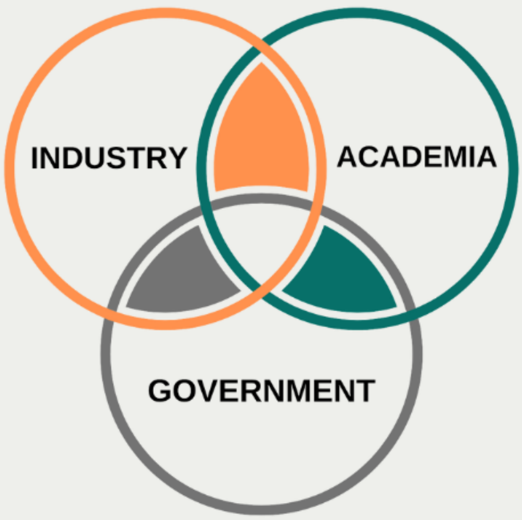
FAST INDIA

FOUNDATION FOR ADVANCING SCIENCE AND TECHNOLOGY

The Ingredients of a Robust Research Ecosystem



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1. About the working paper

This working paper is a part of the ongoing effort by the Foundation for Advancing Science and Technology India (FAST) India to stimulate thought and action in the science and technology (S&T) ecosystem. This note identifies various actors in the research ecosystem and their interaction mechanisms. Subsequently, it develops an outline of the functionalities needed in Indian academic institutions to efficiently interact with multiple actors for better economic and societal research outcomes. Ultimately, this paper aims to support a change in the current focus of many academic institutions, from undergraduate programs and jobs, towards building formidable research capability and, in turn, a robust research ecosystem. This working paper can be cited as '*Singh, Chetandeep and Thukral, Ayushee (2023). "The ingredients of a robust research ecosystem." FAST India Working Paper.*

Important Definitions[1]**:**

- **Government:** The Union Government and all agencies / departments under its purview, the State Governments, and the local Governments constitute the Government setup responsible for R&D activities, funding or performing, or both. Also included are labs that have their R&D activities under the direct control of or administered by the Union Government.
- **Industry:** All resident corporations, including private business enterprises (publicly listed and traded or not) and public business enterprises (i.e. Government-controlled enterprises).
- **Academia:** All universities, colleges of technology, and other institutions providing formal tertiary education programmes, whatever their source of finance or legal status. All research institutes, centres, and labs that have their R&D activities under the direct control of or administered by tertiary education institutions.
- **R&D:** 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.

2. The role of R&D in a modern economy

The role of research in fostering technological advancement and innovation, ultimately leading to economic growth, industrial development and competitiveness, national security and increasing economic opportunity, has been proven over decades and economic systems by economists such as Robert Solow,[2] Mariana Mazzucato,[3] and many others. Findings from research frequently point out that capital investment, technological advancement, and labour inputs collectively form the ladder for the progressive development of a society.

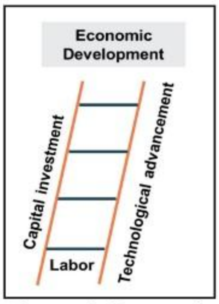

Figure 1: Economic Development

3. Who are the stakeholders in R&D

The Government, Industry, and Academia are the chief stakeholders of R&D activities, performing various roles in the research ecosystem that have evolved over time.[4]

The Government, representing citizens in a democratic state, has multiple expectations from greater technological capabilities: a more profound and broader economic opportunity for all citizens, self-reliance in critical areas to maintain strategic autonomy, and strong national security. It is also important to note that the taxpayer indirectly supports most fundamental research; hence the onus lies on the Government to make sure the money is used efficiently for the nation's scientific elevation.

Industry, including the world of technology-driven startups, performs translational research and identifies markets and distribution channels for serving customer needs with ever-evolving products and services guided by the 'invisible hand'.[5]

Academic institutions such as universities are the incubators of basic scientific knowledge. They are the key ingredient in the quest for a knowledge economy, as stated by Philip Altbach in 2013.[6] Apart from training personnel, these institutions also provide opportunities for interaction with global counterparts that open doors for scientific communication, collaboration and knowledge sharing.

Given Academia's central role in advancing knowledge, it is imperative to create a robust research ecosystem at academic institutions such that Industry and Government can leverage the advances to drive innovation, economic growth, and inclusive development.

Figure 2 visually demonstrates the various interactions between stakeholders. Frameworks to ease the research process have sprouted over the years in the form of research offices, industry liaison offices, technology transfer offices, fundraising offices, and science parks, among others. These entities are primarily housed in academic institutions or centred around them while developing deep linkages with the Industry and Government.

