India @ 75: Science, Technology and Innovation Policies for Development

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India was perhaps the only country among the developing world with a colonial past to have organised and established national science community much before it attained its independence. Nehruvian science and technology (S&T) policy in India's formative years left a distinct imprint in the post-colonial and post-independent India. With a huge population of nearly 1.35 billion people, India is not dependent on food on outside countries since the 1960s. Green and White Revolutions have made immense contribution to develop scientific and technical capacities in agriculture. India's innovation system, including higher education, has given her some comparative advantage through 'human capital' in information technology, biotechnology, pharmaceuticals, space research and so on. In export promotion and economic competitiveness in technology-based industries, we lag compared with East Asian 'Dragons'. India's informal sector poses a formidable challenge with more than 95% of the total labour force, about 550 million, 90% of which is 8th class dropouts. When we begin to assess our national innovation system, one feature that stands out to research observers is few islands of excellence and vast 'hinterlands' of underdeveloped research potential. There is clearly a gap between theory and practice of science policy in India. Our gross expenditure on research and development as a proportion of gross domestic product remained relatively stagnant and, in fact, receded from 0.8% in the 1990s to 0.7% in 2020. In this period, our neighbour, China, left us far behind in S&T for development.

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As India turns 75, one is tempted to look back and reflect on one of the important dimensions of science and society relations (much of the material in this special report is drawn from my forthcoming book Krishna

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[forthcoming]).[1] Coming out of British colonialism, it was indeed a gigantic task for a large country like India to organise and orchestrate science and technology (S&T) institutions to address social, political and development challenges. India was perhaps the only country among the developing world with a colonial past to have organised and established a national science community much before it attained independence. India inherited a well-oiled administrative machinery and institutional structure in S&T. Above all, India was very fortunate to have a cadre of eminent scientists such as Sir C. V. Raman, Homi Jehangir Bhabha, Dr Shanti Swarup Bhatnagar (S. S. Bhatnagar), Acharya Sir P. C. Ray, M. Sircar, Sir Mokshagundam. Visvesvaraya (M. Visvesvaraya), Professor P. C. Mahalanobis, Professor Meghnad N. Saha (M. N. Saha), Sir J. C. Bose, Ashutosh Mukherjee, Dr Janaki Ammal, Dr Kamala Sohonie, Professor Asima Chatterjee, among several others, by the 1940s and 1950s. We were also fortunate to have a visionary like Jawaharlal Nehru who was committed to develop a strong institutional base in science, technology and higher education for India to enable her to draw respect and recognition in the comity of nations. As David Arnold (2013, p. 361) observes, 'Nehru was one of the principal architects of modern India and, through his enduring commitment to science, a leading figure in the formation of India's science policy and practice'. Nehruvian S&T policy in India's formative years left a distinct imprint in the post-colonial and post-independent India. We will also briefly explore the developments in the last few years. In doing so, the purpose is not to eulogise the making of science and policy, but to interrogate critically the claims and counterviews that shaped this large country which still reels under multitude of developmental challenges.

Science and Technology Organisation for Independent India: From the 1940s to 1950s

The period of the 1930s and 1940s in Indian history assumes considerable significance, at least, for three important reasons. The *first* is the declaration of *Purna Swaraj*, that is, complete self-rule (one can even term it as independence) by the Indian National Congress on 26 January 1930. In fact, the Indian flag was hoisted by Nehru on 31 December 1929 on the banks of the Ravi River in Lahore in undivided India. *Second*, as political developments heated up, a small group of Indian intelligentsia who initiated plans for industrialisation and development of future of India suddenly got activated to concretise their plans through the formation of the National Planning Committee (NPC), [2] India's precursor to the Planning Commission (currently called NITI Aayog) in 1937–1938. Leading Indian scientists such as Sir M. Visvesvaraya and Professor M. N. Saha who were quite critical of Gandhi's Sarvodaya perspectives were at the same time ardent supporters of Nehruvian socialist thought, ideas and development of India based on the industrialisation and application of S&T.

As is well known, the 1930s and 1940s radiated two major perspectives on the development and industrialisation of India. M. N. Saha, M. Visvesvaraya, Nehru, Gandhi, J. C. Kumarappa and others entered into a long dialogue and discourse on these themes (Zachariah, 2001). Gandhi and his supporters advocated decentralised development based on Sarvodaya philosophy, prioritising rural India. On the other hand, there was a contrasting perspective of Nehruvian 'socialist thought' and the model of the S&T-led industrialisation process (Bhatt, 1982). Subhas Chandra Bose, who was quite active in the NPC and who succeeded Nehru as the president of the Indian National Congress in 1938, advocated planned economic development. While addressing the 51st session of Indian National Congress at Haripura as a president, Bose advocated planned economic development on socialist lines.

> I have no doubt in my mind that our chief national problems relating to the eradication of poverty, illiteracy and disease, and to scientific production and distribution, can be effectively tackled only along socialist lines. The very first thing which our future national government will have to do would be to set up a commission for drawing up a comprehensive plan for reconstruction (as quoted and drawn from Mishra [2014]).

Gandhian Sarvodaya philosophy and social action presents a contrasting view of industrialisation. According to Kriplani (1961, p. 232), 'Gandhiji conceived of economics not merely in terms of production, distribution, exchange and consumption of material goods and services, but also of how these processes affected the life of the individual and the community and their mutual relations'. In many ways, economics and ethics were seen as two sides of the same coin in the Gandhian thought. Gandhi and his close associates developed a critique of Western models of industrialisation and invoked the relevance of *charkha* (spinning wheel) as a symbol of 'appropriate technology' (AT) and khadi as a symbol of Swadeshi. This remained the centrepiece of Gandhian economics (Kriplani, 1961), which is kept alive in developmental discourse. J. C. Kumarappa, a Gandhian economist and a member of NPC in 1938–1939, did not align with ideas of Bose and Nehru. He tendered his resignation in the later years.

