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8. Science, Technology, and Innovation Policies for Development

India's Contemporary Challenges

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Science and technology (S&T) are not merely instruments of economic growth; they profoundly shape our daily lives, societal structures, and global interactions. Recognizing this, nations around the world have developed science, technology, and innovation policies (STIPs) as strategic frameworks to guide research, innovation, and technological development in ways that support economic, social, and environmental objectives. This chapter takes a sociohistorical approach to examine how contemporary STIPs are shaped and evolve over the decades. It traces the interplay of multiple actors and agencies—government institutions, academic and research organizations, private enterprises, and international collaborations—that have collectively shaped India's S&T landscape. Broadly, the chapter examines India's S&T and innovation trajectory in five overlapping phases, each reflecting unique sociopolitical contexts, policy priorities, and global influences.

Nation-Building Phase (1950s–70s). This phase is marked by Nehruvian optimism, which viewed S&T as the foundation of national development and modernization.[1] The government focused on building institutions of higher learning, national laboratories, and research councils, aiming to create a strong indigenous scientific base.

Technology Policy and Industrial Challenges Phase (1980s). In the 1980s, India began crafting technology policies to promote industrial modernization and technological self-sufficiency. However, this period was also shaped by environmental and industrial challenges. This phase highlighted the need for regulatory frameworks, safety standards, and responsible innovation, balancing industrial growth with social and environmental concerns.

Liberalization Shaping S&T Policies (Post 1991). The economic reforms of 1991 opened a new chapter in India's S&T landscape. Policies during this period emphasized liberalization, globalization, and private-sector participation. There was a surge in software, information technology (IT), biotechnology, and pharmaceutical sectors, and India became increasingly integrated with global research and development (R&D) networks.

Post-2014 Phase Under the Narendra Modi Regime. The Modi era opened a new chapter in the history of STIPs from a development perspective. A striking feature of this period is the presence of policy binaries in the approaches and views of the ruling elites. On one side of the coin, there is a discernible tendency to draw inspiration from India's ancient scientific traditions, often extending to the glorification of the past. On the other hand, the Modi government also launched a series of flagship programs that underscore the role of modern S&T in driving development.

Contemporary Phase of STI: Mission-Oriented Science and Innovation. The Modi 2.0 era marked a mission-oriented approach to science, technology, and innovation. Emphasis was placed on high-priority strategic sectors such as semiconductors, space technology, renewable energy, quantum computing, and artificial intelligence. In this phase, the leadership seems to have woken up to realize the low level of S&T funding and introduced public-private partnership schemes to address the problem.

NATION-BUILDING PHASE (1950s–70s): OPTIMISM TO CRITICAL EVALUATION

Both Jawaharlal Nehru and Mohandas Karamchand Gandhi shared the goals of generating employment, alleviating poverty, and developing India, emphasizing the development of both traditional and modern industries through S&T. However, their approaches differed sharply. Nehru's vision of modern S&T for development was formulated in the 1940s and pursued after Gandhi's death in 1948. It faced little opposition and reflected widespread optimism about science for development.[2] The Congress Party's 1945 manifesto declared that "science in its instrumental fields of activity, has played an ever increasing part in influencing and moulding human life and will do so in even greater measure in the future."[3] Nehru envisioned a synthesis of Soviet-style planning and Western industrial capitalism, reflected in India's early mixed economy.[4] Nehru's unbound optimism of modern S&T for development was clearly evident from his various interactions with decision makers and scientists.

On one occasion Nehru declared that "science alone that can solve the problem of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running over waste, of a rich country inhabited by starving people. I do not see any way out of our vicious circle of poverty except by utilizing the new sources of power which science has placed at our disposal."[5] He sought an alliance with elite Indian scientists—Homi Bhabha, Shanti Swarup Bhatnagar, P. C. Mahalanobis, J. C. Ghosh, and D. S. Kothari—forming an inner circle to drive his vision.[6] In 1947, addressing the Indian Science Congress, Nehru emphasized cooperation between politicians and scientists. Unlike Gandhi, who was quite critical of heavy industrialization strategy for India, Nehru's support for S&T made him a champion for scientific development.[7] He saw science as a solution to poverty, hunger, superstition, and underdevelopment. His strategy included expanding education, skills, and human capital; establishing the Ministry of Scientific Research and Natural Resources in 1947; and establishing five Indian Institutes of Technology (IITs) based on the Massachusetts Institute of Technology model to promote applied research and engineering excellence.[8]

POLICY FOR SCIENCE

The period of the 1950s–70s was marked by a "policy for science" focused on building basic infrastructure, expanding universities, and creating human resources for S&T. Nehru and Homi Bhabha, who is regarded as the father of India's atomic energy program, were instrumental in getting the first official Scientific Policy Resolution passed in the Indian Parliament in 1958. It "was both a testament of faith in science and a vision of society."[9] As David Arnold reminds us, Nehru's commitment to building a strong S&T infrastructure was not mere rhetoric; it was backed by concrete action. Between 1949 and 1959, India's national science budget increased nearly eightfold, reflecting the priority accorded to scientific research and technological development in the formative years of nation-building.[10] By 1970, India had forty-two private and eight public-sector techno-industrial organizations aimed at linking S&T to industry. Mission-oriented agencies like the Department of Atomic Energy (DAE), Council of Scientific and Industrial Research (CSIR), and Defence Research and Development Organization (DRDO) were rapidly established and expanded. One of the notable features of the science-politics alliance of the Nehru era was that the growth and type of S&T institutions in different sectors depended on the elite scientists close to Nehru and their interests.

The scientific elite in the "inner circle" wielded enormous power to command scarce or limited resources both financial and material. The CSIR had no laboratories worth mentioning in 1947, but by the 1950s S. S. Bhatnagar was able to establish a network of fifteen laboratories. Bhatnagar was part of this inner circle and could mobilize resources for building various laboratories of CSIR. C. V. Raman called this the "Nehru–Bhatnagar Effect."[11] This had a parallel in the atomic energy agency with Homi Bhabha as its head. Bhabha managed to mobilize Nehru into setting up the DAE headquarters in Bombay, where he wanted them. Thus, for about two decades after independence the real expansion of S&T infrastructure took place in the CSIR, DAE, and defense-related establishments. Some sectors, notably agriculture and medical research, were marginalized. B. P. Pal, the head of agriculture research, noted that Indian Council of Agricultural Research (ICAR) development lagged behind mission-oriented agencies like the CSIR and DAE. Universities remained largely teaching focused.[12] Edward Shils, editor of a leading science policy journal, *Minerva*, writing on Indian universities, drew attention to the ways in which universities were rendered as mere teaching institutions without any worthwhile research base.[13]

Implicit in "policy-for-science" was the view that once infrastructure in R&D is created, personnel trained, and a set of institutions and universities established, most problems of science and development would be resolved. He firmly believed that a strong institutional base in S&T was essential for modernization, industrial growth, and self-reliance. This vision translated into the establishment of national laboratories, research councils, IITs, and scientific academies, alongside massive public investment in atomic energy, space research, and heavy industries. A great deal of optimism unleashed by Nehru and elite scientists over science and development was the characteristic feature of the policy discourse of this phase. The departure of Mohandas Gandhi in 1948 did not have a major influence on the developmental policies during this phase.

SCIENCE FOR POLICY

Building on the basic infrastructure established in science and technology, the science for policy perspective reflects how India's S&T capabilities began influencing national political expectations of development. Mission-oriented agencies such as the DAE, CSIR, Indian Council of Medical Research, ICAR, DRDO, and Indian Space Research Organization (ISRO) grew rapidly, establishing India's presence in nuclear and space research by the early 1980s. Homi Bhabha in atomic energy and Vikram Sarabhai in Space research laid strong R&D foundations.[14] The ISRO launched its first satellite, Aryabhatta, in collaboration with the Soviet Union on April 19, 1975, followed by Rohini in 1980 using an indigenous launch vehicle. India conducted its first nuclear test, Smiling Buddha, in 1974, and between the 1970s and 1980s, defense and nuclear research budgets increased more than fourfold, paving the way for the second nuclear test, Pokhran II, in 1998. The early 1970s also saw the creation of the Department of Electronics and the Electronics Commission, building on the Tata Institute of Fundamental Research (TIFR) National Centre for Software Development and Computing Techniques.[15]

In agriculture, India achieved self-reliance through the Green Revolution, led by M. S. Swaminathan in collaboration with Norman Borlaug, which dramatically increased food-grain production.[16] The White Revolution, initiated in Gujarat, transformed milk production via Operation Flood I to III (1970–96), creating over 75,000 village cooperatives by the 1990s and growing to 190,000 by 2019, making India the world's largest milk producer. Dr. Verghese Kurien and Anand Milk Union Limited (AMUL) Gujarat, supported by the National Dairy Development Board, strengthened the industrial, trade, and research base in dairy.[17] Most importantly, India became self-sufficient in food grains, milk, and other agro-industrial sectors—an important national task for a population of India's size.[18]

The 1971 Indian Patent Act, which protected patents for only seven years, enabled CSIR laboratories to commercialize essential drugs and facilitated reverse engineering by Indian pharma firms, laying the foundation for India's global leadership in generic medicines, serving over 70 percent of South Asia by 2020. In food technology, the CSIR's baby food process in the 1950s displaced multinational suppliers like Glaxo, supporting AMUL's growth. In industrial innovation, the CSIR's Central Mechanical Engineering Research Institute developed the Swaraj tractor in the 1960s to meet the demands of the Green Revolution.[19]

OPTIMISM SHATTERED

By the early 1970s, the Nehruvian optimism surrounding science-driven development began to erode.[20] The 1973 oil crisis, growing inequalities between urban and rural populations, and the limitations of the Green Revolution exposed the shortcomings of the Nehruvian model and its reliance on "trickle-down" assumptions. Alternatives to this framework began gaining traction, including the rise of the Appropriate Technology (AT) movement, which emphasized context-sensitive, low-cost solutions. During this period, Gandhian development ideas gained legitimacy, inspiring institutions and initiatives that focused on inclusive innovation, such as Barefoot College (Tilonia), Jaipur Foot, Honeybee Network (Ahmedabad), Arvind Eye Care (Madurai), and incremental innovations by Dr. Kurien at AMUL. Even before the Gandhian Institute at Varanasi formalized an AT unit, the Ministry of Industrial Development had created the Appropriate Technology Cell in 1971. In 1974, ASTRA (Application of Science and Technology to Rural Areas) was established at the Indian Institute of Science, Bangalore (IISc), by A. K. N. Reddy, an energy specialist, followed by the Centre of Science for Villages in 1976, connecting national laboratories with rural technical needs.

