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BUILDING INDIA'S INNOVATION ECONOMY:
Catalyzing Private R&D Activity Through the ANRF

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Policy Analysis Exercise

April 2025

BUILDING INDIA'S INNOVATION ECONOMY: Catalyzing Private R&D Activity Through the ANRF

Strategic Recommendations for India's Anusandhan National Research Foundation

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LIST OF ABBREVIATIONS

AIF – Alternative Investment Fund

ANRF – Anusandhan National Research Foundation

BERD – Business Enterprise Expenditure on Research and Development

CSR – Corporate Social Responsibility

CTIER – Centre for Technology, Innovation and Economic Research

CSIR – Council of Scientific & Industrial Research

DAE – Department of Atomic Energy

DBT – Department of Biotechnology

DFI – Development Finance Institution

DPIIT – Department for Promotion of Industry and Internal Trade

DRDO – Defence Research and Development Organisation

DST – Department of Science & Technology

DOS – Department of Space

FoF – Fund-of-Funds

FOAK – First-of-a-Kind

GDP – Gross Domestic Product

GERD – Gross Expenditure on Research and Development

GOI – Government of India

H-Index – Hirsch Index

HEI – Higher Educational Institution

ICAR – Indian Council of Agricultural Research

ICMR – Indian Council of Medical Research

ICT – Information and Communications Technology

I-STEM – Indian Science Technology and Engineering Facilities Map

IISc – Indian Institute of Science

IIT – Indian Institute of Technology

IPR – Intellectual Property Rights

MNC/E – Multinational Company/Enterprise

MOIP – Mission-Oriented Innovation Policy

NDTSP – National Deep Tech Startup Policy

NEP – National Education Policy

NIRF – National Institutional Ranking Framework

ODOE – One District One Equipment

OECD – Organization for Economic Co-operation and Development

OPSA – Office of the Principal Scientific Adviser (to the Government of India)

PAIR – Partnerships for Accelerated Innovation and Research

PLI – Production-Linked Incentive

R&D – Research and Development

RDD&D – Research, Development, Demonstration and Deployment

S&T – Science & Technology

SERCs – (Proposed) Science and Engineering Research Centers

SERB – Science & Engineering Research Board

SME – Small and Medium Enterprise

STI – Science, Technology, and Innovation

TRL / MRL – Technology Readiness Level / Market Readiness Level

WIPO – World Intellectual Property Organization

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EXECUTIVE SUMMARY

Innovation is vital for India's long-term economic dynamism and aspirations to become a developed industrialized nation by 2047 ("*Viksit" Bharat"*). While India's position in global innovation indices has risen in recent years, the country still punches well below its weight. India's government and private sector significantly underinvest in R&D. Notably, the domestic private sector plays a disproportionately minor role in innovation. Indian companies are not among the most innovative in the world and lag in research collaborations. The public-funded research model, while having contributed much to India's goals, has not evolved fast enough to make Indian-origin technologies globally competitive.

In this context, the creation of the **Anusandhan National Research Foundation (ANRF)** by Parliament is a significant step. ANRF will be the primary body providing strategic guidance on scientific research, entrepreneurship and innovation in India. Its objectives include developing India's long-term innovation capacity, promoting an innovation culture and encouraging technological solutions to important national and societal goals. Its mandate includes funding research itself as well as encouraging public and private sector enterprises to invest in its activities. ANRF has a budgetary provision of Rs. 14,000 Crores for its first five years ($1.6 billion, or $320 million per year) and targets raising an additional Rs. 36,000 Crores ($4 billion, or $800 million per year) from the private sector.

The **objectives** of this Policy Analysis Exercise are to: (i) understand the barriers & limitations to increasing R&D in India (ii) analyze global and domestic evidence around successful innovation models (iii) provide actionable recommendations for how ANRF can overcome these barriers to increase India's long-term innovation capacity. Our recommendations are made to the **Office of the Principal Scientific Adviser**'s Policy Analysis and Insights Unit (OPSA-PAIU) and will serve as a knowledge input for the **ANRF Executive Council**. We take a mixed-methods approach combining qualitative and quantitative analysis combined with over 25 field interviews across all key stakeholder categories.

India spends only 0.64% of its GDP on R&D, two-thirds of which is public spending. This is significantly relative to advanced economies, developing country peers and India's development stage in a historical perspective. This systematic underinvestment in innovation must be a starting point. India's closed and centrally-planned early economic structure has a legacy of over-reliance on the government to perform R&D and to a large degree industrialization as well. Even today, public funding is concentrated in over

300 national autonomous research institutions ('national labs') under various government ministries and agencies. A key anomaly is that universities receive a surprisingly low share of public funds, perform a lower share of the research.

Indian companies lag in innovation, technology commercialization, IP generation and collaboration outcomes. The research performed in the country does not reflect in exponential commercial or growth outcomes, which ordinarily would encourage more private activity. Companies are deterred from investing in R&D due to various reasons including short-term public market pressures, lack of export competitiveness, lack of deep "risk capital" markets, limited prior experience in managing R&D, and difficulty in price discovery of intangible assets.

India has made a successful transition from agricultural to service-oriented economy, but without building a large manufacturing base. Recent industry policy initiatives seek to address this. India has most of the conditions required to foster an innovation-led market economy. Indian companies in a few sectors (e.g., space, life sciences, automobiles) have shown the ability to develop novel technologies domestically on their way to competing globally. India's vibrant startup ecosystem suggests entrepreneurial activity and investor appetite can flourish under the right conditions. India also has a large pool of science and engineering talent that must be retained and nurtured.

The public sector typically plays a dominant role in the early stages of national innovation systems. By being a patient funder of research in uncertain areas and developing research ecosystem capacity more broadly, the government influences the overall innovation landscape. Public R&D expenditure can have a "leverage" effect on catalyzing private R&D activity. At all points in time, the interactions between the public and private sectors remain essential. In India too, the public funding must seek to encourage additional private R&D investments, including by absorbing some of the technological and financial risks associated with developing commercial technologies. As conditions improve, the Indian private sector will invest more. This should be a key guiding principle for ANRF's overall policy approach.

There is also a need to reevaluate how innovation generally is 'done'. Fundamental curiosity-driven research ('discovery') and application-focused development ('invention') must reinforce each other. This means the research process should have greater multidisciplinarity, closer interaction between science and engineering, and collaboration between industry, academia and government.

In improving the general conditions for innovation, ANRF should take a view of the entire R&D ecosystem and its interconnected parts. Crucially, universities must be brought into greater focus, and their long-term innovation capabilities need be strengthened.

We identified five **key barriers** to increasing private R&D activity in India: (i) ineffectiveness & unaccountability of public R&D spending; (ii) financing gaps in the innovation lifecycle; (iii) unavailability and inaccessibility of R&D infrastructure; (iv) constraints in developing long-term human capital; and (v) gaps in intellectual property rights protection. These elements together contribute to the overall robustness of the R&D ecosystem. Based on our client's feedback, we **prioritized three** of these barriers for providing detailed policy recommendations to ANRF:

1. **Closing Financing Gaps across the Innovation Lifecycle**
2. **Increasing Access and Availability of Scientific Infrastructure**
3. **Developing Long-term Human Capital for Research & Innovation**

We evaluated potential policy options on **three criteria**: (i) Technical Effectiveness, (ii) Implementation Capacity, and (iii) Political Feasibility. Based on this, **we recommend three distinct "Policy Packages"** , combining three to five distinct policy tools under each.

POLICY PACKAGE 1: Closing Funding Gaps across the Innovation Lifecycle

1. **Policy 1:** *Program grants for multidisciplinary applied science and engineering research centers (SERCs) at universities and aligned with the government's 'National Missions'*
2. **Policy 2:** *Direct non-dilutive funding (grants and concessionary loans) for startups, SMEs and industry to address critical points of failure in the innovation lifecycle*
3. **Policy 3:** *A Fund-of-Funds to co-finance a range of financial investment managers and new financial instruments to support R&D intensive businesses, starting with equity investments*

POLICY PACKAGE 2: Increasing Access and Availability of Scientific Infrastructure

1. **Policy 1:** *A contracting structure for renting existing public R&D labs & infrastructure*

2. **Policy 2:** *A market-driven co-financing model for new and open scientific infrastructure*

POLICY PACKAGE 3: Developing Long-term Human Capital for Research & Innovation

1. **Policy 1:** *Developing a motivated research and innovation culture (school and undergraduate student programming, research fellowships and internship stipends)*
2. **Policy 2:** *Building industry-academia talent linkages (private sector fellowships, professors of practice, industry-academia convenings)*

In the short term, ANRF should seek to address the most critical points of failure or deficiencies in the R&D ecosystem. In the long term, it should seek to strengthen India's R&D talent base, infrastructure availability, research culture, and science contribution to national and public interest. Overall, our recommendations were underscored by five **key guiding principles**: (i) taking a systems-lens of R&D as a whole; (ii) complementarity and additionality to existing government initiatives; (iii) emphasis on mobilizing private R&D investments; (iv) multidisciplinarity and collaboration as core approaches; and (v) accountability by design (monitoring and evaluation, competition, empowering key changemakers).

For our recommended policies, we provide detailed rationales, objectives, implementation plans and measurement outcomes. We also assess the anticipated economic, administrative and political constraints, and strategies to mitigate them.

ANRF has an opportunity to play a key nation-building role for India over the coming decades. The institutional form and scope it takes in its early years will be consequential. Through these steps, it can pave the foundations for India's innovation-led journey towards 'Viksit Bharat'.

CHAPTER 1: INTRODUCTION

1.1 PROBLEM STATEMENT

While India's position in global innovation indices has improved considerably in recent years, R&D investments (public and private sector contributions) are disproportionately low relative to the country's economic size and development aspirations. In 2022, India's overall gross domestic expenditure on R&D (GERD) stood at 0.64% of the total GDP, with the private sector contributing less than 0.2% of the total GDP (Department of Science and Technology [DST], 2023). According to official statistics by the DST, the government still dominates the majority of national R&D expenditure, in stark contrast to advanced and similar economies where the private sector leads in R&D investments and expenditure. The reluctance of the Indian domestic industry to invest in R&D limits the country's ability to become an innovation-driven economy.

1.2 BACKGROUND OF THE PROBLEM

With a current GDP per capita of $2,400 and a growing population, India's development journey over the next 20 years has several hurdles (World Bank, 2024). The government's vision is for India to become a developed nation by 2047 ("Viksit Bharat" by 100th year of independence). India also has goals of becoming "Atmanirbhar" (self-reliant) by increasing its manufacturing base for long-term economic resilience. R&D is integral to this picture.

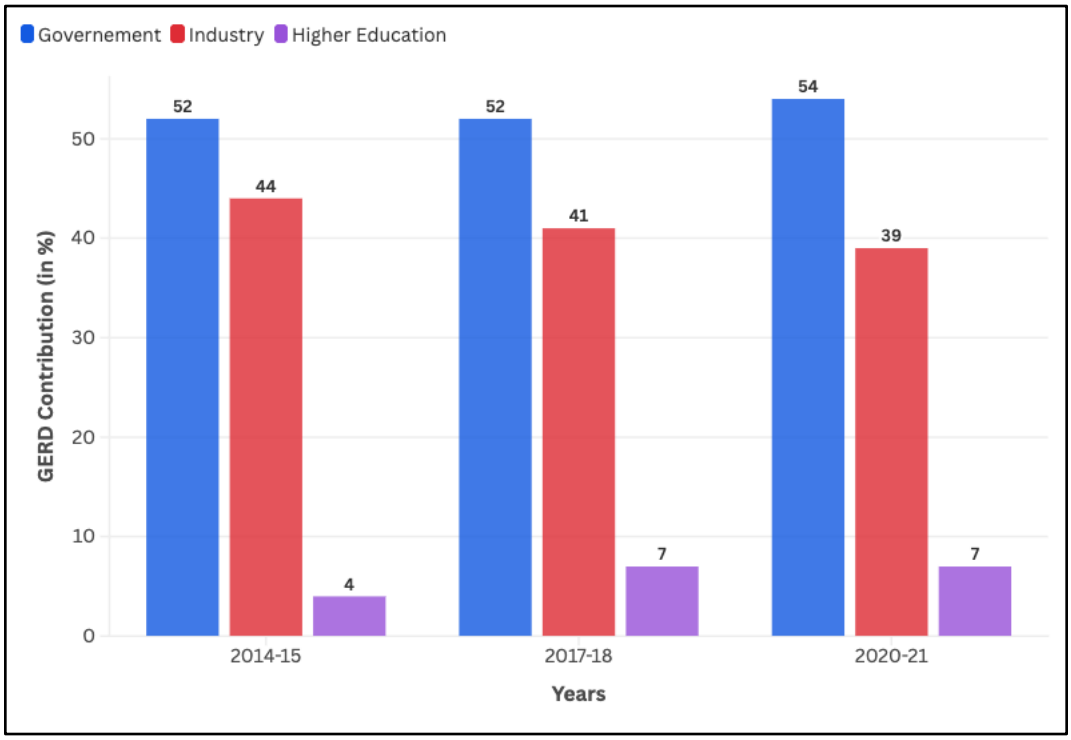
When lower-income economies are in their "catch up" growth phase, their growth rates initially tend to be high but can soon plateau. Countries can enter a "middle income trap", where diminishing economic returns kick in. In fact, growth slowdowns are more pronounced among countries at middle-income levels than low or high-income levels (World Bank, 2024). India is the fastest-growing large economy with a rich, but not indefinite, demographic dividend. To avoid falling into the middle-income trap, India needs to invest in developing globally competitive innovation capabilities that can help deliver long-term economic growth and public value.

Higher investments in science and technology research and development (R&D) are correlated with higher long-term economic growth, productivity, and competitiveness. Today's advanced economies like the EU, USA, Japan, South Korea, Taiwan and Israel invested heavily in R&D in the early and mid-

twentieth century (OECD, n.d.). More recently, China has made extensive and targeted investments towards developing early industrial advantages in generational technologies like semiconductors, AI and renewable energy. India, however, spends disproportionately low on R&D (across various stages) relative to its economic size, development stage, and in comparison to other countries (both advanced economies and developing economy peers).

In advanced economies today, the majority of R&D investments (more than 50%) are by the private sector. Meanwhile, as of 2020-21, India's GERD was a mere 0.64% of its GDP, with over 60% of those investments being driven by government (central, state), state-owned enterprises and higher education sectors. Just over 39% of India's GERD can be attributed to the private sector. Industry contribution to GERD has declined in relative terms in the last 10 years (DST, 2023). Even when compared with countries with a similar GDP per capita, India trails in R&D expenditure as a percentage of GDP and lags in certain innovation indicators (Appendix C).

Figure 1: India's GERD Contribution by Sector of Performance



Source: CTIER Handbook: Technology & Innovation in India 2023

In absolute terms too, both public and private R&D spending has stagnated rather than increased. There has been a legacy of overreliance on the public sector for performing R&D with the concentration of public funding in a select number of national research institutions. Universities and HEIs have received a disproportionately small share of public R&D funding. This has created siloed operations of research institutions, a relatively low emphasis on research in universities, and low involvement of industry (**Appendix C**). Domestic private industry plays a very minor role in developing advanced technologies to drive economic activity (CTIER, 2023). Overall, this reflects a culture that has deprioritized innovation as a key objective and is apathetic to research and development.

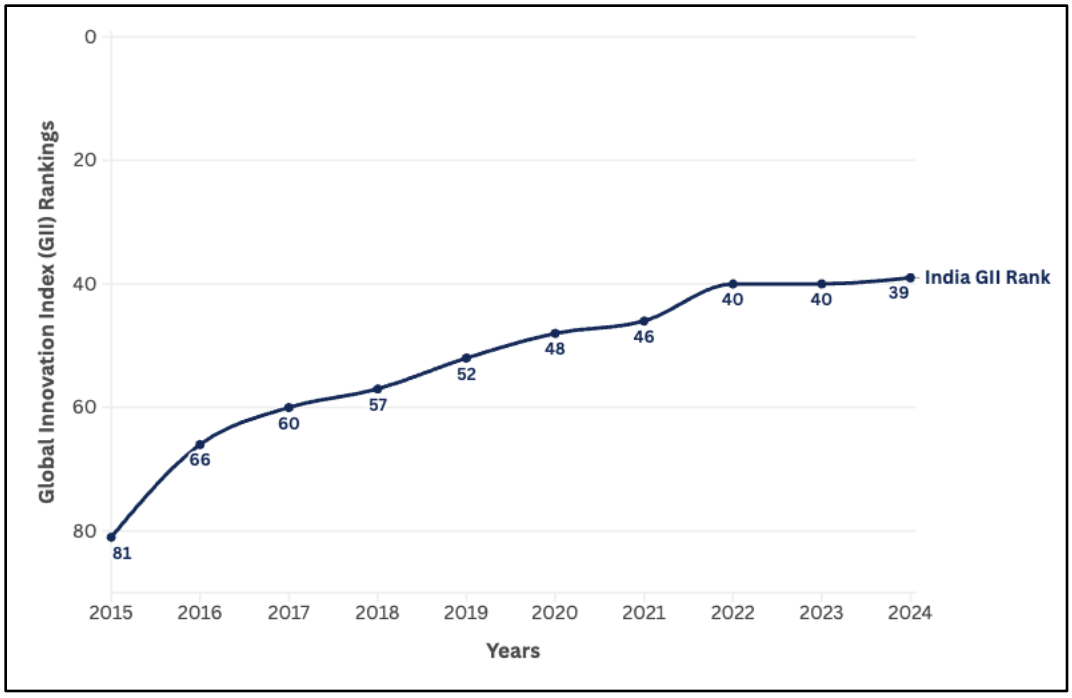
India has been successful in developing a thriving service-based economy in the 21st century. It ranks first worldwide for ICT services exports, highlighting its dominance in technology services. However, the manufacturing sector has remained small relative to the total economic size (WIPO, 2024). India lags in translating R&D activity into science-based entrepreneurship and economic outcomes. While research activity (publications, patents, S&T graduates) has steadily increased in recent years, several concerns remain. The public sector dominated R&D model has not resulted in India developing leadership or self-reliance in critical advanced technologies for the 21st century, with limited exceptions. Domestic companies do not feature among the most innovative in the world (CTIER, 2023). India's booming startups still largely rely on adapting foreign products and technologies locally, incremental technology advancements, business model innovations and value chain efficiencies.

In recent years, India has made notable progress in Global Innovation Index rankings, jumping from 81st in 2015 to 39th worldwide in 2024 (WIPO, 2024). However, it ranks 86th globally in industry-academia R&D collaborations, indicating low interaction between research and real-world applications. Most patents filed in the country are still by multinational companies with India-based R&D centers rather than domestic firms. While India produces a high volume of research papers, their citation impact (H-index and cross-collaborations) needs improvement (WIPO, 2024).

For India to become a global leader in science, technology and innovation, it is imperative to increase the role of R&D investments by the government and the private sector. The domestic private sector especially needs to play a more prominent role in enabling, performing and financing R&D, both in-house and in collaboration with academia and government. There is a need to leverage the complementary relationship between the private and public sectors. India must now prioritize use-

motivated research and technology development to address its unique societal, economic and national security challenges and unlock its full innovation potential.