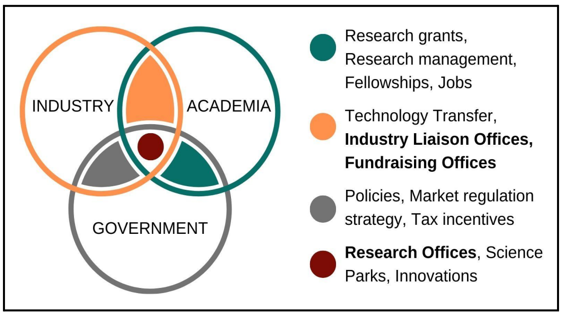

Figure 2: Channels of interaction between R&D stakeholders

4. From research to system development: Role of stakeholders

Auerswald and Branscomb[7] define 'invention' as a commercially encouraging product or idea born of science and technology. Further, they define 'innovation' as a successful entry into a new science or technology-based product in the market. The course taken to turn inventions (the R side of R&D) into innovations (the D side of R&D) thus encapsulates the entire R&D cycle. Both Invention and Innovation are highly uncertain processes with long lead times and are a collective effort.[8] These characteristics define the nature of intervention and finance needed. Uncertainty leads to risk, long lead times call on sustained funding, and the collective spirit of innovation suggests multiple public and private funding sources.

The Entrepreneurial State: Mariana Mazzucato, 2013
Investing funds in research through government-owned agencies has yielded outcomes that have shaped the world. Examples include **Lithium-ion batteries, GPS, Siri voice recognition software, and the Multi-touch screen**. Basic research on these was done at publicly funded entities in the USA, including DARPA and the Department of Energy, and then taken further by enterprises (Apple) to form consumer products such as iPod and iPhone.

The Technology Readiness Level (TRL) measures the maturity of R&D activity ranging from TRL 1 to TRL 9 as per the European Union translation.[9] Across the 9 TRLs, R&D is divided into four stages: basic research (TRL 1 and 2), applied research (TRL 3, 4, and 5), technology development (TRL 6 and 7) and systems development (TRL 8 and 9). On one end of the spectrum, basic research is undertaken for the advancement of knowledge and to answer essential questions for humankind which may lead to disruptive solutions that improve societies but may not necessarily reap the benefits of commercialisation. This kind of research is generally high-risk and requires sustained funding. On the other end, systems development is one short leap away from translation into commercially viable solutions. Systems development, while risky, will not be as uncertain as basic research and may only have short-term funding requirements. While multiple threads of basic research may be picked up and dropped, with only a few resulting in success, the entire spectrum of the R&D lifecycle will need to be crossed to get to systems development. In an ideal scenario, an economy's R&D ecosystem must have a mix of long-term, open-ended research and short-term developments closer to translation.

Historically, research was funded majorly by Federal Governments and confined to priority sectors such as health and defence (until the Cold War era). The latter half of the 20th century saw an expansion of R&D focus areas, a shift in R&D investments from being majorly Government funded to majorly privately funded, and the development of multiple organised entities that perform R&D[10] (including research at academic institutions and private sector firms). The roles performed by the three stakeholders across the R&D lifecycle have evolved over the years from mutually exclusive to ones with blurred boundaries. Efforts to identify these developed roles have resulted in a framework called the 'Triple Helix Model' of interactions.[4] The theory behind this model stems from the idea of a 'knowledge-based economy',[11] which appreciates the amplification of organised R&D that shapes research and looks at various stakeholders in the research cycle as co-dependent and interlinked, requiring channels for effective translation of invention to innovation.[12]