This period also witnessed the emergence of the People's Science Movements (PSM) and Alternative Science Movements (ASM) as counterpoints to the dominance or hegemony of the instrumental modern science trajectory of Nehruvian optimism.[21] In a way, the rise of these movements was indeed a counterhegemonic reaction to the hegemony of instrumental modern science.[22] The PSM was represented by some twenty organizations, and Kerala Shastra Sahitya Parishad was the largest, with fifty thousand members. The ASM grew out of simultaneous efforts by various actors, who initiated an intellectual critique of modern Western science. It was represented by Ashis Nandy and his colleagues at the Centre for the Developing Societies in Delhi; by Claude Alavares in Goa; by Patriotic and People Oriented Science and Technology, Madras; by ecology-based groups such as Chipko in northern India; by Narmada Bacho Anodolan in Central India; and by the Chipko movement, led by environmentalists such as Sunderlal Bahuguna and Chandi Prasad Bhatt.[23]

TECHNOLOGY POLICY AND INDUSTRIAL CHALLENGES (1980s)

The 1980s presented Indian S&T with a double bind. On one hand, basic needs remained a pressing challenge, prompting critical evaluation of prior policies. On the other hand, emerging new technologies in biotechnology and IT-related technologies posed new challenges. The Bhopal Gas tragedy, which claimed over five thousand lives due to a poisonous gas leak from a Union Carbide factory in Madhya Pradesh, highlighted the dangers of neglecting R&D risk assessment—especially given India's heavy technology imports over the previous three decades.[24] In 1987 a Technology Information, Forecasting and Assessment Council was established to examine and evaluate the existing state of the art in technology and directions for future technological developments in various sectors.[25] A technocratic obsession with a *one-dimensional* S&T policy faced criticism from thinkers like Ashis Nandy, Vandana Shiva, Shiv Viswanathan, and Claude Alvares, culminating in their 1989 manifesto *Science, Hegemony and Violence*.[26] The environmental domain was one of the early spheres that relied on the adoption of such impact assessment decision-making tools.[27] With the rise of some anti-science sentiments, P. N. Haksar, a top bureaucrat and close associate of Nehru and Indira Gandhi, issued a public "Statement of Scientific Temper" along with a group of intellectuals.[28]

The 1983 Technology Policy Statement (TPS) emphasized technology assessment and strengthening the indigenous base of these emerging fields. Subsequent policies, including the 1984 Computer and Electronics Policies and the creation of the Centre for Development of Telematics (C-DOT), responded to this vision. C-DOT catalyzed India's telecom expansion, increasing lines from two million to twenty million.[29] The decade also saw the establishment of the Centre for Development of Advanced Computing (C-DAC) in 1988, which developed India's first supercomputer, PARAM 1 GF, paving the way for subsequent generations. The Indian software story began with the National Centre for Software Technology at TIFR in 1985 and the National Centre for Software Development and Computing Techniques, which helped launch India's first email system and prototype multicity Railway Passenger Reservation System.[30] This phase also witnessed developments in enhancing India's defense technology. Itty Abraham points out that "India probably became a nuclear 'power' around 1986, when Rajiv Gandhi was prime minister."[31] Rajiv Gandhi authorized the application of India's nuclear capability to making weapons and authorized the test launch in May 1989 of India's intermediate range ballistic missile Agni-I.[32]

The *one-dimensional* phase of technology policy thrived with Rajiv Gandhi at the helm of affairs and technocrat Sam Pitroda giving technical solutions to social problems. In response to various criticisms over basic needs and the challenges faced by underprivileged sections of people, the government initiated various flagship programs under technology missions in immunization, oilseed, drinking water, literacy, and telecommunications under the charge of Sam Pitroda in 1987. As Harsh Sethi pointed out, the drive of technology missions and innovations was coupled with democracy.[33] It is not surprising that Dinesh C. Sharma noted that "if Nehru was the political patron of Indian science, Rajiv was the political patron of Indian technology. In the Nehru era science developed through politician-scientist alliances, in the Rajiv era technology developed through politician-technocrat alliances."[34] By the 1980s, two distinct streams in the study of science, technology, and society became evident in India. Science policy analysts, such as Ashok Jain, began to highlight the coexistence of elite and subaltern networks of science and society. The elite stream referred to the formal, state-supported scientific establishment. In contrast, the subaltern stream captured the experiences of grassroots innovation and indigenous knowledge systems that often remained outside mainstream policy discourse.[35]

LIBERALIZATION SHAPING S&T POLICIES: POST 1991

The early 1990s marked a turning point in India's economic and technological landscape with the liberalization reforms initiated by Finance Minister Manmohan Singh in 1991. Central to these reforms was the New Industrial Policy, which emphasized export-led growth, a greater role for the private sector as the engine of development, freer market operations, and the pursuit of global niches in international markets.[36] This represented a major departure from India's earlier protectionist and inward-looking import-substitution policies. The post-1991 era signaled a new phase in which S&T became closely intertwined with economic liberalization and market imperatives. It is rather surprising to note that the Indian government did not issue any formal S&T policy after the 1983 TPS until 2003, when Science and Technology Policy (STP) was announced. This policy called for increasing the existing R&D investment as a proportion of GDP from 0.7 percent to 2 percent; attracting Indian global talents; and establishing an intellectual property regime.[37] The National Knowledge Commission, established in 2005, provided recommendations on higher education, research infrastructure, intellectual property, and knowledge dissemination. The STP of 2003 underlined the importance of translating scientific research into commercial applications and societal benefits.[38] India's S&T landscape witnessed significant consolidation and expansion, with four major sectors driving growth and development.

BIOTECHNOLOGY AND PHARMACEUTICALS

Since the early 1990s, India's biotechnology sector has grown rapidly. The Department of Biotechnology expanded its budget from INR 180 million (1986) to 1,863 million (2001), establishing sixteen labs and supporting advanced programs at over thirty-five universities. It created new chairs, scholarships, and six national labs in molecular biology and biotechnology, achieving global standards. A major success was the low-cost hepatitis B vaccine developed by national labs with Serum Institute, Shanta Biotech, and Bharat Biotech, reducing costs from $16.00 to $0.5 per dose.[39] The 1970 Indian Patent Act transformed the pharmaceutical sector by allowing reverse engineering of expired patents, spurring a thriving generics industry. By 1995, thirteen firms controlled 85 percent of the domestic market. With strong R&D links through the CSIR and University Department of Chemical Technology Mumbai, India became the world's largest supplier of generics by 2020, valued at $37 billion with $20 billion in exports and projected to reach $130 billion by 2030.[40]

INFORMATION TECHNOLOGY AND SOFTWARE

Thomas Friedman's 2005 visit to Bangalore inspired his book *The World Is Flat*, reflecting India's global rise.[41] Economic reforms in the 1990s fueled the information and communication technology (ICT) boom. By 2014, India had 950 million mobile users and 200 million internet users. Cities like Bangalore, Pune, Hyderabad, and Delhi–National Capital Region became global R&D hubs for over 1,000 multinationals, including IBM, Intel, Microsoft, and General Electric, employing 244,000 professionals. The IT sector generated $110 billion in revenue and contributed 7 percent of the GDP.[42]

AUTOMOBILE INDUSTRY

India's auto industry expanded with indigenous innovation. Tata Motors developed the Tata Sierra (1991), Estate (1992), Sumo (1994), and Indica (1998)—India's first fully indigenous car. Mahindra and the Mahindra company advanced with models like the Scorpio, Bolero, and XUV500 (2011).[43] Collaborations with IITs boosted R&D in engines and electric vehicles. Production rose from 5.3 million units (2001–02) to 20.3 million (2011–12), contributing 5 percent to the GDP and employing over 320,000 people.[44]

AEROSPACE AND SPACE TECHNOLOGY

India's aerospace and space sectors emerged as global S&T showcases. The CSIR's aerospace laboratories engineered advanced defense projects, including light combat aircraft (Tejas). The ISRO achieved major milestones, developing the polar satellite launch vehicle (PSLV) in 1993 for remote-sensing satellites and the geosynchronous satellite launch vehicle (GSLV) with indigenous cryogenic technology. By 2012 the PSLV had completed over fifty successful launches, and the GSLV achieved ten successful geosynchronous launches out of thirteen attempts. Around 2010, India developed the GSLV Mark III, enhancing capabilities for heavier satellites and interplanetary missions, marking India's leadership in space technology.[45]

S&T IN INTERNATIONAL COLLABORATION

India deepened global science partnerships.[46] It joined the EU's International Thermonuclear Experimental Reactor fusion project, the Facility for Antiproton and Ion Research, and the Galileo satellite navigation system. The Indo-US nuclear deal marked a milestone in science diplomacy. Collaboration with Japan led to the Delhi Metro, which became one of the world's largest networks by 2012.

POST-2014 PHASE UNDER THE NARENDRA MODI REGIME

The Modi era has been marked by a strong political-bureaucratic orientation, with the Prime Minister's Office assuming a central and directive role in shaping the STIPs for the development agenda. This articulation reflected a governance model that is predominantly top-down, leaving relatively limited space for market actors, academic institutions, and civil society compared to earlier regimes—a marked departure from the more pluralistic approach of previous decades.[47] Modi emphasized that "there is a mood of optimism for change in the country, the energy to pursue it and the confidence to achieve it. But the dreams we all share for India will depend as much on S&T as it will on policy and resources."[48]

The optimistic STIPs policy discourse resonated quite well in the international print media. As reported by *Time* magazine on May 7, 2015, Modi declared that "my philosophy, the philosophy of my party and the philosophy of my government is what I call *Sabka saath, sabka vikas*" (take everybody together and move toward inclusive growth).[49] During later years the phrase *sabka vishwas* (everyone's trust) was added. On economic front, *The Economist* on May 24, 2014, indicated a great sense of economic optimism for India with the cover page headline "Strong Man: How Modi Can Unleash India."[50] Unlike most East Asian countries, India has never had a strong state, but instead, optimists argued, it had brilliant entrepreneurs who could wheel and deal the country to prosperity.[51]

The concept of self-reliance in science and technology policy—so central to the Nehruvian era from the 1970s to the 1990s—was revitalized under the Modi government through the Make in India initiative launched in 2014. On August 15, 2014, he clearly spelled out: "I want to tell the people of the whole world: Come, make in India. Come and manufacture in India. Go and sell in any country of the world but manufacture here. We have skill, talent, discipline and the desire to do something. We want to give the world an opportunity: come, make in India."[52]

Voices on innovation and development were much louder than any of the previous governments. As widely circulated in Indian and international print media, optimists believed that the new government was likely to link up the STIPs