Figure 2: India's Ranking in the Global Innovation Index (2015-2024)



Source: Global Innovation Index Database, World Intellectual Property Organization (WIPO)

Table 1: India's Strengths and Weaknesses in the Global Innovation Index Rankings 2024

GII Rank	Strengths	GII Rank	Weaknesses
1	Domestic market scale, bn PPP$	46	Loans from microfinance institutions, % GDP
1	ICT services exports, % total trade	61	Entertainment and media market/th pop. 15–69
6	VC received, value, % GDP	83	Researchers, FTE/mn pop.
7	Intangible asset intensity, top 15, %	85	School life expectancy, years
8	Finance for startups and scaleups†	97	Pupil–teacher ratio, secondary

8	Unicorn valuation, % GDP	101	Top-level domains (TLDs)/th pop. 15–69
13	Cultural and creative services exports, % total trade	103	Knowledge-intensive employment, %
16	Domestic industry diversification	105	Females employed w/advanced degrees, %
18	Global corporate R&D investors, top 3, mn USD	110	ICT access*
19	Citable documents H-index	110	Tertiary inbound mobility, %

Source: Global Innovation Index Database, World Intellectual Property Organization (WIPO)

Global literature emphasizes how R&D and innovation have become critical drivers in sustaining long-term economic growth, especially driven by strong interactions between the public and private sectors. Public investments in R&D have had a crowding in effect for private R&D investments which has led to overall economic growth (**Appendix B**). In India, although the public sector has dominated the spending landscape, the national innovation model is still nascent. This means that government must continue to play a leading role in funding innovation and improving the general conditions for private firms to participate. Beyond funding research, policy must ensure availability of the other elements to incentivize private investments such as regulatory stability, access to talent, and IP protections.

The conventional dichotomy between basic and applied research is now being challenged with a focus on a much closer interaction between science and engineering. In the journey from lab to market, technologies face several challenges leading to "deep tech" companies facing three critical "valleys of death" before wide commercialization (**Appendix B**). In India, the country's scientific and technological community has historically delineated the process of basic, translational and applied research, with different institutions taking up the responsibility of various aspects of the innovation life cycle. This has led to government funding in India has been primarily directed towards early TRLs or fundamental research at elite universities and 'national' R&D labs. Private sector and industry innovation funding have been focused on later TRLs (7-9) resulting in a siloed approach towards innovation with minimal collaboration between industry, academia and government.

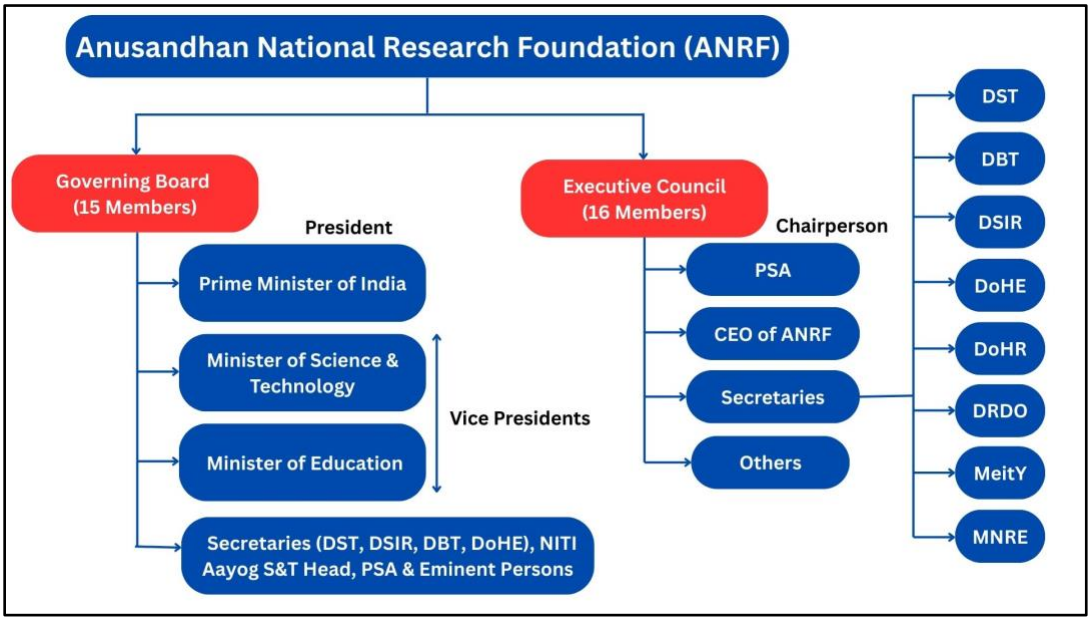
In recent years, there has been a shift by the government towards a 'Triple Helix' model involving closer nexus between these three but has not been completely successful (Singh & Thukral, 2023).

1.3 THE ANUSANDHAN NATIONAL RESEARCH FOUNDATION (ANRF)

The Government of India has established the Anusandhan National Research Foundation (ANRF) to serve as the primary body to provide high-level strategic direction for scientific research, innovation and entrepreneurship in the country. ANRF seeks to foster a culture of innovation, build India's long-term innovation capacity, and promote collaboration between industry, academia and government. It was established by an Act of Parliament in 2023 and operationalized in 2024 (Gazette of India, 2023). ANRF replaces the existing Science and Engineering Research Board (SERB) and will subsume its existing programs (SERB, n.d.).

ANRF is an independent body operating under the guidance of its Governing Board, chaired by the Prime Minister, and Executive Council, chaired by the Principal Scientific Advisor. Operationally, it is led by the Chief Executive Officer. ANRF is expected to bridge gaps in India's STI governance and complement existing initiatives like the Prime Minister Science, Technology, and Innovation Advisory Council (PM-STIAC), Ministry of Science and Technology departments, National Missions, and the multiple scientific agencies under the government.

Figure 3: ANRF Governance Structure



Source: Authors' Design

ANRF has a budgetary provision of Rs. 14,000 Crores for its first five years ($1.6 billion, or $320 million per year) and targets to raise an additional Rs. 36,000 Crores ($4 billion, or $800 million per year) from the private sector (ANRF, n.d.). It is eligible to receive funds from the Central Government through grants, loans, and donations from public sector enterprises, the private sector, foundations, or international bodies. ANRF has the mandate to disburse funds to accelerate R&D in key strategic areas. Its objectives include funding competitive peer-reviewed research and encouraging public and private sector R&D investments. ANRF has already started operations through programs like the Partnerships for Accelerated Innovation and Research (PAIR) and Mission for Advancement in High-impact Areas (MAHA) for Electric Vehicles (ANRF, n.d.).

With the governance and administrative structure of the new institution taking shape, there is an opportunity to address ANRF's long-term role in contributing to India's development and national goals. The institutional form and scope it takes in its early years will be consequential. Based on our assessment of ANRF Act 2023 and conversations with the OPSA officials, we have understood the scope and mandate of ANRF to be the following, as relevant for our PAE:

Table 2: ANRF Mandate and Objectives

Part of the Mandate	Not Part of the Mandate
1. Encouraging greater industry engagement in the government's programs	1. Restricting focus on translational research while ignoring fundamental or basic research
2. Expanding R&D activities beyond elite institutions and large companies	2. Establishing new entities or bodies to delegate ANRF's goals and objectives
3. Providing overall guidance for the development of the innovation ecosystem in the country	3. Launching new programs that are not "additional" in nature in terms of their impact or constituencies supported

Source: Authors' Compilation

CHAPTER 2: RESEARCH DESIGN

2.1 RESEARCH QUESTIONS

This report addresses the following research questions:

1. What are the current barriers & limitations to increasing R&D and innovation in India?
2. What is the available global evidence on successful innovation and R&D models?
3. What policy tools should ANRF use to catalyze private R&D investments and develop India's long-term innovation capacity? How should these policies be implemented?

2.2 RESEARCH METHODOLOGY

The research report focuses on a mixed methods approach combining quantitative and qualitative analysis of global and Indian literature on R&D and innovation models, science, technology and innovation (STI) policies, and public and private sector participation. We combine these with extensive interviews with all key stakeholder categories.

We conducted an initial literature review of relevant global literature on science policy to understand how governments worldwide have encouraged and developed innovation-friendly economies. We also studied evidence from successful innovation models globally. This was accompanied by a literature review of India-specific STI policy papers, which primarily focused on the state of science and technology research and the existing STI governing structures in India. Topics included academic papers, government documents and industry reports that provided information on the state of global science and technology as well as Indian STI-related data and statistics.

We also did a second round of reviews on the literature surrounding innovation financing and R&D accounting. This was primarily focused on understanding the global benchmarks for R&D data collection and accounting mechanisms used by countries worldwide. The objective was to refine existing knowledge of innovation financing tools and to calculate R&D expenditures at a country level.

The literature review phase was followed by data analysis of key components of STI-related data comparing India's position on a global scale. This was done to provide a holistic picture and compare

India's STI and R&D ecosystem with similar economies based on their overall size and per capita earnings. We compiled data from existing databases such as the Organization for Economic Co-operation and Development (OECD's) Science, Technology and Innovation Scoreboard and the World Intellectual Property Organization (WIPO's) Global Innovation Index database.

Key indicators related to GERD and the business enterprise contribution to R&D expenditure (BERD) were taken as metrics for analyzing the extent of India's R&D expenditure gap. Other innovation indicators, such as patent-related data and H-indices of scientific publications, were also compared with India's STI data to understand the puzzling nature of India's rise in the global innovation index while still faltering behind on domestic private sector investment and product/process level innovation in the country.

This was followed by a thorough data analysis of the available Indian private sector and industrial R&D statistics to understand the current state of private sector investment in R&D activities in the country. Since no official BERD survey in the country captures the extent of private sector/industry contribution to gross R&D expenditures, we had to extrapolate from existing industrial R&D reports to analyze the potential for augmenting private sector R&D investment in the country. These reports included those from the Indian Institute of Corporate Affairs (IICA) and the Centre for Technology, Innovation and Economic Research's CTIER Handbook: Technology and Innovation in India 2023.

After secondary research, we conducted fieldwork through interviews with key stakeholders. These interviews were conducted with stakeholders from across academia, government agencies and research institutions, companies, think tanks, and ecosystem bodies in India. From December 2024 to March 2025, 26 formal and informal interviews were conducted in Delhi, Bengaluru, Pune, and Chennai (in person) and remotely. Interviews typically lasted 1 hour. We had subsequent follow-up conversations with several interviewees.

Table 3: List of Interviewees by Indian STI Sector

Type of STI Stakeholder	Number of Individuals Interviewed
Academia	6
Think Tanks / STI Thought Leadership Institutions	8
Government (Executive Agencies)	3
Government (Specialized Programs)	2
Intermediary Institutions	2
Industry Startups, SMEs, Corporates	5
Total	**26**

Source: Authors' Compilation

Based on our primary and secondary research, we identified five interconnected barriers to increasing private R&D investment and industry-academia linkages. We analyzed these from the lens of market and institutional failures. Then following feedback from our client and faculty advisor, we narrowed down the scope of the report to focus on addressing our policy recommendations towards only three of the five barriers initially identified. For the three prioritized barriers, we generated a list of potential policy options. We developed three main policy evaluation criteria around technical effectiveness, implementation capacity and political feasibility to evaluate our options. We further broke down each criterion into measurable indicators for addressing the barriers we identified (detailed in Chapter 4).

Table 4: Policy Evaluation Criteria Overview

Policy Evaluation Criterion	Question
Technical soundness	Will the proposed policy incentivize or unlock greater domestic private R&D spending?
Political feasibility	Can support from necessary political stakeholders be obtained for the proposed policy solution?
Implementation capacity	Can the proposed policy address key administrative and procedural risks?

Source: Authors' Compilation

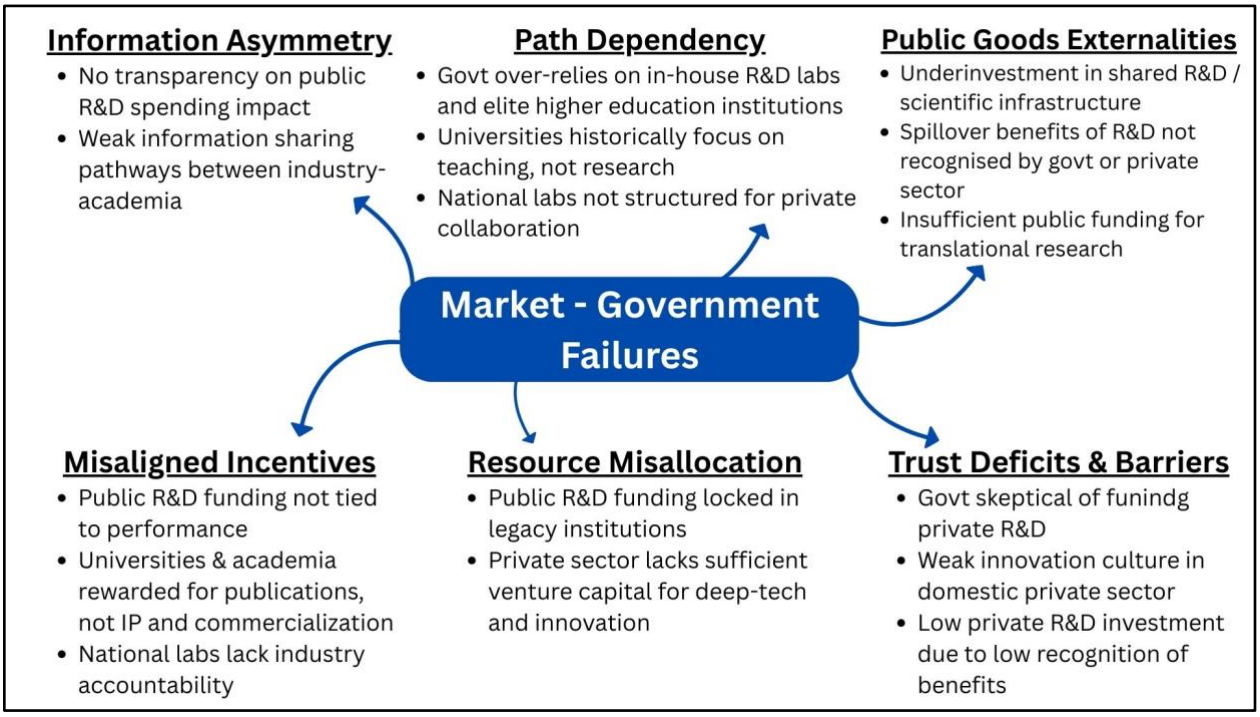
Applying our evaluative criteria, we rejected some of our initially considered policy options. The policy tools or options that passed our evaluation criteria were developed to create three holistic "Policy Packages", one for each of the barriers, with 3 to 5 discrete policy tools under each. These form our final recommendations. The three policy packages include the recommended policy design and implementation plan with milestones, timelines and measurement indicators. We also assessed the economic, administrative and political constraints for the proposed policies including potential unintended consequences during implementation.

We conclude by providing our vision for the governance and strategy of ANRF over the next five years, recognizing its institutional constraints, suggesting potential workarounds, and providing ideas for further research that remain unexplored or under-investigated.

CHAPTER 3: BARRIERS TO INCREASING PRIVATE R&D (FINDINGS & ANALYSIS)

Based on our primary and secondary research, we identified five key interconnected challenges as potential barriers to increasing private R&D investment and industry-academia linkages. These are explained by commonly understood market and institutional failures from economics, as shown in the image below.

Figure 4: A Market-Government Failure Framework for Private R&D Barriers in India



Source: Authors' Compilation

The five barriers and our key insights from interviews and literature review are discussed below.

3.1 INEFFECTIVENESS & UNACCOUNTABILITY OF PUBLIC R&D FUNDING

Overall, our research showed that there is a lack of accountability of public R&D spending by the central and state governments across their various spending avenues (e.g., national labs, Public Sector Undertakings (PSUs), and public-funded higher educational institutions (HEIs). Public expenditure is concentrated in a few national research labs and sectors, and there is inadequate monitoring and evaluation of the impact achieved by these institutions. As a result, public R&D funding has been unable to develop a supportive ecosystem and create a sufficiently large body of fundamental research that would encourage industry to step in to further develop for commercial use. This has prevented public-sector R&D funding from having a multiplier effect in unlocking additional private R&D spending.

Key insights:

- **Inadequate data collection and reporting:** There is infrequent and inconsistent reporting on R&D spending in the country, both public and private. The last update to R&D spending statistics by the Department of Science & Technology (DST) are for the year 2020-21. There is inconsistent reporting of the impact achieved by national labs across various agencies, and data on utilization of individual labs is also lacking. We were also told that no official survey on Business Enterprise R&D (BERD) has ever been conducted in India (Personal Communication, January 2, 2025).

- **Insufficient monitoring & evaluation (M&E):** Our interviews shed light on the absence of a formal, independent M&E mechanism of public R&D spending, for example performance assessment of national labs. This contributes to low accountability on outcomes of public spending (Personal Communication, January 6, 2025). Current data also suggests that there has been low commercialization and IP creation impact relative to the amount of public R&D spending, especially in national labs.

- **Coordination and collaboration failures:** Existing public R&D funding is restrictive, concentrated, with national labs mostly operating in silos. Interviewees highlighted that very few national labs pursue joint R&D projects with industry or with universities. This limits the ability to gain industry feedback on public R&D programs, pursue more use-inspired research and share knowledge between different institutions (Personal Communication, January 2, 2025).

- **Lack of standard taxonomy:** There is still an absence of standard taxonomy for what constitutes R&D and how to account for different types of R&D spending (OECD, 2015). Several interviewees stressed the gap in understanding the impact of R&D spending by multinational companies (MNCs) in India and Indian MNCs abroad.

3.2 FINANCING GAPS IN THE INNOVATION LIFECYCLE

Our research and interviews consistently indicated inadequate funds and lack of innovative financing models across the innovation lifecycle, starting from fundamental research to translational research and commercialization in the market. Beyond fundamental research, there is an overall lack of patient capital to support inventors and entrepreneurs trying to take novel technologies from lab to market. They face "valleys of death" due to funding access while developing technology (technological risk) and demonstrative commercial effectiveness (commercialization risk). The domestic industry is also reluctant to invest due to uncertainty and long timelines.

Key Insights:

- **High capital intensity and lack of risk-absorbing capital:** There are not enough patient and risk-absorbing capital sources that could improve the risk-return profile of investments and attract more traditional investors (Forbes, 2016). Our interviews and research suggest that startups and SMEs working on R&D intensive solutions are particularly constrained for capital. Overall, we felt that the positive externalities from investing in R&D (knowledge spillovers, development of human capital etc.), are not adequately priced in firms' decisions. This has led to inadequate government funding for the private sector and prevented individual companies from making the high initial investments required (Personal Communication, January 9, 2025).

- **Misaligned time horizons:** The long timelines involved in R&D do not align with short term horizons of most companies and funders (and their agents). Most venture capital and private equity funds also have 5-7 year horizons, while deeptech companies may require a longer gestation period.

- **Lack of continuity in fiscal support:** Traditionally, the government has incentivized private sector R&D expenditure through tax incentives. In India, the tax benefits for firms for pursuing R&D have

been revised a few times in the last decade, with benefits trending downwards. This increases reluctance among firms to invest in in-house R&D or contribute to external research institutions.

- **Trust barriers:** Our interviews revealed a historical mutual trust deficit in the government-industry relationship. Governments are skeptical of the actual value created by firms' in-house R&D, making them reluctant to fund companies. Similarly private companies perceive challenges in partnering with public research institutions such as slow administrative processes and uncertainty about value generated from public research (Personal Communication, January 7, 2025).

3.3 INACCESSIBILITY AND UNAVAILABILITY OF SCIENTIFIC INFRASTRUCTURE

Our research revealed a shortage of accessible scientific 'infrastructure' outside of the elite academic and government institutions. Here, we define 'infrastructure' to broadly include physical facilities, equipment and various hardware and software tools required to pursue R&D, such as lab spaces, machines, demonstration testbeds, specialized software etc. Smaller companies, startups and non-elite institutions (like Tier 2 or 3 universities) are unable to access relevant infrastructure. Infrastructure supply also needs to be responsive to changing requirements of industry domains, especially to enable R&D to remain at the cutting edge.

