIER Team extends its heartfelt gratitude to Rakesh Basant, Pankaj Chandra, and Sunil Mani for their continued guidance, support, and generosity of time. A special thanks to industry leaders for sharing their thoughts and insights on industry in India at various roundtables we have conducted over the past years. We have also benefitted from conversations with all R&D professionals who have participated in different cohorts of our executive programme, “Transforming R&D in India”, executed in partnership with Ahmedabad University.

This report has been made possible through the generous funding support of Forbes Marshall and the contributions of its members.

We would like to acknowledge the able assistance provided by past CTIER interns Rajas Ponkshe, Satej Zunjarrao and Shriya Deshpande in the making of this report. Pranali Patil, Shrimoyee Mukherjee and Sukhada Raibole from the CTIER team have contributed to this report at different stages.

Janak Nabar, Swati Joshi, Chaitanya Lekharaju, Nishant Dewaney, Yash Karmarkar, Soumya Misra, Neha Kumari, PJ Nishok, Adil Ahmed

Introduction



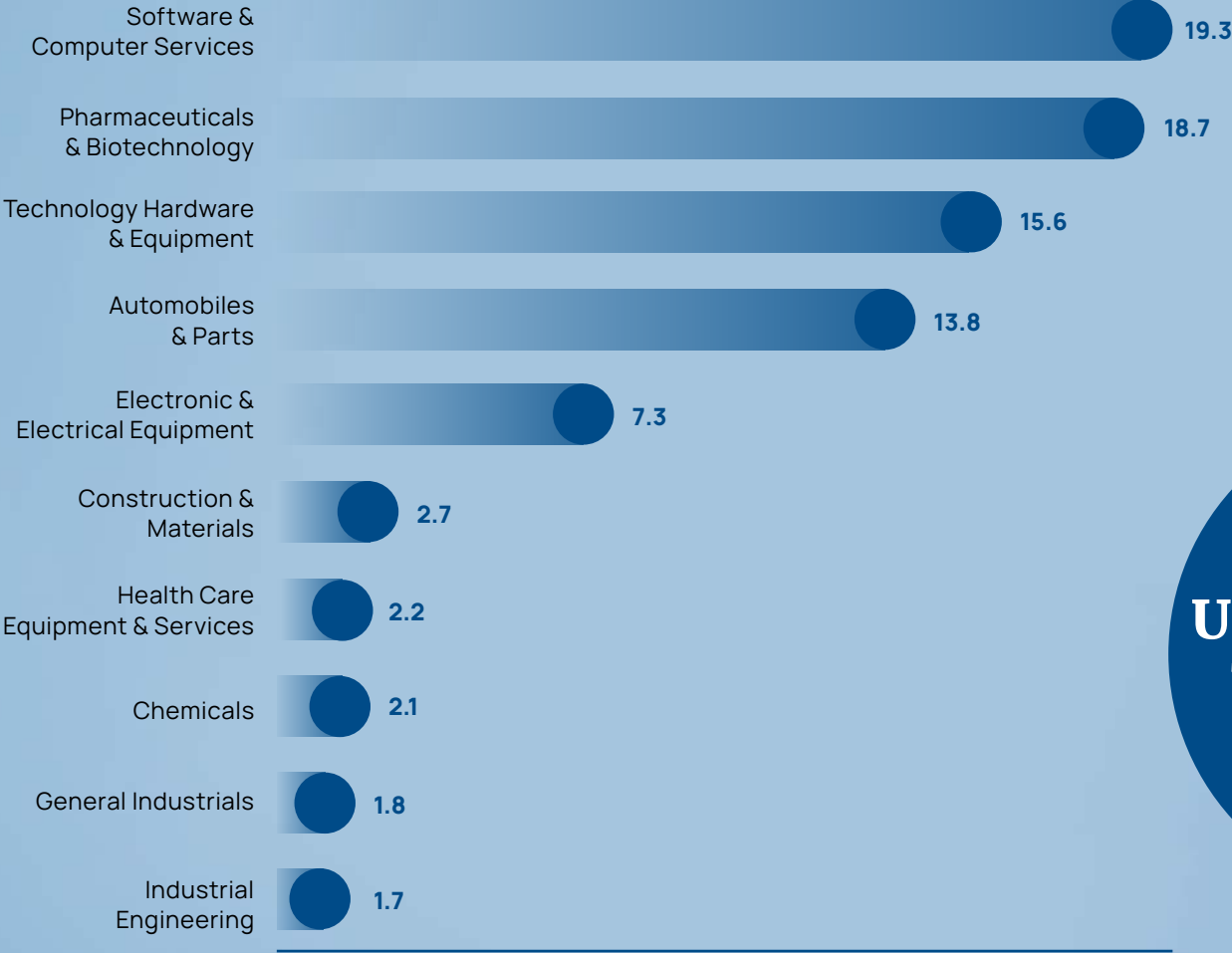
The global economy today faces significant uncertainty, on the trade front due to tariff announcements in the US in April 2025, and continuing geopolitical tensions in several parts of the world. The April 2025 World Economic Outlook by the International Monetary Fund expects global growth to come in at around 2.8 per cent in 2025 and around 3 per cent in 2026, compared to 3.3 per cent in 2024. Several forecasts across economies have been downgraded from earlier estimates on account of the concerns surrounding global trade. Growth in the US is expected to come in at 1.8 per cent in 2025, while China and India are expected to grow at 4 per cent and 6.2 per cent respectively.

As countries adjust to the tariff announcements out of the US, new rules of engagement are being worked out between countries while trade negotiations that have been in the pipeline for a number of years are being fast tracked, such as the recently announced FTA between India and the UK. While there have been concerns for some time about countries moving away from a 'rules-based order' in global politics and economics, the US tariff announcements seem to have provided it an official tone. A blog piece by the IMF's Economic Counsellor and Director of Research, Pierre-Olivier

Gourinchas mentions that the 'global economic system under which most countries have operated for the last 80 years is being reset, ushering the world into a new era'¹, while the Singapore Prime Minister in a speech on 8 April 2025 said, "The recent "Liberation Day" tariff announcements by the US confirms this stark reality: the era of rules-based globalisation and free trade is over."²

For Indian industry, the uncertainty posed by the tariff announcements and geopolitical tensions add another layer of complexity to the disruptions being caused by the rapid pace of technological change underway globally. To understand the competition that Indian firms face in the midst of a changing global industrial R&D landscape, consider Figure 1. The global push in AI/ML etc. is reflected in the significant jump in R&D spending in the global software & computer services sector. It is now the top ranked global sector as seen in Figure 1, with spending on R&D having increased from USD 86 billion in 2015, when it was ranked fourth, to USD 256 billion in 2022.

Figure 1: Structure of Global Industrial R&D



US\$ 1324 Billion
Total Global Industrial
R&D Spending

Sector Share of Total Industrial R&D Spending

Source: CTIER Handbook: Technology and Innovation in India 2025 (forthcoming)

The global industrial R&D landscape is undergoing a fundamental shift, driven by the convergence of traditionally distinct industries, rapid advancements in AI and an increased focus on sustainability. This shift presents opportunities and challenges. To take advantage and combat any challenges this shift poses, Indian industry would need to increase its competitiveness significantly by increasing its investments in R&D and innovation, building the right capabilities, focusing on newer skills and talent, fostering interdisciplinary collaborations and preparing for competition that may no longer come solely from within their traditional sectors.

Followers or leaders?

The purpose of this report is to understand where top Indian R&D firms stand relative to their global peers across indicators such as profitability, R&D intensity, exports, patents; understand how firms are adopting digital technologies across the value chain including the use of AI; highlight the opportunities and risks that firms face as a result of blurring industry boundaries; identify key technologies being worked on for a more sustainable future; and the lessons that hiring practices of global R&D firms

offer Indian firms, in terms of diversity of roles and diversity in talent. Ultimately this report aims to identify areas where Indian industry has the potential to lead and how it should boost its competitiveness through an increased focus on R&D, digital adoption across the value chain and nurturing multidisciplinary R&D teams.

For this report, we have considered data for 119 leading R&D firms across the top 10 sectors for India. We have also considered data for 100 global R&D firms across the same sectors. We have referred to various publicly available sources such as annual reports, investor presentations, company websites, earnings calls and press releases to extract all the relevant information that form the basis of the analysis in the subsequent chapters. We also extracted data from private databases for three years to FY2023 and had interactions on email or in person with around 40 top Indian R&D firms. These 40 firms have either participated in a survey that we conducted for this report or have provided insights on their R&D capabilities during the course of the 'Transforming R&D in Indian Firms' programmes³ and other industry closed door roundtable discussions.