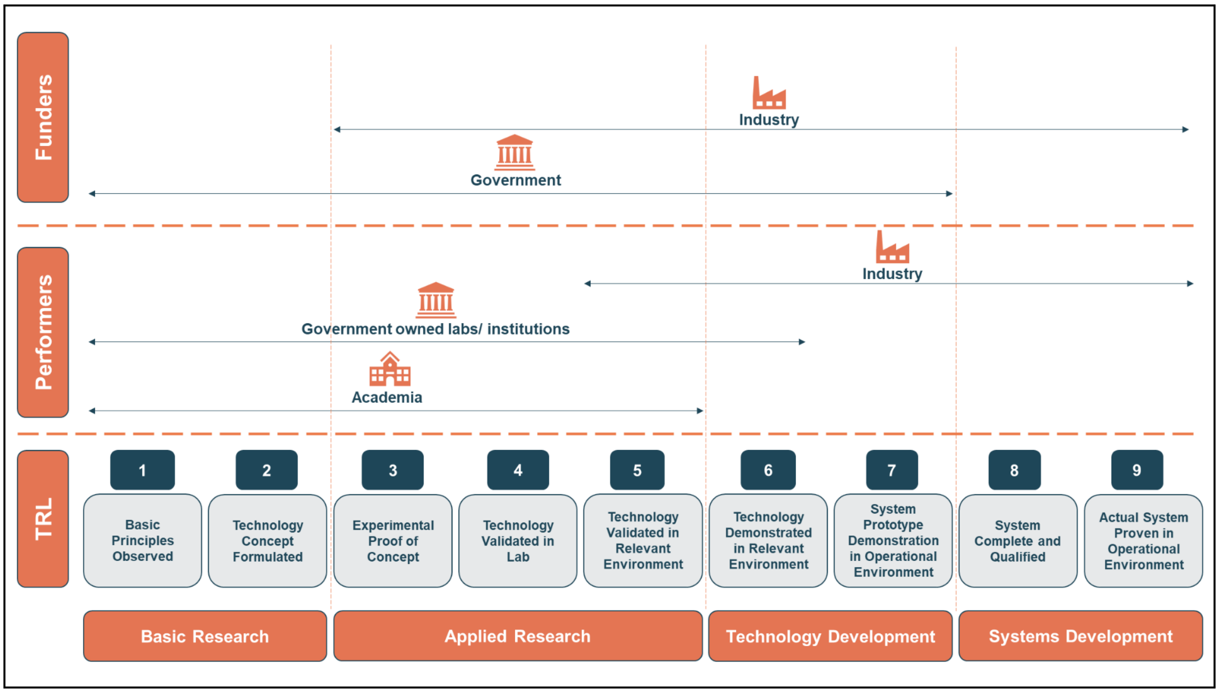

Figure 3: Role of R&D actors along the research cycle (adapted[13])

Figure 3 shows the roles that the Government, Industry and Academia play during various stages of R&D. Division of role as a financier or performer is drawn up based on tasks performed at each stage throughout the R&D cycle. As shown, the Government and Industry share responsibilities of 'funding' and 'performing' R&D activities through institutions / labs / R&D centres under their jurisdiction. Academia only takes up the role of the performer of R&D, and rightly so. Academic institutions should always be generators of evidence-based knowledge that the Industry and Government can utilise. While the academic institutions and Government perform the bulk of the long-term open-ended research until TRL 5 or 6, which may or may not result in commercialisation, the Industry is responsible for converting some of their outputs into market-ready products (TRL 5-9).

4.1 Performers of R&D (Academia and Industry):

According to Vannevar Bush,[14] academic institutions push the frontiers of science into new directions and develop new knowledge that can be converted into usable products and services. These institutions foster basic research (TRL 1-2) and, to some extent, applied research (TRL 3, 4, and 5), which subsequently leads to new patents and scientific publications[15,16,17] and also forms the bedrock of knowledge-based businesses.[18,19] Academic institutions also

> Innovative breakthroughs such as the **X-rays**, Magnetic Resonance Imaging (**MRI**), the **Google search engine** and the **Internet** are some examples for which basic research was done at academic institutions in the USA using public finances channeled through government agencies like the National Science Foundation and National Institutes of Health. Subsequently, the academic research findings combined with other technologies were used by industry members to develop commercially viable products.

collaborate with the Industry to identify market trends to pursue research in priority sectors while creating Industry ready skilled labour force in the process.[20]

Typically identified as the market-facing entity among the three stakeholders, the Industry often takes on the role of (although not limited to) the D side (TRL 5-6 and beyond) of R&D. Industry brings in additional skilled personnel such as marketers, product designers, production engineers and financial managers who work alongside the scientists / researchers to build a product from a research outcome carrying commercialisation potential.[21]

4.2 Financiers of R&D (Government and Industry):

Traditionally, Governments have been a cyclical funder of research across the R&D lifecycle. More recently, with steady growth as a funder and performer, the private sector Industry accounted for 62% of the OECD R&D financed as per 2015 OECD data.[22] However, the high-risk nature of innovation keeps the private Industry from funding basic research but more in favour of investing further downstream as the TRL level increases owing to the immediate rewarding nature of the latter, as stated by Mariana Mazzucato in the book titled The Entrepreneurial State.[23]

The Government must step in to mitigate risk and ensure enough funds are available for basic research (TRL 1-2). Corroborating the fact, Figure 4 shows the US Federal Government had a share of approximately 20% of the total R&D funding while the private Industry accounted for 73% of the share. But when looking at funding shares for basic research, we find that the Federal Government had a 40% share compared to a 33% share by the private industry while the higher education and non-profit sector (non-government, non-academia) accounted for a combined 25% share.