Key Insights:

- **Unequitable access:** Much of the existing infrastructure and facilities for R&D in the country are located at national labs or top universities, like the IITs, IISc, TIFR etc. Interviewees stressed the need to make existing R&D infrastructure in labs and educational institutions more broadly accessible to startups, SMEs and non-elite universities, who may not be able to afford the significant capital investments required to set up their own facilities (Personal Communication, January 9, 2025). Lack of awareness of initiatives such as I-STEM, which seeks to map research facilities across the country, has created an accessibility barrier for innovators and the private sector to utilize available R&D resources.

- **Shortage of world-class infrastructure:** As innovators pursue R&D on the frontiers of their domains, they require enhancements or expansion in infrastructure such as more specialized labs, equipment, machines or software. Such requirements vary by sector and require supply of

infrastructure to respond to demand. This new or upgraded infrastructure should be viewed as a common good that can be nurtured by both the state and private sectors. Interviewees felt that additional investments in developing new R&D infrastructure could create positive externalities and unlock spillover effects for economic growth.

- **Inadequate technician capacity:** Our study suggested that many of these labs currently lack the technical capacity (equipment operators and technicians) and the mandate to contract R&D services for other players (Personal Communication, January 8, 2025).

3.4 CONSTRAINTS IN DEVELOPING LONG-TERM HUMAN CAPITAL

While there is no shortage of science and engineering talent in India, our research revealed critical constraints around motivation to pursue R&D and talent linkages across ecosystem actors. Domestic companies are often unable to attract top research talent (scientists, R&D project managers). Mobility between industry and universities or national labs is low. Several interviews revealed how incentives among researchers and faculty at academic institutions are not aligned with economic or industrial needs, reducing the attractiveness of research collaboration (Personal Communication, December 29, 2024). Research talent inside universities is not incentivized enough to focus on use-inspired research. There are low levels of talent exchange with foreign research institutions.

Key Insights:

- **Low emphasis on research in universities:** There is inadequate emphasis on the role of research inside universities due to historical policy choices. Universities have not taken center stage in the research ecosystem of India and have so far been envisaged as playing a predominantly teaching role. Our research suggests undergraduate curriculum even at top universities does not expose top STEM students enough to R&D or develop their capacity to pursue research. While the National Education Policy (NEP) 2020 seeks to change this culture and increase importance of research in curriculum, the implementation process remains unclear and requires actions from myriad state governments, central government and universities themselves.

- **Inadequate incentives to pursue 'use-inspired' research:** Coordination problems persist between academia, government and industry, with incentives for each entity not promoting collaboration

while encouraging a siloed approach towards innovation. Many interviews focused on how academics' key performance indicators (KPIs) are not geared towards commercializing research with no incentive for industry collaboration (Personal Communication, January 3, 2025). The performance of scientists is usually measured based on research activity, precisely the number of publications, rather than the relevance or impact of that research.

- **Lack of talent mobility and industry–academia collaborations:** Due to the siloed nature of performing R&D activities in the country, an information asymmetry exists between domestic industry and academia. Many of our interviews stressed that minimal communication and interaction between the two have made talent mobility challenging. Absence of linkages between different parts of the ecosystem prevents broader cross-pollination of knowledge. There are limited pathways for mobility for technologists at MNE centers to share their expertise with domestic firms or universities, scientists at national labs to contribute to developing research capacity of universities, and undergraduates and postgraduates to gain industry-relevant R&D exposure.

3.5 GAPS IN INTELLECTUAL PROPERTY RIGHTS PROTECTION

While the government has undertaken several process reforms that have made the process of filing and granting a patent much more streamlined, our research revealed that IP licensing and enforcement remains a key challenge when attracting private sector R&D investment. Compared to other emerging economies, securing and enforcing IP is costly in terms of time, procedure, and compliance. Instances of joint IP sharing are also limited, and the IP licensing and monetizing ecosystem is still relatively underdeveloped.

Key Insights:

- **Lack of awareness and 'culture' around IP:** There is still a significant lack of awareness about what constitutes IP and the benefits of patenting among researchers and firms. Our findings revealed that crucial information is not readily available to firms about potential IP to acquire/processes and products to patent. A historical focus on scientific publications over patents (which is currently changing among elite institutions) has resulted in a low rate of commercialization or tangible output from patents. We noticed that the focus is moving now

towards the quantity over the quality of patents with no measurement of the impact created from both filed and granted patents (data suggests that only 8% of patents in India have actual commercial uses). This is coupled with limited information available to researchers about potential buyers/licensers of their patents or IP. While IP filings in the country have increased in recent years, there needs to be better awareness of strategic IP filing and licensing (Personal Communication, January 14, 2025).

- **Underdeveloped market linkage mechanisms & institutions:** Scientific institutions such as universities and national R&D labs still lack the capacity for implementing IP and patent-related administrative processes. We found that there are also no IP-related offices in institutions (beyond the elite tier 1 institutions) for advising researchers on IP commercialization opportunities and IP-related legal processes, such as enforcement and conflict resolution (Mashelkar, 2002).
- **Costly approval, compliance and conflict resolution processes:** Interviewees suggested that the administrative and bureaucratic process in filing, obtaining and transferring IP are lengthy and require significant time and money investments. Similary, the legal process of conflict resolution can be costly especially considering India's under-resourced legal system.

CHAPTER 4: PROBLEM PRIORITIZATION & EVALUATING POLICY OPTIONS

4.1 PRIORITIZING BARRIERS TO ADDRESS

The five barriers are interconnected and addressing them together improve the general conditions for private and public R&D investment. To align with ANRF's mandate and manage the scope of this PAE most effectively, based on our client's feedback, **we prioritized three of the five barriers** to provide detailed recommendations for ANRF:

1. **Closing Financing Gaps across the Innovation Lifecycle** *(Barrier #2)*
2. **Increasing Access and Availability of Scientific Infrastructure** *(Barrier #3)*
3. **Developing Long-term Human Capital for Research & Innovation** *(Barrier #4)*

4.2 BRIEF NOTE ON DEPRIORITIZED BARRIERS

While we do not make detailed policy recommendations for the two deprioritized barriers (ineffective and unaccountable public funding, and gaps in IP protections), we don't consider them to be lower in importance for ANRF or India's STI governance ecosystem. We seek to address some of the concerns discussed in our findings through the implementation strategies for our proposed recommendations.

ANRF should actively seek to make public R&D spending more accountable and encourage evolution of IP regimes in the country. Further research should evaluate detailed strategies for the government to make public spending more accountable, increase frequency and quality of S&T data, increase awareness about the importance of IP, socialize sector-specific IP guidelines, simplify administrative and legal processes, and increase speed of conflict resolution. ANRF's funding programs should have strong pre and post-award peer evaluation processes that bring together relevant experts from industry and academia. They should track metrics around commercialization and IP generation, long-term scientific talent and capabilities development, and greater coordination among different institutions. Finally, a greater share of public funding should be allocated on a competitive basis, including to national labs, to incentivize healthy competition among public and private research institutions.

4.3 EVALUATION CRITERIA

For the three barriers we prioritized, we created a long list of 6-8 potential policy options (next section). These were evaluated on three criteria with the following key questions:

Table 5: Policy Evaluation Criteria Description

Evaluation Criteria	Key Questions
1. Technical Effectiveness	• *For R&D funding programs*, how likely is the policy to mobilize private investment, improve IP creation and commercialization outcomes, develop a long-term talent pipeline, or encourage cross-system linkages? • *For infrastructure expansion & utilization,* will the policy increase infra access to those currently underserved (e.g. non-elite HEIs, SMEs, startups)? Will it ensure availability of latest state-of-the-art infrastructure in priority sectors? • *For human capital,* will it increase the motivation of scientific talent at all levels to participate in R&D and science-based entrepreneurship? Will it increase talent linkages and knowledge exchange between different types of institutions? • *Overall,* will the policy contribute to increasing India's long-term S&T capabilities and innovation-led economic growth, mobilizing public and private investment, and promoting industry-academia-government collaboration?
2. Implementation Capacity	• Does ANRF or another government agency (charged with implementation) have the financial, administrative and technical resources to implement the policy? • Will this complement existing GOI initiatives?
3. Political Feasibility	• Does the relevant implementing agency have formal and informal authority to implement the policy? • Can required support from other stakeholders be secured? (other ministries or government agencies, national labs, universities, industry)

Source: Authors' Compilation

4.4 SHORTLISTED POLICY OPTIONS

We applied our evaluation criteria on a long list of 6-8 policy options for each of the three barriers. Based on this subjective assessment, we rejected several options and identified 3 to 5 discrete policy tools for each barrier with a reasonable chance of being effective, practical and feasible.

Table 6: List of Initial Policy Options and Evaluation ("Closing the Financing Gap across the Innovation Lifecycle")

Policy	Technical Effectiveness	Implementation Capacity	Political Feasibility	Selected?	Explanation
(1) Fund thematic multidisciplinary research consortiums (grants)	High	High	High	YES	*ANRF could provide grants to research consortiums bringing together various stakeholders and closer interaction between science and engineering*
(2) Directly fund or finance promising private entities (grants, concessionary debt)	High	High	High	YES	*ANRF could prioritize grants to startups/SMEs to absorb technical & commercialization risk, while encouraging concessionary debt for large industrial R&D demonstration projects ("first-of-a-kind" projects)*
(3) Fund S&T clusters to in turn fund domestic companies/researchers (grants)	Medium	Medium	Medium	NO	*Rejected due to concerns over duplicating existing efforts at universities, 'scope creep' at clusters, administrative complexity*
(4) Fund investors or asset managers like VCs, AIFs, MFs (Fund-of-Funds)	High	High	Medium	YES	*ANRF could act as a Limited Partner providing capital to investors that meet certain criteria, to fund promising*

					private companies or projects
(5) Provide additional tax incentives to private companies for spending on R&D (fiscal policy)	Medium	Low	Medium	NO	*Rejected as feasibility depends on Finance Ministry's other fiscal considerations (OPSA could make general recommendations); limited evidence of tax breaks leading to more R&D by Indian firms*
(6) Amend GFR to require govt. agencies & national labs to contract more R&D to the private sector ("Govt. as Buyer")	Medium	Low	Low	NO	*Rejected due to administrative and political complexities in amending GFR, and concerns over crowding out of universities*

Table 7: List of Initial Policy Options and Evaluation ("Increasing Access and Availability of Scientific Infrastructure")

Policy	Technical Effectiveness	Implementation Capacity	Political Feasibility	Selected?	Explanation
(1) Allow existing public R&D infrastructure to be used by startups and SMEs	High	High	Medium	YES	*ANRF could increase utilization of existing infrastructure at 'national labs' (e.g., through 'pay as you go' models) broader access to R&D-related tools & equipment for private sector and universities*
(2) Increasing technical staff capacity in	High	Medium	Medium	YES	*ANRF could encourage national labs to review and improve capacity of*

national labs through hiring & training					*technical staff, including additional hiring or training support*
(3) Improve adoption of existing resource-sharing initiatives like I-STEM and ONOS	High	High	High	YES	*ANRF could increase awareness, adoption and general usability of existing government initiatives for sharing S&T resources*
(4) Transition national labs into R&D service providers for the private sector	Medium	Low	Low	NO	*Rejected due to administrative & political feasibility concerns (drastically changing or diluting national lab mandates)*
(5) Co-finance the private sector to build new "open" infra and facilities	High	Medium	High	YES	*ANRF could co-finance new state-of-the-art infrastructure required for various sectors or for demonstration & deployment*
(6) Co-finance the private sector to build new "open" infra and facilities	Medium	Low	High	NO	*Rejected due to financial feasibility, concerns over 'scope creep' at clusters, administrative complexity, and low market signaling*

Table 8: List of Initial Policy Options and Evaluation ("Developing Long-Term Human Capital for Research and Innovation")

Policy	Technical Effectiveness	Implementation Capacity	Political Feasibility	Selected?	Explanation
(1) Fellowships or stipends for young researchers to work	High	High	Medium	YES	*ANRF could fund PhD or post-doc students to gain industry exposure at leading*

with MNC Research Centers					*MNCs, while increasing supply and lowering cost of top scientific talent for companies*
(2) Introduce academic credit for research and entrepreneurship at universities	High	Low	Low	NO	*Rejected due to administrative and political concerns, as authority over curriculum distributed across Ministry of Education, state governments, universities and various technical agencies (e.g. AICTE); OPSA may still make general recommendations aligned with NEP 2020*
(3) Fund students to pursue R&D internships abroad	Medium	Medium	High	YES	*ANRF could provide financial support to undergrad and graduate students selected to pursue R&D at top foreign universities and research institutions*
(4) Increase awareness and interest in R&D & entrepreneurship among school students	High	Medium	Medium	YES	*ANRF could increase awareness and attractiveness of research careers among school students by exposing them to leading researchers and institutions (e.g. universities, national labs)*
(5) Establish 'Professor of Practice/ Eminence' positions at academic institutions for industry leaders and top scientists	Medium	Medium	Medium	YES	*ANRF could incentivize industry leaders (domestic firms, MNEs) or top Indian-origin scientists living abroad to engage with universities, share knowledge, and provide industry perspectives for*

					teaching and research programs
(6) Change performance assessment criteria (from publications to patents, industry collaborations etc.) of professors to incentivize science-based entrepreneurship	Medium	Low	Low	NO	*Rejected due to concerns over challenging autonomy of universities, education ministries and potential for crowding out curiosity-driven fundamental research; as above, OPSA may make general recommendations aligned with NEP 2020*
(7) Provide economic incentives for academics to pursue entrepreneurship	Medium	Low	Low	NO	*Rejected due to the expected pushback by universities and educational institutions along with the inability to get academics to dedicate their teaching time to entrepreneurship even with economic incentives*
(8) Organize Industry-academia fairs by S&T Clusters	Medium	Medium	High	YES	*ANRF could promote more frequent convenings of industry and academia for sharing knowledge, finding collaborators and tech transfers*

Source: Authors' Compilation

4.5 OVERALL GUIDING PRINCIPLES BEHIND RECOMMENDATIONS

The 3 to 5 policies selected under each barrier were grouped and balanced to prepare an overall policy "Package" for each barrier i.e., we propose three policy packages (Chapter 5).

Our recommendations take both the short and long term into account. In the short term, ANRF should seek to address the most critical points of failure or deficiencies in the R&D ecosystem. In the long term, it should seek to strengthen India's R&D talent base, infrastructure availability, research culture,

and science contribution to national and public interest. In our view, the design and implementation of these policies should be informed by the following **five guiding principles**:

1. **System lens:** As the apex government body providing strategic direction on science and technology, ANRF should take a complete view of the entire innovation lifecycle, of all the stakeholders involved, and their interactions. Government policies should develop capabilities of underserved parts of the ecosystem and specifically emphasize universities as key actors in the national innovation model. They should also develop underlying factor resources like infrastructure and human capital which improve the capacity of public and private institutions involved in performing R&D.

2. **Complement existing government initiatives:** Proposed policies should integrate with and build on existing government S&T efforts, such as OPSA's other initiatives, DST programs, National Missions, S&T clusters, and national labs. Some of our recommendations are aligned with high-level ideas proposed in other government announcements. We provide detailed action plans and policy design proposals for the government to take these ideas forward.

3. **Mobilize the private sector:** Industry must have skin in the game and should be incentivized through public policy. Both financial and non-financial policies should have a leverage effect on increasing private R&D investment, and should have measurable goals as such. A key goal should be to encourage evolution of culture of domestic companies to be similar to MNEs to propel India at the emerging technological frontier. Private sector, including startups and SMEs, should be proactively included in developing solutions for India's key national priorities.

4. **Multidisciplinarity & collaboration as core features**: ANRF-funded programs and policies should encourage greater multidisciplinarity in R&D through closer interaction of science, engineering and design. They should also promote greater industry-academia-government linkages and international collaborations for designing research priorities, conducting and financing R&D, and talent exchanges.

5. **Accountability by design:** ANRF should insist on rigorous and independent evaluation of its programs, including through pre and post-award peer evaluation, regular reporting, and expanding the range of metrics measured to include outcomes related to commercialization

and contribution to national goals. Accountability can also be strengthened by promoting greater competition between stakeholders for receiving ANRF funds. Finally, ANRF-funded programs should identify specific individuals and teams as change agents. They should be entrusted with clear goals and empowered through financial and non-financial support.

While we have refrained from providing an overall budget estimate for our proposed policies, we believe a reasonable estimate of Rs. 1,400 Crores per year (or ~$160 million per year), or 50% of the government's allocated amount for ANRF should be used for new programs launched under it.

CHAPTER 5: RECOMMENDATIONS: THREE POLICY PACKAGES

5.1 POLICY PACKAGE 1: CLOSE FINANCING GAPS ACROSS THE INNOVATION LIFECYCLE

RATIONALE AND GOALS

ANRF's funding programs should strengthen India's long-term innovation capabilities in service of its national and public interest. Public funds should target underfunded areas and critical leverage points in the translation journey (Mani, 2010). At the same time, ANRF must use its policies to encourage availability of public and private capital for all stages of the innovation lifecycle.

We do not recommend new funding programs for basic or fundamental research, though an increase in allocation to some existing programs is suggested. The government supports a growing volume of basic research at universities and national labs. Notably, ANRF's PAIR program ('Partnerships for Accelerated Innovation and Research') follows a 'hub-and-spoke' model to connect elite national universities with others where research is at a nascent stage (especially state universities). Overall, ANRF funding should be used to achieve the following objectives:

1. **Promoting more multidisciplinary and collaborative use-inspired research:**
   ANRF should use its funding functions to promote multidisciplinary and collaborative research models that challenge the basic-applied research dichotomy (**Appendix B**) and bridge the 'discovery' and 'invention' cycle in the form of co-created research priorities, information and talent exchange, and clear milestones. Universities must be brought into greater focus and R&D should be more clearly linked with major national goals.

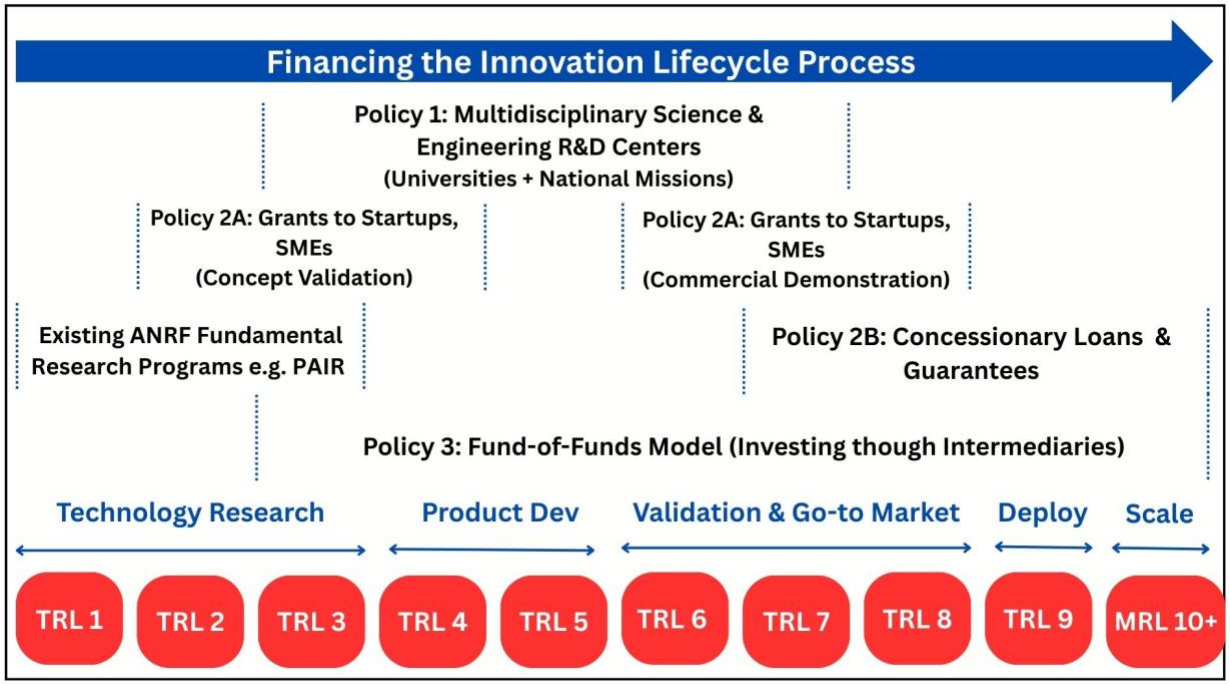
2. **Ensuring capital availability to help companies cross the "valleys of death":**
   ANRF should directly fill gaps by providing patient capital at those points in the innovation cycle when companies have the highest risk of failure (The Hindu, 2025). Companies face three "valleys of death" in the lab-to-market journey (**Appendix B**).