Figure 2: Universe of Data Analysis



Data Extracted for

214
Indian

100
Global

Firms

3 Years Data R&D intensity, profit as a share of sales, R&D as a share of profit, patents, adoption of digital technologies, R&D focus areas

10 of the top firms from each sector except for software & computer services, food producers, oil & gas, aerospace & defence and electronic & electrical equipment

5 firms in each sector analysed for adoption of digital technologies and R&D team sizes

2700+ Job adverts analysed

40 Firms: email and in person interactions

For R&D Hiring Practices

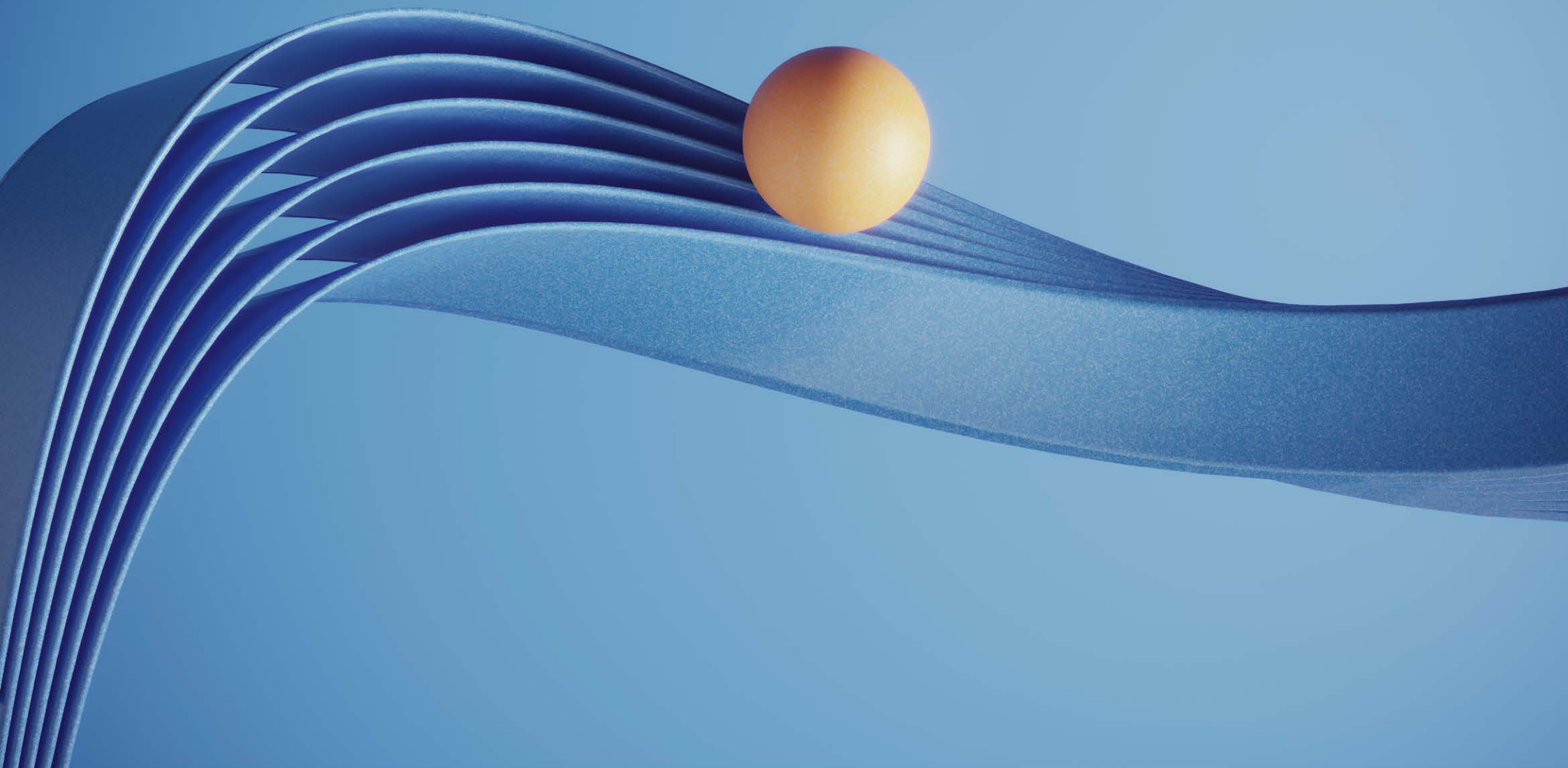
State of R&D and innovation in Indian industry

- India's top R&D spenders are fairly profitable by international standards. There are 7 sectors where the top Indian R&D spenders have higher profit as a per cent of sales compared to their global counterparts but have significantly lower R&D intensity.
- Besides the software & computer services and pharmaceuticals & biotechnology sectors that have a high share of exports in total sales, other sectors are largely domestic focused despite presence in the international market.
- Indian firms must increase their investments in R&D to become globally competitive and contribute to boosting India's high technology exports.
- Indian firms are starting to adopt digital technologies across the value chain by leveraging all the unstructured data they have collected over the years.
- Indian firms are employing digital technologies to address lapses in the production process, forecast demand, identify maintenance needs and improve customer interactions.
- Indian firms are leveraging AI for quality control, understanding customer preferences and improving productivity.
- AR/VR is being used by Indian firms for customer engagement and employee training.
- IoT is being used by Indian firms for machine health monitoring and is being integrated into products.

- Digital twins are being used by Indian firms for prescriptive analytics and to provide customers with product insights.
- The adoption of technologies like blockchain and quantum computing is at a nascent stage in Indian industry.
- The effort around AI-powered drug discovery appears to be led by software firms. Given the service oriented nature of Indian software firms, much of the work in AI-powered drug discovery pertains to services in identifying molecules.
- Boundaries that once clearly separated sectors such as pharmaceuticals, software, automotive and energy are dissolving as software firms lead AI-powered drug discovery and autonomous vehicles, while oil & gas companies venture into lithium extraction. The blurring of industry boundaries not only presents new opportunities for Indian firms but also potential threats to incumbent firms across sectors.
- There is an opportunity for Indian pharmaceutical firms to be bold and ambitious by leveraging the strengths of the Indian software industry for the adoption of digital technologies and integration of AI.
- Autonomous vehicles is a technology area that is expected to see significant growth by 2030. The absence of regulation for autonomous vehicles in India means wider adoption of this technology is unlikely for some time. Indian software and automobile firms could explore joint opportunities in autonomous vehicle technology and target markets with more favourable regulation where adoption rates are expected to be high like China, Europe, Japan and the US.

- The world is moving towards a sustainable future. Alternate batteries such as aluminium air batteries, sodium ion and zinc ion batteries are some of the key technologies that are likely to aid in this move and areas where India could lead. Indian firms are already working in these areas.
- Indian firms must build capabilities to complement their R&D spending, leading to an increase in their innovation output and in turn the Indian economy. To build truly effective R&D teams would require drawing individuals from science, technology and the humanities with capabilities that range from understanding market dynamics and competition to managing IP and anticipating future trends.

Industrial R&D in India



If India has to see high economic growth of 8 to 10 per cent over the next two decades to cross the USD 20 trillion mark and become globally competitive in technology, Indian industry would need to lead the way.

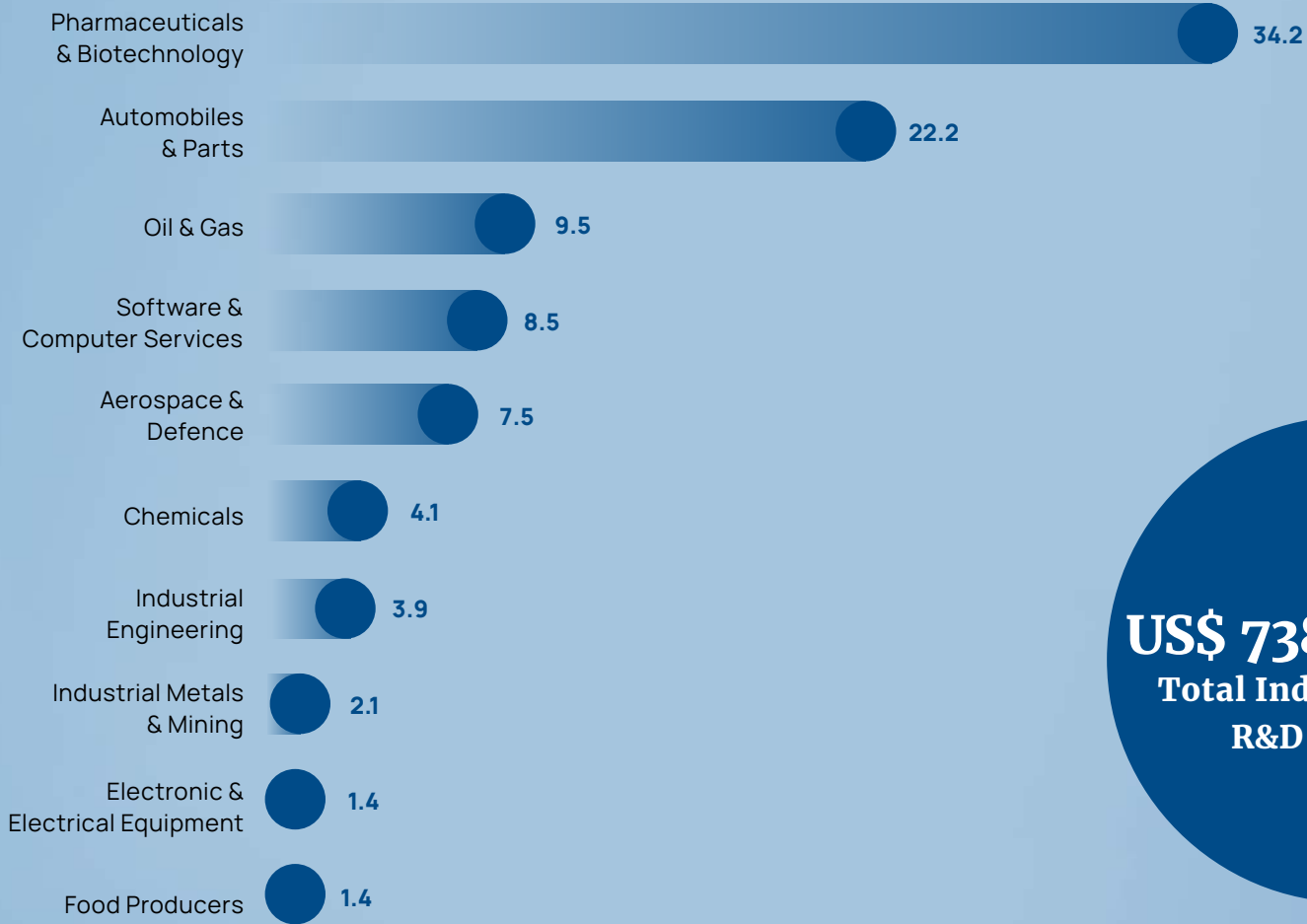
To navigate the rapidly changing global industrial R&D landscape and be better prepared for the increased competition going forward, Indian industry would need to significantly increase its investment in R&D and innovation. The total expenditure on R&D by Indian industry in FY2023 was USD 7.4 billion. This was less than a fifth of what Alphabet as a single firm spent on R&D. While investments in industrial R&D have been increasing over the years, it has taken over a decade to double the investment from USD 3.7 billion in FY2011 to USD 7.4 billion in FY2023. Indian industry's share in national R&D remains low at around 40 per cent.⁴ The Indian government continues to be the largest spender on R&D. India is an outlier compared to economies like the US and China that dominate the global technology landscape, where national R&D investments are led by their respective industries. The first step for Indian industry would be to correct this and increase its share in national