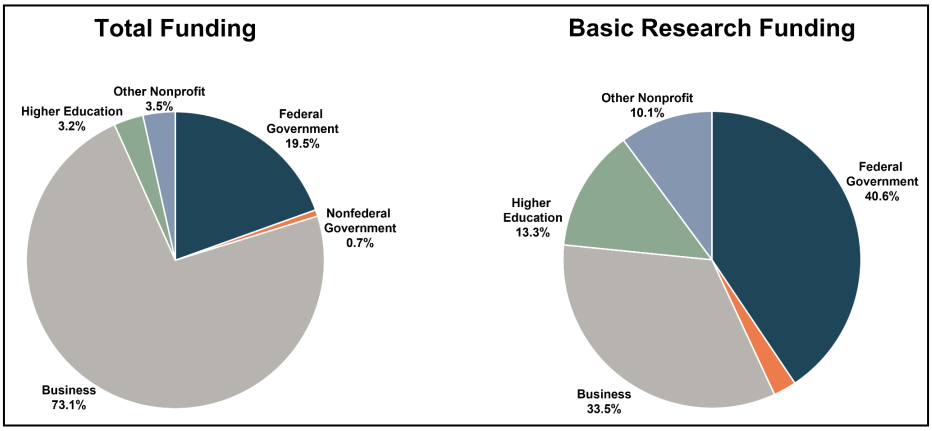

Figure 4: US R&D funding by sector, 2019[24]

4.3 Enabler of R&D (Government):

With changing market needs and challenges, Governments need to shift to a 'mission-oriented' approach for Government-funded R&D programs.[25,26] Further, new research has shed light on the role of the Government, such that it creates policies that help 'shape' a market or 'create' one that opens up opportunities for private investors to come in.[27] This is even more important considering the Government utilises public funds for R&D. The Government also provides the constructs required to conduct R&D in the form of academic infrastructure, market creation and incentivisation.[28]

To obtain the support of private Industry and their wealth of resources (financial and human) in the race to become technological superpowers, Governments provide the private sector with several direct and indirect support systems in the form of subsidies, loans, grants, allowances and tax benefits to incentivise the private sector to spend more on R&D. Extensive research points towards the positive effect of such incentives on private Industry funding R&D activities.[29,30]

India's National Electric Mobility Mission Plan (NEMMP 2020)[31] and Production Linked Incentive (PLI)[32] scheme present a case for the Government's active role in creating a market, incentivising research and mitigating risk for the private sector to invest in electric vehicles and the results are starting to show.[33]

5. Global scenario of stakeholder interaction instruments

Creation, integration, and dissemination of knowledge are most efficient when multiple stakeholders (for sources of information and finance) are involved and work in tandem. Equally important is the effective management of the said knowledge.[34] The benefits of collaborative R&D include reducing costs and risks, access to new technologies and markets, and promoting competition are well documented.[35] Over time, successful linkages showing the key ingredients for such interactions between Government, Universities and Industry have emerged and evolved.[36] Table 1 below shows various interaction instruments between the stakeholders and the frameworks in place to establish the linkages.

Interactions	Interaction Enabler	Interaction Task	Instruments of Interaction				
			USA	Germany	Japan	China	India
Academia-Government	Federal Agency, Research Office, Grant making agency	Research strategy, Grants management, Funds management	» National Science Foundation (**NSF**), » National Institutes of Health (**NIH**)	» **Fraunhofer Society** for Applied Research, » **Max Planck** Society for Basic Research	» Japan Science and Technology Agency (**JST**)	» Dept. of Basic Research, » Dept. of High and New Tech, » Many others + Affiliated programs	» National Research Foundation (**NRF**) (Proposed) » Currently through Government and Private funding agencies
Academia-Industry	Industry Liaison Office, Fundraising Office	Intellectual Property, Technology transfer, Licensing, Fundraising,	» Formation of **Bayh-Dole Act** in 1980 (granting permission of ownership of patent to inventors) » Patent-License startup model	» Formation of **Inventors' Law** in 2002 (on the lines of Bayh-Dole Act) » Innovation system strongly influenced by industry	» Adoption of **Bayh-Dole Act** in 1999 » Intentional shift from basic research to application and commercialization	» Adoption of **University-Industry Alliances on Collaborative Development Engineering** in 1992 » Subsequent and regular upgradations to IP laws	» **No law** in place to foster Academia-Industry linkages » The Protection and Utilization of Public-Funded Intellectual Property Bill, 2008 was introduced in the Parliament: **currently stands withdrawn**
Industry-Government	Chamber of Commerce	Policies, Tax incentives, Market regulation	» Tax Credits, Tax Deductions (100% on R&D expenses)	» Green Tech given preference (Sustainability, Decarbonization) » Tax Credits, Cash Grants, Loans	» Digital Transformation (5G) enabled incentives in addition to carbon neutrality » Tax Credits	» Additional incentives for TASC + HNTE based companies working in advanced tech » Reduced Tax Rates, Tax Deductions, Tax Exemptions, Tax Holiday	» Tax Deductions (100% on in-house R&D) » Reduced from 200% due to misuse

Table 1: Instruments of interaction between stakeholders (Tax incentives - EY Guide[37])

Academia-Government partnerships: Federal research agencies such as the National Science Foundation (NSF), established in 1950 in the USA, take up granting funds and directing research towards priority sectors.[38] Research offices / grants management offices act as intermediaries between researchers and grant-making bodies at academic institutions. These structures have helped ease the administrative burden on scientists and researchers.[39]