Subhas C. Bose, Nehru, Visvesvaraya and Saha dominated the deliberations and planning agenda of NPC in the early 1940s. As India progressed towards the mid-1940s, three other plans were articulated by different stakeholders and intelligentsias. In contrast to the Nehruvian perspective of NPC, in 1944, there emerged a *Plan for Economic Development of India*, popularly known as the *Bombay Plan*, which was put forward by industrialists such as Purshottamdas Thakurdas, J. R. D. Tata, Ghanshyam Das Birla, Lala Shri Ram, Kasturbhai Lalbhai, John Mathai, A. D. Shroff, Ardeshir Dalal and few others. Even though Gandhian ideas were debated and discussed for quite some time since the 1920s, S. N. Agarwal of Wardha put forward a *Gandhian Plan in 1944* which focused on small-scale industries and agriculture. In a surprising move, one of India's leading thinkers and founder of Radical Humanist Movement M. N. Roy put forward a *People's Plan* in 1945.

As Kumar (2001, p. 250) observes, 'Gandhi's politics were convenient, but his economics were not. Although socialism remained an ideal for many (including Nehru and Saha), a version of democratic socialism with a mixed economy was accepted by NPC as the basis for future development'.

The *third* important reason for which the period of the 1930s and 1940s is considered significant is the visit of Archibald Vivian Hill (A. V. Hill). He won the Nobel Prize in 1922 and was professor at the Royal Society. He was invited by the government in 1943 to advise on the organisation of scientific and industrial research as part of India's post-War reconstruction plan. His report on *Scientific Research in India* (1944), in fact, found support from Nehru's regime and leading scientists such as S. S. Bhatnagar, J. C. Ghosh, P. C. Mahalanobis, among others. This report became a blueprint for the organisation of S&T and its institutional growth in the post-Independence period. A. V. Hill's report and its recommendations had far-reaching implications for India. Under the leadership of Nehru as the prime minister, almost all S&T agencies came under one umbrella ministry. Hill himself argued for centralisation (which he would not prescribe for Britain), and this suited Bhatnagar, Bhabha and other elite scientists close to Nehru. Centralisation and concentration of power were to become the hallmark of the scientific establishment in post-independent India (Kumar 2001, p. 257). No analysis is complete without exploring the role of Indian *Trimurti in science organisation* in the 1950s. Their views and perspectives on science influenced Indian science policy, beyond the institutions they nurtured. As Raina and Jain (1997) remind us, this was also the era of 'big science' institutions led by some well-known elite Indian scientists.

***Trimurti* in Science Organisation**

S. S. Bhatnagar and Origins of CSIR

Bhatnagar on completing his doctoral thesis at the University of London with a well-known British chemistry Professor F. G. Donnan returned to India in the early 1920s as a faculty at the Banaras Hindu University after his post-doctoral research in Germany. His technological innovation on finding solution for Attock Oil Company in drilling at Rawalpindi got him national recognition. Bhatnagar refused any personal monetary benefit and instead placed ₹150,000 royalties at the disposal of the university for research. By the late 1930s, Bhatnagar earned professional recognition. This was also the time when the government was looking for a suitable professional for leading the industrial research agency. In 1939, under Arcot Ramaswamy Mudaliar, Bhatnagar was called on to head the Board of Scientific and Industrial Research (BSIR) formed on 1 April 1940 for a period of two years (Krishna, 1994).

The efforts of Mudaliar and Bhatnagar led to the constitution of the Council of Scientific and Industrial Research (CSIR) in 1942 as an autonomous body under the provisions of the Societies Registration Act, 1860 (Act No. 21). Bhatnagar had a close and easy relationship with Nehru planned and established a chain of national laboratories after Independence. By 1943, five national laboratories, namely the National Chemical Laboratory, the National Physical Laboratory, the National Metallurgical Laboratory, the Fuel Research Station and the Glass and Ceramics Research Institute were planned with budgetary provisions. Bhatnagar acquired the reputation of being an 'empire-builder'. He built a chain of 11 national laboratories from 1947 to 1954 and 22 more to follow. Was this done at the cost of the university system? It is further reported that A. V. Hill himself was alarmed at this pace of laboratory expansion in India after 1947 and warned Bhatnagar, 'lest by getting all the best people away from the universities you may dry up the source of scientific talent, or at least training, for the next crop of scientists'.[3]

Homi Bhabha and Origins of TIFR

Homi Jehangir Bhabha was a close family member of the Tata Industries. After his school education in India, Bhabha landed in Cambridge in 1927. All the big names in physics and nuclear research were at Cambridge University at that time. Heisenberg, Schrödinger, Paul Dirac, Niels Bohr, Louis de Broglie and Lord Rutherford were engaged in their research at that time. Bhabha had the opportunity of taking lectures from Paul Dirac and entered research in Physics at the Cavendish Laboratory. He completed his PhD in nuclear physics in 1933 under Ralph H. Fowler. C. V. Raman who was heading the Physics Department at the Indian Institute of Science, Bengaluru (IISc), invited Bhabha. By 1943, Bhabha became a full professor at IISc and was already a big name in nuclear research. Bhabha was motivated and committed to build frontier science base in India. On 12 March 1944, he wrote a letter to Sir Sorab Saklatvala, the then chairman of the Sir Dorab Tata Trust, for financial contribution to build School of Physics and an institute.