TABLE 8.1 MAIN SCIENCE TECHNOLOGY AND INNOVATION (STI) POLICIES OF GOVERNMENT, 2014–22

Modi government's flagship programs	Main STI policies	Main STI policies
Make in India (2014)	National IPR Policy (2016)	Science, Technology and Innovation Policy (2013 and 2020)
Digital India (2015)	Startup India Action Plan (2016)	National Data Sharing and Accessibility Policy (2012)
Start-Up India (2016)	National Telecom Policy (2012)	National Policy on Biofuels (2018)
National Skill India Mission (2015)	National Policy on Skill Development and Entrepreneurship (2015)	National Policy on Software Products (2019)
Green India (2014)	Technology Vision 2035 (2016)	National Policy on Electronics (2019)
Smart Cities and Urban Development (2016)	National Innovation and Startup Policy 2019 for Students and Faculty	National Cyber Security Policy (2013)
Clean India (Swachh Bharat) (2014)	National Policy Academic Ethics (2019)	National Digital Communications Policy (2018)
Atal Bhujal Yojana (2019)	National Education Policy (2020)	National Biotechnology Development Strategy (2020)
Jal Jeevan Mission (2019)	National Geospatial Policy (2022)	

Source: Author's compilation from published government documents. IPR = Intellectual Property Rights.

agenda with the socioeconomic development spectrum.[53] STIP 2013, from the previous regime, was endorsed by the government. Modi said, "The arms of science, technology and innovation must reach the poorest, the remotest and the most vulnerable person. This is an enterprise of national importance in which each of us—government, industry, national laboratories, universities and research institutions—have to work together. Too often, a discussion on S&T is reduced to a question of budgets. It is important and I am confident that it will continue to grow."[54] During 2014 and 2019, the government identified a number of national flagship programs such as Digital India, Green India, and more, as shown in the first column of table 8.1.[55] The table also shows various S&T policies issued until 2022. They demonstrate how S&T has moved beyond laboratories and research institutions to become directly embedded in national missions addressing urban infrastructure, public health, digital connectivity, energy, and environmental sustainability.

S&T POLICIES FOR DEVELOPMENT

DIGITAL INDIA

Launched on July 1, 2015, the Digital India program aimed to use technology for governance, citizen empowerment, and socioeconomic growth—continuing earlier digital initiatives. Its three pillars—digital infrastructure, services on demand, and citizen empowerment—transformed connectivity. With BharatNet expansion, India now has one of the world's largest online populations: 1.38 billion Aadhaar identities, 1.21 billion mobile phones, and 806 million internet connections. Platforms like Aadhaar, UPI, DigiLocker, and e-Sign revolutionized service delivery. UPI made India a global digital payments leader, with transactions rising from 9.3 million (2017) to 186.77 billion (April 2025).[56]

STARTUP INDIA

Launched in 2016 by Department of Promotion of Industry and Internal Trade, Startup India reshaped India's entrepreneurial landscape. From under 100 start-ups in 2017, the number rose to 55,000 in 2021 and 159,000 by 2025. Start-ups are reported to have spread across 620 districts.[57] Over 55,000 start-ups include at least one woman founder, and India now hosts 107 unicorns, ranking third globally. Growth is strongest in fintech, healthtech, and edutech. Government funding, incubators, and state policies such as Maharashtra's have strengthened the ecosystem.[58]

SMART CITIES

The Smart Cities Mission (2015) aimed to modernize one hundred cities with smart infrastructure and governance.[59] Numerous reports in the media have criticized the concept and targets of Smart Cities. However, progress has been limited—only 1.8 percent of allocated funds were used by April 2018, and no city was fully "smart" by 2024. Despite large investments, the program has largely remained at the planning stage.[60]

CLEAN INDIA

Launched to eliminate open defecation by October 2019 and improve waste management, Clean India achieved partial success. About 110 million toilets were built (2014–19), yet surveys showed that 10 percent still lacked access in 2019.[61] A World Bank–supported survey concluded in February 2019 that 10 percent of people in India remain without access to toilets. Another survey in four northern states found that between 2014 and 2018, nonaccess to toilets has come down from 70 percent of the population to 44 percent in these regions.[62] Many of the issues with the toilet-building program arose from making clean water available for rural toilets and linking them to sewage and sanitary systems.

NATIONAL MISSION FOR CLEAN GANGA

Closely related to the Clean India mission was the National Mission for Clean Ganga, the river that runs 2,525 km through several states of India and is also known as Namami Ganga. The main objectives of this mission were to "ensure effective abatement of pollution and rejuvenation of the river Ganga."[63] The major science and technical factors attributed to the failure of the mission concern river flow data and its interpretation, environmental impact assessment, sludge control, and technical know-how for sewage treatment plants and their technological capabilities.[64] In 2018 the Centre for Science and Environment, New Delhi, observed that "even after 4 years and an allotment of Rs 22,000 crore . . . flagship program is far from being a success."[65]

SKILL INDIA MISSION

Irrespective of the type of government, the supply and demand processes in skill development continue to pose a big challenge for India. This is because approximately 570 million people (about 90 percent of the total workforce) compose the informal sector in India in 2024. The government set up a target of skilling 400 million people by 2022.[66] Empirical studies by Sushil Sharma and Santosh Mehrotra show that only a modest rise has been witnessed in various schemes, falling below the set targets.[67] An International Labor Organization study in 2022 revealed that India was able to train just over half a million apprentices out of a workforce of 570 million in 2022–23.[68]

NEW EDUCATION POLICY 2020: DRAWING INSPIRATION FROM ANCIENT INDIAN SCIENCE

The Indian government issued a new National Policy on Education in 2020 (NEP 2020). The government targets about a 50 percent gross enrollment ration (GER) by 2035. One of the major thrusts of the NEP is to promote Indian languages and Sanskrit. The new policy envisions increasing the national investment in education from the current 3 percent to 6 percent of GDP. In higher education, the policy proposes a four-year multidisciplinary undergraduate course and seeks to rapidly promote the development of multidisciplinary colleges and universities. It proposes to evolve three distinct categories of universities—namely, research universities, teaching universities, and autonomous degree-granting colleges.

One can see a noticeable shift in the contemporary S&T policy cultures, particularly in education policies. The importance given to Indian science in the ancient period, to traditional concepts, and to some elements of Vedic knowledge was evident from the policy discourse and the NEP 2020 report. For instance, while speaking at the 104th session of the Indian Science Congress (ISC) on January 4, 2015, Modi said, "We in India are the inheritors of a thriving tradition of Indian S&T since ancient times' mathematics and medicine, metallurgy and mining, calculus and textiles, architecture and astronomy. The contribution of Indian civilization to human knowledge and advancement has been rich and varied."[69] Just a year before, on October 25, 2015, Modi, speaking with a group of doctors and professionals in Mumbai, claimed that genetic science existed in ancient times. Reproductive genetics and plastic surgery, he said, were known in those times—otherwise, how could one explain Lord Ganesha?[70]

At the 105th ISC in March 2018, Dr. Harsh Vardhan, science minister, reminded the audience that Stephen Hawking once said that the Hindu Vedas had a theory that trumped Einstein's theory of relativity. Dr. G. Nageshwar Rao, the vice chancellor of Andhra University, in a paper presented at the 106th ISC, said, "We had 100 Kauravas from one mother because of stem cell and test tube technology."[71] Given the overarching views of leadership, it is not surprising to see the NEP's thrust on the indigenization of educational orientation and its focus on ancient thought. It has been clearly spelled out in the document as well as by the leadership in the education ministry. As observed by the NEP, "the rich heritage of ancient and eternal Indian knowledge and thought has been a guiding light for this policy. The aim of education in ancient India was not just the acquisition of knowledge as preparation for life in this world, or life beyond schooling, but for the complete realization and liberation of the self."

The National Council of Educational Research and Training (NCERT), which is mandated to formulate and prepare school curriculum and textbooks, has sought to implement NEP recommendations, which has evoked some criticism in the last couple of years. For instance, as reported in *Scientific American*, the NCERT had dropped the periodic table and the theory of evolution as propounded by Charles Darwin from the science syllabus for Class 10.[72] This has evoked sharp criticism and response from three science academies (Indian National Science Academy, Indian Association of Cultivation of Science, and NAS) in India. In a joint statement, they clearly pointed out that this is a "retrograde step to remove the teaching of the theory of evolution from school and college curricula or to dilute this by offering non-scientific explanations or myths." Dinesh C. Sharma, science journalist, asserts that "the removal of Darwin from the school syllabus is not an innocuous change. Seen in the context of revivalism and a return to the so-called ancient science, it is a retrograde step for the teaching of science and an onslaught on rational thinking and scientific temper. It can adversely impact the quality of higher education in science, scientific research and India's position as a formidable S&T power in the world community."[73] Recently, on August 26, 2025, speaking at an event at the Indian Institute of Science, Education and Research, Bhopal, Union Minister Shivraj Singh Chauhan told students that "we had the pushpak Vimana long before the Wright brothers invented the airplane. Drones and missiles that we have today were already with us for thousands of years, we have read all this in the Mahabharata. Our country's S&T were already developed thousands of years ago."[74]

During the Modi regime, however, higher education witnessed a significant quantitative expansion, particularly in the number of premier institutions. The network of IITs, once confined to a handful of elite campuses, expanded to 23 by 2024. In parallel, the number of Indian Institutes of Management (IIMs) grew to 20. At the same time, India witnessed a rapid rise in the number of central universities, state universities, and private universities, making it one of the world's largest higher-education systems, with more than 1,113 universities and over 42,000 colleges. The NEP 2020, presented as a landmark reform in India's education sector, sought to restructure school and higher education with a vision rooted partly in the country's cultural and civilizational heritage. The document frequently highlighted the "glorious past" of ancient Indian universities such as Nalanda and Takshashila and emphasized the need to draw inspiration from Indigenous traditions of knowledge, philosophy, and holistic learning.

RESEARCH AND INNOVATION AT UNIVERSITIES

One of the major gaps identified in the policy is the absence of a concrete road map for strengthening research intensity in Indian universities. Indian universities and colleges have experienced significant growth in the past decade and a half, with policies focused on expansion, equity, and excellence in higher-education institutions. The data on research output from universities indicates that this sector contributes to approximately 70 percent of total publications but accounts for less than 7 percent of gross expenditure on R&D (GERD) in 2020.[75] A small proportion of R&D efforts and funding in the university sector appears to be focused on a limited number of universities. Consequently, the research base is also concentrated within a small number of universities as a whole. The low level of R&D effort and research intensity in Indian universities is closely associated with a relative stagnation or decline in the number of postgraduates and doctoral degrees produced. The research output of Indian universities has been criticized for being insufficient and of relatively low quality compared to international standards.[76] The lack of substantial R&D investments in universities over the past two decades has significantly aborted their ability to compete at the international level, as evident from their absence in the top rankings of world-class universities.