Academia-Industry partnerships: The Bayh-Dole Act[40] of 1980 in the US was a significant turning point in the commercialisation of research in the USA. The act deals with intellectual property arising from federally funded research. Adopting the act allowed inventors (universities and small businesses working non-profit) to retain ownership of inventions and commercialise their outcomes through patenting, licensing and technology transfer. The Bayh-Dole act proved to be a major catalyst for new research and gave rise to the commercialisation of research through spin-outs, licensing activities, and technology transfer.[41] It didn't take long for countries like Germany and Japan to adopt similar policies for intellectual property management. Over time, the interaction between Academia and Industry has come to be facilitated by Industry liaison offices, technology transfer offices, and incubators that take care of the commercialisation of research.[42,43]

Industry-Government partnerships: The MEDEA initiative of the French Government for microelectronics integration into select applications illustrates effective Industry-Government partnerships. The structure ensured Governmental decision-making on research priorities supported the needs of the Industry, cementing the link between the two through cost-sharing.[44]

While commonplace in advanced economies like the USA, Germany, Japan, and now even China, Government-Industry-Academia linkages are yet to mature in India fully.[44]

Impact of stakeholder interactions: Interactions between stakeholders have resulted not only in successful research outcomes across economies but have also translated into improvements in metrics such as the Global Innovation Index. It can be seen from Table 2 that structures facilitating organised stakeholder interaction lead to efficient research ecosystems corroborated by the number of researchers in R&D per million. It is imperative to note that a country's higher spending on R&D as a percentage of its GDP is a precursor to any such linkages being facilitated.

	USA	Germany	Japan	China	India
Impact of Linkages	» **Rise in Tech Transfer Offices** in univs post Bayh-Dole Act (23 previously to most univs now), » **Increase in commercial arrangements** like spinouts, incubators, etc.	» **Translation of research into products** and technologies by government policies » Government progressively less involved in research activities	» Adoption of Bayh-Dole Act **increased Tech Licensing Offices** » Industry-Academia linkages increased correspondingly	» Chinese version of Bayh-Dole Act awarded universities far more than their US counterparts » Resulted in **rapid increase in transfer of knowledge from academia to industry**	» **No law** in place to foster Academia-Industry linkages
R&D spend as a % of GDP (2020)	3.45	3.14	3.26	2.40	0.7
Researchers in R&D per million (2020)	4281 (2019)	5393	5455	1585	253 (2018)
Global Innovation Index rank (2021)	3	10	13	12	46

Table 2: Impact of stakeholder interplay in the R&D ecosystem[46,47,48,49,50]

6. Challenges India faces in stakeholder interactions

India faces challenges to R&D stakeholder interactions at individual, institutional and policy levels. We list these below.

6.1 Structural disengagement between stakeholders: The actual scenario, as illustrated in Figure 5, shows that the primary reason for the non-translation of research outcomes into new technology is the lack of overlap between Academia and Industry. This disengagement results from a scientific establishment where research labs exist outside Academia, such as the extensive networks of labs funded by the Council of Scientific and Industrial Research (CSIR), the Indian Council of Agricultural Research (ICAR), the Indian Council of Medical Research (ICMR). Scientists in these labs do not teach students, and moreover, more than 90% of Indian students study in institutions where less than 10% of the research is conducted.[51] Further, stakeholders judge themselves on different metrics. Academia gives importance to publications, while the Industry tends to move according to market trends. This lack of common goals causes differences in expectations, incentives and even outcomes. Subsequently, this gap in understanding the other stakeholders' capabilities and limitations is primarily responsible for the 'Valley of Death'.[52] In the ideal scenario, there need to exist instruments that tie stakeholders to work collaboratively towards creating effective research outcomes.