On 14 April 1944, the Dorab Tata Trust responded positively which laid the foundation of the Tata Institute of Fundamental Research (TIFR) with Homi Bhabha as the director and D. D. Kosambi and R. P. Thatte as the founding research faculty, which opened on 1 June 1945 (see the letter quoted in Deshmukh [2010]). The institute was formally inaugurated by Sir John Colville, the Governor of Bombay, on 19 December 1945. As Anderson (2010, p. 120) points out, one-third of TIFR funding in formative years came from CSIR, one-third from the Bombay government and one-third from the House of Tatas. The institute was housed at Kenilworth, a bungalow on Pedder Road, Bombay (present Mumbai), given by the House of Tatas. Some of the leading Indian scientists who joined TIFR are Raja Ramanna, B. V. Thosar, S. Ramanathan, M. S. Narasimhan, M. G. K. Menon, B. M. Udgaonkar, Virendra Singh, Govind Swarup, Obaid Siddiqi, R. R. Daniel, G. S. Gokhale, Alladi Ramakrishnan, B. V. Sreekantan, among others (see the letter quoted in Deshmukh [2010]). In building the institution at TIFR, Homi Bhabha was very particular in attracting meritorious and brilliant scientists and build research groups around them, giving them full autonomy and support for research and advancement of knowledge.

M. N. Saha and the Saha Institute of Nuclear Physics (SINP)

Whereas Homi Bhabha designed and planned TIFR with the aid of his extended family ties with Tatas, Bhatnagar had to entirely depend on the colonial government, and particularly on Nehru, for the expansion of CSIR after Independence. Saha, like Bhatnagar, coming from a relatively poor background, had to struggle a lot on two fronts: personal and colonial regime since the 1930s. He introduced nuclear physics in 1940 as part of the university physics curriculum in the University of Calcutta as a Palit professor. With support from Nehru, he received a fund from the Sir Dorabji Tata Trust for the procurement and construction of a cyclotron, a type of particle accelerator which produces radio isotopes, at the Palit Laboratory in 1941. As the detailed account of Phalkey and Wang (2016) shows, by the time the Atomic Energy Committee (AEC) was established in 1946, lot of research went into building the nuclear research group at the Palit Laboratory under Saha in Calcutta (present Kolkata). The support of Homi Bhabha from Tatas and his proximity to Nehru enabled to make Bombay (present Mumbai) as the main research centre in nuclear energy research. Saha contested these decisions, but as things turned out, his ideas were in a way marginalised. Saha, though continued his professional contacts with AEC and CSIR, resolved to build his institution Saha Institute of Nuclear Physics (SINP) from the base already created with the Cyclotron Group at the Palit Laboratory. In contrast to Homi Bhabha's TIFR and AEC with relatively enough budgets to create a base, Saha had to really struggle for money in building SINP. As Anderson (2010) draws attention, Saha could mobilise hardly ₹740,000 by 1947. The foundation stone was laid in April 1948 by Shyama Prasad Mukherjee (Asutosh Mukherjee's son). Saha in 1938 launched the well-known journal *Science and Culture* and edited it till his demise in 1954. This journal contains one of the best discourses Indian science policies in the 1940s and 1950s.

Unbound Optimism and Public Response: From the 1950s to 1970s

Both Nehru and Gandhi had the common objective of creating employment, removal of poverty and developing India; and both emphasised the need for developing traditional and modern industries through the use of S&T. However, their methodologies differed dramatically. Nehru's vision of modern S&T for development in the 1940s and, even later after Gandhi's demise, in the 1950s and 1960s did not find any real opposition. This era witnessed a great deal of optimism about science and development. The manifesto of the Congress Party for the first national government in 1945 declared:

> 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…. Industrial, agricultural and cultural advance, as well as national defence depend on it. Scientific research is, therefore, a basic and essential

> activity of the state and should be organised and encouraged on the widest scale. (Sitaramayya, 1969)

Nehru's vision of development, in large measure, was based on the confluence between 'Soviet socialistic planning' and potential of Western industrial capitalism. This was reflected in the initial economic planning of 'mixed economy' of the country. Nehru sought to develop a close partnership, an alliance, with the elite Indian scientists in putting his ideas into action after Independence. Homi Bhabha, S. S. Bhatnagar, P. C. Mahalanobis, J. C. Ghosh and D. S. Kothari were some of the elite scientists who can be considered as the inner circle of Nehru. It is inconceivable to explore the growth of S&T in this initial phase, bypassing the subject of science and politics. As early as 1947, addressing 34th session of the Indian Science Congress, Nehru initiated the alliance with scientists by observing that in India there was a growing realisation of this fact that the politician and scientist should work in close co-operation. In contrast to Gandhi's critical stance over modern S&T, Nehru's modern, secular image and most of all his unquestioned support of science made him a 'messiah' for the development of science in India. The scientific community, in general, and the elite could immediately identify with his vision of science and development for they also found a promoter of their interests (Ahmad, 1985). Nehru's unbound optimism of modern S&T for development was clearly evident from his various interactions with decision-makers and scientists. On one such occasion, he declared:

> It is 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 utilising the new sources of power which science has placed at our disposal.[4]

Nehru's vision of development through S&T was intimately connected with the rapid expansion of education, skills and human capital, and hence with higher education institutions. He created the ministry of Scientific Research and Natural Resources in 1947 to coordinate and promote activities in S&T nation-wide. Indian Institute of Technologies (IITs) were conceived and established at a time when Nehru's vision of building modern India dominated the national development agenda. The *Scientific Policy Resolution* (SPR) clearly stated:

> The wealth and prosperity of a nation depend on the effective utilization of its human and material resources through industrialization. The use of human material for industrialization demands its education in science and training in technical skills. Industry opens up possibilities of greater fulfillment for the individual. India's enormous resources of manpower can only become an asset in the modern world when trained and educated (Source: https://thesciencepolicyforum.org/wp-content/uploads/2020/05/SPR-1958.pdf).