CONTEMPORARY PHASE OF STI: MISSION-ORIENTED SCIENCE AND INNOVATION

During the last few years, India's scientific and technological capabilities have gained international recognition, particularly in the field of space research. The ISRO achieved a historic milestone by successfully launching the Chandrayaan-2 and Chandrayaan-3 missions in 2019 and 2023. While the former, through Rover, could study the moon's surface by entering lunar orbit, the latter successfully landed on the lunar surface. Building on this momentum, the ISRO also launched the Aditya-L1 mission on September 2, 2023, which was India's first dedicated solar observation satellite, marking a significant step in solar research and climate-related space science. Recently, on June 30, 2025, the ISRO, jointly with NASA, successfully launched an Earth-observing satellite.[77]

Despite severe global disruptions, India successfully developed and manufactured indigenous vaccines, including Covaxin and Covishield during the COVID-19 pandemic. Millions of Indian citizens were vaccinated in a remarkably short span of time, highlighting the country's capacity for mass healthcare delivery in emergencies. Furthermore, India exported 162.9 million doses of vaccine to numerous countries under initiatives like Vaccine Maitri, strengthening its

TABLE 8.2 MISSION-ORIENTED INNOVATION PROGRAMS, 2025

Name of the mission/year of initiation	Budget allocated in INR (million) 2025–26 (in million US$)
National Geospatial Mission (2025)	1,000 (11.76)
National Mission for Artificial Intelligence (2024)	20,000 (235.29)
Mission Mausam (2024)	17,520 (206.11)
National Quantum Mission (2023)	6,000 (70.5)
National Green Hydrogen Mission (2022)	6,000 (70.5)
India Semiconductor Mission (2021)	140,000* (1674)
Deep Ocean Mission (2021)	6,000 (70.5)
National Electric Mobility Mission Plan (2020)	53,220 (626.11)
National Mission on Interdisciplinary Cyber-Physical Systems (2018)	9,000 (105)
Ayushman Bharat—National Health Infrastructure Mission (2018)	42,000 (494.11)
National Biopharma Mission (2017)	3,000† (35.29)
Atal Innovation Mission (2016)	27,500 (323)‡
National Supercomputing Mission (2015)	2,650 (31.17)
Mission for Integrated Development of Horticulture (2015)	2,180 (25.64)
Jawaharlal Nehru National Solar Mission (2010)	242,240§ (2,849.88)
International Solar Alliance (2015)	
National Program on Nano Science and Technology (2017)	NA
INSPIRE (2010)	16920 (199)

* Includes the development of semiconductors and display manufacturing ecosystem; semiconductor fab units; set up of ATMP (assembly, testing, marking, and packaging) and OSAT (outsourced semiconductor assembly and test) units; Semiconductor Laboratory in Mohali; design-linked incentive scheme etc.

† Jointly with the World Bank

‡ For four years

§ Total solar energy budget allocation

Source: Aditi Agrawal, "Budgetary Allocation for MeitY Up by 48%; Focus on Electronics, Semiconductors," *Hindustan Times*, February 1, 2025, https://www.hindustantimes.com/india-news/budgetary-allocation-for-meity-up-by-48-focus-on-electronics-semiconductors-101738405554095.html#google_vignette.

global standing in public health diplomacy.[78] Recognizing the success of its space and vaccine missions, the government began to adopt a "mission-mode" strategy, in which scientific and technological efforts are concentrated on mission-oriented innovation programs (table 8.2).

The global discourse around the Fourth Industrial Revolution (4IR), which gained prominence at the World Economic Forum (WEF), provided a strong external stimulus for Indian leadership to accelerate its strategic reorientation. The WEF's 2016 articulation of the 4IR sent out a compelling message.

Its defining feature lay in the convergence of digital, biological, and physical technologies, leading to profound systemic shifts. The breadth and depth of these transformations signaled nothing short of a paradigm shift—reshaping systems of production, reconfiguring organizational and managerial practices, and redefining governance frameworks.[79] Together with the 4IR, the rise of China posed a new set of challenges. For India, this served as a wake-up call to pursue mission-oriented S&T approaches, foster cross-sectoral collaboration, and enhance investments in frontier technologies such as artificial intelligence, advanced materials, quantum technology, robotics, and biotechnology. In the last decade, more than a dozen frontier science and innovation missions were launched, as shown in table 8.2. Some leading science missions deserve brief explanation.[80]

NATIONAL QUANTUM MISSION

About US$1.12 billion has been allocated for the National Quantum Mission since 2020.[81] India has established four quantum hubs focused on computing, communication, sensing and metrology, and materials and devices. It targets satellite-based secure quantum communications over 2,000 km within India, long-distance secure links with other countries, intercity quantum key distribution, and multinode quantum networks with quantum memories. Efforts include the design and synthesis of quantum materials—including superconductors, novel semiconductor structures, and topological materials—for quantum device fabrication. The development of single-photon and entangled-photon sources/detectors will support quantum communications, sensing, and metrology applications.[82] One of the important steps taken immediately after launching the mission was to developing courses for and promote advanced research at leading Indian universities.[83] India's effort remains nascent: TIFR has developed a 7-qubit system, while a Bengaluru-based startup announced 25- and 64-qubit processors, aiming to scale up to 300 qubits in the near future. In the medium term, the plan is to develop quantum computers with 50 to 1,000 qubits in eight years (2025–33).

NATIONAL MISSION FOR ARTIFICIAL INTELLIGENCE

Tracking the international developments taking place in emerging technologies such as AI, India decided to initially invest INR 103,720 million (US$1.25 billion) to expand its computing infrastructure and capacity to create local data centers. In five years the plan is to set up computing capacity for ten thousand graphic processing units under public-private partnership.[84] The National Mission for Artificial Intelligence aims to establish a platform to integrate AI into various sectors such as healthcare, agriculture, education, and more.[85] One of the important projects that has already taken shape at IIT Madras is to build multiple large language models relevant to the Indian language ecosystem.[86] At the National Informatics Centre, a center for excellence in AI has already been established.[87] Another important aspect of the AI mission is to become self-reliant on cloud services for security and critical data. Serious attempts have been made to take advantage of India's base in software computing.

INDIA SEMICONDUCTOR MISSION

Having "missed the bus" in the 1980s and 1990s, India launched the India Semiconductor Mission in 2021 to accelerate domestic capabilities, reduce dependence on imports, and promote self-reliance in this critical sector. An investment of INR 760,000 million, or about US$9 billion, was budgeted for five years. The main objectives are to establish semiconductor fabs and display fabrication units to create a domestic manufacturing capacity in the new generation of technologies. Micron Technologies announced an assembly and testing facility in Gujarat in collaboration with the mission.[88] OSAT facilities are also being set up by the Tata Group and Renesas and its joint venture partners in Assam and in Sanad, Gujarat. The semiconductor company CG-Semi is expected to roll out the first Made in India chip from this pilot facility.[89] In February 2024 the Tata Group announced a partnership with Powerchip Semiconductor Manufacturing Corporation, Taiwan, the world's fourth-largest chipmaker from Taiwan, to set up India's first commercial fab in Dholera, Gujarat. The fab is estimated to cost INR 910,000 million or US$11 billion and is likely to generate 20,000 jobs. This fab will manufacture up to 50,000 wafers per month.[90] The C-DAC, serving as the nodal agency, will advance chip design infrastructure tailored to both domestic and global markets.[91] With 97 percent of the initial Semiconductor Mission 1.0 (₹76,000 crore) fund already committed, the government is likely to launch Semiconductor Mission 2.0 with a budget of ₹1.76 lakh crore.

NATIONAL GREEN HYDROGEN MISSION

The National Green Hydrogen Mission seeks to position India as a global hub for the production, utilization, and export of green hydrogen and its derivatives. The total budget earmarked through the Ministry of New and Renewable Energy is INR 197,440 million, or US$2.322 billion. Two distinct financial incentive schemes are proposed for the manufacture of electrolyzers and the production of green hydrogen.[92] To accelerate innovation, the mission will establish a public-private partnership framework for R&D through the Strategic Hydrogen Innovation Partnership.

NATIONAL ELECTRIC MOBILITY MISSION

The National Electric Mobility Mission provides a road map for the adoption and manufacturing of electric vehicles in India, aiming to enhance national fuel security and promote environmentally friendly transportation. The budget outlay is INR 259,380 million, or US$3 billion. The PLI (Production Linked Incentive) Scheme for Advanced Chemistry Cell, with a budget of INR 181,000 million, or US$2.1 billion, has been launched. Another scheme is the PM Electric Drive Revolution in Innovative Vehicle Enhancement, with a budget outlay of INR 109,000 million, or US$1.282 billion. The fourth is the PM e-Bus Sewa-Payment Security Mechanism to deploy thirty-eight thousand electric buses with the outlay of INR 34,350 million, or US$404 million. The fifth is the Scheme for Promotion of Manufacturing of Electric Passenger Cars in India, with a budget outlay of INR 41,500 million, or US$488.2 million.[93] These schemes and new initiatives are expected to further boost domestic production and reduce import dependence.

NATIONAL MISSION ON INTERDISCIPLINARY CYBER PHYSICAL SYSTEM

The Department of Science and Technology is implementing a multistakeholder National Mission on Interdisciplinary Cyber Physical System (NM-ICPS). The mission was approved by the government with an outlay of INR 36,600 million or US$430 million for a period of five years. The NM-ICPS is a comprehensive mission aimed to achieve complete convergence with all ministries, departments, and stakeholders in robotics, AI, digital manufacturing, big-data analysis, deep learning, quantum communication, and the Internet-of-Things by establishing strong linkages between academia, industry, government, and international organizations.[94]

NATIONAL BIOPHARMA MISSION

The National Biopharma Mission encompasses biotechnology, pharma, and vaccines, with a focus on public-private partnerships. India's bioeconomy has expanded thirteen times, growing from $10 billion in 2014 to $130 billion in 2024, with a projection to reach $300 billion by 2030. The private sector has been the primary driver of growth in India's biotechnology industry, supported by a range of government initiatives. These include the establishment of the Biotechnology Industry Research Assistance

TABLE 8.3 R&D EXPENDITURE AS PERCENTAGE OF GDP AND S&T OUTPUT: INDIA VERSUS CHINA, 1990–2025

Year	India GERD/GDP percent	India S&T output*	China GERD/GDP percent	China S&T output*
1990	0.8	10113	0.5	6407
1995	0.62	10907	0.7	9624
2000	0.74	21000	0.9	22702
2005	0.81	24000	1.3	36985
2010	0.82	60555	1.7	308769
2015	0.7	80195 (2013)	2.1	351526 (2013)
2020	0.64	149213	2.4	669744
2021	0.66	—	2.5	—
2022	0.7	—	2.6	—
2023	0.7	228174	2.6	932712
2024	0.65	—	2.7	—
2025	0.7	—	2.8	—

* Based on NSF data (Web of Science).