R&D investments. The increased investments in R&D by Indian industry should be used to accelerate the adoption of digital technologies, pursue emerging global technology opportunities and invest in building multidisciplinary R&D teams.

The structure of industrial R&D in India differs vastly from the world

India's industrial R&D spending is dominated by the pharmaceuticals & biotechnology and automobiles & parts sector. These two sectors account for over 50 per cent of industrial R&D in India, whereas globally as we have seen in Figure 1, the top 3 sectors - software & computer services, pharmaceuticals & biotechnology and technology hardware & equipment - account for over 50 per cent of industrial R&D.

Figure 3: Structure of Indian Industrial R&D



US\$ 7380 Million
Total Indian Industrial
R&D Spending

Sector Share of Total Industrial R&D Spending

Source: CTIER Handbook: Technology and Innovation in India 2025 (forthcoming)

Indian firms are profitable but not investing enough of their profits in R&D

India's top R&D spenders on average are fairly profitable compared to their global counterparts. We considered 84 top R&D spenders across Indian's top 10 industrial R&D sectors. There were 5 sectors that had a representation of 10 firms each. For the remaining 5 sectors, the distribution of the 34 firms was as follows: oil & gas had 7, software & computer services had 9, aerospace & defence had 5, electronic & electrical equipment had 5 and food producers had 8 firms. These 84 firms accounted for over 60 per cent of industrial R&D spending in FY2023. As seen in Figure 4, besides the pharmaceuticals & biotechnology, oil & gas and the industrial engineering sector, firms in the remaining 7 sectors had a higher profit as a per cent of sales on average compared to the top global R&D firms.

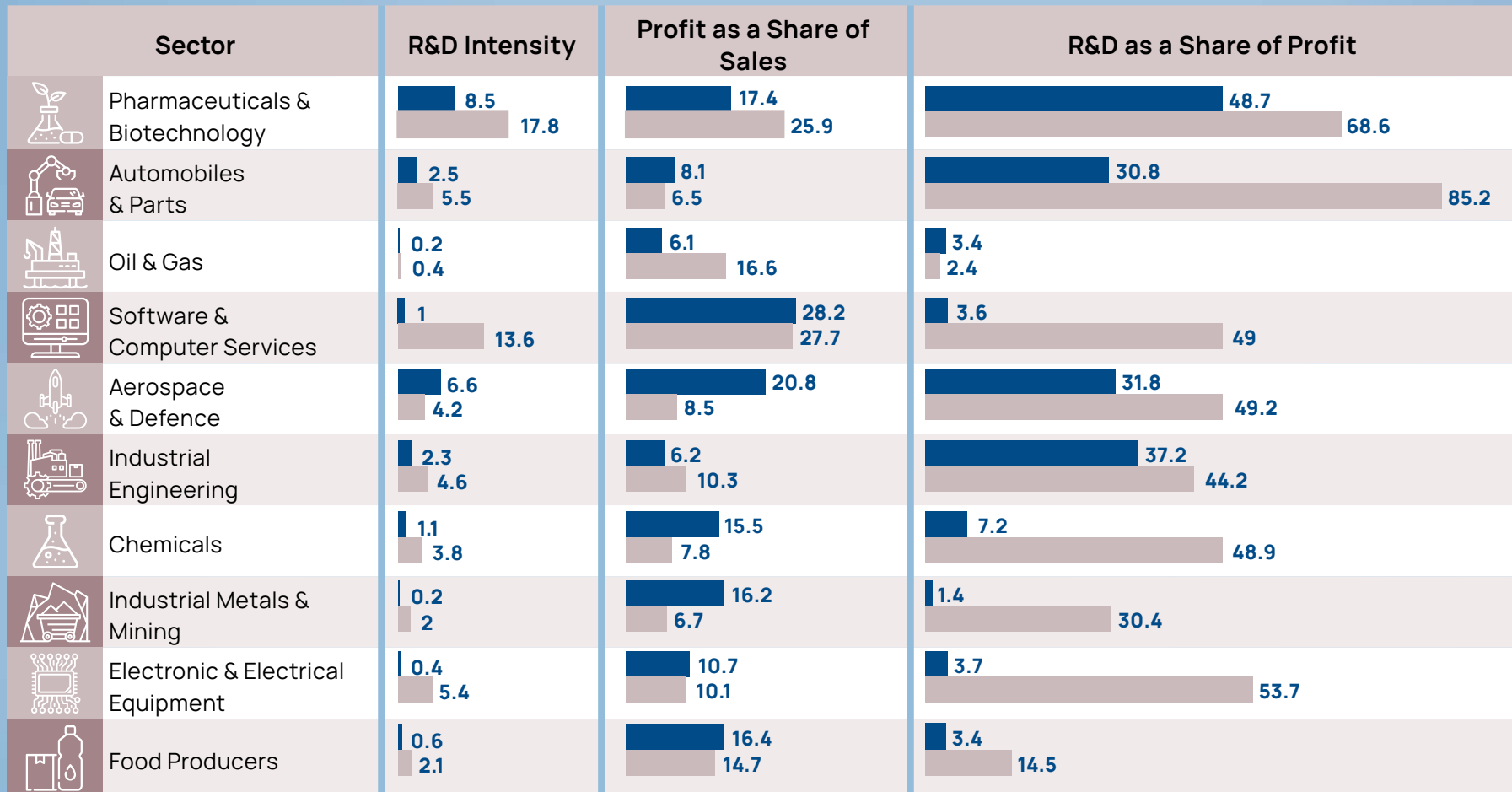
Indian firms do not invest enough of their profits on R&D. When one compares the average R&D spend as a share of profits for the three years to FY2023, there is a large gap between the share of spend for the global firms compared to Indian firms for 9 of the sectors. For example, in some of

our top R&D sectors like automobiles & parts, Indian firms on average invested just 30.8 per cent of their profits on R&D compared to around 85 per cent for the top global firms. In the software & computer services sector, Indian firms spent just 3.6 per cent of their profits on R&D, while globally this was around 49 per cent. The low level of spending on R&D by most Indian firms is also reflected in the low R&D intensity compared to the global firms for most sectors.

Indian firms need to tap more into global markets

Apart from the software & computer services and pharmaceuticals & biotechnology sectors that have a high share of exports in overall sales, the other top R&D sectors appear to be largely domestic focussed. For these other top R&D sectors, the share of exports in sales range from 2.5 per cent for aerospace & defence to 33.5 per cent for chemicals as seen in Table 1. While several sectors are present in a number of international markets, they must look to grow their presence in these markets and become more competitive through a sustained focus on innovation. They must capitalise on their international presence to learn from buyers in these markets and upgrade their technology offerings.

Figure 4: Comparison of Top 10 Indian and Global R&D Spenders



Source: Annual Reports (various years) of Indian Companies; EU Industrial R&D Investment Scoreboard (various years)

Note: Figures are based on 3 years average from FY2020-21 to FY2022-23 for 84 Indian firms and 100 global firms

Indian Firms Global Firms

Table 1: Exports as a Share of Sales and International Markets Served

Sector	Exports as a Share of Sales	Number of International Markets Served
Pharmaceuticals & Biotechnology	64.4	80
Automobiles & Parts	11.7	61
Oil & Gas	14.1	26
Software & Computer Services	95.3	47
Aerospace & Defence	2.5	7
Industrial Engineering	17.5	68
Chemicals	33.5	46
Industrial Metals & Mining	14.1	20
Electronic & Electrical Equipment	8.9	51
Food Producers	4	22

Source: Annual Reports (various years) of Indian Companies; Prowess, data downloaded in October 2024

Note: Based on data for 84 Indian firms

Indian firms must gain a better understanding of intellectual property management

Over the three years to FY2023, the patents granted abroad to the top R&D firms in the pharmaceuticals & biotechnology sector, software & computer services sector, oil & gas sector and the chemicals sector have outnumbered the patents granted by the Indian patent office. In the case of the automobiles & parts sector, there is a higher number of patents that the firms have obtained from the Indian patent office over the same period compared to the patents granted abroad. The patents that were granted abroad to the 84 firms across the 10 sectors accounted for around 12 per cent of total patents granted abroad to residents in India. The patents granted by the Indian patent office to these firms accounted for less than 5 per cent of total patents granted by the Indian patent office in the three years to FY2023.