In fact, the plan to establish specialised engineering institutions took roots around 1945 when the government set up the Sarkar Committee. It is within this policy framework and Nehru's vision that the plans for creating specialised engineering institutes emerged. The government, after Independence in 1947, established five IITs in Kharagpur, Bombay (now Mumbai), Madras (now Chennai), Kanpur and Delhi. The Massachusetts Institute of Technology model was perceived as a possible answer to the lack of high-level engineering training in India and possibly also to promote an institutional research model in which applied research rather than basic research was pre-eminent (Chandra, 2009). From S&T policy perspectives, one can trace various developments in this period in terms of two conceptualisations, namely policy for science and science for policy (Brooks, 1964).

Policy for Science

This period reflects a phase of 'policy for sciences' during which the main emphasis was on creating a basic infrastructure for S&T in the country, including the expansion of the university sector for the supply of required human resources. As noted, India's finest five institutes of technology were planned.[5] From the 1950s to the early 1970s, infrastructure in S&T also included substantial efforts to build what may be termed the techno-industrial capacity—the engineering, consulting, design and development organisations. There were 42 such organisations by 1970 in the private sector and 8 in the public sector. They were promoted basically to bring about a coupling between S&T in the processes of capital goods industries, to absorb imported technology in areas such as power, chemicals and metallurgy, and to complete turnkey processing plant. Major mission-oriented science agencies such as Department of Atomic Energy (DAE); CSIR; Indian Council of Medical Research (ICMR); Indian Agriculture Research Institute, expanded in the 1960s; Defence, Research and Development Organisation (DRDO); Indian Space Research Organisation—among other institutions—were established and rapidly expanded during this phase.[6] Homi Bhabha, regarded as the father of India's atomic energy programme, and Nehru were instrumental in getting the first official *Scientific Policy Resolution* passed in the Indian Parliament in 1958. As Rahman (1983, p. 1) observed, 'The SPR was both a testament of faith in science and a vision of society'. It is an important landmark as it recurrently legitimised the funding and expansion of the S&T institutional base.

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. In other words, the *policy for science* can be largely explained in terms of informal science policy determined by the alliance.[7] Although Nehru was instrumental in chalking out planned economic development through Five-Year Plans, and in a way he was one of the founders of India's Planning Commission, India's first Five-Year S&T Plans (1974–1979) came into being only in 1973.[8] It is rather interesting to note that, apart from the 1958 SPR, there were no specific S&T policy statements issued during the Nehru regime. The only economic and budgetary signals given were contained in the Five-Year Plans. Even though Nehru consulted with a wide section of scientific intelligentsia, the science–politics alliance of the Nehru era led S&T growth into some 'specific' directions. The scientific elite close to Nehru regime, particularly those in the 'inner circle', can be said to have wielded enormous power to command scarce or limited resources—both financial and material. CSIR had no laboratories worth mentioning in 1947, but by the 1950s S. S. Bhatnagar was able to establish a network of 15 laboratories. C. V. Raman called it the *Nehru–Bhatnagar Effect*.[9] This had a parallel in the atomic energy agency with Homi Bhabha as its head. Bhabha managed to mobilise Nehru into setting up the DAE headquarters in Bombay where he wanted it. India put lot of policy thrust on atomic energy rather than coal R&D utilisation in the 1950s and 1960s. Thus, for about two decades after Independence, the real expansion of S&T infrastructure took place in CSIR, DAE and defence-related establishments. As some analysts rightly pointed out in the early 1970s:

> It is perhaps not surprising to find that decisions regarding the allocation of scientific resources, for example, have been taken not on the basis of the advice tendered to the political leadership by either of these bodies [referring to Science Advisory Body to the Cabinet and Planning Commission], but as result of informal and tacit interactions between concerned individuals in the scientific community, the executive and the polity. Even today decisions about defence, public health, atomic energy, industrial research and even agricultural research are apparently being taken almost independent of the formal national science policy. (Parthasarathi, 1974)

Sectors Marginalised

With hindsight, as the structure of S&T institutional growth reflects, agriculture, rural technology and medical research were some of the important fields of Indian S&T which witnessed only marginal prospects until the late 1960s. The close alliance between Nehru and elite scientists in industrial research and atomic energy had its own consequences for other areas. It is not surprising that the 'grand old' agriculture scientist, Benjamin P. Pal (1977, p. 50) lamented[10]:

> … [H]ow much the application of science to agriculture might have advanced if Nehru had been directly associated with ICAR [Indian Council of Agriculture Research] in the way in which he was associated with the CSIR and DAE. It is a pity that when these modern scientific organisations were set up, the older ICAR was not drastically reorganised on similar lines.