Council to strengthen industry-academia linkages and promote innovation. Much of the sector's expansion has been supported by contract manufacturing in the biopharmaceutical segment, encompassing the production of vaccines, diagnostics, biotherapeutics, and biosimilars for global markets.[95] Apart from the Department of Biotechnology, which houses more than twenty-five labs and research institutions, the mission established twenty-one research facilities for biomanufacturing.

ATAL INNOVATION MISSION

The Atal Innovation Mission (AIM) was launched in 2016 to cultivate an innovative mindset among school students holistically through Atal Tinkering Labs (ATLs). The aim was to equip young minds to explore, experiment, and create. During 2016–19 the government allocated INR 10,000 million or US$117.6 million to create ten thousand ATLs in various Indian schools. The mission received a budget of US$323 million in 2025. In addition to this, the Ministry of Education allocated INR 1,286,500 million (US$14.8 billion) to establish fifty thousand ATLs in government schools by 2030 to foster innovation and practical learning among students. The AIM has successfully operationalized seventy-two Atal Innovation Centres across India, which are reported to have incubated twenty-nine hundred start-ups.[96]

FUNDING IN SCIENCE AND TECHNOLOGY

Despite ambitious policy initiatives and the growing importance of technology-driven development, India's GERD as a share of GDP has remained relatively stagnant over the last three decades. In the 1990s, GERD hovered around 0.8 percent of GDP, but by 2025 it had slightly receded to approximately 0.7 percent. More than 50 percent of GERD is consumed by strategic sectors of atomic energy, space, and defense. The rest, spread across various sectors and programs, pose constraints in realizing the objectives of these programs. The comparative growth of GERD/GDP for India and China can be seen in table 8.3. In Purchasing Power Parity terms, India's GERD in 2024 is approximately US$71.3 billion, whereas China's GERD stands at US$494.7 billion. Further, while India's total R&D spending has grown in absolute terms over the past decades, the private sector's share of GERD has remained relatively low, hovering around 35–40 percent, compared to more than 70 percent in countries like China.

ROLE OF PRIVATE SECTOR IN R&D

Globally, private industry accounts for nearly 70 percent of GERD in countries such as South Korea, Japan, and across the Organisation for Economic and Co-Operative Development countries. In contrast, the share of private-sector R&D expenditures in India remained stagnant, at around 25–30 percent from the 1990s until 2015, and has only marginally increased to 35–40 percent in recent years. As Naushad Forbes of the Confederation of Indian Industry points out, private R&D spending in India still amounts to a mere 0.3 percent of GDP, compared with a global average of 1.5 percent. Interestingly, about 70 percent of the world's top five hundred multinational corporations have established Global Capability Centres in India, creating significant employment opportunities for Indian scientists and engineers. For example, General Electric employs nearly five thousand engineers in India while Bosch has a workforce of around twenty thousand Indian engineers. This raises an important question, as Forbes argues: If foreign multinationals can leverage India's talent pool so extensively, why have leading Indian firms such as Reliance and L&T failed to make comparable investments in R&D?[97]

One key reason is that leading Indian private firms have not been investing in R&D in proportion to their profits and business turnover, unlike their counterparts in Japan and South Korea. To examine this issue more closely, the Office of the Principal Scientific Adviser to the Government, in collaboration with the Ministry of Corporate Affairs, commissioned a study in 2023–24 on the state of private-sector R&D in India. Out of 1,000 listed firms reviewed, the report was able to identify only the top 20 R&D-intensive companies for 2022 and 2023.[98] The top 20 out of 911 Indian firms accounted for 71 percent of the country's total R&D expenditure in 2023. Despite this concentration, Indian firms lag significantly behind their international counterparts, particularly in neighboring China. For example, in 2023–2024, just 2 Chinese companies—BYD, an electric vehicle manufacturer, and Tencent, active in AI and automation—invested US$7.48 billion and US$8.9 billion, respectively, in R&D, far exceeding the expenditures of individual Indian firms.

This chronic underinvestment in scientific research has increasingly been recognized as a structural barrier to linking S&T policies to development objectives as well as to India's aspiration of becoming a knowledge-driven economy. In response the government established the Anusandhan National Research Foundation (ANRF) in 2023.[99] Two other agencies—namely, the Research and Development Innovation Scheme and Vigyan Dhara Scheme, were created to enhance India's GERD. Additionally, the budget for the Innovation in Science Pursuit for Inspired Research (INSPIRE) Scheme was increased by more than threefold, from INR 5,460 million, or US$64.2 million, in 2012 to INR 16,920 million, or US$199 million, in 2025. This scheme was created to attract, nurture, and retain meritorious talent in S&T.

ANUSANDHAN NATIONAL RESEARCH FOUNDATION

The ANRF aims to fund the mission orientation in science in frontier areas such as AI, quantum technologies, biotechnology, advanced materials, and clean energy.[100] By adopting a mission-oriented approach, the ANRF signals India's determination to break free from decades of low R&D intensity and to accelerate its transition toward becoming a global player in science, technology, and innovation. The ANRF was conceived along the lines of the US National Science Foundation (NSF), with a mandate to catalyze high-quality research across universities, research laboratories, and industry. It was charged with disbursing US$6 billion to universities and laboratories over five years—with 70 percent of this coming from nongovernmental sources and industry. The overall budgetary provision for the ANRF is ₹1 lakh crore or US$11.34 billion. The government in 2025 allocated INR 20,000 million or US$235 million.

RESEARCH, DEVELOPMENT, AND INNOVATION SCHEME

The government launched the Research, Development, and Innovation (RDI) Scheme in July 2025, backed by a substantial budgetary allocation of ₹1 lakh crore (approximately US$11.34 billion).[101] The RDI Scheme is designed to catalyze private-sector participation in high-impact, cutting-edge research and innovation, ensuring that the commercialization of scientific breakthroughs closely aligns with national development priorities.[102] By complementing the ANRF's focus on foundational research, the RDI Scheme represents a strategic policy shift toward a mission-oriented innovation ecosystem, bridging the gap between basic science and applied industrial research.

VIGYAN DHARA SCHEME

The Vigyan Dhara Scheme came into effect on January 16, 2025. The scheme was allocated INR 14250 million, or US$167.64 million. It merges three key umbrella schemes of Department of Science and Technology into one.[103] Under the Vigyan Dhara early-stage mentorship support (National Initiative for Developing and Harnessing Innovatios–Seed Support) program, support has been extended to thirty-six Technology Business Incubators (TBIs) located across India. These TBIs serve as critical platforms for nurturing early-stage start-ups and translate innovative ideas into viable commercial ventures.[104]

PRODUCTION LINKED INCENTIVE SCHEME

The PLI Scheme launched in 2020 aids firms' technological capabilities to boost manufacturing and attract both local and global firms to India.[105] The scheme identified fourteen key sectors (e.g., electronics, pharma, solar Photovoltaic modules, autos and automobile components, telecom, textiles, specialty steel, drones, etc.) where India has the potential to scale up through establishing R&D and technological capabilities. The *Business Standard* reports that one product, smartphones, witnessed a boost of about $US12 billion in exports in the current financial year.[106] The total outlay budget across all sectors is INR 1.97 lakh crores, or US$22 billion. With the PLI Scheme, policymakers expect to increase the manufacturing proportion of India's GDP from 17.7 percent in 2024 to at least 24 percent in the coming few years.[107]

CAPACITY BUILDING AND HUMAN RESOURCE DEVELOPMENT SCHEME

This scheme, with a total outlay of INR 22,770 million, was launched recently on September 24, 2025.[108] It was implemented by the CSIR and will cover all R&D institutions and universities across the country. The initiative provides a wide platform for young, enthusiastic researchers aspiring to build careers in academic institutions, industry, and national R&D laboratories. This step will certainly aid doctoral and postdoctoral scholars but may not build research intensity in the university sector.

CONCLUDING REMARKS

In 1947, India's life expectancy at birth was barely 35–37 years; by 2024–25 it had nearly doubled to around 73.4 years.[109] The under-5 mortality rate, which stood at 260 per thousand in 1950, declined sharply to 32 in 2025. Inequality, according to Thomas Piketty, widened between the rich and poor because of liberalization and globalization.[110] However, more than 170 million people were also lifted out of poverty in the two decades preceding the COVID crisis. With a population of nearly 1.4 billion, India has not relied on external food aid since the 1960s. The Green and White Revolutions, supported by India's agricultural science community, made immense contributions to building national capacities in food and dairy production. Yet, as M. S. Swaminathan has consistently reminded us, the task ahead lies in achieving a second Green Revolution founded on sustainability and resilience in agricultural systems. These remain no small achievements by any standards. The progress illustrates that S&T have had a direct impact on society, but the pace has been very slow. Fifty-five percent of the population, nearly 700 million, are still dependent on agriculture but contribute only 18 percent of GDP. There is a big challenge for India in this sector.

Notwithstanding criticisms of the present regime, it is undeniable that the Nehruvian era (1950s–80s) laid a strong institutional foundation for science, technology, and higher education in India. This period saw the creation of national laboratories, research councils, and specialized institutes that became the backbone of India's scientific enterprises. Institutions such as the IITs and IIMs emerged as centers of excellence in engineering, technology, and management, with the IIT brand gaining global visibility through its alumni network in Silicon Valley—numbering over eleven thousand by the 1990s. IIT graduates have significantly contributed to India's ICT growth, which accounts for 8 percent of GDP in 2025. India's mission-oriented agencies in space and atomic energy also achieved international recognition, and the scientific temper fostered during this era continues to shape the nation's innovation trajectory.

The first two phases examined in this chapter—the nation-building and technology policy eras—demonstrate how sustained investments in education and S&T infrastructure laid the foundation for later policy initiatives. However, India's experience in export promotion and high-technology competitiveness was limited, except in sectors such as software and biopharma. Postindependence S&T policies were primarily directed toward self-reliance and import substitution, aiming to develop indigenous capacities in heavy industry, defense, atomic energy, and space. While these efforts succeeded in reducing technological dependence, they constrained export orientation and global integration. Consequently, as East Asian economies advanced, India's innovation system lagged, leading economists in the 1990s to describe it as a case of "low payoffs from a relatively well-developed scientific and technological infrastructure."[111]

The 1991 economic reforms marked a decisive shift in India's science, technology, and industrial policy. Moving beyond the limitations of import substitution, policymakers sought greater global integration, private-sector participation, and technology transfer through foreign collaboration. The reforms accelerated GDP annual growth to an average of over 7.5 percent, driving industrial expansion and the rise of internationally competitive sectors such as IT, pharmaceuticals, and biotechnology. In the S&T sphere, emphasis shifted toward industry-academia collaboration, technology incubation, and research commercialization. Unlike the earlier self-reliance model, the post-1991 framework aimed to harness global knowledge networks while strengthening domestic capabilities.