Table 2: Patents Granted in India and Abroad for top Indian R&D Firms

Sector	Total Patents Granted in India	Total Patents Granted Abroad
Pharmaceuticals & Biotechnology	172	428
Automobiles & Parts	1305	263
Oil & Gas	395	484
Software & Computer Services	906	1640
Aerospace & Defence	95	0
Industrial Engineering	780	20
Chemicals	168	328
Industrial Metals & Mining	458	51
Electronic & Electrical Equipment	58	6
Food Producers	6	2

Source: XLSCOUT, data downloaded in October 2024

Note: Figures are based on patents granted cumulatively from FY2020-21 to FY2022-23

Much of the patents granted abroad to Indian residents are likely being granted to MNC R&D centres that have a presence in India, while the patents granted by the Indian patent office would be largely to non resident patentees.

There is a need for greater awareness in Indian industry about the role and uses of Intellectual Property (IP) not only from a protection standpoint, but also in its potential for revenue generation. It is plausible that firms are using various mechanisms to protect their IP, such as patents, secrecy and even controlling their distributor channels. However, given the rapid changes in technology and the blurring of industry boundaries, it would be increasingly important for firms to protect their IP through patents, especially when competing globally, and scout for opportunities to monetise their IP. This could be through licensing agreements with firms across sectors, or through the creation of spinouts.

Realising India's R&D ambitions

The top Indian R&D spenders are profitable by international standards. They must now increase their investments in R&D and become globally competitive. India's high technology exports as a share of manufactured exports was 12.5 per cent in 2022.⁴ This is low when compared to the US and China, where the share is around 20 per cent. Increasing firm investments in R&D will contribute to boosting India's high technology exports. There is a need for firms to gain a more robust understanding around intellectual property management. This will open up newer opportunities for revenue generation firms and potentially help in the creation of new business ventures.

Indian industry must capitalise on its strengths in pharmaceuticals & biotechnology, automobiles & parts and software & computer services. It must continue to grow capabilities in sectors like aerospace & defence and electronic & electrical equipment. It must seek new opportunities in sectors like healthcare equipment &

services where there is clear domestic demand. As we shall see in the chapter on Disruptive Trends in Industrial R&D, there are opportunities in AI-powered drug discovery, alternate batteries or even autonomous driving where cross sectoral collaborations could help spur R&D investments and help achieve our R&D ambitions.

Digital Adoption and Innovation in Indian Industry



The pace of digital transformation, driven by advances in Artificial Intelligence (AI), Internet of Things (IoT), Augmented or Virtual Reality (AR/VR), quantum computing and the like, is driving firms globally to invest and adopt these technologies rapidly to maintain their competitive advantage. For Indian firms, this digital transformation presents an opportunity to play catch up or leapfrog their global counterparts.

In this chapter, we look at how digital transformation is taking place in Indian Industry. In particular, we explore how the adoption of digital technologies is adding value across different aspects of a firm's operations, from managing inventory and improving production efficiency to customer engagement and enhancing after sales services. We also consider how Indian firms are integrating digital technologies into products to drive innovation.

Indian firms are employing digital technologies to address lapses in the production process, forecast demand, identify maintenance needs and improve customer interactions. In our sample, over 80 percent of firms have adopted or plan to adopt AI. For AR/VR and IoT, we see nearly

50 percent of firms have either adopted or have plans in place to adopt these technologies.

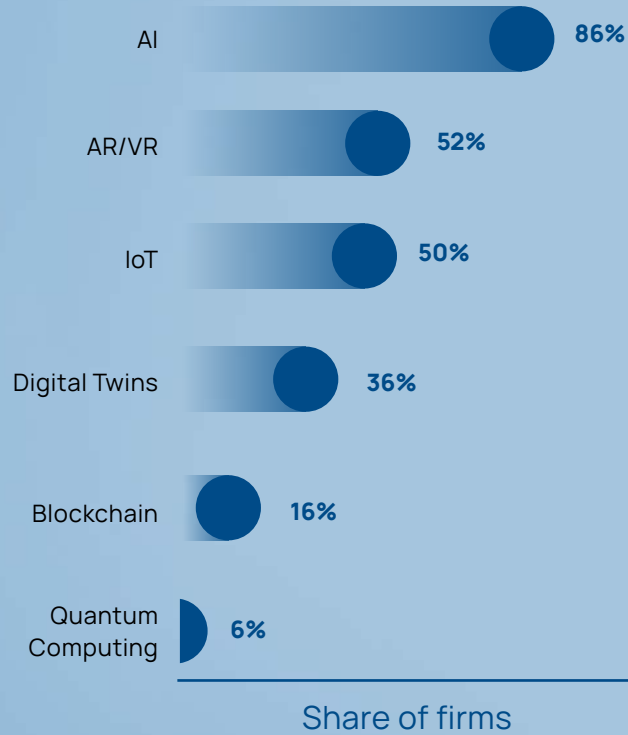
Indian firms are leveraging AI for quality control, understanding customer preferences and improving productivity. AR/VR is being used by firms for customer engagement and employee training. IoT is being used for machine health monitoring and is also being integrated into products. Digital twins are being used for prescriptive analytics and to provide customers with product insights, while technologies like blockchain and quantum computing are gradually being adopted.

AI is helping redefine Indian industry's value chain

The AI-powered digital tasting room by Tata Consumer Products is an exciting example of an Indian firm leveraging AI to enhance their product quality. This leading food producer firm is using AI to forecast the taste profile of tea from different estates based on historical data to help ensure consistent experience for customers.⁵

Figure 5: Adoption of Digital Technologies by Indian Firms

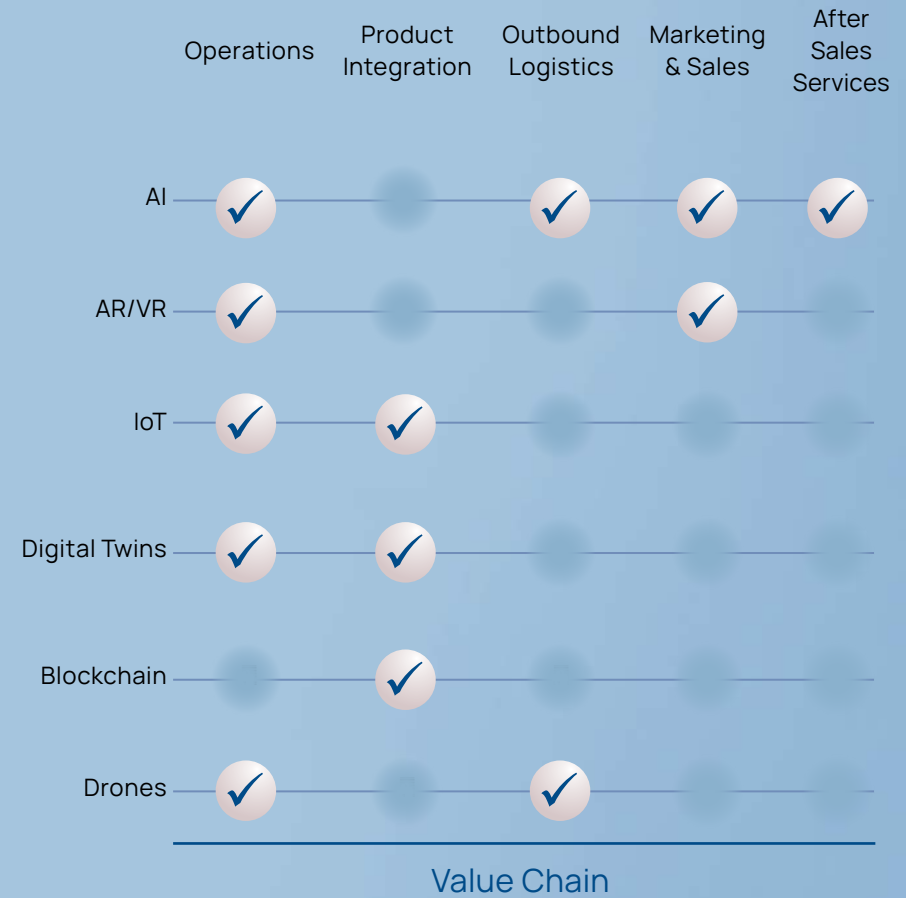
Top R&D Spenders are Increasingly Looking to Adopt AI



Source: Annual Reports (various years) of Indian Companies; Company Websites

Note: Sample consists of 5 firms from each of the top 10 Indian R&D sectors

Use Cases in Value Chain Captured



Source: Annual Reports (various years) of Indian Companies; Company Websites

Note: Sample consists of 5 firms from each of the top 10 Indian R&D sectors

AI is being used to identify defects across sectors. Laurus Labs, a leading pharmaceuticals & biotechnology firm, is using AI for rapid inspection and sorting of tablets and capsules⁶, whereas firms in the automobiles & parts sector are using it to detect paint defects with high accuracy.

Anticipating demand, identifying market trends and responding to changing consumer preferences are other areas where Indian food producer firms like Marico are increasingly using AI.⁷ Firms in the oil & gas industry are using AI to anticipate demand from consumers, distributors and even individual fuel stations across the country, benefitting their logistics and sales-related activities.