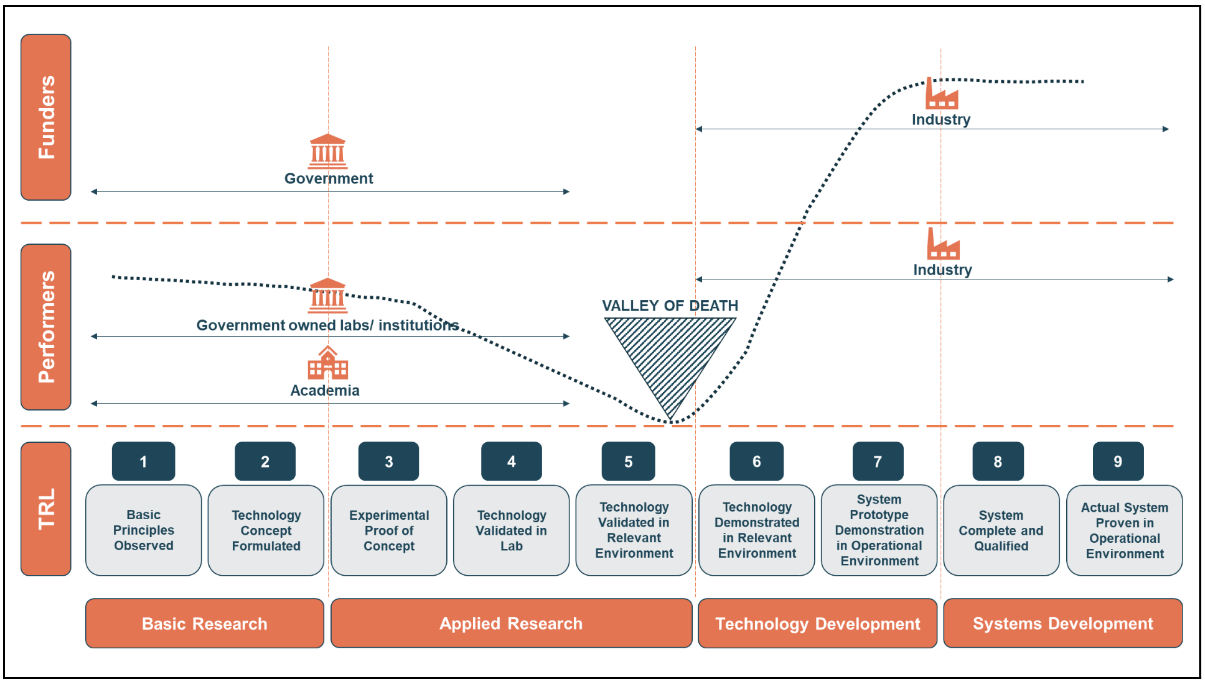

Figure 5: Valley of Death

6.2 Lack of Research Universities: Publicly funded research does not happen at universities in India but is instead concentrated in Government-owned entities such as the Defence Research and Development Organisation (DRDO), Department of Space (DoS), Department of Atomic Energy (DAE), ICAR, and CSIR which collectively account for 82% of the total R&D expenditure of the Union Government.[48] Higher education institutions received a measly 6.8% of the total national R&D expenditure in 2017-2018 compared to the Union Government sector, which received the lion's share of 45%.[48] More than 50% of the Union Government's funds intended for higher education are available to a mere 3% of institutes like IITs, IISc and NITs.[53] India should aim to create a number of world-class higher education institutes. By definition, a world-class research university may be defined as one that supports teaching and research while retaining the autonomy to decide the teaching content, hiring of resources and admissions of students.[54]

6.3 Lack of relevant IPR policies: The Protection and Utilisation of Public-Funded Intellectual Property Bill, 2008, stands withdrawn from the Parliament due to multiple challenges identified in its framework.[46] Largely modelled on the Bayh-Dole act, the Indian version came under criticism for not considering the Indian context and blatantly using the US system. Additionally, over-emphasis on the IT sector and complete ignorance of others, such as Healthcare, became reasons for the bill's downfall. However, even a decade later, the country still doesn't have a policy that incentivises research innovation. While many Academia and Government-owned research centres have their intellectual property frameworks,[55] there still exists a need for a uniform policy at a national level.

6.4 The Indian Industry conundrum: Only one Indian entity (Tata Motors Limited) featured in the top 100 global spenders on R&D in 2019.[56] The fact that India's industrial R&D expenditure is minuscule, as seen in Table 3, begs the question that despite being the 3rd largest producer (by volume) for pharmaceuticals[57] and having a $200 bn worth of IT Industry,[58] why does India not have a more significant share in global R&D? Why have prominent industrial houses of India largely stayed away from investing in research in India? Why have companies such as Mahindra (Pinninfarina in Italy, MNATC in USA) and Tata (TATA Elxsi in Germany) invested crores of rupees in acquiring and setting up research centres outside India? Why have Indian Industry stalwarts always leaned towards extending financial endowments to foreign universities rather than creating strong frameworks for research within the country? The argument circles back to a lack of interaction between the stakeholders of R&D and how simplification of linkages through frameworks can help identify bottlenecks and shortcomings as well as develop a sense of trust amongst stakeholders.

Country	No. of companies performing R&D in 2021	Value of R&D (bn Euros)
USA	779	343.56
China	597	140.95
Japan	293	111.06
Germany	124	86.94
France	66	32.02
South Korea	60	33.43
India	25	4.37

Table 3: Distribution of companies and R&D by country (as per EU Industrial R&D investment scoreboard)[59]

6.5 Government-owned entities perform most research: Another fascinating piece of data points out one of the fundamental drawbacks of the Indian R&D ecosystem is that the Government performs and funds more than half of the research activity taking place in the country. All major global countries, as depicted in Table 4, show almost three-fourths of the research being performed by the corporate sector but India still relies heavily on the Union Government. In 2019, the top five companies with the largest R&D expenditures: Alphabet, Microsoft, Huawei Investment & Holding, Samsung Electronics and Apple spent 17 times more on R&D than the combined spending of all surveyed Indian listed companies. In the same year, the contribution of Indian listed companies to the global corporate spending on R&D was merely 0.5%.[56] This points towards a lack of policy interventions that incentivise the Industry to spend on scientific R&D. In other economies, the Government has, over the years, pulled back from being the primary driver of scientific R&D to a facilitator of research, assisting the Academia and Industry in their quest for innovation.