Historically speaking, another consequence of the science–politics nexus of the Nehru era is the relative stagnation in the proportion of R&D funds for the university sector. Though higher education in universities witnessed considerable expansion from 25 to 105 universities during 1947 and 1975, the locus of R&D somehow was restricted to the mission-oriented science agencies. As a rough estimate, the university component of the total R&D expenditure remained less than 6% per annum from the 1960s to 1990s. One reason for the domination of mission-oriented science agencies (such as DAE and CSIR) was that the elite scientists who were close to the political establishment were from these agencies, and the tradition continues even today. The academic community did not play a major part in S&T policy decision-making processes. The university sector had to depend on science agencies for doctoral and post-doctoral scholarships for a long time. The universities in India were in a large measure seen as teaching institutions since the science agencies such as CSIR, DAE and others accounted for most of the research funding. As Edward Shils (1969), expert on Indian higher education, pointed out, 'Universities were rendered as mere teaching institutions without any worthwhile research base'. Philip Altbach (2012), Andre Beteille (2010) and others have recurrently reflected on the marginalisation of research base in the Indian university sector.

Optimism

Implicit in the *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 S&T for development would be accomplished. A great deal of optimism was reflected by Nehru and elite scientists over science and development in the policy discourse of this phase. Further, creating a base in science was seen as crucial for absorbing and eventually replacing the foreign technology, as well as generating new capacities in technological innovation for the industrial development of the country. While the ethos of governance reflected a 'top-down' model of operation, the policy-for-science perspective adopted by the political–bureaucratic regime in S&T pushed forward the policy instruments of import substitution and self-reliance in S&T development most vigorously during this phase. Although Gandhian values and his Sarvodaya model had considerable influence in the 1940s, the departure of Gandhi in 1948 did not have a major influence on the developmental policies during this phase and till about 1973.

Science for Policy

Having laid some basic infrastructure in S&T, *science-for-policy* perspective reflects series of S&T developments which begun to feed into political expectations. The science agencies DAE, CSIR, ICMR, ICAR, DRDO and ISRO witnessed considerable growth and continued to legitimise policy expectations. By the early 1980s, India entered the nuclear and space 'clubs' of the world. Homi Bhabha in Atomic Energy and Vikram Sarabhai in the Department of Space laid strong research and development foundations by the 1980s. ISRO launched its first satellite called *Aryabhatta* on 19 April 1975 in collaboration with the Soviet Union. On 18 July 1980, ISRO launched second Indian satellite called *Rohini* successfully in the relevant orbit by an India-made launch vehicle. In the field of nuclear energy and its progress, India detonated her code-named Smiling Buddha, the first nuclear explosion on 18 May 1974. The period between the 1970s and 1980s witnessed more than fourfold increase in defence and nuclear research budget which later in the 1990s enabled the country experiment with second nuclear explosion called Phokran II in May 1998. The Department of Electronics and the Electronics Commission were created in early 1970 and 1971, respectively, to expand and promote national-level electronics and computing technology. These departments, in fact, can be said to be spin off origins from TIFR and DAE. A National Centre for Software Development and Computing Techniques (NCSDCT) was spin off from TIFR and transferred to the Department of Electronics later.

In agriculture, India experienced relative success in the *Green Revolution* in food grain production and the 'White Revolution' in milk cooperatives and development of the dairy industry. From a short phase of food dependency and imports of wheat from the United States and other countries, India became self-reliant in food production due to success in the Green Revolution. This was led by agriculture scientists such as M. S. Swaminathan, B. P. Pal and others in collaboration with Norman Borlaug who leveraged agricultural research and technology increase agriculture productivity in India. The 'While Revolution', which mainly involved cooperativities of milk farmers on all India basis, particularly began in Gujrat. The White Revolution involved increase in milk production through three policy and programme strategies known as Operation Flood I, II and III between 1970 and 1996 (FICCI, 2020). These strategies led to a rapid rise in the formation of more than 75,000 village cooperatives in the 1990s and increased to a whopping 190,000 by 2019.[11] By the 1990s, India became the world's largest milk producer. Dr Kurien and his associates at the Anand Milk Union Limited (the main institution which catalysed the milk cooperatives) resisted several 'internal' and 'external' moves to abort the Indian milk food industry. With the co-operation of the government, particularly Prime Minister Lal Bahadur Shastri, Kurien established the National Dairy Development Board to further strengthen the industrial, trade and research base in the milk sector. 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 (Baviskar & Attwood, 1995; Kurien, 2005, 2007).

Catalysed by the Indian Patent Act of 1971, which protected patents for only seven years, CSIR laboratories were able to successfully develop processes that helped Indian pharma companies exploit drug patents in commercialising some important essential drugs. Indian pharma firms in collaboration with CSIR's five drug research labs attained very high technological capability in reverse engineering in putting generic drugs into the market. Over 70% of South Asian population depend on essential generic drugs sourced from India in 2020. Roots of this pharma capability can be traced to the impact of the 1971 Patent Act and R&D capabilities of CSIR labs in drugs and chemicals. Further, in food technology, the CSIR process on baby food, developed in the mid-1950s, replaced the multinational Glaxo by 90% by the 1960s. This process led to the growth of a successful cooperative milk industry in the state of Gujarat known as Amul which produces baby milk food under the same name. In the 1960s, the CSIR laboratory, Central Mechanical Engineering Research Institute, Durgapur, designed and developed an indigenous tractor (Swaraj manufactured by Punjab Tractors Ltd) to meet the then growing demands of the Green Revolution (Chaudhury, 1985; Jain & Mathur, 1990; Mande, 2020).