3. **Mobilizing private capital to fund companies across the innovation lifecycle:** ANRF should also encourage development of more private funding mechanisms and the capital markets to finance companies and technologies at different stages.

RECOMMENDED POLICIES

We propose **four funding programs** (grouped under three policies) addressing the entire innovation lifecycle: establishing multidisciplinary research centers with universities and National Missions at their focus; grants (to smaller companies) and loans (for first-of-a-kind industrial R&D projects); and a fund-of-funds structure to seed other investors. Our proposed policy package balances proposals for new innovative research models with more detailed action plans for the government's existing or announced initiatives and National Missions.

Figure 5: A Financing Strategy for the Innovation Lifecycle



Source: Authors' Design

Each funding program should have an empowered Program or Portfolio Manager with both autonomy and accountability. We also propose establishing a Technology Partnerships support function at ANRF to enable ANRF-funded programs & organizations to partner with industry and academia for co-designing priorities, conducting joint research and technology transfer. This function can connect similar offices at the universities, national labs and industries. Finally, the funding-related policies should be accompanied by robust peer review and performance evaluation processes.

Policy 1: Program grants for multidisciplinary applied science and engineering research centers at universities and aligned with National Missions ("SERCs")

Similar to the PAIR program, we propose a hub-and-spoke model of universities but with a more "invention" or engineering focus than the PAIR program, multidisciplinary collaboration (between the sciences, engineering, design), alignment with key national goals (National Missions), and encouraging industry linkages. SERCs will research complex technologies aligned with long-term national and public interests.

As part of the policy, elite universities (top 25 NIRF and Institutes of Eminence) partner with other universities, steadily improving their research capabilities (top 200 NIRF), government S&T initiatives, and industry. ANRF should provide core program grants for SERCs (up to 10 years) to pursue invention-focused, transdisciplinary and collaborative research projects. While oriented towards long-term useful technologies, they should work on time-bound projects (5-7 years) with clear interim and final milestones. These milestones should be related to intellectual property generation, technology transfers, commercial outcomes and talent development. Initially, two SERCs can be identified and after three years, two additional candidates can be identified.

To align SERCs more broadly with India's long-term strategic goals, we propose the initial SERCs be set up under the guidance of a sponsoring National Mission (**Appendix A**). The PMSTIAC, chaired by the OPSA, has identified eleven National Missions in strategic areas like deep ocean exploration, AI, quantum technology, electric vehicles and natural language translation, and biosciences. Besides funding research, ANRF can perform a convening function to support the lead Mission agencies in preparing long-term innovation roadmaps, connecting with academia and industry, and adopting promising commercial solutions (Mashelkar et al., 2024).

SERCs should include researchers from both science and engineering disciplines. The project selection process should include the SERC hub university, the National Mission and its lead agencies, ANRF Program Manager, external scientists and industry advisors. Problem definitions should be decided in consultation with industry and should be around achieving specific technical milestones.

SERCs would also have autonomy to pursue contract research and joint research projects with industry. These external projects can be funded through a combination of private contract revenue, donations and existing funding programs of the relevant lead government agencies. Consequently, ANRFs should be evaluated on additional revenue streams along with technology and commercialization milestones discussed above. SERC projects should also be eligible to apply for additional competitive ANRF matching grants (refer to Policy 2A) as bridge funding towards specific milestones like prototyping, testing and pilots.

SERCs may also seek to actively involve national labs, although this may be politically and administratively challenging. A provision can be made in the policy to allow national labs to be 'co-hubs' in the absence of a National Mission. The national labs should be actively involved in co-creating priorities, conducting joint projects, sharing knowledge, and enabling access to infrastructure (refer to Policy Package 2). SERCs should be mapped to S&T clusters and share in their resources but should function independently. Clusters can help identify ongoing R&D projects in their network universities as SERC candidates or participants.

SERCs should have strong emphasis on technology transfer. While in the first few years they should be supported by the proposed ANRF Technology Partnerships office (previous section), over time they should seek to develop their own capabilities to engage in joint research with industry and technology transfer. Another key component of SERC's success will be to access and nurture scientific talent (refer to Policy Package 3). ANRF grants can be used to fund Professor of Practice positions for industry professionals or Emeritus Professors from leading academic institutions. Similar to PAIR, core funding can be used to support researchers including PhD, post-doc, graduate student fellowships, facilities and equipment.

Policy 2: Direct non-dilutive funding (Grants & Concessionary Loans) for startups, SMEs and industry to address critical points of failure in the innovation lifecycle

This policy seeks to implement existing funding recommendations made by OPSA under a direct funding model to support startups, SMEs, and industry through non-dilutive funding. Two instruments (grants and concessionary loans) are proposed, and each should be managed under a separate "fund", have different eligibility and evaluation criteria, and with dedicated Program or Portfolio Managers. The objective is to support companies near the three critical "valleys of death" in the innovation lifecycle (**Appendix B**). We provide detailed action planning for high-level ideas proposed in existing national policies.

Policy 2A: A Two-stage Grants Framework to fund smaller companies (university spinoffs, startups, SMEs) and research networks during pre-commercialization and commercialization stages *(builds on National Deep Tech Startup Policy Recommendation 3.4)*

- **"Concept Validation" project grants**: To support pre-commercial startups, SMEs or research consortiums on technologies that are yet to overcome science risk and demonstrate proof-of-concept in a lab environment (typically around TRLs 3 to 4). Funding can be for companies and researchers to achieve specific milestones such as application testing, minimum viable products (MVPs) and early prototyping. Follow-on grants and top-up matching grants can be provided based on successfully completing milestones or raising private investments or donations.

- **"Commercial Demonstration" project grants:** To support university spinoffs, startups and SMEs working on more advanced applications to demonstrate their commercial viability (typically around TRLs 5 to 7). Funding can be provided towards specific milestones like developing pilot products, field testing, early production, exploring market readiness.

- **"Challenges" and "Hackathons"**: From time to time, ANRF should fund open competitions for researchers or companies to perform specific outcome-oriented innovation, for example, develop prototypes, solve specific technical problems, propose novel system designs etc. Areas for should be sourced from government agencies, national missions, national labs and industry.

Policy 2B: Direct Concessionary Loans and Guarantees (co-financing) to finance 'First-of-a-Kind' (FOAK) industrial R&D projects *(builds on National Deep Tech Startup Policy Recommendation 3.6)*

- **Concessionary debt for pilot demonstration of large-scale projects**: ANRF can co-finance, alongside other debt providers, corporate or project finance loans for commercializing novel technologies on an industrial scale. These can be broad public and private goods which require large-scale prototyping before manufacture, such as nuclear energy, waste-to-energy conversion, hard-to-abate sectors, carbon capture technologies etc. ANRF loans should support capital investment projects aimed at proving commercial viability of technologies. Like the Production Linked Incentive (PLI) schemes, funding could also be linked to production targets. ANRF can provide concessionary and subordinated debt to reduce financial risk for other lenders and companies. ANRF can demonstrate a few early "lighthouse" investments and its learnings can help other public agencies develop their own loan programs over time.
- **Guarantees and blended finance co-investments:** ANRF should also actively source and co-invest in blended finance deals with reputed DFIs, impact investors, philanthropy and mainstream lenders. ANRF's funding should be used as catalytic capital such as through first-loss guarantees, risk-sharing facilities and subordinate debt (Afcha and López, 2014). ANRF can participate in blended finance deals structured by organizations like IFC. ANRF funds could also cover expenses related to technical assistance, performance evaluation and implementation for supported projects. Instruments like 'Technology Impact Bonds' (NDTSP Recommendation 3.9) or working capital loans can be experimented with.

Policy 3: Fund-of-Funds to finance a range of financial investment managers and new financial instruments to support R&D-intensive firms, starting with equity investors

Policy 3 proposes a **Fund of Funds (FoF)** to enhance long-term capital availability for R&D-intensive private sector companies. This builds on NDTSP Recommendation 3.3. The FoF would act as a Limited Partner (LP) by allocating capital to other investment managers while catalyzing more financial instruments and funding models to cater to different stages of the innovation lifecycle. Instead of picking winners among investors, ANRF could alternatively adopt a blanket policy of 'last resort underwriter' to fund any asset manager that meets a specified criteria such as deeptech investing track

record, fund size or investment approach. The FoF should be eligible to receive funds from the Central Government through grants and loans, donations from public sector enterprises, the private sector, philanthropist organizations, foundations or international bodies for R&D. The FoF could have another Ministry as lead, however ANRF should be represented on its steering or investment committee.

The Fund's **mandate** will be to:

1. In the short term, finance venture capital (VC) including corporate VCs, private equity (PE), and alternative investment funds (AIFs) targeting deep-tech startups and SMEs.

2. For the long term, promote development of capital markets and financial instruments, such as public market funds, private debt funds, blended finance, and impact investing.

3. Engage a broad range of donors to raise funds for the FoF, such as private foundations, businesses and individuals, both Indian residents and non-residents.

ANRF's key functions are related to investment and convening. Initially the investment mandate should be restricted to capitalizing equity investors which can be deep-tech specialist or generalist VCs, PEs and other AIFs. Direct equity investments should also be avoided initially. ANRF will select asset managers, monitor portfolio outcomes, and provide technology transfer support to investee companies that request them.

In addition, ANRF should bring together a range of participants, including financial institutions (FIs), financial regulators, investors, donors, industry and technologists to catalyze additional financial instruments (Hall & Lerner 2014). For example, it could seek feedback from mutual funds and industry on structuring investment products to invest in small cap and large cap public companies with promising growth prospects, high R&D intensity and a high risk-return profile. This could even spur the creation of new asset groupings, for example, as seen in various other industry-specific or ESG funds. Over time, the FoF's investment mandate can be extended to include a range of public equity managers, private debt funds and impact investors.

5.2 POLICY PACKAGE 2: INCREASE ACCESSIBILITY AND AVAILABILITY OF SCIENTIFIC INFRASTRUCTURE

RATIONALE AND GOALS

ANRF has been given the responsibility to ensure the diffusion of R&D activities beyond elite institutions and tier 1 cities in the country. The development of scientific physical infrastructure will be instrumental in achieving this goal. We recommend ANRF focus its efforts with regard to scientific and R&D infrastructure in two ways:

1. **Utilization of Existing R&D Infrastructure**

   Many national R&D labs and academic institutions possess advanced physical scientific infrastructure that remains underutilized due to a lack of structured mechanisms for sharing these resources. This focus aligns with existing government initiatives, such as the ODOE, which advocates for an equitable distribution of laboratory resources across districts, fostering innovation at the grassroots level.

2. **Upgradation and Development of New Scientific Infrastructure**

   Beyond the existing scientific infrastructure, the country lacks sufficient facilities to scale innovations beyond the research and development phase. Physical infrastructure that supports the latter stages of the technology commercialization cycle is needed, enabling startups, SMEs, and academic institutions to test and scale their innovations more effectively.

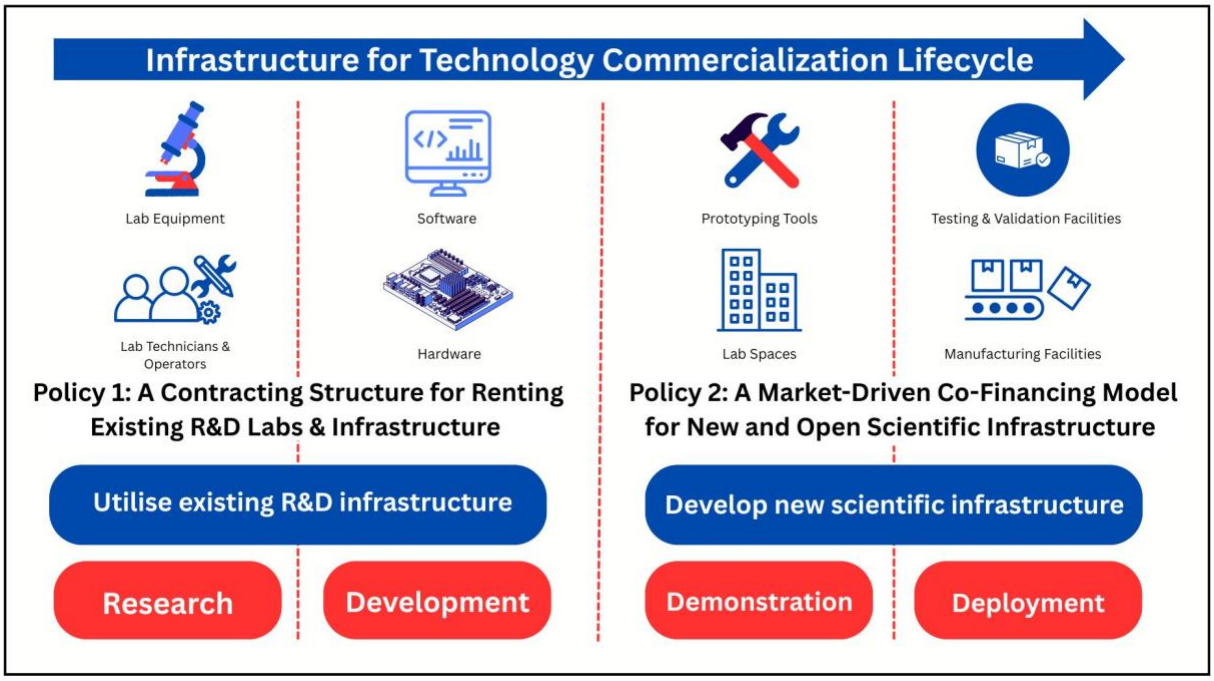
Our policy proposals seek to ensure the availability and accessibility of scientific infrastructure across the technology commercialization cycle. Existing initiatives, such as the Indian Science Technology and Engineering Facilities Map (I-STEM), can be given more prominence to create awareness about the platform and integrate new policy proposals (I-STEM, n.d.).

RECOMMENDED POLICIES

ANRF should take a technology commercialization lifecycle approach when addressing the scientific community's physical infrastructure needs. While the effective utilization of existing scientific infrastructure can help solve the research and development phase, the plan to develop new facilities can cater to the demonstration and deployment phase.

Based on the above philosophy, we propose two policies for a scientific infrastructure development strategy for technology commercialization. Through these policies, ANRF can push for the democratization of access to high-end scientific resources while fostering stronger industry-academia linkages.

Figure 6: An Infrastructure Development Strategy for Technology Commercialization



Source: Authors' Design

Policy 1: Contracting structure for renting existing R&D labs & infrastructure

The policy will allow national R&D labs and elite (and non-elite) higher educational institutions to legally rent out their R&D infrastructure and facilities on a pay-as-you-go basis. This will enable private sector companies, particularly SMEs, to access high-end R&D facilities without the need for large capital investments, promoting more industry-academia collaboration.

Policy 1 focuses on the initial stages of the technology commercialization cycle by improving access to scientific equipment, technology licenses, and skilled technicians. This is critical for researchers and academics who often lack the resources to conduct advanced R&D independently. R&D infrastructure should not be limited to equipment and facilities but also focus on soft infrastructure, such as R&D services provided by operators and lab technicians. This policy also addresses the need to build capacity within these national labs and academic institutions to offer R&D services to those in need.

This aligns with existing initiatives, such as the ODOE, which advocates for an equitable distribution of laboratory resources across districts, fostering innovation at the grassroots level (Hindustan Times, 2025). The policy should leverage the I-STEM to include more facilities and equipment while promoting awareness among tier 2 and tier 3 city institutions, thereby expanding the reach of collaborative opportunities.

This policy would focus on the initial part of the technology commercialization cycle, focusing on the research and development aspect by improving the accessibility of the following:

- **Scientific and Technical Equipment** - The policy would be taking forward the recently announced 'One District One Equipment' program, which focuses on solving the underutilization of laboratory equipment issues in each district across the country. Laboratory equipment for conducting R&D experiments can be leased out for a fixed fee (depending on the location). It can be used in-house to allow startups, SMEs and academic researchers to access underutilized scientific equipment.
- **Technology (Software and Hardware)** - For many R&D activities, the procurement of key software licenses and other hardware can become a high-cost barrier for R&D expenditure. This policy would allow government-run academic institutions and national R&D labs to get key

software licenses and hardware tools, which can then be leased out to startups and SMEs looking to work with such technology products. The existing scheme of One Nation One Subscription (ONOS) can be scaled up to include key software licenses and hardware design tools.

- **Technical Human Capital** - Currently, several academic institutions and national R&D labs lack skilled talent and technicians who can work with scientific infrastructure. Through this policy, ANRF should focus on enhancing the technical capacity of such institutions and labs by conducting a comprehensive landscape assessment of existing technicians and R&D equipment operators at government-funded research institutions. ANRF can engage with skill development institutions such as the National Skill Development Council (NSDC) to build technical expertise and ensure that R&D labs are well-equipped to support cutting-edge research services and foster stronger collaborations with the private sector.

Apart from this, awareness programs to inform researchers, academics, SMEs, and startups about initiatives that already provide access to R&D facilities and support services must be an important component of the policy. ANRF should also focus on the marketing and awareness campaign of I-STEM in Tier 2 and Tier 3 cities and make the gradual opening of I-STEM facilities to the private sector (primarily catering to startups and SMEs) a priority.

Policy 2: Market-driven co-financing model for new and open scientific infrastructure

The policy focuses on ANRF's ability to co-finance open scientific infrastructure (which currently does not exist in the country) in partnership with other private sector players. ANRF will provide initial seed capital (for example, 20% of the project capital costs) as a loan or guarantee to companies investing in the development of new scientific infrastructure.

Policy 2 would focus on the latter part of the technology commercialization cycle, with more emphasis on building infrastructure for the demonstration and deployment of scientific and technological breakthroughs by research institutes and private sector entities. This infrastructure shall be made open and available to all public and private players who are interested in using them for a fee (fixed depending on who the user is). This includes:

- **Demonstration Testbeds** - Demonstration testbeds will be crucial for ANRF to develop, which can help smaller private sector players such as startups and SMEs along with academic research institutes, showcase their ability to scale up technologies and understand their performance when deployed on a larger scale.

- **Prototype & Pilot Batch Manufacturing** - Most startups, SMEs and even academic research institutions in the country lack the infrastructure and tools to prototype their inventions and innovations. ANRF, along with the private sector, can help improve the accessibility of such manufacturing tools for smaller private sector players and academic research institutions to help them reach the MRL stages. These can be the first manufacturing tools to determine if a particular scientific discovery or technological innovation is ready to be deployed in the market.

- **Production Facilities & Lab Spaces** - This remains the final piece of the puzzle in the technology commercialization process, with the infrastructure in place to ramp up production and deployment of technological innovations. There is currently a shortage of such large-scale production facilities, especially for startups and SMEs looking to scale up their processes. ANRF, with interested private sector companies, can develop large-scale lab spaces and production facilities that smaller players can rent out and use in the innovation ecosystem.

In this case, public funding alone cannot meet the scale of infrastructure development required for a country like India. The co-financing model leverages ANRF's catalytic capital to mobilize private sector contributions, encouraging industry participation and a market-driven approach towards new infrastructure development.