Although the post-1991 liberalization era is not always explicitly acknowledged in current policy narratives, successive governments have continued to strengthen the national innovation system shaped since the 1990s. Since 2014, policies have emphasized technology-driven development, private-sector innovation, and global competitiveness, reflecting continuity with earlier reforms. Initiatives such as Make in India, Digital India, and Startup India, along with missions in space, biotechnology, and renewable energy, highlight efforts to achieve scientific self-reliance while engaging with global knowledge networks. Despite rhetorical shifts, recent strategies represent a pragmatic extension of the liberalization legacy, aiming to build a dynamic and globally integrated innovation ecosystem.

The Modi government's flagship programs—including Digital India, Clean India, and Smart Cities—explicitly link S&T to national development, reflecting efforts to improve living standards and modernize infrastructure such as highways, ports, and airports. By all accounts, flagship initiatives, with the exception of Digital India, have made visible progress but continue to fall short of their stated targets, rendering their outcomes only partially successful in 2025. Large-scale missions in space, renewable energy, biotechnology, and health aim to position India within emerging global technological domains like AI and quantum computing. Significant reforms have been introduced in the governance of the science, technology, and innovation system. However, India's GERD-to-GDP ratio has remained stagnant at around 0.7 percent for over two decades, severely limiting high-risk research, advanced technology development, and global competitiveness. Persistent underinvestment in R&D continues to constrain India's transition toward a fully knowledge-driven economy.

India and China in the early 1990s were at similar levels of R&D investment at around 0.7 percent of GDP. Interestingly, India's science output, based on the Institute of Scientific Information database, indicated nearly ten thousand papers per year in 1992 compared to fewer than six thousand by China.[112] In 2024, China overtook India by releasing four times India's science output as measured by the Science Citation Index data base. How did this happen? During these years, Chinese R&D and GDP scaled up from 0.7 to 2.7 percent. The decade long goal of scaling up the education budget from 3 to 6 percent of GDP is still a big dream for India. Even though 65–70 percent of the total national science output is produced by universities, they are allocated only about 5–6 percent of GERD, for some thirty universities. What has come to be known as the *Humboldtian goal* remains to be accomplished. Two and a half decades of relative stagnation in national R&D investments have drastically thwarted universities' ability to compete at the international level with the top-ranked world-class institutions. Whereas China has been able to place about a dozen universities in the top 100–200 band, no Indian universities figure in this bracket of rankings, and only 3–5 Indian universities rank in the 250–300 bracket.

Finally, the government has woken up to recognize India's significant limitations and has sought to address these by launching several R&D and innovation-funding schemes, including the ANRF, in recent years. However, a major structural challenge lies in the design of these schemes. For example, in the ANRF over 70 percent of the promised budget is contingent on public-private partnerships, placing a heavy reliance on private-sector contributions.[113] Without a substantial increase in India's overall investment in science and technology—ideally raising GERD to 1.5–2 percent of GDP in the coming three years—the national innovation system is likely to remain subcritical, limiting its ability to respond to global technological challenges and compete on the international stage.

Indian universities have a long distance to travel before they can accomplish the Humboldtian ideal in at least 25 percent of the 1,113 universities. At the same time, this ideal stands for the democratic values of free thought, research, and teaching autonomy, with strong public support. The marginalization of research funding and the lack of intense research is not unrelated to the low level of innovation and university-industry relationships at universities. With the exception of IITs, IISc, IIMs, and few central universities and institutions of national importance, there is a dearth of innovation culture in the Indian university system as a whole.

While the NEP 2020 generated optimism by proposing structural reforms and invoking India's knowledge traditions, it fell short of laying down an actionable strategy and road map for increasing research intensity at universities and nurturing world-class academic institutions. Feeling proud of ancient Indian contributions in fields such as mathematics, medicine, logic, and linguistics is both natural and justified. However, the tendency in knowledge traditions to conflate myths with scientific knowledge and present them as historical fact has emerged as a troubling stream within contemporary science discourse in the political domain. Such narratives risk undermining genuine achievements by blurring the line between evidence-based inquiry and cultural pride, thereby weakening the credibility of India's rich scientific tradition.

The micro, small, and medium enterprise sector is vital to India's economy, contributing 37 percent of GDP, 30 percent of services, 40 percent of exports, and 7 percent of manufacturing while employing 60 percent of the workforce.[114] Future comparative advantages will rely less on cheap labor and natural resources and more on value additions through innovation and technology. Globalization now calls for a rural innovation system that places educational and S&T institutions at the center of district- and village-level industrialization. Universities, colleges, and Indian Institutes of Technology must play a key role in this new paradigm of regional and rural innovation.

At seventy-seven, when a nation pauses to introspect, meaningful benchmarks become necessary. What better comparison than China—similar in population size and also, like India, beginning as a largely agrarian economy in the 1940s. As we enter the third decade of the twenty-first century, China's global rise is best understood through the perspective of a developmental state. In the early 1980s, over 75 percent of the population in both India and China relied on agriculture. Through a systematic program of rural industrialization, China managed to bring this figure down to about 24 percent by 2025, while in India nearly 55 percent of the population remains dependent on agriculture. The essence of China's development miracle lies in the strength of its innovation system, which played a pivotal role in virtually eradicating poverty by 2025. Since the economic reforms launched by Deng Xiaoping in 1978, China's GDP expanded at an average rate of nearly 9 percent for three decades, more than quadrupling within just fifteen years to reach close to US$19 trillion—positioning it firmly as the world's second-largest economy after the United States. What explains this remarkable transformation? STIPs played a pivotal role in building China's national innovation system and driving its economic ascent. Today, China stands as the world's second-largest investor in R&D, after the United States, and has established itself as a leading global producer of knowledge. It is here that India can draw a lesson or two in the art of the theory and practice of science policy.

NOTES

1. Nehruvian optimism in India refers to Jawaharlal Nehru's conviction that the establishment of strong institutional infrastructure in science and technology would, over time, generate transformative impacts on national development. Nehru envisioned that once a critical mass of infrastructure and talent was created, these institutions would catalyze a self-sustaining cycle of innovation, industrial growth, and social progress, eventually bridging India's developmental gaps with advanced economies.

2. Venni V. Krishna, *The Indian Science Community: Historical and Sociological Studies* (Routledge, 2025), chaps. 5 and 6. See also Venni V. Krishna, "India @ 75: Science, Technology and Innovation Policies for Development," *Science, Technology and Society* 27, no. 1 (2022): 123. Much of the exploration for phase 1, 1950–70, is drawn and revised from these sources.

3. P. Sitaramayya, *History of the Indian National Congress*, vol. 2 (S. Chand, 1969).

4. This approach involved government ownership of key industries alongside private enterprise, aimed

at economic planning, industrial and technological development, and balancing national goals with market-based activities.

5. “The Tragic Paradox of Our Age,” *New York Times Magazine*, September 7, 1968; *Science Reporter* 1, no. 7–8 (1968). These quotes of Nehru have been in circulation for quite some time in science and technology study writings.

6. Homi Jehangir Bhabha was a close family member of Tata Industrial Enterprises and a nuclear physicist. He is the founding director of India’s leading Tata Institute of Fundamental Research in Bombay, created in 1945. He is also well-known as the father of India’s nuclear program. Shanti Swarup Bhatnagar was a colloid chemist and the first director-general of the Council of Scientific and Industrial Research, which currently houses about thirty-eight national laboratories. The CSIR was created in 1942, and S. S. Bhatnagar had a very close association with Pandit Nehru. He was also scientific secretary to the Atomic Energy Commission and head of the University Grants Commission. Prasantha Chandra Mahalanobis was a well-known statistician and founder of the Indian Statistical Institute. He was selected by Pandit Nehru as a member of India’s Planning Commission. He is the architect of India’s Second Five Year Plan (1956–61). J. C. Ghosh was an Indian chemist and director of the Eastern Higher Technical Institute in 1950, which became the Indian Institute of Technology Kharagpur in 1951. D. S. Kothari was another close associate of Pandit Nehru. He was a physicist and advisor to the Ministry of Defence, chairman of the University Grants Commission, and later head of the Defence Research and Development Organization, which currently houses fifty-two national laboratories.

7. For those interested in a broad and much deeper historical social history of science in India, see Deepak Kumar, *Science and Society in Modern India* (Cambridge University Press, 2023), chap. 6 on “Science for Development,” 117–45.

8. Nimesh Chandra, “Academia-Industry Interface: Modes of Knowledge Production and Transfer at the Indian Institute of Technology” (PhD diss., Centre for Studies in Science Policy, Jawaharlal Nehru University, 2009).

9. In fact, this expression was used by the late A. Rahman, the ex-director of the CSIR in New Delhi in the 1970s. It is said that Homi Bhabha and Nehru were the authors of the 1958 Scientific Policy Resolution.

10. David Arnold, “Nehruvian Science and Postcolonial India,” *Isis* 104 (2013): 360–70.

11. Chandrasekhara Venkata Raman was an Indian physicist who won the Nobel Prize in Physics in 1930.

12. B. P. Pal, “Science and Agriculture,” in *Science and Technology*, ed. B. R. Nanda (Vikas, 1977), 43–54.

13. E. Shils, “The Academic Profession,” *Minerva* 7, no. 3 (1969): 345–72.

14. Vikram Sarabhai is known as the father of the Indian space science program. He was the founder of the Physical Research Laboratory in Ahmedabad in 1947 and was chair of the Indian National Space Commission. He later became the chief of the ISRO.

15. For detailed information on these institutions, see Krishna, *Indian Science Community*.

16. M. S. Swaminathan was an agricultural scientist known as the father of India’s Green Revolution. Norman Borlaug received the Nobel Peace Prize for developing a disease-resistant strain of dwarf wheat that increased food production and helped feed the world’s hungry, thereby preventing widespread famine. India’s Green Revolution success is due to his original research.

17. Verghese Kurien is well-known as the father of India’s White Revolution and was behind the rapid expansion of the AMUL brand of milk products in India in the 1950s that replaced Glaxo and took 80 percent of the market as the major baby food producer and supplier in India.