Optimism Shattered

Optimistic assumptions about science to development underlying the perspective of *policy for science* began to erode from the early 1970s. The oil crisis in 1973, coupled with the rise of alternative and AT movements, raised questions about S&T for development. An important development during this phase is the emergence of a critical stream of thinking and writings which pointed towards the failure of S&T efforts over three decades. The main issues were the increasing disparities between the urban rich and rural poor as a result of S&T-based developments including the Green Revolution.[12] There evolved a consensus over the failure of 'trickle -down' theories, which justified the optimistic assumptions of the Nehruvian 'model' of the S&T-based development approach. In fact, alternatives to the Nehruvian economic framework that came into policy focus from the late 1960s. The 'wave' of AT which began in the mid-1970s gained momentum during the rule of the Janata Party Government.1[3] This was also the period when the Gandhian perspectives on development gained some currency and provided legitimacy to decentralised development and institutionalised several inclusive innovation institutions. Barefoot College, Tilonia; Jaipur Foot; Honeybee Network, Ahmedabad; Arvind Eye Care, Madurai; and several incremental innovations engineered by Dr Kurien at Amul are some examples.[14] Even before the Gandhian Institute at Varanasi institutionalised the AT Unit, Appropriate Technology Cell was created in the Ministry of Industrial Development in 1971. In 1974, Application of Science and Technology to Rural Areas (ASTRA) was established at IISc Bangalore by A. K. N. Reddy. Centre of Science for Villages was founded by Devendra Kumar in 1976. It was created to play an intermediary role in connecting national laboratories with the needs and demands of rural areas which badly required technical inputs for various problems.

The major impact of this movement was the issue of alternatives and the choice of technology in the process of development. Jain (2002) explores S&T networks operating in society in terms of 'elite' and 'subaltern' streams. The disenchantment over the role of modern S&T in society was clearly evident from the emergence of the People's Science Movements (PSM) and Alternative Science Movements (ASM). In a way, the rise of these movements was indeed a counter-hegemonic reaction to the hegemony of instrumental modern science (Krishna, 1997). Coupled with this were the environment and ecology groups which occupied centre stage of politics and decision-making by the early 1980s, signalling the importance of civic culture (Guha, 1988).[15] The PSM groups and their programmes of action are concerned with the areas of science popularisation, literacy, educational innovations, environment, the indigenous base of modern technology and rural technologies. Kerala Shastra Sahitya Parishad, the leading agency of PSM with a full-time membership of some 50,000 science activists, came into prominence in the 1970s and 1980s. On the other hand, the concerns of ASM groups varied from the intellectual positions to environment and ecology, forest policies, indigenous knowledge systems and management of big dams. The ASM grew out of simultaneous efforts by various actors who initiated an intellectual critique of modern, Western science parallel to the emergence of grass-root groups interested in ecology and groups that promoted indigenous systems of knowledge and practices. Ashis Nandy and his colleagues at the Centre for the Developing Societies in Delhi; Claude Alavares in Goa; Patriotic and People Oriented Science and Technology (PPST), Madras[16]; ecology-based groups such as 'Chipko' in Northern India; Narmada Bachao Andolan (Save the Narmada Movement) in central India[17]; and the *Chipko* Movement, led by Sunderlal Bahuguna and Chandi Prasad Bhatt are some of the prominent intellectuals whose activities were part of ASM.

Tragedy in the Midst of Technology Policy

The 1980s continued to throw up several challenges. This was the decade when Indian S&T was entangled in a double-bind situation. On the one hand, the issue of basic needs posed a challenge and led to a critical evaluation of the policies followed by the government. The Bhopal Gas tragedy, which claimed more than 5,000 human lives because of a poisonous gas leak from a Union Carbide factory in Bhopal, exposed the dangerous consequences of not paying attention to R&D risk assessment. This was particularly crucial when India was transferring massive foreign technology during the preceding three decades. 'One-dimensional' technocratic obsession with S&T policy came under heavy criticism from Ashis Nandy, Vandana Shiva, Shiv Viswanathan, Claude Alvares and others. They went on to publish their manifesto on *Science, Hegemony and Violence* in 1988 (The United Nations University).

On the other hand, the rise and importance of new technologies (microelectronics, information technologies, biotechnologies and so on) and their institutionalisation posed a new challenge with regard to their absorption, development and diffusion. In a way, it is not surprising that the 1983 *Technology Policy Statement* stressed the need for technology assessment studies, and the importance of these new technologies and strengthening their indigenous base. The 1984 *Computer Policy*, *Electronics Policy* and the setting up of *Centre for the Development Telematics* (C-DOT) was in response to the call of Technology Policy Statement. C-DOT led to digitising India's telecom revolution in later years, but in the short term helped India expand from 2 million to 20 million telephone lines (Pitroda, 2011). Moving on from telecommunications, the 1980s also witnessed the creation of the Centre for Development of Advance Computing in 1988 which built India's first supercomputer PARAM with 1 GF, paving the way for succeeding generation of super computers (Pitroda & Pitke, 2011). Little known is the fact that Indian software story began with the establishment of National Centre for Software Development and Computing Techniques (NCSDCT) in 1974 in TIFR, rechristened as National Centre for Software Technology in 1985 (Ramani, 2011; Sarma & Krishna, 2010; Sharma, 2009). These efforts in new technologies led to the first email system to be operated in India by the early 1980s, and the prototype of the multi-city Railway Passenger Reservation System was planned and demonstrated by NCSDCT. Later, the Computer Maintenance Corporation of India built advance systems based on these initial plans. One notable feature that we can see in India's S&T policy in the 1980s and early 1990s was the technology denial regime from USA in super computing, space technologies and some critical components in high technology. In both sectors India responded with indigenous high technological contributions.