We recommend that ANRF use its access to funding to catalyze greater private sector investments in the development of scientific infrastructure. We do not recommend that ANRF lead the financing of new scientific infrastructure but focus on providing the proper incentive structure for bigger private players to contribute to scientific infrastructure development, which could be used by different stakeholders in the innovation space.

A way to incentivize large conglomerates to co-finance such scientific infrastructure would be to create a financially sustainable model with high utilization rates and a risk-sharing consortia-based approach (Trikha & Chongtham, 2021). By bringing together multiple private players in a consortium for such

infrastructure projects, the financial burden is shared, and risk is reduced for any single investor. Each participant could use and access the facilities proportional to their investment share, ensuring a respectable return on capital. Additionally, rent, fees and user charges from smaller startups, SMEs and other research institutes can help generate steady revenue, improving both cost recovery and long-term fiscal sustainability for the infrastructure.

We recognize that a part of the policy focuses on financing and creating new infrastructure in the scientific domain. However, we recommend letting ANRF provide seed capital and any other economic incentives (tax breaks) if the private sector expresses interest in developing such new scientific facilities. ANRF can focus instead on promoting and developing partnerships with the private sector to encourage infrastructure development projects.

We also recommend that ANRF refrain from conducting full-scale financial due diligence on these projects, thereby reducing administrative and technical burdens. Instead, it should collaborate with established financial institutions and leverage their expertise for rigorous financial assessments on any infrastructure project plan. This approach can ensure that proposed projects receive a scrutinized evaluation while allowing ANRF to focus on its core mission of catalyzing infrastructure development.

These private sector-developed scientific facilities can be cutting-edge to meet the latest technological advances, procure the latest equipment and support companies' needs with product development, prototyping, testing, validation etc. Additionally, these can also act as incubators and also provide mentoring services that can guide startups and SMEs in their technology commercialization process.

Table 9: Breakdown of Recommended Scientific (R&D) Infrastructure Policies

Proposed Policy	Technology Commercialization Stage	Target Group
Policy 1: Contracting Structure for Utilizing Existing R&D Labs & Infrastructure	Research & Development (R&D)	Academic researchers (PhDs), scientists & academics
Policy 2: A Market-Driven Co-Financing Model for New and Open Scientific Infrastructure	Demonstration & Deployment	Deep-tech startups, SMEs, early-stage companies

Source: Authors' Compilation

5.3 POLICY PACKAGE 3: DEVELOPING LONG-TERM HUMAN CAPITAL FOR RESEARCH & INNOVATION

RATIONALE AND GOALS

ANRF, as the apex scientific research foundation has to play a role in developing human capital and fostering scientific talent. Its mission should emphasize bridging the academia-industry gap and creating a research and innovation-oriented culture in the country. We recommend that ANRF address two key challenges that persist within the research and innovation ecosystem:

1. **Creation and retention of an R&D-friendly culture**

   India still lacks a strong culture of research and innovation at the school and higher education levels. Research careers are still undervalued, with limited economic incentives to pursue science. Elite institutions dominate the research landscape, leaving state-level universities and tier 2 and tier 3 city institutions with minimal exposure to cutting-edge R&D activities.

2. **Improving academia-industry linkages to unleash innovation**

   India's academia-industry collaboration remains weak, with limited overlap between academic research outputs and industry needs. Information asymmetry between academic institutions and private sector firms further exacerbates this divide. Industry veterans rarely engage with academic institutions, limiting mentorship opportunities and practical insights into industry requirements.

Apart from the above two areas, we recommend that ANRF also focus on advising state governments to implement some of the policy proposals stated in the National Education Policy (NEP) related to research activities. This includes creating a provision for recognizing research-related activities as academic credit in educational institutions. Since the topic of education comes under the purview of the State governments, ANRF can act as an advisory body enabling students to gain academic credit for their research work, encouraging them to engage in practical, hands-on research and fostering a stronger link between academia and industry.

RECOMMENDED POLICIES

We propose two options which would be ANRF's dedicated effort into creating a research and innovation-oriented talent pool (Policy 1), which cuts across the existing silos and enhances collaboration (Policy 2) between the actors in the science and tech space:

Table 10: Breakdown of Human Capital Stakeholders and their Needs

Stakeholder	How can ANRF address their Needs
School-level students	Build scientific temperament and give exposure to research and entrepreneurship early
Undergraduate and graduate students	Encourage learning by doing and learning from others
PhDs and Postdocs	Promote multidisciplinary collaboration and help generate new research and IP
Senior scientists (at national R&D labs)	Encourage partnerships with academic institutions, generate and commercialize IP
Entrepreneurs	Help in technology commercialization and scale companies
Domestic firms and SMEs	Access best research talent and encourage collaborations with academic institutions
MNCs/GCCs	Share knowledge and talent through academic partnerships and produce joint IP with domestic firms
Indian-origin foreign university researchers & scientists	Retain talent and provide opportunities to young Indian researchers to collaborate with foreign universities

Source: Authors' Compilation

Policy 1: Developing a motivated research and innovation culture

The policy details how ANRF can create a motivated, R&D-oriented academia and workforce in the country. The key objective is to ensure that the culture of R&D and innovation is inculcated in individuals from a young age and that cutting-edge research occurs across all tiers of academic institutions in the country. Under the proposed policy, we recommend two tools to achieve the objective set out through the policy:

Policy 1A: School & undergraduate innovation & entrepreneurship awareness drives

ANRF can start a nationwide awareness drive focusing on the benefits of research, innovation, and entrepreneurship at the school and undergraduate levels. These programs can be done in collaboration with the existing Atal Innovation Mission and their Tinkering Labs. Through this program, ANRF can play a role in imbibing motivation to become researchers, innovators, and entrepreneurs at a young age.

We recommend that ANRF focus on ensuring that R&D and innovation activities have prominence in the school and undergraduate higher education space, which percolates further than the elite academic institutions in tier 1 cities.

These nationwide awareness drives have the potential to cultivate a scientific temperament among school and undergraduate students by highlighting the benefits of research, entrepreneurship, and innovation (Khanna, 2022). Programs aligned with initiatives like the AIM will foster curiosity-driven learning and push students towards careers in innovation and entrepreneurship. This early exposure to concepts related to science and R&D will introduce a culture of motivated talent for India's innovation ecosystem, thereby leading to an innovation-centric private sector willing to spend more on R&D.

Policy 1B: Specialized fund for pursuing research internships under National Missions

ANRF should create a specialized fund for graduate-level (bachelor's and master's) students to pursue research internships under the technology missions already identified by the Indian government. This policy would provide students with hands-on research experience and global exposure in key technology areas (EVs, AI, Quantum, Green Hydrogen etc.) that are already deemed strategic by the government. Ultimately, students can pursue research opportunities in such technologies through the support of ANRF, leading to innovation and entrepreneurship in these technologies. It would also extend learning opportunities beyond just elite institutions, thereby ensuring inclusivity across regions and educational tiers.

We recommend that the fund should cater to students who are willing to take up unpaid or low-paid research internships in Indian and foreign universities related to any of the technology missions identified. Since many students cannot access research internship opportunities in foreign universities

due to meagre funding, this program can become a source for motivated undergraduate and graduate students to access such research opportunities. In this way, ANRF can support young researchers and students interested in pursuing research and PhDs to gain credible lab-level work experience in Indian or foreign research labs.

This fund can help foster a strong R&D culture in key technologies under the identified National Missions by offering students direct exposure to cutting-edge research in priority technology areas. Hands-on research experience and mentorship from leading scientists and technologists can empower students to develop novel solutions in the space.

Policy 2: Building the industry-academia talent linkage

This policy stresses the role of ANRF in bridging the industry-academia divide and creating a science and technology ecosystem with more collaboration and partnerships in the country.

The options detailed in this policy can help alleviate the existing information asymmetry and trust deficit that exists between academic institutions and industry or private sector firms. This can help improve private sector participation in the overall R&D expenditure as well as help academic institutions engage in translational research from the lab to the market. Some options include:

Policy 2A: Private sector fellowship program for young researchers

ANRF can partner with research centers of different multinational companies (MNCs) and Indian conglomerates in the country that have their R&D centers here to curate this fellowship program. The program will place young up-and-coming researchers doing their PhDs to spend a semester engaging in R&D activities at a private sector lab to understand industry R&D requirements. This would help create a seamless talent movement pipeline from universities to the industry. The fellowship program will also help students and academics transition into real-world applications of their research, encouraging industry-relevant innovation and reducing talent gaps in R&D.

Different MNCs have set up state-of-the-art R&D centers in the country, with most of their cutting-edge research happening in their Indian offices. The Global Capability Centers (GCC) have also become

hotspots of innovation in the country. As part of the fellowship, ANRF can identify the list of private firms engaging in such cutting-edge industrial R&D and which have become innovation hubs.

ANRF's role in this initiative will be limited to matchmaking, identifying and connecting suitable private sector research centers with prospective PhD students and post-docs from universities. The hiring and placement processes, covering all aspects from applications to the final selection, will remain the responsibility of the private firms and the academic institutions involved. This approach ensures that ANRF remains focused on facilitating partnerships and enabling access to cutting-edge industry R&D without having additional administrative and managerial responsibilities.

Policy 2B: Establish Professor of Practice positions at eminent institutions

ANRF can also double down on the existing PAIR program to identify and establish academic positions for industry veterans at key academic institutions. The responsibility of such professors of practice positions will be primarily MNCs and domestic private sector engagement in bringing industry partnerships to educational institutions (Kamat, Sagar & Narayanamurti 2020). While these positions can be created at the Hubs of the PAIR program, the main objective would be to incentivize industry collaboration and partnerships in all the Spokes (the lower-ranked academic institutions) attached to that particular Hub. This can achieve a two-fold objective of both industry-academia partnership as well as industry engagement moving beyond the elite academic institutions.

Additionally, this policy also focuses on attracting Indian scientist diaspora from abroad by leveraging initiatives such as Project Vaibhav, which connects scientists and scholars of Indian origin with domestic research institutions (DST, n.d.). By creating unique positions for returning diaspora scientists and creating private R&D engagement opportunities, these accomplished researchers can directly contribute to R&D programs at academic institutions in close collaboration with Indian private sector partners. The expertise that the Indian scientific diaspora would bring can improve these institutions' technical capabilities and create additional international networks. Finally, they can drive industry-academia engagement while catalyzing high-impact innovation across the ecosystem.

Policy 2C: Convene semi-annual industry-academia fairs at established S&T Clusters

ANRF can also act as a national convener, bringing academic institutions and industry representatives together every 6 months at all the major S&T clusters through a conference or fair. This can help bridge the information asymmetry gap that currently exists between industry and academia, helping inform each other about the research areas, questions and directions being undertaken by each entity. By doing this, academics can learn more about industrial R&D opportunities, and industry representatives can identify specific researchers in academic institutions who are working on the research questions that the industry is interested in.

These fairs can facilitate direct exchanges between academic researchers and industry representatives, fostering collaboration on ongoing projects. By bridging the gap between academic research and industry needs, these fairs can also galvanize additional private sector R&D investments and encourage more collaborative innovation efforts. As the industry gains clarity on current research pursuits and expertise at academic institutions, they have incentives to invest more in or co-develop targeted research projects with selected academic partners. This can improve technology transfers, knowledge sharing, and the development of commercial technologies as a result of public-private partnerships.

CHAPTER 6: CONCLUSION & PATH FORWARD

ANRF has an opportunity to play a key nation-building role for India over the coming decades. It should take a long-term view of its mission, and the steps required to fulfill it. It should target critical ecosystem levers initially, such as bridging disciplines and stakeholders, mobilizing risk-absorbing capital for R&D-intensive businesses, accessing scientific infrastructure widely, and developing long-term talent. Meanwhile, ANRF must encourage greater accountability in public spending, starting with insisting on gold-standard independent expert or peer review processes, outcomes focus (for translational research) and regular reporting in its programs and initiatives.

We believe that there are still existing research gaps that need to be filled for understanding the innovation landscape in India better. While we have touched upon it in our report, there are some research questions for which more granular data and insights are required. Further studies can be done on (1) Understanding the specific reasons behind low private sector in-house R&D expenditure through firm-level surveys (2) Designing the optimal incentive structure for academics to pursue science-based entrepreneurship at an academic institution level (3) Evaluation of existing policies related to innovation and R&D financing measures and (4) Potential of private universities and state public universities to drive R&D and innovation activities as a landscape study.

Since it is a new institution, we feel that in-depth academic studies on ANRF and its programs can be a bit premature at this time. However, there is immense potential for further studies on multiple topics related to ANRF in the future such as (1) The sectoral focus of ANRF programs (2) Evaluation of existing technology missions and (3) The role of ANRF in promoting role of research in universities and evolving the academic curriculum.

Some of our policy recommendations are aspirational in nature, even as they independently consider implementation and political feasibility in context. ANRF may choose to sequence different initiatives more cautiously. We hope our policy framing will nonetheless add to its consideration set.

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APPENDIX A: ABOUT THE CLIENT

The external client for this Policy Analysis Exercise is the 'Policy Analytics & Insights Unit' of the Office of the Principal Scientific Adviser to the Government of India (OPSA-PAIU).

The Office of the Principal Scientific Adviser (OPSA) aims to provide pragmatic and objective advice to India's Prime Minister, Cabinet and the Government on matters related to science and technology (PSA, n.d). OPSA-PAIU, located at the Indian Institute of Science (IISc) in Bengaluru provides data analysis and policy support for OPSA's various initiatives, including the PM-STIAC, Anusandhan National Research Foundation (ANRF), National Deep Tech Startup Policy, International Technology Engagement Framework (ITEF), Chief Science Advisers Roundtable (CSAR) and various other national and international technology policy initiatives.

The OPSA also oversees eleven 'National Missions', started under PM-STIAC, that aim to address critical long-term national goals through science and technology. The Missions aim to bridge prepare national long-term science & technology roadmaps around key national priorities like natural language translation, quantum technologies, artificial intelligence, electrical vehicles, biodiversity, circular economy and waste management, deep ocean exploration, biosciences and health. OPSA has also spearheaded the establishment of Science and Technology (S&T) Clusters, which are regional STI networks for fostering collaboration among universities, industry and government ministries.

We primarily worked with the Chief Policy Advisor of the OPSA-PAIU to create a knowledge product that the OPSA may propose to the leadership of ANRF. Our report aims to provide a strategic vision for ANRF on behalf of the OPSA-PAIU for increasing R&D investments and improving India's long-term innovation capacity in line with ANRF's broader objectives.

APPENDIX B: EVIDENCE FROM GLOBAL R&D & INNOVATION LITERATURE

Global literature reveals that R&D and innovation are critical drivers in sustaining long-term economic growth, driven by strong interactions between the public and private sectors.

PUBLIC-PRIVATE COLLABORATION IN INNOVATION

Most countries' innovation journey begins with the public sector taking on a leadership role. Public funds support basic research, seed infrastructure and facilities, and absorbs risk in areas where private sector is hesitant to deploy capital. Policy plays an important role in developing research institutions, science and engineering talent, integrating teaching and research functions of universities, strengthening IP regimes and promoting linkages between stakeholders. The government also plays a key role in directing resources towards important national priorities. Over time as the economies mature, the private sector takes on a greater role in financing R&D.

However, even as the private sector's role in funding and performing R&D increases, the government and private sector continue to interact heavily and are interdependent. Public R&D funding continues to support basic research that feeds into the private innovation pipeline. The government also creates an enabling environment for improving collaborations, streamlining the technology commercialization process, providing tax incentives and grants, and continuing to de-risk emergent sectors.

There is strong evidence globally that public investments in R&D have an effect on crowding in private R&D investments and contribute to overall economic activity in the short and long runs. In fact, the increase in aggregate economic output and productivity from public investments is shown to be permanent, strengthening long-term dynamism of economies (De Lipsis et al., 2023). Public spending has spillover effects of enhancing productivity even in sectors not targeted by initial R&D investments.

In India, although the public sector has dominated the spending landscape, the national innovation model is still nascent. This means that government must continue to play a leading role in funding innovation and improving the general conditions for private firms to participate. Beyond funding research, policy must ensure availability of the other elements to incentivize private investments such as regulatory stability, access to talent, and IP protections.

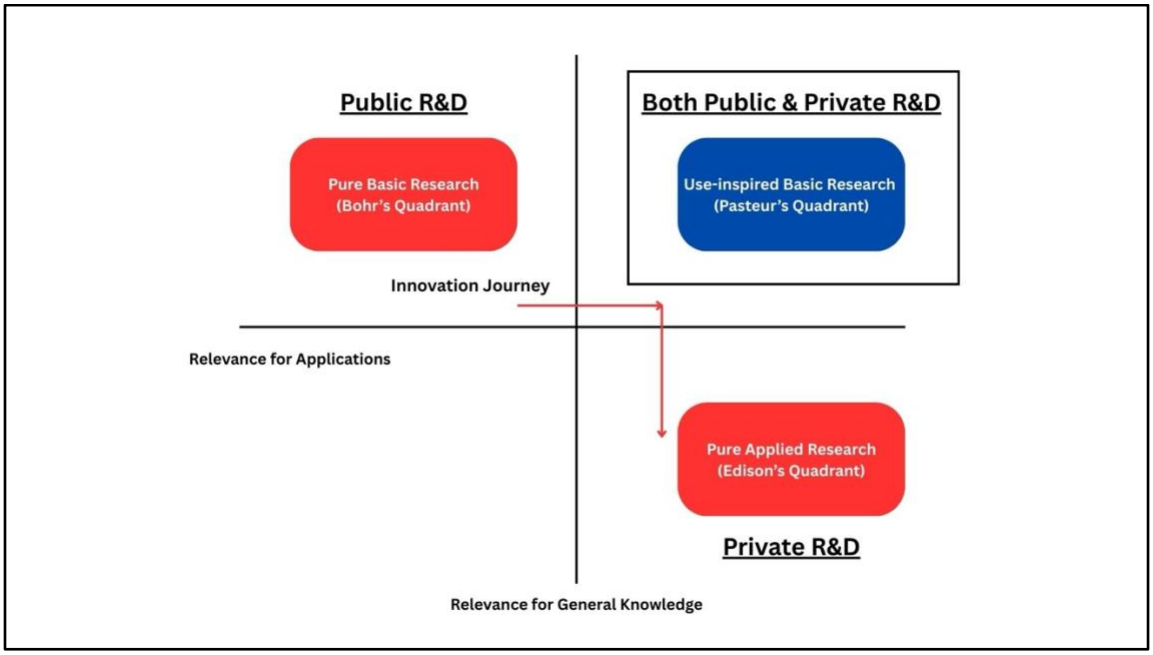
MANAGING THE INNOVATION PROCESS

Conventionally, 'Research' and 'Development' (R&D) have been considered two distinct components of innovation. Research is generally understood as the process of increasing the pool of knowledge, while development is the process of creating useful solutions from research; the former is more traditionally associated with the sciences and the latter with engineering. In other conceptual models, R&D is followed by 'Demonstration' of technologies in lab and commercial settings and 'Deployment' in the market ("RDDD", American Energy Innovation Council, 2023).

Another common distinction conventionally drawn is between basic and applied research. This dichotomy is increasingly being challenged today as encouraging a linear view of the research process and obscuring its complex and multiple nature. Instead, innovation is considered a complex, nonlinear and innovation process. One alternate framework considers 'discovery' (fundamental curiosity-driven research) and 'invention' (application-focused development) to better describe the components of innovation (Narayanamurti et al., 2013). The process of invention can uncover new areas for further discovery, and new discoveries can, but may not necessarily, lead to new inventions. In practical terms, this view emphasizes much closer interaction between science and engineering. This view is illustrated by 'Pasteur's Quadrant' of scientific research (Stokes 2011), where basic research is itself 'use-inspired'.