	USA	Germany	Japan	China	India
R&D performer (2019)	Corporates **73%** Government **10%**	Corporates **69%** Government **13%**	Corporates **79%** Government **8%**	Corporates **77%** Government **15%**	Corporates **37%** Government **56%**

Table 4: Share of R&D performers[60]

India is still grappling with the question of whether to regard research as a public service or a tool for economic development. While it may not be explicitly accepted, the paucity of channels available for the commercialisation of research outputs coupled with an equal lack of incentives to perform research narrates a different story. Perhaps it is a conglomeration of several factors, such as lack of quality and quantity of researchers, lack of relevant reformist policies and something as fundamental as low Government expenditure on R&D. Working in tandem, these create obstacles in the research cycle that ultimately make research seem like an onerous task. Nevertheless, resolution of the identified issues at various stakeholder levels is possible only if research outputs are seen as building blocks for economic development. Issues identified in this section require foundational effort in a bid to create a robust research ecosystem. Academia, identified as the stakeholder that can act as the cardinal seat to facilitate stakeholder interactions, is the first point of any intervention and should thus be strengthened with appropriate skills that initiate the creation of a solid research community.

7. Identified functionalities for academic institutions

Over the years, several new roles and professionals have blossomed in the higher education sector. These new roles are designed to provide researchers with opportunities that enhance their research outcomes through new linkages between the Government, Industry and Academia. Trained professionals perform functions such as research management, enabling stakeholder collaborations, assisting in the commercialisation of research outcomes, fundraising, and managing alumni networks. Such functionalities have steadily grown over the years in academic institutions[61] and have been seen to occupy a 'third space' as defined by Whitchurch[62] - roles not entirely administrative but also non-academic.

FAST India proposes some of these functionalities in Figure 6 that it feels are essential conduits to building an ideal research ecosystem.

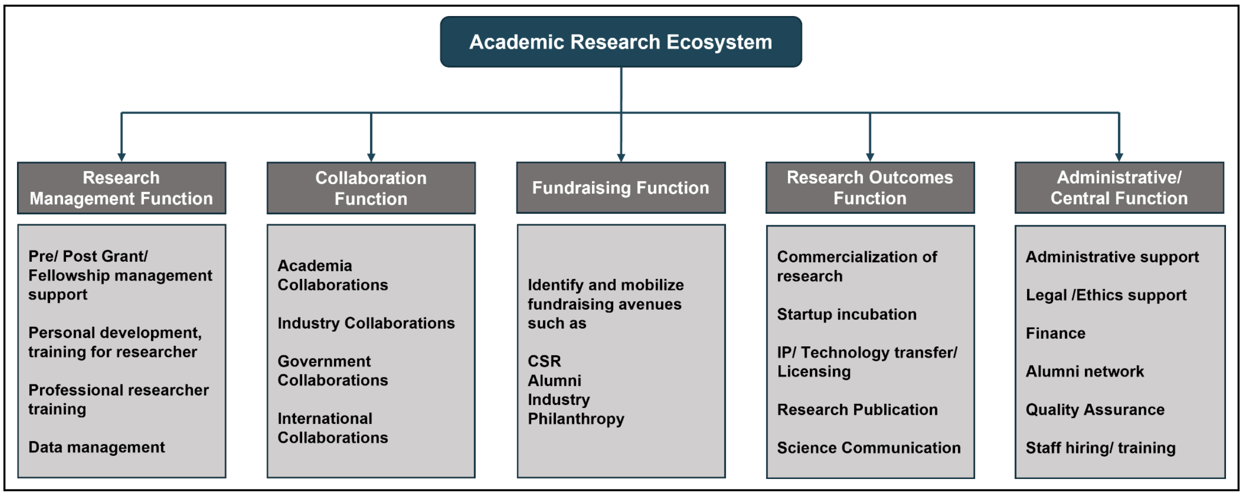

Figure 6: Functions for effective research ecosystems

7.1 Research Management Function: The need for research management functions within academic institutions has been boosted by an increased focus on research output quality and efficient management of grants and funds to researchers.[63] This functionality is aimed at providing a balance between institutional targets of performing research and the ability of academics to perform research. Support for pre and post-grant activities such as grant application submissions, funds management, access to infrastructure and training where necessary encapsulates the activities of this functionality.