Another field of S&T that received a big boost during the mid-1980s was biotechnology when the government set up the Department of Biotechnology (DBT), with an annual budget of ₹180 million. India's front ranking Centre for Cellular & Molecular Biology was also formally established in 1982 which pioneered the techniques of DNA finger printing in India—later on, led to the creation of the Centre for DNA Fingerprinting and Diagnostics laboratory in Hyderabad. The period from the mid-1980s to 1990 was one of the considerable political instabilities with frequent government changes.[18] The *one-dimensional* phase of technology policy thrived during Rajiv Gandhi at the helm of affairs, with technocrat Sam Pitroda giving technical solutions to social problems. If civil society raised a problem, the government was ready with a technical solution. In response to various criticisms over basic needs and the challenges faced by underprivileged sections of people, the government initiated various flagship programmes under Technology Missions in immunisation, oilseeds, drinking water, literacy and telecommunications under the charge of Sam Pitroda in 1987. 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' (Sharma, 2009).

The 1990s: *The World is Flat*

Impressed by his field trip to Bangalore software hub and interactions with Nandan Nilekani at Infosys, Thomas Friedman, on reaching home back in the United States whispered to his wife that 'The World is Flat'.[19] A ray of hope that Friedman witnessed happening down in South India actually got ignited with the liberal economic reforms of Manmohan Singh as the finance minister of India in 1991. The main thrust of new economic reforms was the introduction of New Industrial Policy which focused on exports, larger role for the private sector as the engine of growth, freer operation of markets and global niche in world markets. It was a major departure from the earlier protectionist policies and an ‘inward-looking’, import-substitution regime. Notwithstanding criticisms from different quarters, the new economic reforms brought the industry-market-based S&T policy culture into the centre stage of economic and commerce policy regime. Liberal economic reforms based on market principles influenced both mission-oriented public science agencies and private industry players. R. A. Mashelkar, the head of CSIR, through a ‘Vision Document’ spelled out several of these new measures to generate 30% of its budget from outside CSIR sources. He also set a target to generate 50% of its budget and 100% of its operational budget from non-governmental sources through industry partnerships and by selling its technologies (CSIR, 2001; Mashelkar, 1995). This change was not confined to CSIR but spread to other science agencies. With hindsight, even though Indian economic liberalisation did not transform the Indian economy compared to East Asian miracle or China, there are some bright spots in few sectors of economy with innovation-led growth and technological capabilities. Sectors and technology developments, for which strong foundation was laid through new technology policies, deserve some space.

Biotechnology and Pharmaceuticals

As early as 1991, as one of the leading biologists has observed, ‘for a government outfit, DBT has been extraordinarily active, vibrant and forward looking’ (Padmanabhan, 1991, pp. 510–513). DBT’s budget witnessed almost tenfold increase from ₹180 million in 1986 to 1863 million in 2001. Within a decade, DBT expanded with about a half-dozen laboratories and currently houses some 16 laboratories. Major achievements of DBT are its contribution to the creation of postgraduate and doctoral programmes in biotechnology in about 35 universities, the creation of new Chairs, scholarships and, above all, the expansion or creation of 6 new national laboratories in molecular biology and biotechnology research which have developed world-class facilities over 15 years.[20] The 1990s witnessed establishment and strengthening of biotechnology laboratories and basic research groups in CSIR, ICMR and ICAR. R&D and innovation capacities also witnessed a steady growth as biotechnology patents more than doubled from 172 in 1995 to 395 patents in 2002. India attracted global attention in 2000 when a group of national laboratories, including the private biotech firms such as Serum Institute, Shanta Biotech and Bharat Biotech, developed three vaccines for Hepatitis B at a fraction of US$ 0.5 per dose compared to the imported vaccine of US$ 16 per dose (Kumar et al., 2004). As Ramani and Guennif (2014, p. 196) pointed out, ‘the challenge for the Indian pharmaceutical firms was to expand their knowledge base, which was firmly embedded in organic and synthetic chemistry, to integrate the life sciences based and associated techniques’. Research on vaccines and biopharmaceuticals initiated in DBT labs led to the spin-off effect in private pharmaceutical firms for investing in R&D in biotechnology. This paved a way for the emergence of the biopharma sector in India. In the early 1990s, Biotechnology Consortium of India Limited (BCIL) was set up by DBT with an investment of ₹5,000 million in collaboration with about a half-dozen financial, venture capital and private firms. There were some 320 companies and 240 institutions linked to the biotech sector by 2010. A notable development has been the creation of 'bio-valley' in Hyderabad which has dozen leading biopharma firms and research labs. BCIL and DBT collaboration proved to be an important milestone for India emerging as an important player in biotechnology commercialisation.