Breaking these dichotomies and scaling innovation requires taking an extended time view and institutional structures that encourage purposeful multidisciplinary collaboration between science and engineering, alongside long-term support for curiosity-driven research. R&D or innovation-related activities are inherently complex in nature and integrate multiple forms of capital – human, physical, financial, and intellectual – to develop an innovative product, service or technology. Hence, a systems-lens is essential. This would ensure that each R&D and innovation ecosystem component is not treated independently but as interdependent parts.

Figure 7: Quadrant Model of Scientific Research



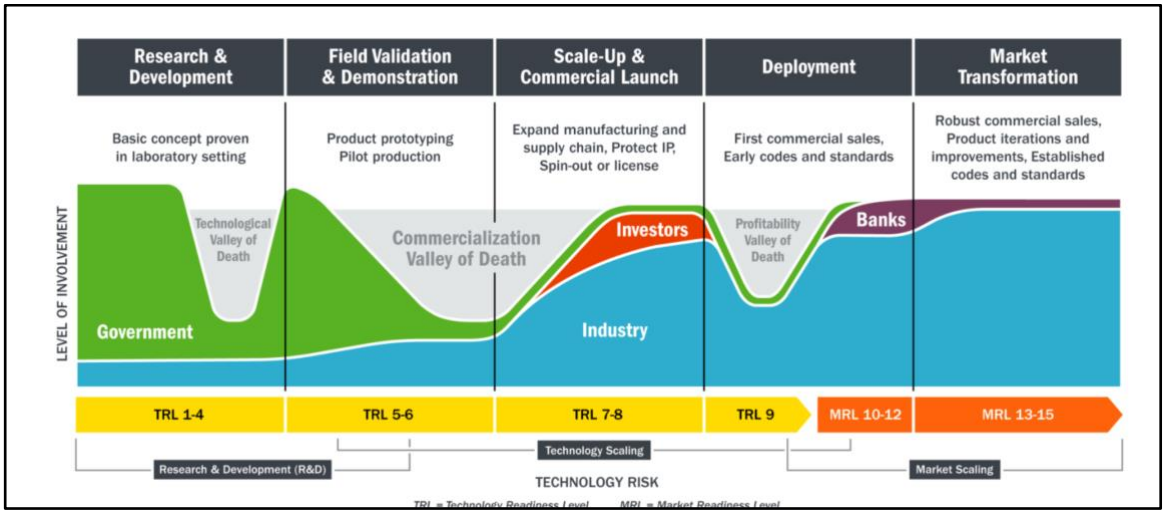
Source: Authors' Design

Another commonly used conceptual framework is that of Technology Readiness Levels (TRL), developed by NASA. While this again conceptualizes innovation as a linear process, nonetheless it is still helpful when applied to specific technologies. In the journey from lab to market, technologies face several challenges: high capital intensity, science and engineering risk, techno-economic feasibility, market readiness and adoption, commercialization, scaling, IP defensibility, and regulations. Capital intensity remains high as technologies enter the market due to costly infrastructure and long timelines. Usually this is when industry steps in. Notably, "deep tech" companies face three critical "valleys of death" before wide commercialization:

1. **Technological valley of death (science risk):** Around TRLs 3-4. The key uncertainty companies face is developing working proofs of concept and testing in a lab environment.
2. **Commercialization valley of death (demonstration risk):** Around TRLs 5-8. The key uncertainty companies face is demonstrating feasibility in a commercial environment.

3. **Profitability valley of death (scaling risk):** Around TRLs 9-10. Key uncertainties here are developing a sustainable business model (cash flows to finance opex, capex and R&D), expanding the market, and achieving technology-based competitive advantages.

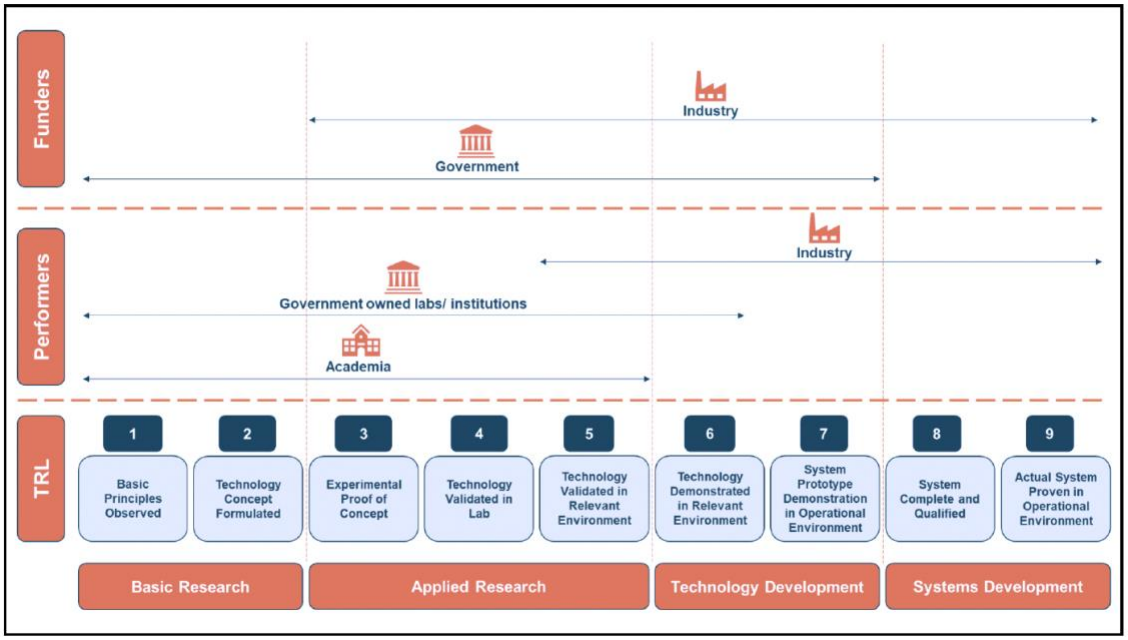
Figure 8: The TRL Based Innovation Lifecycle



Source: US Department of Energy

In India, the country's scientific and technological community has historically delineated the process of basic, translational and applied research, with different institutions taking up the responsibility of various aspects of the innovation life cycle. Traditionally, government funding in India has been primarily directed towards early TRLs or fundamental research at elite universities and 'national' R&D labs. Private sector and industry innovation funding have been focused on later TRLs (7-9).This has resulted in a siloed approach towards innovation with minimal collaboration between industry, academia and government. In recent years, there has been greater emphasis by the government on a 'Triple Helix' model involving closer nexus between these three (Singh & Thukral, 2023).

Figure 9: The Triple Helix Model of Innovation



Source: The Ingredients of a Robust Research Ecosystem, FAST India

Increasingly, mission-oriented innovation policies (MOIPs) are being employed globally to set targets and milestones for breakthrough innovations (Mazzucato & Dibb, 2019). In India, the eleven 'National Missions' launched by the government under PM-STIAC present an opportunity to align innovation efforts around key national goals. MOIPs share common features: clear objectives and milestones, cross-sector collaboration, and a focus on public value creation. Cases in point are early examples in the US like Bell Labs and DARPA, and more contemporary ones like the European Union's climate missions, Japan's Moonshot R&D Program, and ARPA-E's support for climate technologies in the US.

Innovation thrives in clusters. Global evidence suggests that India's approach to innovation would benefit from greater collaboration between stakeholders and greater multidisciplinarity (between science, engineering and design) in research. Better alignment and feedback loops between industry, academia and government can ensure R&D spending contributes to creating markets and public utility.

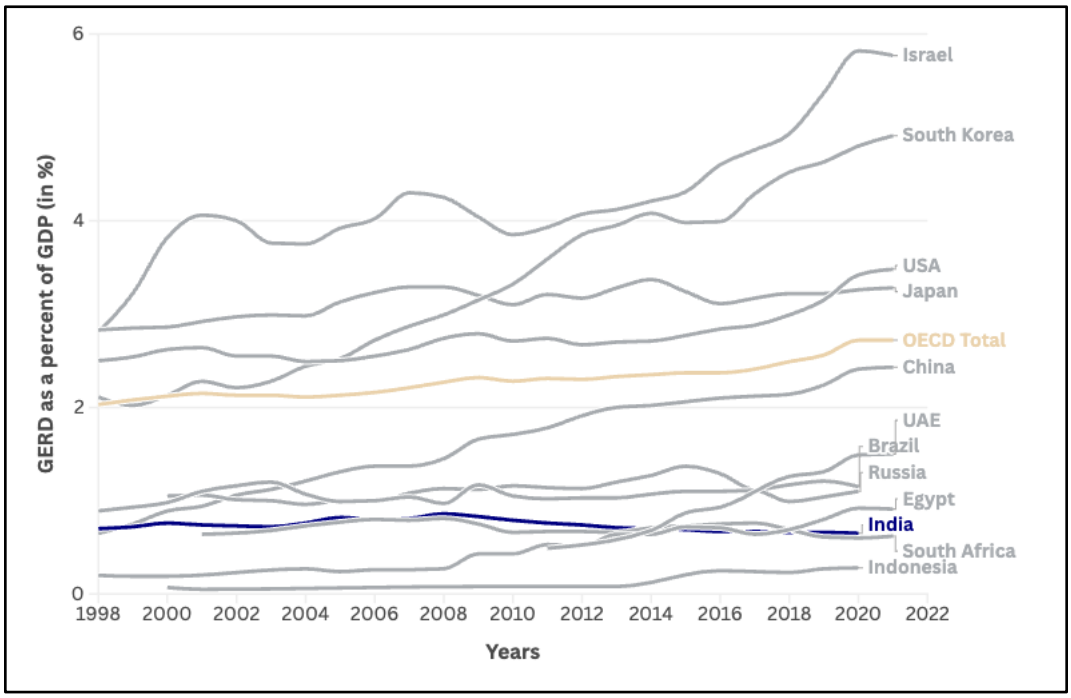
APPENDIX C: INDIA'S R&D AND INNOVATION LANDSCAPE

OVERALL R&D LANDSCAPE

At the outset, India's total gross expenditure on R&D (GERD) remains critically low as a percentage of GDP and relative to its development status. Despite the country's recent advancements in many innovation indicators, the meagre expenditure on R&D hampers its ability to climb the innovation ladder and become a leader in science and technology.

India is the fifth-largest economy globally, with a total of $3.568 trillion and a GDP per capita of just over $2,400. India's Gross Expenditure on R&D (GERD) stands at 0.64% of GDP, far below the global average of 2.6%. Advanced economies, both large and small, like the USA (3.47%), China (2.41%), South Korea (4.8%) and Israel (5.71%), have much higher GERD as a percentage of GDP (OECD, n.d.).

Figure 10: Historical GERD Comparison between India & BRICS, Select OECD Countries



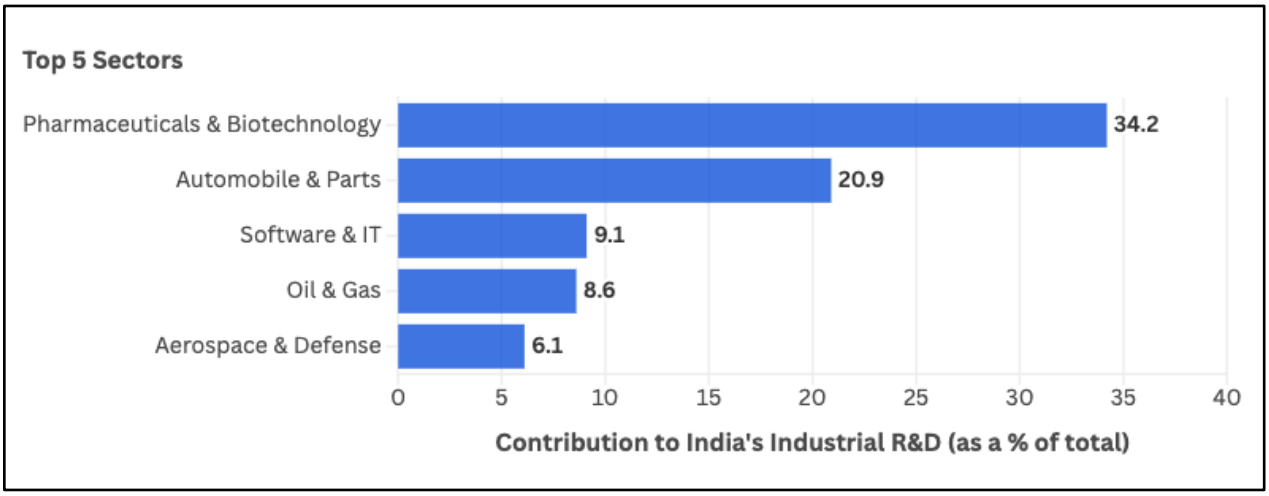
Source: Science, Technology & Innovation Indicators Database, OECD

Even when compared with countries with a similar GDP per capita, India trails in expenditure as a percentage of GDP. For instance, Egypt, which has a GDP per capita of just over $3,000 and a much smaller economy in absolute terms, spent 0.72% of its GDP on R&D in 2022. Apart from being low, India's GERD has also stagnated between 0.6–0.7% over the last decade, even as its economy has grown. This contrasts sharply with East Asian countries like China, Japan, and South Korea, which dramatically increased R&D spending as their economies developed. The NITI Aayog Innovation Index Report 2019 as well as the Department of Science and Technology's Updated R&D Statistics Report 2022-23, emphasizes on the need to increase R&D spending in line with India's development status.

As per the 2023 Global Innovation Index data by the World Intellectual Property Organization (WIPO), India ranks among the top three globally in the total number of scientific publications and the amongst the top six by the total number of filed patents. Yet, its disproportionately low R&D spending low relative to its developmental status remains a puzzling statistic.

India's R&D investments are also concentrated in a few sectors. The top R&D intensive sectors as of the financial year 2021-22 in the country is provided in the figure below:

Figure 11: Top 5 Highest Contributing Sectors to India's Industrial R&D



Source: CTIER Handbook: Technology & Innovation in India 2023 (Data: Prowess)

INNOVATION INDICATORS

PUBLICATIONS

Between 2017 and 2021, India ranked fifth globally in cumulative publication output, contributing around 641,594 publications (4.2% of the world total). However, these publications' impact, measured by the Category Normalized Citation Impact (CNCI), remains below the global average. Alongside Japan and Brazil, India has one of the lowest CNCI scores among major economies.

In industry collaborations, India has the lowest share among select emerging economies, with only 1.1% of publications involving at least one industry co-author. This is significantly lower than leaders like Japan (5.6%) and Germany (5.5%). Similarly, India's international collaboration rate is modest at 25.6%, just above China (24.8%) but far behind leaders like UK (55.4%) and Germany (54%). Fostering industry and global research partnerships are critical for enhancing quality and impact of scientific output.

Table 11: Country-wise Comparison of Scientific Publications (2017-21)

Country	Share in Global Publication Output (%)	Category Normalized Citation Impact (CNCI)	Share of Industry Collaborations (%)	Share of International Collaborations (%)
USA	25.1	1.3	3.6	34.3
UK	7.6	1.4	4.1	55.4
Germany	6.1	1.3	5.5	54
Japan	4.2	0.9	5.6	32
Brazil	2.4	0.9	1.7	38.9
China	19.1	1.1	2.1	24.8
India	**4.2**	**0.9**	**1.1**	**25.6**
Israel	0.8	1.4	3.2	50.3
S Korea	2.8	1.1	4.3	31.3

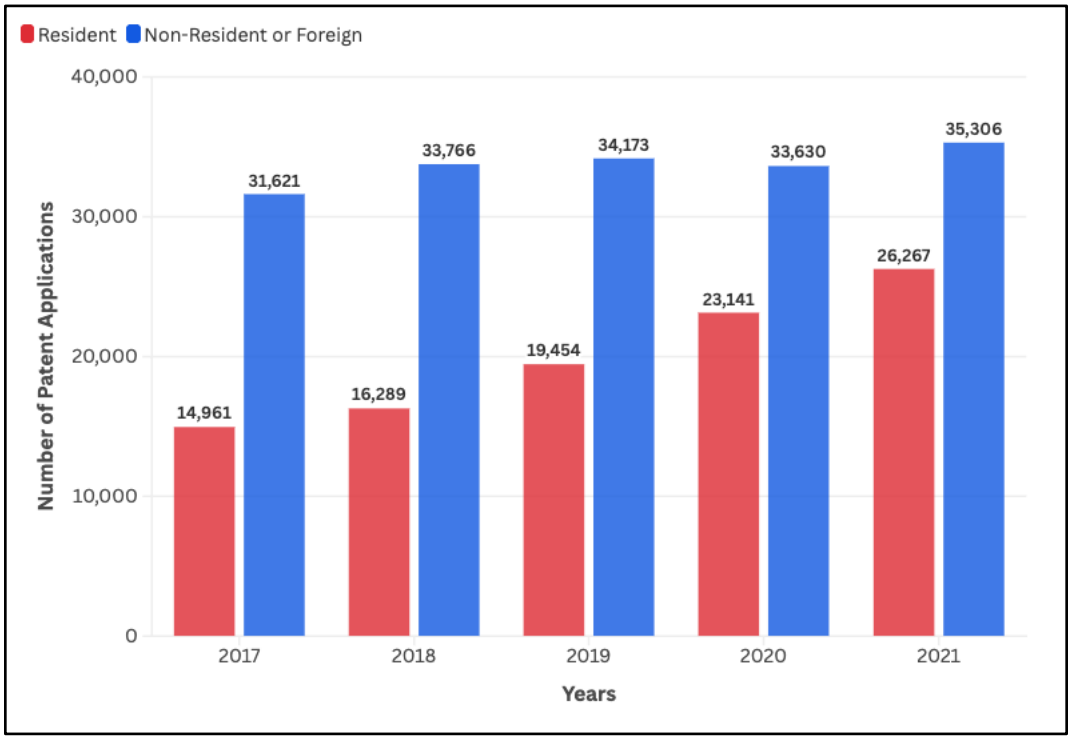
Source: CTIER Handbook: Technology & Innovation in India 2023 (Data: InCites)

PATENTS AND INTELLECTUAL PROPERTY

India has made steady progress in international patent filings over the past decade. The number of patent applications filed abroad by Indian entities increased significantly from 7,073 in 2011 to 16,896 in 2021. In the same period, China saw international patent filings multiplied more than five times from 20,357 in 2011 to a staggering 111,960 in 2021. In the field of IP, India still remains far behind global leaders like the United States, Japan, and China.

While the scientific activity of domestic Indian companies is increasing, non-residents and MNCs continue to dominate patent filings and awards with the Indian Patent Office (CTIER, 2023). Domestically, India recorded 61,573 patent applications in 2021, ranking fifth globally. Indian citizen and resident patent applications saw steady growth during this period, with their share increasing from 32% in 2017 to 43% in 2021.