18. B. S. Baviskar and Donald W. Attwood, *Finding the Middle Path: The Political Economy of Cooperation in Rural India* (Westview Press, 1995); Verghese Kurien, *I Too Had a Dream*, as told to Gouri Salvi (Roli Books, 2005); and Verghese Kurien, “India’s Milk Revolution: Investing in Rural Producer Organizations,” in *Ending Poverty in South Asia: Ideas That Work*, ed. Deepa Narayan and Elena Glinskaya (World Bank, 2007), 37–67.

19. Shekhar Mande, “The Key Role of CSIR in the Battle Against Covid,” *Hindustan Times*, September 25, 2020; Shekhar Chaudhury, “Collaborative Innovation: The Case of Swaraj Tractor,” *Vikalpa* 10, no. 1 (1985): 95–98.

20. The meaning of the title *Shattered* should be understood as pointing out that the expectations of the science and technology vision held by Nehru were not a big success. There were cracks in this vision. While the outcomes did not always match the ambitious expectations—owing to structural constraints, resource limitations, and weak links between research and industry—the Nehruvian legacy nonetheless laid the foundation for India’s subsequent achievements in areas such as space, atomic energy, agriculture, and pharmaceuticals.

21. See note 1 above regarding Nehruvian optimism.

22. V. V. Krishna, “Science, Technology and Counter Hegemony—Some Reflections on the Contemporary Science Movements in India,” in *Science and Technology in a Developing World: Sociology of the Sciences Year Book 1995*, ed. T. Shinn, J. Spaapen, and V. V. Krishna (Kluwer Academic Press, 1997), 375–411.

23. See Patriotic and People Oriented Science and Technology, https://www.ppstindiagroup.in; Right Livelihood, https://rightlivelihood.org/the-change-makers/find-a-laureate/medha-patkar-and-baba-amte-narmada-bachao-andolan.

24. As indicated in Wikipedia, on December 3, 1984, over 500,000 people in the vicinity of the Union Carbide India Limited pesticide plant in Bhopal, Madhya Pradesh, India, were exposed to the highly toxic gas methyl isocyanate in what is considered the world's worst industrial disaster. A government affidavit in 2006 stated that the leak caused approximately 558,125 injuries, including 38,478 temporary partial injuries and 3,900 severely and permanently disabling injuries. Estimates vary on the death toll, with the official number of immediate deaths at 2,259. Others estimate that 8,000 died within two weeks of the incident occurring and that another 8,000 or more died from gas-related diseases.

25. See Ashok Jain and V. P Kharbanda, "Strengthening Science and Technology Capacities for Indigenisation of Technology: The Indian Experience," *International Journal of Services Technology and Management* 4, no. 3 (2003): 234–54.

26. For instance, Sam Pitroda in his various talks underlined the point that for every developmental problem one can find a technical or technological solution. "One dimension" basically refers to finding technological solutions to various social and economic problems. Ashis Nandy, *Science, Hegemony and Violence: A Requiem for Modernity* (Oxford University Press, 1989).

27. Aviram Sharma and Poonam Pandey, "The Institutionalisation and Practice of Technology Assessment in India," Elgar Online, October 15, 2024, https://www.elgaronline.com/edcollchap/book/9781035310685/book-part-9781035310685-29.xml.

28. See Arnold, "Nehruvian Science and Postcolonial India."

29. Sam Pitroda, "Telecom Revolution and Beyond," in *Homi Bhabha and the Computer Revolution*, ed. R. K. Shyamasundar and M. A. Pai (Oxford University Press, 2011).

30. S. Ramani, "R&D in Software Technology at the National Centre for Software Technology, 1960–2001," in *Homi Bhabha and the Computer Revolution*, ed. R. K. Shyamasundar and M. A. Pai (Oxford University Press, 2011); Dinesh Sharma, *The Long Revolution: The Birth and Growth of India's IT Industry* (HarperCollins, 2009); and Sarma Mahesh and V. V Krishna, "State and the Software: Public Policies in the Shaping of Indian Software Sector," *Service Industries Journal* 30, no. 1 (2010): 25–42.

31. Itty Abraham, "The Ambivalence of Nuclear Histories," *Osiris* 21, no. 1 (2006): 49–65.

32. V. Siddhartha, "The Evolution of Science and Technology in India Since Independence," in *UNESCO History of Humanity*: Vol. 7, *The Twentieth Century*, ed. Sarvepalli Gopal and Sergei L. Tikhvinsky (UNESCO, 2008), https://www.academia.edu/39822958/The_Evolution_of_Science_and_Technology_in_India_since_Independence. Siddhartha also mentions that "Indira Gandhi created the Department of NonConventional energy sources in 1982. By the mid-1990s India had the world's fourth-largest installed capacity of grid-connected electric power generated by the wind."

33. Harsh Sethi, "The Great Technology Run," *Economic and Political Weekly*, May 14, 1988, 999–1002.

34. Sharma, *Long Revolution*.

35. See Ashok Jain, "Networks of Science and Technology in India: The Elite and the Subaltern Streams," *AI and Society* 16 (2002): 4–20.

36. See Isher Judge Ahluwalia and I. M. D Little, *India's Economic Reforms and Development: Essays for Manmohan Singh* (Oxford University Press, 2012).

37. Jahnavi Phalkey, "From Development to Innovation: Policy for Science and Technology in India," in *The Hoover Institution's Survey of India*, ed. Šumit Ganguly and Dinsha Mistree (Hoover Institution, 2025).

38. See Phalkey, "From Development to Innovation."

39. Nandini K. Kumar, Uyen Quach, Halla Thorsteinsdóttir, Hemlatha Somsekhar, Abdallah S. Daar, and Peter A. Singer, "Indian Biotechnology—Rapidly Evolving and Industry Led," *Nature Biotechnology*, December 22, 2004, https://pubmed.ncbi.nlm.nih.gov/15583682.

40. See *Forbes* report, "The Rise of India's Pharmaceutical Industry to a Forecasted $450 Billion," November 16, 2024, https://www.forbes.com/sites/krnkashyap/2024/11/16/the-rise-of-indias-pharmaceutical-industry-to-a-forecasted-450-billion.

41. *New York Times Magazine*, April 3, 2005. Thomas Friedman observed Columbus: "In 1492 Christopher Columbus set sail for India, going west. He had the Nina, the Pinta and the Santa Maria. He never did find India, but he called the people he met 'Indians' and came home and reported to his king and queen: 'The world is round.'" On Friedman's visit to India he observes, "I set off for India 512 years later. I knew just which direction I was going. I went east. I had Lufthansa business class, and I came home and reported only to my wife and only in a whisper: 'The world is flat.'"

42. V. V. Krishna, "RIO Country Report 2015: India," *JRC Science for Policy Report*, European Commission, 2016, https://publications.jrc.ec.europa.eu/repository/handle/JRC102465?mode=fullfile:///Users/vennikrishna/Downloads/jrc102465_rio%20country%20report%202015%20india.pdf.

43. Wiley Jeep in India has been quite famous since the late 1940s, and it has a history of supplying this vehicle to militaries. Mahindra produces a number of auto vehicles, including multi-utility vehicles, light commercial vehicles, and three-wheelers.

44. See Krishna, "India @ 75."

45. Pallav Bagla and Subhadra Menon, *Destination Moon: India's Quest for the Moon, Mars and Beyond* (HarperCollins, 2008).

46. V. V. Krishna and Rajiv Mishra, "Policy Brief on India's Science and Technology Cooperation with the European Union and Other Select Countries," Centre for Social Innovation, 2016.

47. In the previous regime, the technocracy, the mainstream media, and captains of industry aired their views quite freely to the extent of even criticizing the government on various policy matters concerning big technology decisions. One can say that this is no more the case. Several captains of industry seem to be toeing the policy discourse coming from the Prime Minister's Office.

48. Narendra Modi, address to the 102nd Indian Science Congress, January 3, 2015.

49. Nikhil Kumar, "How Narendra Modi Wants to Change India," *Time Magazine*, May 7, 2015.

50. " Strong Man: How Modi Can Unleash India," *The Economist*, May 24, 2014.

51. "Strong Man."

52. India Brand Equity Foundation, "Overview," September 2024, https://www.ibef.org/economy/make-in-india#:~:text=Make%20in%20India%20is%20amanufacturing%20infrastructure%20in%20the%20country.

53. *Time Magazine*, May 18, 2015. The magazine showcased Modi on the front page with the captions "Why Modi Matters" and "How Narendra Modi Wants to Change India."

54. Modi, address to the 102nd Indian Science Congress.

55. Phalkey, "From Development to Innovation."

56. *Economic Times*, India, July 4, 2019.

57. Tanya Aggarwal, "Reflections on the First Decade of 'Startup India,'" Observer Research Foundation, July 21, 2025, https://www.orfonline.org/research/reflections-on-the-first-decade-of-startup-india.

58. Aggarwal, "Reflections on the First Decade of 'Startup India.'"

59. India Brand Equity Foundation, "Smart Cities Mission: Objectives, Implementation & Impact," n.d., https://www.ibef.org/government-schemes/smart-cities-mission.

60. "Here's How BJP's Flagship Smart Cities Mission Echoes Failures of UPA Government," *Business Standard*, November 7, 2025.

61. CNN World, October 5, 2019.

62. CNN World.

63. Department of Water Resources, River Development and Ganga Rejuvenation Ministry of Jal Shakti, Government of India, https://www.jalshakti-dowr.gov.in.

64. Banjot Kaur, "Namami Ganga: 5 Reasons Why Ganga Will Not Be Clean by 2020," Down to Earth, October 15, 2018.

65. Kaur, "Namami Ganga."

66. The instruments to achieve that goal were the flagship schemes: Pradhan Mantri Kaushal Vikas Yojana (PMKVY; 2015 to present), Deen Dayal Upadhyaya Grameen Kaushalya Yojana (DDUGKY; 2014 to present), and the National Apprenticeship Promotion Scheme (NAPS; 2016 to present), which promised to address the glaring skill gaps. Harshil Sharma and Santosh Mehrotra, "Skill Development in India: The Facts Behind the Figures," *India Development Review*, February 25, 2025, https://idronline.org/article/livelihoods/skill-development-in-india-the-facts-behind-the-figures.

67. For instance, formal vocational training witnessed a modest rise from 2.4 percent in 2004–05 to 4.1 percent in 2023–24. Nonformal increased from 4.4 percent to 11.6 percent; nonformal self-learning from 3.9 percent to 7.1 percent; nonformal on the job from 1.7 percent (2012) to 9.3 percent for the same period ending 2024. In 2017–18, 29 percent of vocational trainees undertook courses lasting over two years, which halved in a matter of six years. By 2023–24, this figure plummeted to just 14.29 percent. Meanwhile, the share of trainees attending courses shorter than six months dramatically increased from 22 percent to 44 percent. The placement rate for PMKVY 1.0 (launched in 2015) stood at 18.4 percent, which marginally increased to 23.4 percent under PMKVY 2.0 before sharply declining to 10.1 percent under PMKVY 3.0.