7.2 Collaboration Function: Central to the creation of a knowledge-based economy lies trans-organisational knowledge sharing. Facilitation of such knowledge sharing requires intelligent interfacing using unique management skills and organisational designs that leverage and streamline the flow of information between members.[44] Bringing together stakeholders (Inter/ Intra - Government, Industry, Academia) presents one of the toughest challenges since they come in with very different traditions, expectations, disciplinary roots, and cultures.[64] Circumventing these complex fundamental issues to ensure a thriving research ecosystem requires skilled professionals who are well-versed in the culture and jargon of stakeholders and can manage these networks effectively.

7.3 Fundraising Function: Academic institutions need to nurture additional funding sources to expand their research base beyond what is possible with core funds/ grants from Government sources. Universities across the world actively seek out new sources of funding, such as philanthropy as additional revenue streams,[65] and research also suggest that institutions can no longer afford to sideline additional funding.[66] Fundraising professionals actively seek out avenues for financial support through curated fundraising campaigns, alumni relations, public relations, and marketing[67] and, as such, need to be professionally trained in these activities.

7.4 Research Outcome Function: Studies have conclusively shown that the presence of organised structures (that mediate a conversation between stakeholders of research activities) leads to a rise in research outcomes such as publications, patents, licensing activities, and sponsored research.[68,69] These outcomes need to be managed by structures of their own, such as Technology Transfer Offices and Science Parks. Further, to ensure effective workflows, they need to be staffed with adequately skilled personnel experienced in Business Development activities, Industry Liaisoning, Product Design, Project Management and Managing inbound requests for sponsored and consultancy research.

7.5 Administrative/ Central University Function: Tasks such as financial support, administrative support, hiring support, quality assurance, and compliance indirectly support the creation of an effective research ecosystem by streamlining processes of a non-academic nature. Ensuring timely disbursement of funds, for example, removes unnecessary pressure from the researcher, who can then continue to perform their core work more efficiently. Another example is quality assurance, both in terms of inputs (hiring of researchers/ scientific personnel) and outputs (high-quality research) that ensures high standards in the research ecosystem value chain hence created.

Given below in Figure 7 is an ideal Academic research ecosystem, central to which lies the research lab and is supported directly and indirectly by functionalities as listed above.

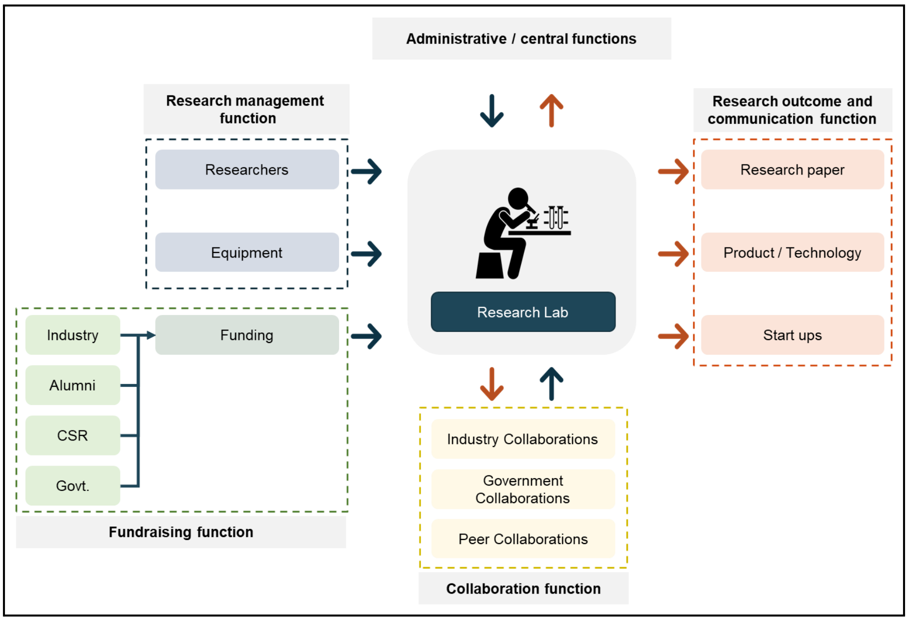

Figure 7: The ideal academic research ecosystem

8. Conclusion

It is no secret that Indian R&D outcomes have not quite reached the levels of success that they should have, given the talent and resources available. However, attempts have also been made to identify bottlenecks, and timely interventions have led to India becoming one of the largest startup ecosystems in the world. India's progressive rise in the Global Innovation Index ranking is another positive sign. These are successes that one should take inspiration from and try to bridge gaps identified in the academic sector to build effective, collaborative and efficient research ecosystems.

Although many loopholes need to be addressed, the adoption of the recommended functionalities in academic institutions is sure to set the ball rolling in the right direction. Upcoming papers shall focus on each of the functionalities in greater detail while also listing down successful examples from a global perspective.

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