Figure 12: Comparison of Resident & Non-Resident Patent Applications in India (2017-21)

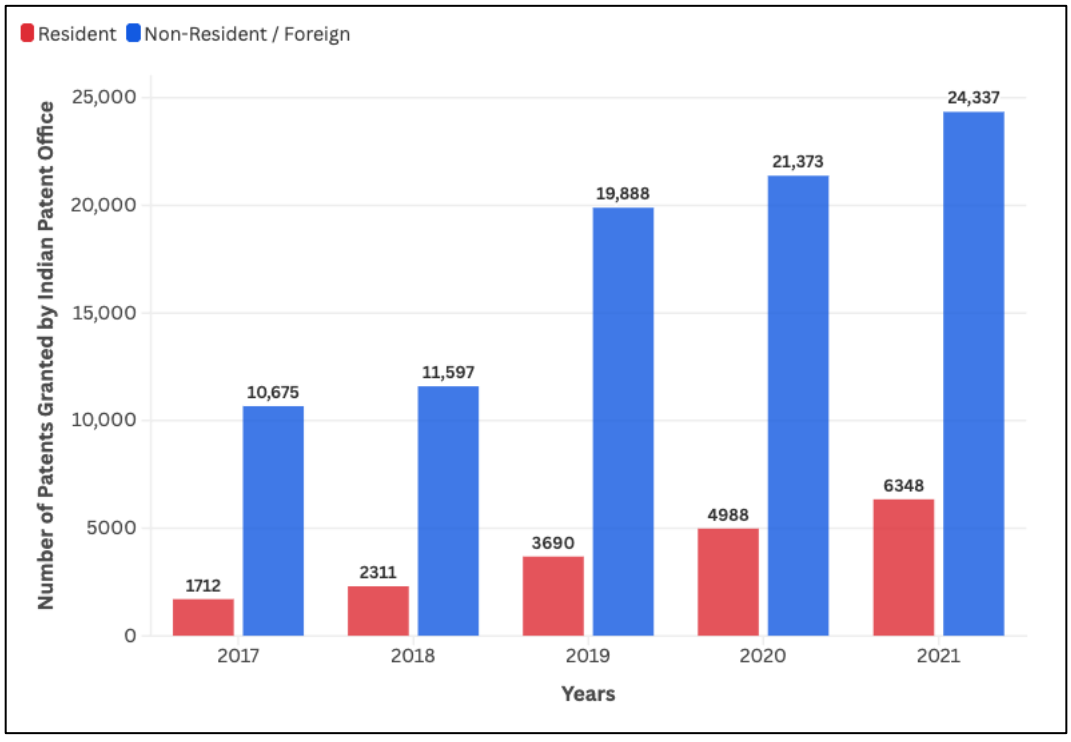


Source: CTIER Handbook: Technology & Innovation in India 2023 (Data: WIPO IP Data)

In terms of patents granted, the Indian Patent Office granted 6,384 patents to resident applicants, while 24,337 patents were granted to non-resident applicants in 2021, highlighting a significant disparity. This trend is inverted in emerging economies like China, Japan, and South Korea, where the number of patents granted to residents is much higher than that of non-residents. The gap between patents granted to non-residents and residents in India has widened over time.

Similar to R&D expenditure, patent applications in India are primarily concentrated in specific sectors. In 2021, over 60% of total patent applications were filed in computer science and electronics, mechanical engineering, chemical technologies, and communication technologies. Notably, the number of patents filed in computer science and electronics has doubled since 2019, highlighting India's increasing focus on digital technologies. However, the commercialization of patents remains limited, with most innovations failing to transition into market-ready products or services.

Figure 13: Comparison of Resident & Non-Resident Patents Granted in India (2017-21)

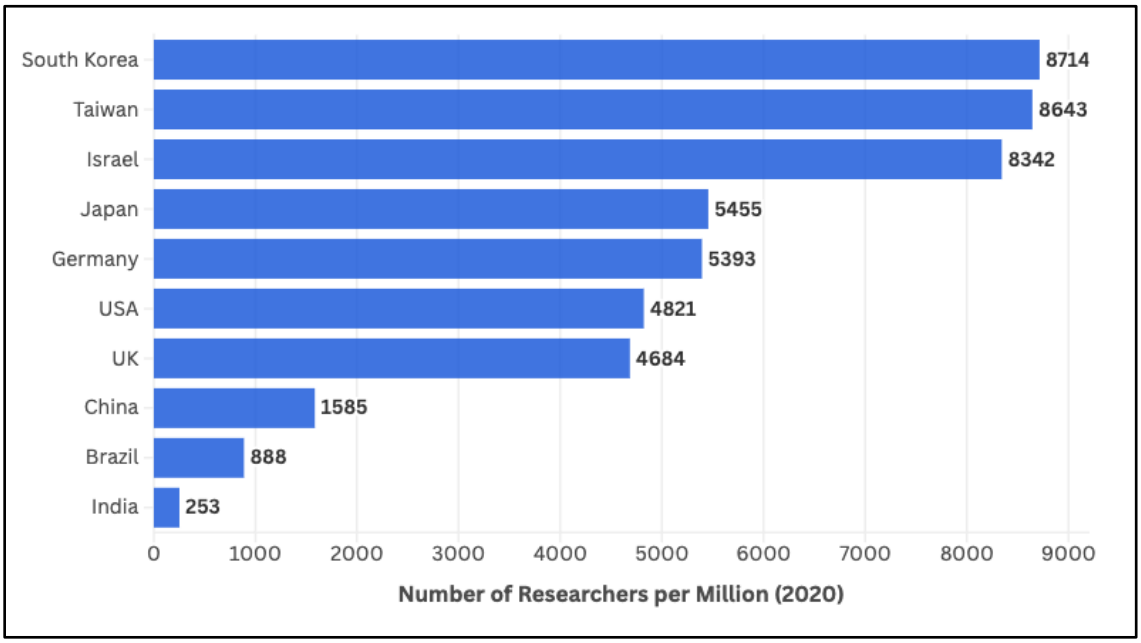


Source: CTIER Handbook: Technology & Innovation in India 2023 (Data: WIPO IP Data)

SCIENTIFIC TALENT

In 2020, India had a mere 253 researchers per million people, significantly lower than any other advanced or emerging economies. The universities and higher educational institutions (HEIs) in the country have historically prioritized teaching over research, with limited emphasis on building robust research ecosystems. India's researcher density lags behind not only advanced economies but also several developing nations, reflecting a severe talent shortage in its research ecosystem. Another factor compounding this issue is the phenomenon of brain drain from India, where many talented Indian engineers, scientists and researchers have sought opportunities abroad thereby reducing the talent pool in the country (Choudhury et al., 2023). In contrast, countries such as China and Taiwan have successfully leveraged their overseas science and engineering diaspora to bolster research capacity and drive innovation at home.

Figure 14: Country-wise Comparison of Researchers per Million Population (2020)



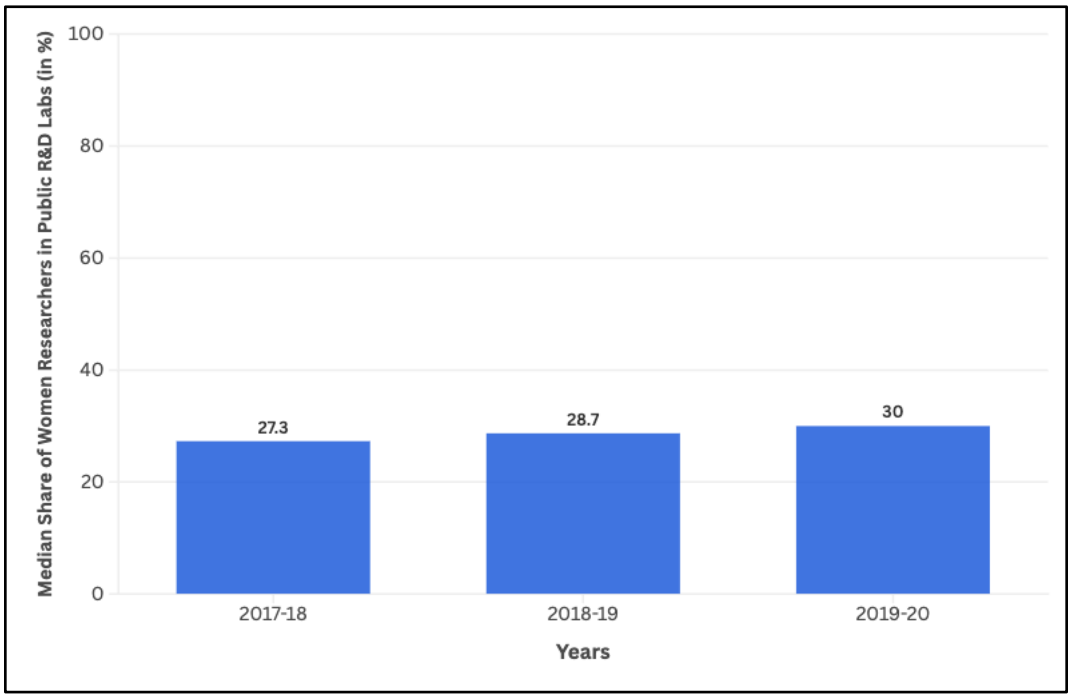
Source: CTIER Handbook: Technology & Innovation in India 2023 (Data: UNESCO Institute)

India's production of science and engineering PhDs has been declining. In 2021, India awarded only 16,162 science and engineering PhDs, a sharp decline from 24,321 in 2020. By comparison, China

awarded 47,069 PhDs in 2021, followed by the U.S. with 41,701. However, despite the overall numbers, India's share of science and engineering PhDs as a percentage of total PhDs is comparable to that of China and Israel and significantly higher than Japan and South Korea (UNESCO, 2021).

Gender disparity remains a persistent challenge in India's R&D landscape. Women account for less than 20% of researchers in public and private sectors, and this has remained stagnant for nearly a decade. In higher education, the share of women researchers is even lower at 13%, far below the global average of 30%, as reported by UNESCO. As per a study of the public-funded R&D institutions conducted by OPSA, Confederation of Indian Industry and CTIER, the share of women researchers in these institutions was a mere 30%. While there is gender parity in STEM education at the PhD level in the sciences, significant gaps remain in engineering and technology disciplines (UNESCO, 2021).

Figure 15: Share of Women Researchers in Indian Public R&D Labs (2017-20)



Source: CTIER Handbook: Technology & Innovation in India 2023 (Data: UNESCO Institute)

PUBLIC SECTOR R&D

At the onset of independence, India started as a closed and centrally planned economy. This resulted in the Indian state driving the research and innovation agenda with limited industry and private sector involvement. The state became the sole enabler, financier, and performer of innovation and R&D-related activities in the country. The private sector had little incentive to innovate, driven by a lack of foreign competition and a license and permit system that artificially capped sales. The establishment of premier academic institutions and national R&D laboratories under the Council for Scientific and Industrial Research (CSIR—a network of public national R&D labs) in the 1950s paved the way for the State to participate in the entire innovation lifecycle, from basic to translational to applied research.

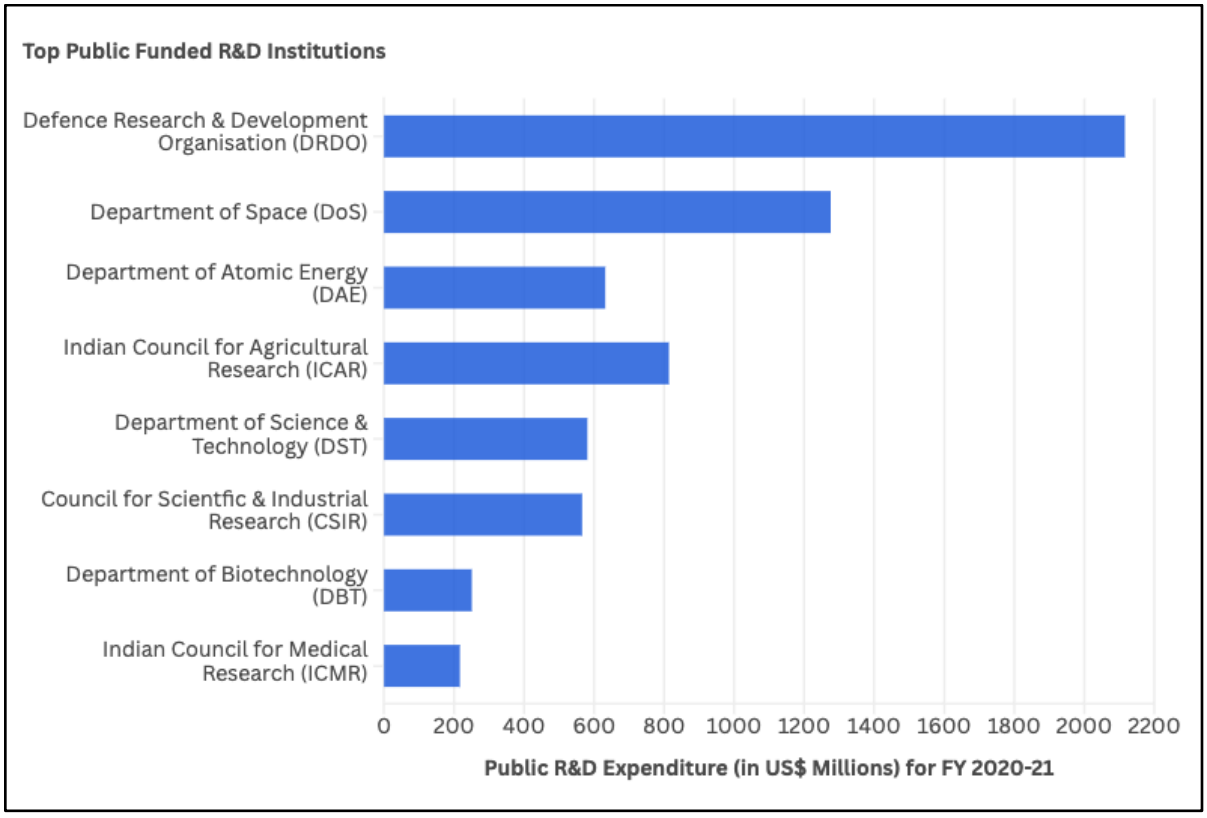
This resulted in a legacy of overreliance on the public sector for performing R&D, concentration of public funding in a select number of national research institutions, siloed operations of research institutions, a relatively low emphasis on research in universities, and low involvement of industry. Even after the 1991 economic liberalization reforms, the government remains the primary funder of R&D while domestic industry transitioned to a more services-oriented economy.

'NATIONAL LABS'

India has 310 publicly funded 'national R&D labs', operating under various executive bodies, government ministries and autonomous government bodies. Around 37 of these are under the CSIR network, and the rest are directly under government administration or government-funded research institutions. These labs are central to advancing research in strategic sectors such as space, defense, atomic energy, agriculture, and medical research development. However, their outcomes regarding standard innovation indicators such as scientific publications, intellectual property generation, technology commercialization, and industry collaborations remain below par.

National labs account for a significant share of public R&D funding. According to official statistics, in 2020–21, 84% of the central government's R&D expenditure was to 12 major government agencies. Eight of these agencies accounted for 95% of spending: the DRDO (defense; 31%), DOS (space; 18%), ICAR (agricultural research; 12%), DAE (atomic energy; 11%), CSIR (industrial research; 8%), DST (science & technology; 7%), DBT (biotechnology; 4%), and ICMR (medicine; 3%) (DST, 2023).

Figure 16: Top Government-Funded R&D Institutions in India (FY 2020-21)



Source: CTIER Handbook: Technology & Innovation in India 2023 (Data: DST S&T Indicators Tables R&D Statistics 2022-23)

Overall, the technology commercialization rate of research from national labs remains low. Most of the patents filed by these institutions are not translated into market-ready products or technologies. National labs related to strategic and national security—such as DRDO, ISRO, and DAE—receive substantial funding but produce a smaller percentage of publications. Other non-strategic sectors' agencies such as agriculture (ICAR), medical research (ICMR) and biotechnology (DBT), show better performance in innovation indicators but still lag behind in proportion to the funding they receive. The culture of cross-collaboration is minimal in these national labs, with only a tiny fraction of their research conducted jointly with the private sector or universities.

UNIVERSITIES AND HIGHER EDUCATIONAL INSTITUTIONS (HEIS)

Universities and HEIs receive a disproportionately small share of public R&D funding. Universities have historically been imagined as teaching institutions with minimal emphasis on producing cutting-edge research or research as an input in teaching. This is especially true outside a few elite universities like the Indian Institutes of Technology (IITs) and Indian Institute of Science (IISc).

Universities and HEIs account for only 8.8% of public R&D expenditure, as per official DST statistics for the year 2020–21. This is a significant structural difference compared to innovation systems globally. Despite this, they contribute significantly to research output. Compared to the funding they receive, HEIs contribute a relatively high percentage of India's total research publications (Table 12). This highlights their relative "productivity" compared to other types of research institutions.

However, there is also significant variability in research output across public universities. Elite institutions such as IITs and IISc lead in publications, patents, and global rankings while other public universities at the state level in tier 2 and tier 3 cities often struggle due to limited funding, lack of infrastructure, and inadequate faculty support for research.

Table 12: Top 10 Performing Indian R&D Institutions by Scientific Publications (FY 2020-21)

Rank	Institution	Number of Publications	Category Normalized Citation Impact	Industry Collaborations (%)	International Collaborations (%)
1	Council of Scientific & Industrial Research (CSIR) - India	30845	0.92	0.7	22.84
2	Indian Council of Agricultural Research (ICAR)	17557	0.69	0.46	16.47
3	Indian Institute of Science (IISC) - Bangalore	13793	1	1.83	33.89
4	Department of Science & Technology (India)	13063	0.98	0.58	32.53

5	Indian Institute of Technology (IIT) - Madras	12807	1.03	1.8	32.37
6	Indian Institute of Technology (IIT) - Kharagpur	12774	0.94	1.17	24.38
7	Indian Institute of Technology (IIT) - Bombay	12722	1	2.07	32.69
8	Indian Institute of Technology (IIT) - Delhi	12328	0.95	1.77	24.6
9	All India Institute of Medical Sciences (AIIMS) New Delhi	10594	1.07	1.06	19.36
10	University of Delhi	10087	0.99	0.54	29.17

Source: CTIER Handbook: Technology & Innovation in India 2023 (Data: DST S&T Indicators Tables R&D Statistics 2022-23)

PRIVATE SECTOR R&D

India's private sector has not focused on innovation as a key driver for performance improvements and new market creation. In 2021, only a handful (24) of Indian domestic firms featured in the list of top 2,500 R&D spending private firms (these 2,500 firms account for 90% of total global industrial R&D). While Indian firms had a presence in the pharmaceuticals & biotechnology, automobiles & parts, software & IT and the chemical sector, there are no domestic firms in the remaining six of the top 10 global R&D investing sectors (Aggarwal et al., 2024). A dearth of previous evidence from private firms successfully leveraging R&D expenditures to become innovation leaders has also prevented other domestic firms from taking the innovation route (Personal Communication, January 3, 2025).

Table 13: Top 10 Sectors by Global Industrial R&D Expenditure and Country Comparison (2021)

Sector	R&D Spending (US$, Mn)	# of Firms	USA	UK	GER	JPN	BRA	CHN	IND	ISR	KOR	TWN
Pharmaceuticals & Biotechnology	240,519	478	263	18	10	25	0	79	11	1	10	0
Software & Computer Services	225,846	336	196	8	6	5	1	73	2	9	2	3
Technology Hardware & Equipment	185,628	207	71	1	3	15	0	47	0	3	4	44
Automobiles & Parts	155,487	148	28	4	14	25	0	45	5	1	7	1
Electronic & Electrical Equipment	93,266	249	41	7	10	30	0	106	0	2	5	24
Industrial Engineering	39,481	167	28	4	19	22	1	52	0	0	2	0
Construction & Materials	34,863	65	4	0	2	10	0	35	0	0	2	0
Chemicals	28,250	114	21	2	8	28	0	33	1	0	5	1
Health Care Equipment & Services	25,414	89	46	4	7	6	0	13	0	0	0	0
General Industrials	23,106	64	15	1	5	12	0	16	0	1	5	1
Top 3 sectors	**651,993**	**1,021**	**530**	**27**	**19**	**45**	**1**	**199**	**13**	**13**	**16**	**47**
Top 10 sectors	**1,051,860**	**1,917**	**713**	**49**	**84**	**178**	**2**	**499**	**19**	**17**	**42**	**74**
Total (2500)	**1,236,061**	**2,500**	**822**	**95**	**114**	**233**	**4**	**678**	**24**	**22**	**53**	**84**

Source: CTIER Handbook: Technology & Innovation in India 2023 (Data: EU Industrial R&D Investment Scoreboard 2022)

Indian offices of top global Multinational Enterprises (MNEs) and Global Capability Centers (GCCs) are significant contributors to industrial R&D and remain crucial to improving the innovation ecosystem. These organizations often invest more in R&D and generate more intellectual property than domestic firms. This underscores their role in driving innovation (Kamat, Sagar & Narayanamurti 2020). Some of these firms also collaborate with Indian universities, showcasing the potential for knowledge transfer and joint research efforts. For instance, Bosch (research center at IISc) and other MNEs have established partnerships with Indian universities to work on cutting-edge technologies. Leveraging these collaborations is crucial for enhancing the overall R&D ecosystem.