Indian software & computer services firms are employing AI-based assistants to boost productivity in code development and to structure knowledge from a firm's database to provide useful insights to teams interacting with clients.

AR/VR is providing immersive experiences to customers and employees

AR/VR is enabling Indian firms to embark on new and innovative marketing campaigns. Marico has created an interactive platform using AR to provide a transformative experience to customers. This platform is allowing customers to engage with their products to understand various health and nutritional benefits.⁷ Multiple firms in the automobiles & parts sector are using AR/VR to enhance their sales engagement by providing customers with an interactive experience of life-size models of vehicles as well as virtual test drives.

Indian aerospace & defence firms are deploying AR/VR technologies for the purposes of quality testing and meeting design requirements. Sectors as diverse as industrial metals & mining and software & computer services are using this technology to train employees.

IoT is transforming operations and impacting product and service offerings

From our discussions with some of the leading Indian R&D intensive firms it is clear that they have plans to use IoT on a much wider scale, not just to improve their operational efficiency and address predictive maintenance needs but to also integrate it within their product offerings.

The increasing use of IoT for product and service differentiation is evident in the automobiles & parts sector, where Indian firms are working to provide customers with connected vehicle services like remote vehicle control, diagnostics and location tracking. Similarly, Indian firms in the electronic & electrical equipment sector are enabling customers to control smart lights through voice assistance. In the ceiling fan segment, smart sensing capabilities that respond to room temperature and humidity are being introduced.

Tata steel is expanding its service offerings through its industrial consulting division. It is looking to provide AI-enabled IoT and is co-developing mining 4.0 technologies

to automate mining operations and minimise on-site human involvement. This is in collaboration with TEXMiN, an innovation hub based in IIT (ISM) Dhanbad.⁸

Nascent adoption of digital twins and other digital technologies

Indian firms across diverse sectors like industrial metals & mining, oil & gas and chemicals are using digital twins to develop complex prediction models that enable energy management as well as provide prescriptive analytics for manufacturing. In the automobiles & parts sector, digital twins are being used to provide consumers with features such as battery degradation estimation and fault prediction in their vehicles.

Tata Steel is using drones in their mining process for geospatial mapping, analytics and monitoring⁹, while the oil & gas sector is using drones for pipeline inspection to improve safety. Drones are being used in the automobiles & parts sector to manage inventory by geotagging and identifying vehicles. Blockchain is being used by firms in the sector to strengthen cybersecurity of connected vehicle platforms.

Conclusion

Indian firms are beginning to adopt digital technologies across the value chain by leveraging all the unstructured data they have collected over the years. This is a welcome change from a few years ago where the term 'digital technologies' had a limited presence in the vocabulary of technology leaders even from some of the larger firms in India. Even today, we are seeing a number of leading R&D firms that participate in the 'Transforming R&D in Indian Firms' programme take up digital transformation as part of their capstone projects to enhance their R&D function.

At present much of this adoption or the development of digital technologies appears to be taking place through initiatives that are undertaken in house. Indian firms could look at potential opportunities residing with startups for faster adoption as well as expanding their product portfolios with digital offerings.

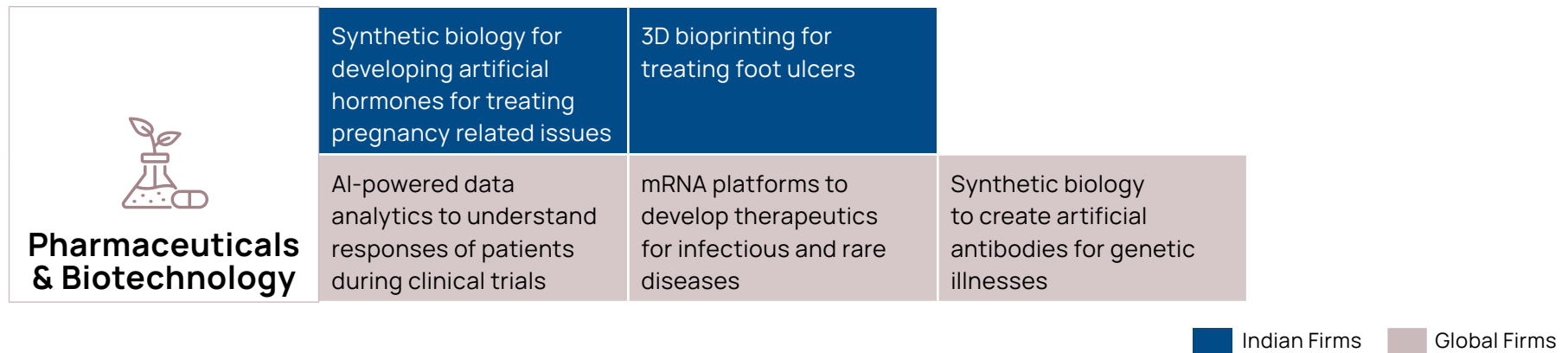
An abstract graphic featuring a central, flowing, blue ribbon-like shape that curves upwards and then downwards. Two spheres are attached to the ribbon: a larger, bright orange sphere on the upper curve and a smaller, muted blue sphere on the lower curve. The background is a solid, light blue color. The overall aesthetic is clean, modern, and futuristic.




Disruptive Trends in Industrial R&D



There are three distinct disruptive trends shaping global research strategies. First, industry boundaries are blurring. Second, rapid developments in AI and other digital technologies are disrupting how research is done. Third, the increased focus on sustainability is presenting firms with new innovative opportunities. These disruptive trends have been observed globally for some time. Indian firms would need to focus on adapting to these three disruptive trends. They need to be prepared for the competition that could emerge from firms not just in their sectors, but also from other sectors.




In this chapter, we draw on examples of research being undertaken by global firms, to provide context for where Indian firms are relative to their global peers. We have compiled a list of global emerging technologies across the top 10 R&D sectors for India, presented in Figure 6.¹⁰ Using key examples from this list, we showcase the disruptions underway in global industrial R&D, consider how leading Indian firms are adapting to these disruptions, identify potential new opportunities for Indian firms and highlight the challenges they should be prepared for.

Figure 6: Examples of R&D Focus Areas


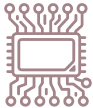



 <p>Automobiles & Parts</p>	Hydrogen IC engines and fuel cells to reduce carbon emission			
	Quantum computing to identify alternative materials for electric powertrains	Autonomous driving operated under certain conditions with driver to take control if prompted	Battery recycling by recovering raw materials from spent EV batteries	
 <p>Software & Computer Services</p>	AI-powered drug discovery using De Novo design	Autonomous driving only in structured and monitored environments		
	AI-powered drug discovery using De Novo design	Autonomous driving operated under favourable weather conditions and with limited speed in certain conditions	Demonstration of data stored in manufactured DNA using fully automated system	AI driven identification of new battery materials
 <p>Oil & Gas</p>	Aluminium air batteries that are lighter and last longer than lithium ion batteries	Cylinders for safe storage of green hydrogen	Process for high quality anode material for sodium-ion batteries	
	Direct lithium extraction from underground reservoirs of saltwater	3D printing for rapid prototyping during the designing and testing phase	Quantum computing for simulations to optimise and reduce energy consumption during industrial processes	Mobile carbon capture to reduce vehicular emissions

 Indian Firms  Global Firms



 <p>Aerospace & Defence</p>	AI enabled autonomous underwater drones for defence application	Lithium ion battery solution for submarines	
	Quantum technology for secure communications	Discovery of novel materials for aircraft foils using machine learning	Autonomous flights using computer-vision based systems
 <p>Industrial Engineering</p>	Electrolysers for hydrogen production	Exploring hydrogen fuel and lithium ion batteries as an alternative power source for drones	
	AI enabled autonomous underwater drilling using cabinless electric vehicles		
 <p>Chemicals</p>	Sodium batteries as an energy storage solution	Battery recycling by recovering raw materials from spent EV batteries	
	Enhance plant growth using CRISPR	Battery recycling by recovering raw materials from spent EV batteries	

 Indian Firms  Global Firms

 <p>Industrial Metals & Mining</p>	<p>Research on recycling aluminium from aluminium air batteries</p>	<p>Specialised steel pipes for hydrogen transportation</p>
	<p>Carbon capture and storage using steel slag to produce permeable bricks</p>	
 <p>Electronic & Electrical Equipment</p>	<p>Lithium ion battery powered community grid energy storage</p>	
	<p>Gen AI based system to help users in designing production facilities</p>	<p>Sodium batteries that have high energy density</p>
 <p>Food Producers</p>	<p>Developing a biodigester which uses cattle manure to produce clean biogas in order to support sustainable agriculture and creating disease and pest tolerant crops</p>	
	<p>Wearable device which monitors sounds and posture of the patient during eating to overcome swallowing difficulties</p>	

Source: Annual Reports (various years) of Indian Companies; Company Websites

Note: Sample consists of 119 Indian firms and 100 global firms

 Indian Firms  Global Firms

Boundaries between sectors are blurring

Globally, we are seeing boundaries blur on the research and innovation front across previously distinct sectors. For example, research on AI-powered drug discovery is being undertaken by both software and pharmaceutical firms, research on autonomous vehicles is being undertaken by both software and automobile & parts firms, research on CRISPR for improved plant varieties is being undertaken by chemical firms and research related to lithium extraction is being undertaken by global oil & gas firms.