68. Santosh Mehrotra and Harshil Sharma, "The Illusion of Skill Development in India: Decoding the Sudden Increase in the 'Vocationally Trained,'" *The Wire*, January 1, 2025, https://thewire.in/labour/the-illusion-of-skill-development-in-india-decoding-the-sudden-increase-in-the-vocationally-trained.

69. *Economic Times*, January 4, 2015.

70. Maseeh Rahman, "Indian Prime Minister Claims the Genetic Science Existed in Ancient Times," *The Guardian*, October 29, 2014, https://www.theguardian.com/world/2014/oct/28/indian-prime-minister-genetic-science-existed-ancient-times.

71. Saskia Solomon, "The False Scientific Claims Made During Modi's First Term," *The Caravan—a Journal of Politics and Culture*, June 26, 2019, https://caravanmagazine.in/science/false-scientific-claims-modi-first-term.

72. Dyani Lewis, "India Cuts Periodic Table and Evolution from School Textbooks," *Scientific American*, June 1 2023, https://www.scientificamerican.com/article/india-cuts-periodic-table-and-evolution-from-school-textbooks.

73. Dinesh C Sharma, "Biology Without Darwin. Next, Physics Without Newton and Einstein?," The Wire, India, April 23, 2023, https://thewire.in/education/biology-without-darwin-next-physics-without-newton-and-einstein.

74. "Pushpak Viman Predated Wright Brothers' Plane," *Times of India*, August 26, 2025, https://timesofindia.indiatimes.com/city/bhopal/long-before-wright-bros-plane-we-had-pushpak-vimana-shivraj/articleshow/123511626.cms.

75. This situation might improve in the future with the initiation of new funding schemes such as the ANRF and RDI.

76. See also S. K Bansal, Vivek Kumar Singh, and Philipp Mayr, "Comparing Research Performance of Private Universities in India with IITs, Central Universities and NITs," *Current Science* 116, no. 8 (2019), 1304–13.

77. See "India's Moon Landing Is a Stellar Achievement—and a Win for Science," *Nature*, August 24, 2023, https://www.nature.com/articles/d41586-023-02685-4; "NASA and ISRO Launch First Joint Mission to Map Earth's Shifts in Striking Detail," *Nature*, July 30, 2025, https://www.nature.com/articles/d44151-025-00138-7.

78. See the report by Jyoti Sharma and S. K. Varshney, "India's Vaccine Diplomacy Aids Global Access to COVID-19 Jabs," *Nature India*, February 17, 2021, https://www.nature.com/articles/nindia.2021.31.

79. World Economic Forum, The Fourth Industrial Revolution: What It Means, How to Respond," January 14, 2014, https://www.weforum.org/stories/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond.

80. Due to the limitations of space, only some select missions are explored hereafter.

81. T. V Padma, "India Bets Big on Quantum Technology," *Nature*, October 3, 2020, https://www.nature.com/articles/d41586-020-00288-x.

82. See the portal of the Principal Scientific Advisory to the government: https://www.psa.gov.in/mission/national-quantum-mission/26.

83. Sanjay Vishwakarma and Srinjoy Ganguly, "Making Indian Universities Quantum Ready," *Nature India*, June 14, 2023, https://www.nature.com/articles/d44151-023-00068-2.

84. Sahana Ghosh, "India's US$1.25 Billion Push to Power AI," *Nature India*, March 17, 2024, https://www.nature.com/articles/d44151-024-00035-5.

85. The mission emphasizes building a robust infrastructure for AI development, which includes enhancing computing capabilities and creating an ecosystem conducive to innovation. The main focus areas are developing skills and talent, training AI models, and generating AI technologies using R&D.

86. Sibussiso Biyela, Amr Rageh, and Shakoor Rather, "As AI Giants Duel, the Global South Builds Its Own Brainpower," *Nature India*, https://www.nature.com/immersive/d44151-025-00085-3/index.html.

87. National Informatics Centre, Government of India, "AI in eGovernance," n.d., https://www.nic.gov.in/centre-of-excellence-for-artificial-intelligence.

88. Micron, a US firm, is building a new facility that will enable assembly and test manufacturing for both DRAM and NAND products. "Micron Announces New Semiconductor Assembly and Test Facility in India," June 22, 2023, https://investors.micron.com/news-releases/news-release-details/micron-announces-new-semiconductor-assembly-and-test-facility.

89. Press Information Bureau, Government of India, "SEMICON 2025: Building the Next Semiconductor Powerhouse," September 1, 2025, https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=155130&ModuleId=3.

90. Tata Group, "Tata Group to Build the Nation's First Fab in Dholera," press release, February 29, 2024, https://www.tata.com/newsroom/business/first-indian-fab-semiconductor-dholera.

91. Konark Bhandari et al., "A Tech Policy Planning Guide for India-Beyond the First 100 Days," Carnegie Endowment, https://carnegieendowment.org/research/2024/11/tech-policy-planning-guide-india?lang=en#the-next-steps-for-indias-semiconductor-strategy.

92. This aligns with India's vision of achieving self-reliance through clean energy while also serving as an inspiration for the global clean energy transition. By fostering large-scale adoption of green hydrogen, the mission will drive significant decarbonization across key sectors of the economy, reduce reliance on fossil fuel imports, and enable India to assume both technological and market leadership in this emerging domain.

93. Ministry of Health and Family Welfare, Government of India, "The Status of Implementation of the National Electric Mobility Mission Plan," press release, February 13, 2025, https://www.pib.gov.in/PressReleasePage.aspx?PRID=2102783.

94. The mission works with all the concerned ministries/departments to identify their technology needs, develop solutions, and offer technical support. The mission aims to develop technology platforms to carry out R&D, translational research, and product development and incubate and support start-ups as well as commercialization.

95. India's competitive manufacturing costs attract global biopharma companies seeking to reduce production expenses. Its cost-effective vaccine production has made it a leading supplier of DPT (diphtheria, pertussis, tetanus) and measles vaccines.

96. NITI Aayog, Government of India Atal Innovation Mission, https://aim.gov.in.

97. Naushad Forbes, "Towards Innovations-Driven Industrial Transformation of India," Institute for Studies in Industrial Development, *ISID Policy Briefs 23-08*, December 2023, https://isid.org.in/wp-content/uploads/2024/01/PB2308.pdf.

98. Office of the Principal Scientific Adviser, Government of India, "Study of Corporate Sector Data on R&D Expenditure by Top 1000 Listed Companies in India," June 4, 2024, https://iica.nic.in/Images/Fothcoming_Program-24/Research_RD_Expenditure.pdf.

99. Government of India, *The Gazette of India, The Anusandhan National Research Foundation*, August 14, 2023, https://dst.gov.in/sites/default/files/NRF.pdf.

100. The design of the ANRF also seeks to foster a culture of interdisciplinary collaboration, strengthen linkages between academia and industry, and promote translational research that directly addresses national developmental priorities. Equally important, the ANRF emphasizes broad-based participation by including state governments, private-sector enterprises, and philanthropic contributions in its funding model—marking a significant departure from the earlier system, which relied heavily on central government allocations.

101. There is some analysis on RDI and NRF, keeping in view India's low level of budgetary provisions for S&T at a global level. Council for Strategic and Defense Research, "Funding Innovation: Assessing India's New RDI Scheme," July 11, 2025, https://csdronline.com/blind-spot/funding-innovation-assessing-indias-new-rdi-scheme.

102. RDI's key objectives include encouraging private enterprises to invest in frontier research, supporting mission-critical technological areas (as detailed in table 8.1), and fostering the development of a resilient and self-reliant innovation ecosystem. In addition, the scheme emphasizes economic security, sectoral flexibility, and the promotion of indigenous capabilities, creating an environment where both public and private actors collaborate to drive sustainable growth and technological leadership.

103. It seeks to promote technology development and deployment, with a particular focus on increasing collaboration between academia, government, and industry, as well as supporting start-ups.

104. Through this initiative, the TBIs have further allocated seed funding to seventy-two start-ups, carefully selected based on their innovation potential, market readiness, and technical feasibility. The selection process is overseen by the Seed Support Management Committee of each respective TBI, ensuring a transparent, merit-based, and rigorous evaluation.

105. Press Information Bureau, Government of India, "PLI Scheme: Powering India's Industrial Renaissance," August 24, 2025, https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=155082&ModuleId=3.

106. Surajeet Das Gupta, "Record Shipments, Powered by PLI: Smartphones Exports Cross Rupees 1 trn in 5 Months," *Business Standard*, September 14, 2025, https://www.business-standard.com/economy/news/record-shipments-powered-by-pli-smartphone-exports-cross-1-trn-in-5-mths-125091400761_1.html.

107. Juhi Todi, "But Did We Really 'Make in India'?," Down to Earth, September 25, 2024, https://www.downtoearth.org.in/governance/but-did-we-really-make-in-india.

108. Prime Minister's Office, Government of India, "Cabinet Approves DSIR Scheme 'Capacity Building and Human Resource Development' with an Outlay of Rs.2277.397 Crore," September 24, 2025, https://www.pmindia.gov.in/en/news_updates/cabinet-approves-dsir-scheme-capacity-building-and-human-resource-development-with-an-outlay-of-rs-2277-397-crore/?comment=disable.

109. Siddharth Kumar Singh, "India's Healthy Life Expectancy Lags a Decade Behind Total Lifespan," *The Hindu*, May 9, 2025, https://www.thehindu.com/news/cities/Hyderabad/indias-healthy-life-expectancy-lags-a-decade-behind-total-lifespan/article69557576.ece.

110. Sidhartha and Surojit Gupta, "India Can Grow Even Faster with Less Inequality," *Times of India*, December 14, 2024, https://timesofindia.indiatimes.com/business/india-business/india-can-grow-even-faster-with-less-inequality-economist-thomas-piketty/articleshow/116310271.cms.

111. See N. Rosenberg, "Science and Technology Policy for the Asian NICs: Lessons from Economic History," in *Science and Technology Lessons for Development Policy*, ed. R. E. Evenson and G. Ranis (Intermediate Technology, 1990), 149–50.

112. J. Gaillard, V. V. Krishna, and Roland Waast, *Scientific Communities in the Developing World* (Sage, 1997), 43–44.

113. Magilan Karthikeyan, "Government's Shift to Private Research Funding: Is It the Right Move for India's Future?," *The Wire*, February 25, 2025, https://thewire.in/education/governments-shift-to-private-research-funding-is-it-the-right-move-for-indias-future.

114. SME Chamber of India, "SME Sector in India," https://smechamberofindia.com/about-msme-in-india.php.