India also has a nascent but growing 'deep-tech' startup ecosystem, measured by the number of startups and venture capital investments. A total of $677 million went towards deep-tech investments during 2023 (Speciale Invest, 2024). Reports like the Indus Valley report by Blume Ventures and India's Deep Tech Revolution report by Speciale Invest highlight the need for longer-term, patient finance to improve R&D expenditure and innovation in deep tech ventures (Blume Ventures, 2025). They point to challenges such as long gestation periods for technology commercialization and high capital intensity. The growing deep-tech entrepreneur base offers an opportunity for private investors and larger firms looking for M&A opportunities to spend more on innovation and develop IP in key areas.

Finally, the Indian government has set ambitious manufacturing goals, with policies increasingly emphasizing the importance of innovation. Initiatives such as Aatmanirbhar Bharat and Production-Linked Incentive (PLI) schemes aim to promote self-reliance and domestic manufacturing, necessitating increased investment in R&D. The government has initiated key mission-mode policies to spur growth in innovation-potential sectors such as AI, quantum, green hydrogen and electric vehicles (EV). These policies serve as tailwinds to developing domestic industrial R&D .

APPENDIX D: POLICY PACKAGE 1 IMPLEMENTATION PLAN ("Closing Financing Gaps across the Innovation Lifecycle")

Policy 1: Program grants for multidisciplinary applied science and engineering research centers at universities and aligned with National Missions ("SERCs")

Implementation Timeline

Table 14: Implementation Timeline Policy Package 1 (Policy 1)

1 Year Timeline	3 Year Timeline	5 Year Timeline
Appoint Program Manager reporting to ANRF CEO and secure Program Budget	First two centers operational	Next two centers operational
Release Program guidelines, Evaluation Criteria and Open Applications to HEIs	Conduct and publish results of impact assessments of operational centers	Review impact assessments of all operational centers and publish results
Start identifying 3-4 advance candidates from S&T cluster programs, National Labs, National Missions early efforts (e.g., T-hubs in Quantum Mission); industry feedback	Open applications for the next 2 SERCs	Open applications for the next 2-5 SERCs with a preference to co-investment with the private sector
Appoint an evaluation committee comprising industry, academia, and government to decide SERC annual evaluation process	Update screening criteria based on any learnings	Operational SERCs begin to develop their own tech transfer functions

Measurement Indicators

1. **Private sector contributions**: % of SERC revenue coming from research contracts, co-investment rounds size etc.
2. **Technology development**: TRLs progressed; spinoff companies; patents and IP developed; prototypes, demonstrations, testing etc.
3. **Commercialization**: IP transfers (royalty or licensing agreements); customers secured; sales revenue; follow-on funding secured etc.

4. **Talent linkages**: degrees awarded to SERC students, gender mix, visiting professorships or professors of practice etc.; industry and international collaborations

Economic, Administrative and Political Constraints

1. **Economic**: Securing the budgetary allocation is essential, and funds should be drawn from approved ANRF budget in Parliament. Raising money externally presents a challenge due to the complicated governance structure, as funds can be directed to the university, the ANRF, or the government agency. It is important to emphasize donations to the ANRF as a central strategic and resource allocation body.

2. **Administrative**: A key administrative challenge is finding expert committees and building institutional capacity to effectively review proposals. The ANRF's technology transfer function should complement the efforts within the broader ecosystem and integrate activities, rather than duplicating existing initiatives.

3. **Political**: Political support is crucial for securing the involvement of national labs. The push and advocacy from OPSA and the PMO would significantly help in this regard. However, a political constraint arises when national labs receive ANRF funding. The ANRF may choose not to directly fund national labs but can instead use its core grants to SERCs for covering infrastructure contracting costs or funding joint appointment positions for specific national lab scientists at the network universities.

Policy 2: Direct non-dilutive funding (grants & concessionary Loans) for startups, SMEs and industry to address critical points of failure in the innovation lifecycle

Implementation Timeline

Table 15: Implementation Timeline Policy Package 1 (Policy 2)

1 Year Timeline	3 Year Timeline	5 Year Timeline
Appoint Program Managers reporting to ANRF CEO and secure Program Budget	Conduct and publish results of impact assessments of both grants and loans	Conduct and publish results of impact assessments of grants/loans
Decide 3-year and 5-year funding budgets	Conduct 2 "challenges" for problems identified by national labs or industry	Evaluate direct equity capabilities through augmenting Program team
Decide first 3-4 investment themes through roundtables with industry, startups, co-investors (AIFs, VCs, banks, DFIs), government agencies (Missions, labs). Source co-lending opportunities	Initial evaluation of additional investment themes (2-3) to be added	
Appoint Investment Committees comprising industry, academia, govt.		
Open applications, publish investment criteria, annual reporting requirements. Drive awareness in partnership with HEIs, S&T clusters (grants) and Banks/DFIs (loans)		

Measurement Indicators

1. **Technology Development**: Progress on Technology Readiness Levels (TRLs), including prototypes, MVPs, and successful pilot products; Number of patents and intellectual property (IP) generated; New technologies or products emerging from the funded startups and SMEs.

2. **Commercialization**: Number of technology transfers (licenses, royalties) and commercialization deals struck by funded companies.; Volume of sales revenue generated by startups, SMEs, and

industry participants funded through the program.; Follow-on funding secured by program participants, demonstrating the ability to scale further.

3. **Private Sector Contributions**: Percentage of revenue coming from private sector contracts, co-investment rounds, and other private funding sources; Growth in the number of industry collaborations and joint ventures supported by ANRF funding.

4. **Talent Linkages**: Number of scientists or students working on programs (e.g., PhDs, post-docs).; Diversity metrics (e.g., gender mix of funding recipients) balance, international collaborations).

Economic, Administrative, and Political Constraints

1. **Economic**: Securing a sufficient allocation of funds for the program will be the first point of order, as in other funding policies. ANRF programs should be well capitalized to meet the demand for both grants and loans. These should be managed under separate funds to ensure transparency and focus. Success of the loan program in general depends a lot on the external investment environment, financial markets, and types of infrastructure or industrial projects other lenders are looking to finance. There may be challenges in maintaining the balance between pre-commercialization and commercialization during investments.

2. **Administrative**: Developing the capacity to manage such large-scale funding, including setting up a robust grant management office, will require significant institutional development within ANRF. Expertise in managing grants and loans, especially non-dilutive forms of funding, is critical. The administrative burden of evaluating applications and conducting impact assessments will require dedicated staff, including Program Managers and evaluators with experience in both academia and industry. Another constraint is the ability to build partnerships with external partner institutions like co-lenders to secure an investment pipeline.

3. **Political**: Securing political support for ANRF to play a central role in direct funding allocation may be politically sensitive, as it could be seen as competing with other government funding mechanisms (e.g., DST schemes). This could be mitigated by aligning the program with the existing PLI scheme. ANRF could be seen as an advisory body suggesting additional considerations for this scheme. Involving national labs and other government agencies as co-investors or collaborators in

the debt fund could also face political hurdles due to the need for coordination between multiple stakeholders. The program's reliance on matching funds and participation from industry partners may require navigating complex political landscapes.

Policy 3: Fund-of-Funds to finance a range of financial investment managers and new financial instruments to support R&D-intensive firms, starting with equity investors

Implementation Timeline

Table 16: Implementation Timeline Policy Package 1 (Policy 3)

1 Year Timeline	3 Year Timeline	5 Year Timeline
Appoint Program Manager and Fundraising Managers reporting to ANRF CEO and secure Program Budget	Fund 2-3 asset managers	Evaluate expanding investments to venture debt funds, mutual funds and impact investors based on market conditions
Decide 3-year and 5-year investment budgets and portfolio mix	Conduct and publish results of impact assessments of grants/loans	Conduct and publish results of impact assessments of grants/loans
Roundtables with industry and co-investors (AIFs, VCs, banks, DFIs): first 3-4 investment themes, investment criteria, source co-lending opportunities	Socialize illustrative blended finance models and any learnings from ANRF	Evaluate direct equity capabilities through augmenting Program team
Publish annual impact assessment criteria for ANRF FOF. Launch a **Statement of Interest** inviting proposals from asset managers. Appoint Investment Committees comprising seasoned investors	Initial evaluation of additional investment themes or instruments to be added to strategy	
Due diligence of applications and convene public markets investors (MFs, AIFs) to develop instruments for public markets	Identify 2-3 public markets instruments for ANRF to fund	

Measurement Indicators

1. **Amount disbursed and companies supported:** Total capital allocated through the FoF; number of startups, SMEs, and larger companies funded through the FoF.
2. **Technology advancement and commercialization**: Measurement of innovation outputs such as patents, prototypes, technology commercialization, and market-readiness achieved by funded companies.
3. **Mobilization of capital and types of financial instruments**: Diversity of sources of capital attracted by the FoF, including foreign and domestic investors, private foundations, and philanthropic organizations; Progress in developing new financial instruments tailored to R&D-intensive companies (e.g., ESG funds, risk-sharing facilities).
4. **General Partner (GP) Returns**: Returns generated by the FoF's investments in other funds and syndicated deals.

Economic, Administrative, and Political Constraints

1. **Economic**: Securing adequate funding from both government and private sources will be critical. The FoF will require strong backing to ensure it is well-capitalized, especially as it aims to leverage private sector participation and manage co-investments. The success of the Fund will depend on the ability to attract diverse sources of capital, including international donors, corporates, and philanthropic organizations. Challenges may arise in mobilizing funds in line with the proposed Rs. 500 Crore annual allocation.
2. **Administrative**: Developing a robust governance structure for managing the FoF will be complex. This includes the need for Program Managers, Investment Committees, and administrative support to ensure transparency and proper oversight of investments. The capacity for identifying asset managers, conducting due diligence, and managing syndicated deals will require specialized expertise. Additionally, the administrative burden of tracking impact assessments and ensuring effective reporting could stretch existing resources.

3. **Political**: There may be challenges in politically aligning the FoF with other government-backed funding programs such as DPIIT's Deep tech Fund. This could create competition for resources or lead to duplication of efforts. The political environment will influence the ease with which foreign investors can participate, particularly through channels like foreign pension funds and insurers. Coordination with foreign missions and international bodies will be critical to attract global capital. Bureaucratic hurdles could slow down the establishment of financial instruments, especially in public markets. ANRF must work closely with SEBI, FIs, and government ministries to navigate these obstacles.

APPENDIX E: POLICY PACKAGE 2 IMPLEMENTATION PLAN ("Increasing Access and Availability of Scientific Infrastructure")

Policy 1: Contracting structure for renting existing R&D labs & infrastructure

Implementation Timeline

Table 17: Implementation Timeline Policy Package 2 (Policy 1)

1 Year Timeline	3 Year Timeline	5 Year Timeline
Launch of the I-STEM awareness campaign amongst the innovation ecosystem	Devising a financial model for the private sector to access I-STEM facilities for a price	
Identification and cataloguing of scientific equipment across districts in the country on I-STEM	Mapping and bringing all academic and research institutions' equipment and facilities on the I-STEM platform	Monitoring and evaluation of the use of R&D equipment contracts and creating a new inventory
Creation of a contract or pay-as-you-go model depending on equipment being borrowed and location	Evaluation of the existing pricing structure and contractual terms of said all R&D services to private entities and academic institutions	
Identification and listing of key software licenses and hardware tools to procure	Bulk purchase of software licenses, hardware tools and distribution	Ensuring software upgrades and new hardware tools for purchase for institutions
Commission an assessment of the existing capacity of lab technicians and operators in research institutions	Develop a strategy with NSDC to upskill existing technical staff as well as devise a hiring plan for building capacity	

Measurement Indicators

1. **Collaboration & Participation**: Number of private sector entities (especially SMEs) utilizing national R&D labs and higher education institutions for research activities; number of pay-as-you-go contracts signed; number of external projects conducted at national labs.

2. **Accessibility Improvement**: Increase in utilization rates of scientific and technical equipment under the "One District One Equipment" program; Volume of R&D raw materials procured and distributed

via the e-marketplace platform; Number of software licenses leased out to private entities and academic institutions.

3. **Awareness & Outreach**: The number of Tier 2 and Tier 3 city academic institutions onboarded onto platforms like I-STEM; awareness surveys of university researchers.

Economic, Administrative and Political Constraints

1. Economic: The policy needs to be formulated in a matter which ensures sustainable revenue generation from leasing and renting services to offset operational costs. Developing the pricing models that balance affordability for private entities with cost recovery for institutions would be challenging.

2. **Administrative:** Capacity building and recruiting enough skilled technicians or operators to manage and maintain high-end scientific equipment is required. This must also be coupled with integration efforts across multiple stakeholders such as ANRF, national labs, academic institutions, and private companies that requires additional administrative capacity.

3. **Political**: Securing stakeholder support from national labs, higher education institutions, and policymakers for implementing the policy effectively would be essential. Apart from the political support, legal hurdles related to contracting public infrastructure for private use while maintaining compliance with existing norms and laws will be a hurdle for successful implementation.

Policy 2: Market-driven co-financing model for new and open scientific infrastructure

Implementation Timeline

Table 18: Implementation Timeline Policy Package 2 (Policy 2)

1 Year Timeline	3 Year Timeline	5 Year Timeline
Identification of S&T clusters and associated sectors for scientific infra development	Sector-specific allotment of infra development projects to S&T clusters (first 5)	
Put out an RFP and Call for Proposals for gauging private sector interest in developing testbeds, manufacturing tools and production facilities	Start of development of first five scientific infra projects at each cluster with private sector partners	Completion of testbeds and prototyping tools for use, which can be leased out to the private sector, independent researchers and academic institutions

Measurement Indicators

1. **Infrastructure Development:** Number of new demonstration testbeds, prototyping tools, simulation sandboxes, and production facilities established; Percentage of infrastructure capacity utilized by startups, SMEs, and academic institutions.

2. **Private Sector Contributions:** Percentage of private sector funding mobilized for infrastructure projects relative to ANRF's seed capital (targeting 75% private sector contribution); Amount of R&D expenditure claimed as CSR contributions or tax credits by private sector partners.

3. **Technology Commercialization:** Number of prototypes created using co-financed prototyping tools; Number of technologies successfully tested in demonstration testbeds; Number of technologies scaled up and deployed in production facilities.

Economic, Administrative and Political Constraints

1. **Economic:** Securing sufficient seed capital from ANRF's budget to kickstart co-financing initiatives would be difficult. Effectively structuring loans and guarantees programs to encourage private

sector participation in infrastructure development while avoiding revenue loss for the government is a challenge.

2. **Administrative**: Ensuring S&T clusters have adequate institutional capacity to implement and manage co-financed projects efficiently is a state capacity challenge. Establishing clear governance frameworks for managing co-financed infrastructure projects would be essential. Apart from the development of infrastructure, setting up systems for tracking utilization rates, financial contributions, and project outcomes in real-time would be an administrative challenge.

3. **Political:** Securing support from government departments, national labs, and policymakers for implementing the co-financing model would require time. Addressing any legal hurdles related to public-private partnerships in scientific infrastructure development should also be taken care of.

APPENDIX F: POLICY PACKAGE 3 IMPLEMENTATION PLAN ("Developing Long-Term Human Capital for Research & Innovation")

Policy 1: Developing a motivated research and innovation culture

Implementation Timeline

Table 19: Implementation Timeline Policy Package 3 (Policy 1)

1 Year Timeline	3 Year Timeline	5 Year Timeline
Kickstarting entrepreneurship awareness programs in Tier 1 cities and their educational institutions	Partner with the Atal Innovation Mission's existing Tinkering Labs to conduct entrepreneurship workshops in educational institutions	Create and start an entrepreneurship mentoring program for interested students at institutions to help conceptualize their ideas
Set up an initial fund for specifically sponsoring research internships for students (undergrad and graduate)	Expand the fund to include any international and global research opportunities for students at foreign universities and research institutions	Monitoring and evaluation of disbursed funds under the program to ensure that there is adequate funding available for students

Measurement Indicators

1. **Participation**: Number of students participating in entrepreneurship awareness programs, especially in collaboration with Atal Innovation Mission and Tinkering Labs; Number of Tier 2 and Tier 3 cities covered by awareness campaigns.

2. **Internship Placements:** Percentage of funds disbursed for research internships; Number of students successfully completing research internships in Indian and foreign universities.

3. **Research & Innovation Outcomes**: Increase in student-led entrepreneurial initiatives (e.g., startups or projects) emerging from awareness programs. Educational metrics on skills acquired during internships (such as certifications, research publications, and patents).

Economic, Administrative and Political Constraints

1. **Economic**: Scaling and expanding educational and awareness programs to Tier 2 and Tier 3 cities will require additional logistical and economic investments over the long run. Setting up an additional research fund (apart from the existing PM research fellowships) could face funding hurdles.

2. **Administrative**: There is a need to establish independent panels for evaluating internship applications and disbursing funds transparently which is an administrative challenge. Collaborating effectively with partners like Atal Innovation Mission to implement entrepreneurship awareness programs at scale could run into hurdles.

3. **Political**: Convincing state governments to adopt academic credit provisions for research activities, given that education is under their purview could lead to political hurdles.

Policy 2: Building the industry-academia talent linkage

Implementation Timeline

Table 20: Implementation Timeline Policy Package 3 (Policy 2)

1 Year Timeline	3 Year Timeline	5 Year Timeline
Set up the structure of the fellowship, along with identifying MNCs, domestic industry partners and their labs to host researchers	Creation of an independent panel and clear recruitment structure with industry partners to determine the fellowship program structure	Map the talent movement between industry R&D partners and academic institutions to check for innovation outcomes
Create a proposal for the establishment of a professor of practice position for PAIR Hubs	Start and complete the recruitment drive for identifying industry leaders to fill these Professor of Practice positions	Provide a roadmap to these Professors of Practice to develop industry partnerships in the Spokes institutions of the PAIR program
Identify the schedule for holding the industry-academia fairs across the S&T clusters	Start with hosting half yearly fairs at each S&T cluster with academic institutions and industry partnerships	Scale up the program to cover Tier 2 and Tier 3 cities where the industry engagement is minimal

Measurement Indicators

1. **Fellowship Effects**: Number of PhD students participating in the fellowship program; Number of fellows placed in private sector R&D centers; Number of patents, publications, or prototypes developed by fellows during their industry tenure; Percentage of fellows transitioning into full-time industry roles post-fellowship.

2. **Professorship Outcomes**: Number of industry collaborations facilitated by professors of practice. Number of Spokes (lower-ranked institutions) benefiting from partnerships initiated by professors of practice.

3. **Industry-Academia Engagement**: Number of joint projects, MoUs, or partnerships signed during the fairs; Growth in co-authored research papers and patents between academic institutions and private firms; Participation rates from Tier 2 and Tier 3 cities in fellowship programs, fairs, and professor-led initiatives.

Economic, Administrative and Political Constraints

1. **Economic:** Ensuring sustainable funding for semi-annual fairs to ensure long-term sustainability without relying on government funding is a challenge. Encouraging private sector firms to sign up for fellowships and actively engage in partnerships could lead to budgetary constraints.

2. **Administrative**: Identifying capable private R&D centers and firms to host fellows across different sectors of science and technology could be a logistical roadblock. The establishment of robust systems to track program outcomes (such as fellow placements and industry collaborations) while also ensuring accountability of the programs requires additional administrative capacity.

3. **Political**: Convincing private sector players to actively engage in funding and hosting fellowship programs would need political maneuvering. Gaining support from central and state government-funded academic institutions for implementing professor positions and promoting participation in industry-academia fairs is an additional political challenge.