Advanced AI models are being developed by global software firms like Isomorphic Labs (owned by Alphabet) and Microsoft to accelerate drug development. De novo drug design¹¹, an approach to developing novel compounds without relying on existing chemical compounds, is being adopted by Isomorphic Labs to push the boundary of AI-powered drug discovery. Isomorphic Labs is using this approach to develop drugs for oncology, cardiovascular and neurodegenerative diseases, aiming to advance them to clinical trials by late 2025.¹² TamGen, a chemical language model developed by Microsoft, allows for the generation of

diverse and novel chemical compounds. In collaboration with Global Health Drug Discovery Institute, China, Microsoft is using TamGen for drug discovery to treat tuberculosis.^{13,14} In India, the effort around AI-powered drug discovery is being spearheaded by software firms. A paper published by TCS in Future Medicinal Chemistry mentions adopting the de novo design to identify small molecules to potentially inhibit the target protein 3CL protease in SARS-Cov-2.¹¹ However, given the service oriented nature of Indian software firms, much of the work in AI-powered drug discovery pertains to services in identifying molecules.

Autonomous vehicles are gaining traction in some advanced economies as well as China and are expected to see significant growth by 2030. The Society of Automotive Engineers (SAE) has defined six levels of automation, ranging from Level 0 (no automation) to Level 5 (no human intervention).¹⁵ Advancements in this technology have reached Level 3 and Level 4 in the last few years. These levels allow vehicles to operate independently in specific areas with detailed maps, under favourable weather conditions and with limited speed. In Level 3, the driver would be expected to take control when prompted.¹⁶ Stellantis, a global automobile & parts firm, has developed Level 3 technology that supports

autonomous driving at speeds of up to 60 kmph¹⁷, while Waymo, a subsidiary of global software firm Alphabet, launched its Level 4 cab services in Phoenix, USA, in 2020. Waymo has since expanded to San Francisco, Los Angeles and is undertaking weather assessments in other cities it plans to enter in 2025 and 2026.¹⁸

According to a 2024 article by Goldman Sachs, Level 3 vehicles are likely to account for 10 per cent and Level 4 vehicles are likely to account for 2.5 per cent of global car sales by 2030. The highest adoption rates are expected to be in China, Europe, Japan and the US.¹⁹ Appropriate regulation is being put in place in these countries that will help facilitate the adoption of this technology.²⁰ In India, Wipro has designed and developed autonomous vehicles to function in structured environments such as technology parks, hospital campuses and small townships.²¹ However, the absence of regulation for autonomous vehicles in India means wider adoption of this technology is unlikely for some time. Indian software and automobile firms should explore joint opportunities in autonomous vehicle technology and target markets with more favourable regulations.

The blurring of industry boundaries also presents potential threats to Indian firms. For example, Indian food producer firms may see sectoral disruptions due to the use of technologies being produced by global chemical firms like Syngenta, that is using CRISPR for haploid induction to enhance plant traits and speed up the process of introducing new varieties. Syngenta is working on this technology to increase climate resilience in plants.²²

Another example of challenges being posed through the blurring of boundaries is for mining firms globally. Mining firms looking to enter lithium production may find themselves up against oil & gas firms in the future. Exxon Mobil is looking into lithium extraction by using traditional drilling methods to tap underground reservoirs of saltwater that is rich in lithium. Using a technology called Direct Lithium Extraction, Exxon Mobil is potentially offering a more sustainable alternative to conventional lithium mining through the extraction of lithium from brine solution.²³

Emerging technologies are disrupting how firms conduct research

We have seen how AI is being adopted by firms for diverse purposes, from anticipating demand and responding to changing consumer preferences to boosting productivity in code development. We consider examples of how AI and digital technologies are impacting global and Indian R&D.

Global pharmaceutical firms are leveraging AI and machine learning capabilities of software firms to analyse and identify potential molecules for drug development. AI is making clinical trials more efficient to speed up drug development. AstraZeneca, a global pharmaceutical firm, has partnered with UK based Qureight to harness its AI-powered data analytics platform to better understand how patients with rare lung diseases respond to new drugs in clinical trials.²⁴ Indian software firms are leveraging AI for drug discovery. Apart from helping in the identification of new molecules, Indian software firms are offering bespoke services to pharmaceutical firms to digitise their drug development process.

We do not find many Indian pharmaceutical firms engaging AI for drug development. This comes at a time where the average R&D intensity of India's top pharmaceuticals & biotechnology firms has declined from 12.2 per cent in 2015 to 9.4 per cent in 2023.^{4, 25, 26, 27} While there are examples of firms partnering with global AI-led firms to work on various aspects of the drug development process, AI-powered drug discovery appears to be at a nascent stage in India.

The use of GenAI is increasingly finding applications in diverse sectors beyond drug discovery. For example, Siemens, a global electronic & electrical equipment firm, has developed a Gen AI based system to assist users in designing hydrogen production facilities.²⁸

Advancements in 3D printing are changing the way research is being performed within Indian firms. From bioprinting in the pharmaceuticals sector to metals and alloy printing of components in the automobiles & parts sector and rapid prototyping in the industrial engineering sector, 3D printing is helping reduce development timelines. Globally, in the oil & gas sector, Shell is using 3D printing to design and test offshore structures.²⁹

Going forward quantum computing is likely to disrupt current digital technologies. This will have implications for how research is performed across sectors. For example, Shell in collaboration with Leiden University and VU University in the Netherlands, is using quantum computing to simulate chemical reactions and reduce energy consumption in industrial processes.³⁰ Bosch, a global automobiles & parts firm, in collaboration with IBM is leveraging quantum computing to identify rare earth alternatives for carbon neutral powertrains like electric motors and fuel cells.³¹

Sustainability is a driver in the technologies being developed

Alternate batteries, battery recycling, green hydrogen and carbon capture are some of the key technologies that are likely to aid in this move. Global and Indian firms are working on these technologies to exploit potential opportunities inherent in this transformation.

The research related to alternate batteries cuts across a number of sectors that include chemicals, automobiles & parts, industrial metals & mining, oil & gas and software & computer services. For example, BASF is working on iron

flow batteries, while Microsoft and Volkswagen are working on lithium metal batteries. In India, there are significant opportunities in aluminium, sodium and zinc based batteries given that India is the second largest producer of aluminium³², the third largest producer of salt³³ and the fourth largest producer of zinc.³⁴

Aluminium air batteries have high energy density, are lighter and last longer compared to lithium ion batteries. Indian Oil is collaborating with Israeli firm Phinergy in the area of aluminium air battery and holds a patent for advancements in this type of battery.³⁵ Hindalco has signed an MoU with Indian Oil and Phinergy to research on and supply essential components for the battery.³⁶

When it comes to sodium based batteries, firms like CATL based in China have developed second generation batteries with energy density over 200 Wh/ kg.³⁷ In India, Tata Chemicals is working on sodium chemistry for energy storage solutions.³⁸ Oil & gas firms in India are working on sodium based batteries, especially on anode materials.

For zinc ion battery technology, Tata Steel is collaborating with the Centre for Nano and Soft Matter Sciences, Bengaluru. They are exploring using materials

from the steel value chain for various components of this rechargeable battery.

While the search for alternate batteries continues, battery recycling will be just as important. Increased battery applications across sectors will place a burden on critical minerals like lithium and cobalt. Globally, firms like BASF and Volkswagen have launched pilot projects to recover raw materials from spent electric vehicle batteries. In India, Tata Chemicals, too, has successfully started the recovery of cathode materials from lithium ion batteries at its Mumbai facility.³⁹ As part of its MoU with Indian Oil and Phinergy, Hindalco is also conducting research on recycling of aluminium used in aluminium air batteries.

Another area of interest for global and Indian firms is the hydrogen ecosystem that encompasses production, storage, transportation and its use in propulsion systems. While Indian oil & gas firms are working on setting up hydrogen production facilities, there have also been successful developments towards solving the challenges on the storage and transportation front. Indian Oil has successfully developed a prototype storage cylinder, while Tata Steel has developed specialised steel pipes to transport hydrogen.⁴⁰

Carbon capture is also gaining attention. Chinese firms like China Petroleum & Chemical Corporation have developed solvents to efficiently capture carbon⁴¹, while Saudi Arabia's Aramco has developed mobile carbon capture technology to reduce vehicular emissions.⁴² In India, oil & gas firms are focused on using the captured carbon for enhanced oil recovery and for producing value added chemicals.

Conclusion

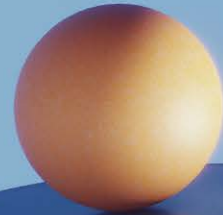
Indian firms need to increase their focus on R&D and innovation as part of their firm strategy and adapt to the three disruptive trends of blurring industry boundaries, rapid advancements in AI and other digital technologies and the increased focus on sustainability. Apart from increasing their spend on in house R&D, Indian firms should seek collaborations and partnerships to exploit newer opportunities and respond to global technology trends arising from these disruptions.

AI-powered drug discovery is at a nascent stage in India. This is an opportunity for Indian pharmaceutical firms to be bold and ambitious and push for greater technological deepening by leveraging the strengths of the Indian software industry to aid drug discovery.

The absence of regulation for autonomous vehicles in India means wider adoption of this technology is unlikely for some time. Indian software and automobile firms should explore joint opportunities and target markets with more favourable regulation.

There are significant opportunities in alternate batteries for Indian firms especially for aluminium, sodium and zinc based batteries. In addition to alternate batteries, battery recycling will be just as important for Indian firms to focus on. The global hydrogen ecosystem offers opportunities, especially with work being done by Indian firms with respect to the storage and transportation of hydrogen.

The R&D Talent Imperative



Rapid developments in technology are impacting the way firms are structuring their R&D teams. To understand the hiring practices and the capabilities that Indian and global firms are seeking, we analysed over 2,700 R&D job advertisements across 100 firms that included both Indian and global top R&D spenders.

In this chapter, we consider how firms are taking advantage of, and responding to, the shift in the global industrial R&D landscape and are increasingly building multidisciplinary and diverse R&D teams. A peek into how global research teams are tapping into multidisciplinary capabilities was provided by Dr Vikas Trivedi from the European Molecular Biology Lab, Barcelona in his plenary talk at the Asia-Pacific Innovation Conference 2023 that had been jointly organised by CTIER and Ahmedabad University. Dr Trivedi pointed out that, for his research on 'Self-organisation in Multicellular Systems', his team included individuals with capabilities in molecular biology, physics, optics, and data science.

Besides analysing job advertisements, we have also drawn upon insights from various closed-door industry discussions, our interactions with a large pool of R&D

individuals in the 'Transforming R&D in Indian Firms' programme and other R&D focused interventions we have undertaken for firms to further understand the current structures of R&D teams in Indian firms and their future hiring plans .

R&D teams in Indian firms

There are two important data points in the Indian context that we must recall here. First, our top R&D firms are profitable by global standards across a number of sectors and second, we fall short of the global average R&D spending as a share of sales for several sectors. Scaling up investments in talent that would make R&D teams future ready would be an important starting point, especially for firms that are serious about transforming their R&D functions.

When we look at current R&D team compositions at Indian firms, we find that the R&D team sizes range from less than 1 per cent of the total workforce for sectors like oil & gas, software & computer services and industrial metals & mining to more than 5 per cent for sectors like pharmaceuticals & biotechnology, automobiles & parts, aerospace & defence and chemicals. Besides the difference

we see in the R&D team sizes as a share of the total workforce, there appears to be a difference across sectors in terms of the degree qualifications (diploma, bachelor's, master's, PhDs) the R&D workforce is equipped with. There is a tendency for R&D teams in sectors like automobiles & parts, aerospace & defence and industrial engineering to have a larger share of diploma and bachelor's degree holders. Teams in sectors like pharmaceuticals & biotechnology, chemicals, oil & gas and industrial metals & mining on the other hand are dominated by master's degree and PhD holders.

There is an urgent need for Indian firms to build the capability that will help them select the right R&D projects, make the right investments in technology and increase their innovation output. The 'Transforming R&D in Indian Firms' programme aims to do just that for existing R&D teams. However, Indian firms need to start thinking differently about their future hires to build truly world leading R&D teams.

Global hiring practices

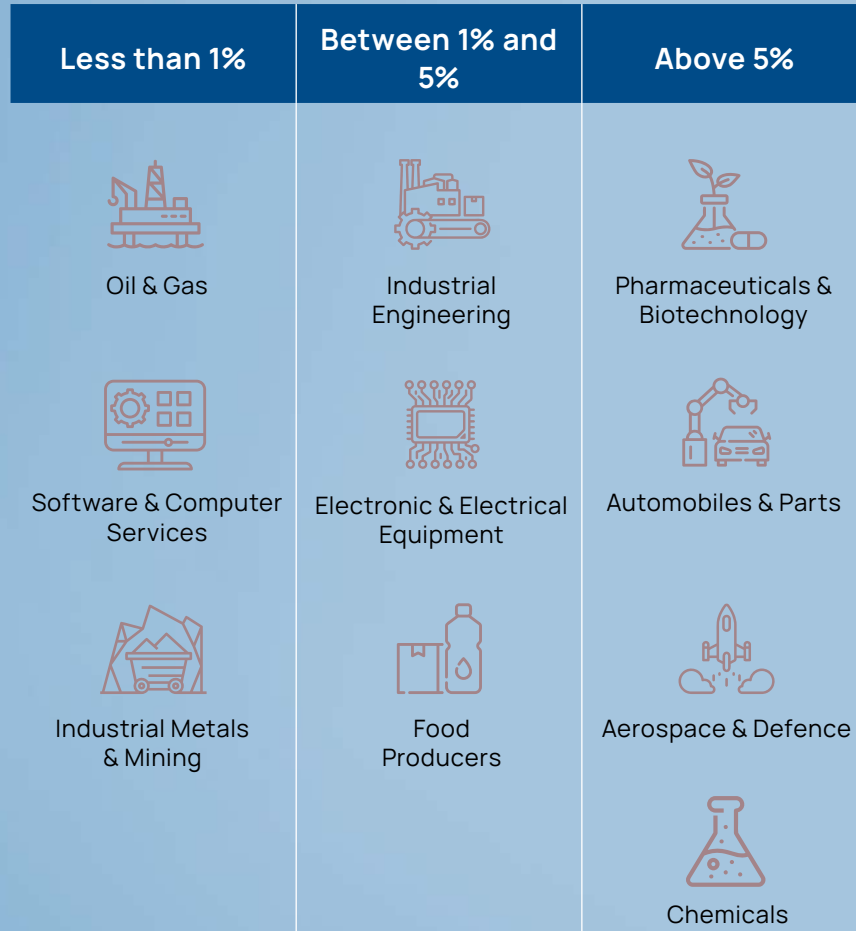
Global firms are seeking capabilities that go beyond the traditional technical R&D roles. They are building multidisciplinary teams to combat the challenges being posed by the shift in the global industrial R&D landscape.

Global firms are beginning to embrace newer work trends and are open to hybrid roles that allow for greater flexibility. The focus on multidisciplinary teams, diversity and hybrid roles for certain positions is creating new and exciting possibilities as firms target a wider global talent pool to drive innovation.

AI/ML and data science capabilities are being sought after for a wide range of applications. For example, Johnson & Johnson is hiring AI scientists to work on AI-powered drug discovery, while Microsoft is hiring data scientists to develop models that would support the expansion of data centres while reducing carbon emissions.

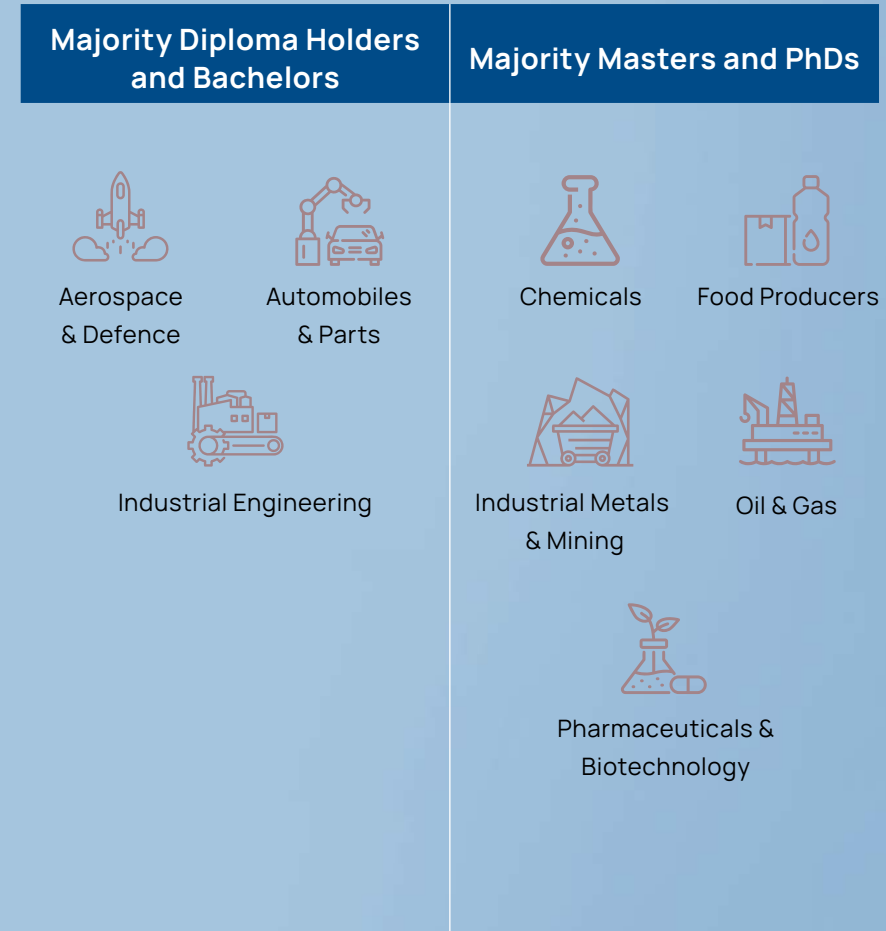
Psychologists and demographers are being hired across a number of sectors to identify consumer preferences and conduct surveys. Mercedes Benz is hiring individuals with a background in psychology to enhance the user experience of its in-car infotainment and connected car systems, while Unilever is hiring them to understand consumer and market trends and identify strategic growth opportunities for its ice cream product line. Software & computer services firms like Meta are hiring demographers to gather accurate data through surveys to train their machine learning models.

Figure 7: R&D Team Size as a Share of Total Workforce



Note: Sample consists of 5 firms from each of the top 10 Indian R&D sectors

Figure 8: R&D Team Composition by Academic Qualification



Note: Based on responses from 22 Indian firms

Figure 9: R&D Capabilities Sought by Global Firms

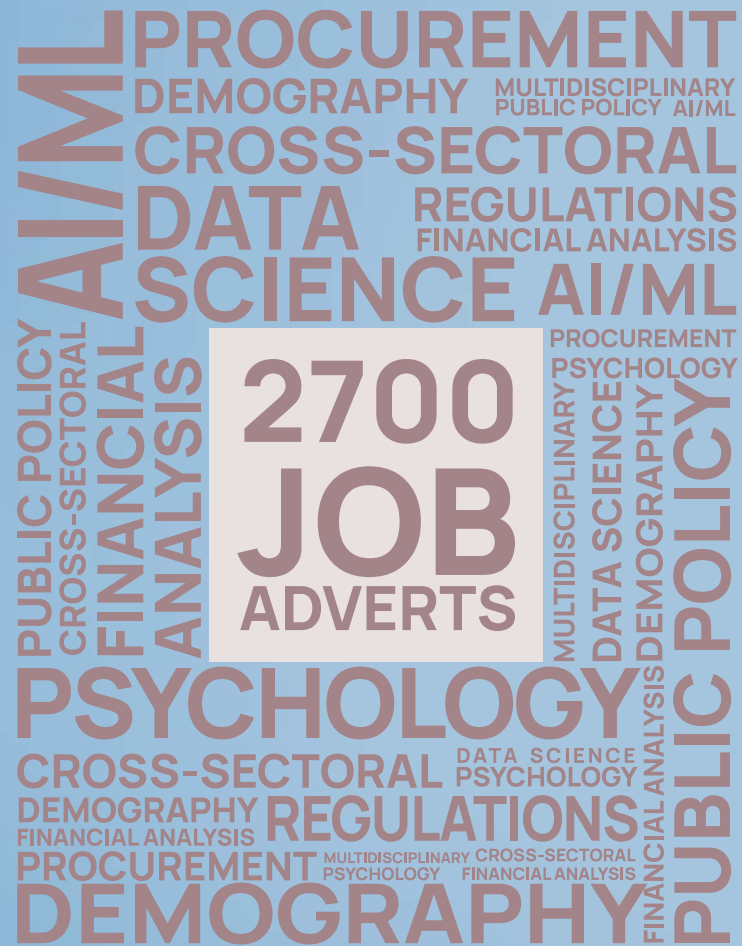
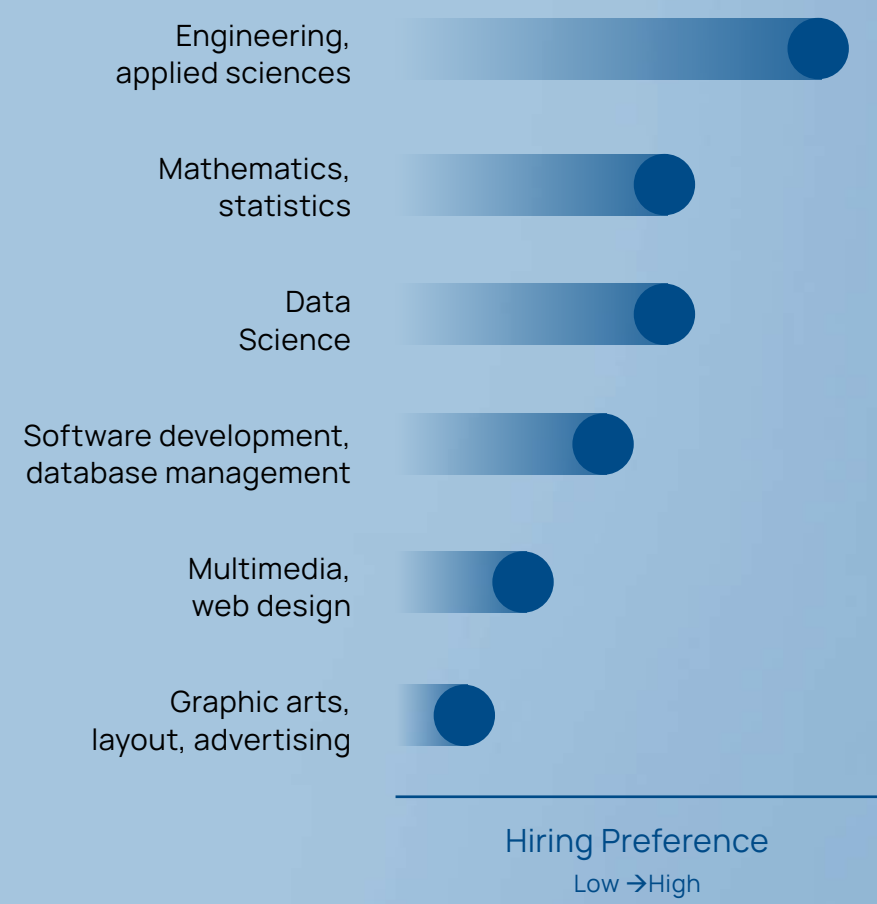


Figure 10: Indian Industry's Hiring Preferences for R&D



Note: Based on responses from 22 Indian firms

Professionals with an understanding of public policy and regulation are being sought while procurement roles are starting to get embedded within R&D teams. ABB, a global industrial engineering firm, is hiring individuals to track relevant environmental policies and regulations and support its product teams with life cycle assessments and environmental product declarations. Boeing and AstraZeneca are hiring procurement professionals within their R&D teams to ensure that specific procurement requirements for R&D are met efficiently.

Other interesting vacancies being advertised include positions for financial analysts to perform valuation analysis and help prioritise the R&D portfolio, as well as positions that would require individuals to provide cross-sectoral insights and adapt technologies from other sectors.

These examples highlight the hiring practices of global firms that are doing their best to attract a diverse set of individuals with varied qualifications. The firms are also trying to attract qualified applicants irrespective of race, colour, religion, disability status and even gender identity by clearly stating their commitment to being an equal opportunity employer in these job adverts. Some of

the roles, be it in AI or procurement, are being advertised as hybrid positions which is likely to attract an even wider pool of applicants.

Conclusion

Indian firms must build capabilities to complement their R&D spending. To achieve this, they would need to focus on multidisciplinary skills that go beyond technical skills and understanding business needs. A number of top Indian R&D firms that we have interacted with across sectors continue to have a preference for candidates with a background in either engineering or applied sciences, while areas like data science, mathematics and statistics are gradually gaining importance. Interestingly areas like software development and database management for the manufacturing sectors seem to be less of a priority in terms of immediate hiring.

Building truly effective R&D teams would require bringing together diverse individuals with capabilities that range from understanding market dynamics and competition to managing IP and anticipating future trends. Multidisciplinary teams drawing from science, technology and the humanities will be key to understanding consumer preferences and delivering differentiated offerings. For Indian firms to build such multidisciplinary teams, they will have to compete with global firms for the best talent. This will require them to have a heightened focus on diversity, equity and inclusion (DEI) initiatives while providing more remote and hybrid opportunities to complement such efforts.

The current rollback of DEI initiatives by global firms⁴³ coupled with immigration uncertainties in several advanced economies presents a unique opportunity for Indian firms to attract top talent back to India. China's Thousand Talents Plan was able to attract top technologists back to China, and was one of the factors that has contributed to the Chinese industry moving up the technology value chain. If India too has to attract top talent, we would need to create meaningful opportunities in pre-commercial industrial R&D labs as well as in our firms for product related industrial research, besides creating opportunities in startups and academia.⁴⁴

**What must
Indian Industry do?**



Indian firms must place R&D at the core of their corporate strategy to transform into proactive leaders, build a strong global footprint and become truly competitive. They must place R&D at the core of their corporate strategy and transform into proactive leaders. They must increase R&D investments, accelerate the integration of digital technologies, pursue emerging technology opportunities, build multidisciplinary teams and foster a shift in the innovation mindset of the firm.

Increase in house R&D spending

Firms must view R&D as a long term strategic investment, using it to develop products that cater to global and Indian needs.

Accelerate the integration of digital technologies into the R&D value chain

While digitalisation can significantly reduce development cycles, enhance product quality and enable a faster response to market shifts, these benefits can only be

realised if firms invest in the capabilities required to deploy and integrate these tools effectively. To build these capabilities, firms must leverage the strengths of the Indian software industry.

Actively pursue emerging global technology opportunities

Indian firms should pursue technology developments in areas such as autonomous vehicles, alternate batteries and battery recycling. As the nature of competition changes, maintaining competitiveness requires agility and strategic foresight. Benchmarking current R&D practices against global industry standards, identifying new opportunities through startup acquisitions and collaborations with industry and academia are key enablers in this pursuit.

Build multidisciplinary R&D teams

Indian firms must build teams that bring diverse perspectives from various disciplines such as data science, psychology and public policy. They must invest in developing future ready

competencies such as systems thinking, design thinking and strategic foresight.

Foster a shift in the innovation mindset

Indian firms must shift their mindset from incremental to radical, from imitation to leadership, from risk aversion to calculated experimentation. Indian industry must step forward with intent, reimagine its approach to innovation and actively position itself as a leader in emerging technology domains.

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Over the years, CTIER has become the foremost think tank for innovation in India. Our unique analysis and insights have informed policies introduced to strengthen India's R&D and innovation ecosystem. The Centre's programmatic interventions have helped build the capabilities needed to transform Indian industry into an innovation powerhouse. CTIER has also been at the forefront of shaping academic thought in the economics of innovation.