Closely associated with the biotechnology sector is India's pharmaceutical sector. This sector was transformed after the landmark Indian Patents Act, 1970 which protected patents between 5 and 7 yearly only. The Act enabled Indian firms and institutions to perform reverse engineering on expired patents in India and bring generic drugs into the market. By 1995, there were 13 Indian companies among the top 20 firms which controlled 85% of the market (Krishna, 2007). Two studies by Langow (1998) and Lalitha (2002) demonstrate that technological capabilities by Indian firms witnessed steady improvements between 1978 and 2000. For instance, Cefuroxime consumed 10 years to produce generic drug after reverse engineering, but by 2000, this period was reduced to 3 years in the case of Ciprofloxacin. India has mastered the art of frugal innovation in pharmaceuticals. For instance, drugs such as psoriasis and cholesterol reduction cost a small fraction of what it costs in the United States (Prahalad & Mashelkar, 2010).[21] Jayaraman (2005) study on India's top 20 pharma firms showed that their revenues increased by 134% from US$ 483 million to US$ 652 million during 2003 and 2005. Much of this success can be traced to the R&D efforts of five drug and chemical laboratories of CSIR which in varying ways contributed to the technological capabilities of Indian pharma companies during the era of 1970s to 1990s. Indian generic companies, notably Cipla, made AIDS drugs affordable in Africa and elsewhere for a fraction of the cost in developed countries. Recent report from Arvind Sahay, Professor of Marketing and International Business at IIM Ahmedabad reveals that in 1969, Indian pharma firms had just 5% share of the Indian market and by 2020 it replaced the global pharma to the extent of 85%. India contributes over 20% by value to the global generics market. The pharma industry in India is worth US$ 37 billion with exports accounting US$ 18 billion. As Sahay concludes, 'Pharma can do for India what software was able to do in the 1990s and 2000s. India became the back office. Let this be the moment that triggers the acceleration of the movement to becoming the *Pharmacy to the World*' (Sahay, 2020).

IT Software

The second industry sector that has emerged in the 1990s is Information and Communication Technology (ICT) software. Government role has been substantial as more than 50 software technology parks operate accessing various tax benefits.[22] In a country where about 50% of the population is illiterate and an equal number live in poverty, the IT policies are directed at harnessing the IT revolution and at the same time keeping social justice and equity in the forefront of the policy agenda. There are more than 950 million mobile subscribers in 2014 in India and more than 200 million internet users. The most dynamic aspect of Indian economy in the last decade has been the emergence of hotspots for global R&D, global innovation, and market for information-based ICT products and high technology manufactures. India has been a major destination of foreign direct investment in R&D and an attractive knowledge-based location for transnational corporations such as IBM, Intel, Microsoft and General Electric. In 2014, there over 1,000 multinational firms that have established R&D centres or laboratories in various cities of India. Between 2000 and 2013, these centres increased at an annual rate of 13.8%, giving employment to 244,000 professionals in 2014. These centres mainly operate in ICT, biotechnology, pharmaceuticals, telecommunications and automobiles. During 2002 and 2013, Bangalore, Pune, Chennai, Kolkata, Delhi NCR and Hyderabad's high technology cities were among the major destinations for foreign R&D centres (Krishna, 2016a). Indian IT and services industry contributed about 7% of GDP in 2014 and generated revenues to the tune of US$ 110 billion (Krishna, 2016a).

Auto Sector

The auto sector assumed some importance in this phase of Indian S&T policy. India's three major auto firms, namely Tata Motors and Mahindra and Mahindra (M&M) launched indigenous new models of sedans, sports utility vehicles (SUVs) and trucks.[23] M&M developed vehicles such as Scorpio, Bolero, Xylo, XUV 700, XUV 300 and Alturas G4. On the other hand, Tata Motors launched passenger cars such as Indica, Nano, Tiago, Altroz and Tigor. In SUVs, they launched Safari, Harrier and Nexon in the last few years. Both M&M and Tatas have invested in R&D and design laboratories and developed indigenous engine models for their cars. Both these firms in recent years have also launched electric vehicles. The third major auto firm Ashok Leyland is the second largest Indian vehicle maker. All these firms have developed R&D labs and have evolved technological capabilities in collaboration with Indian academic institutions, particularly IITs (Krishnan, 2011). Indian automobile production increased from 5.3 million units in 2001-2002 to 20.3 million units in 2011-2012. Nearly 19% were cars and the rest were two- and three-wheeler vehicles. In 2012, the Indian automotive industry provided direct employment to more than 320,000 people and contributed 5% of India's GDP. As Rajnish Tiwari and Katharina (2017) from a detailed study of the Indian auto sector conclude,

> The growing domestic automobile market, export opportunities and the increased emphasis of OEMs on high-quality, innovative solutions have created a context for component suppliers to ramp up their innovation capabilities…has developed unique frugal innovation pathways that manage to circumvent the various shortcomings of India's innovation ecosystem, by building on some key strengths of that very ecosystem.

Space and Frontier Research

The sector which has put India on the global S&T map is the aerospace industry CSIR's national aerospace laboratories are involved in several defence strategic projects including the Light Combat Aircraft Tejas. India developed high technological capabilities in launching satellites on commercial basis and its space missions to reach Moon and Mars witnessed government support and progress in this phase (Bagla & Menon, 2008). A somewhat big lead in launching satellite began around the early 1990s with the development of the Polar Satellite Launch Vehicle (PSLV) with the maiden flight in 1993. This was for launching remote-sensing satellite in the Sun-synchronous orbit. PSLV was considered as work horse which completed more than 50 launches of satellites for both India and foreign countries by 2012. The other important vehicle developed by ISRO is the Geosynchronous Satellite Launch Vehicle (GSLV). India was able to develop cryogenic technology for the launch of satellites in the geosynchronous orbit. During 2000 and 2010, out of total 13 launches of satellites, 10 were successful through the GSLV platform. Around 2010, India developed GSLV Mark III.[24] The technology denial regime which led to the indigenisation of space technologies bore fruits through these developments.

India's strength in advances of S&T attracted global attention. India entered into collaboration with the European Union and became partner in some key technology and big science projects in the decade preceding 2014. Apart from these collaborative ventures in emerging technologies, India entered into collaboration with the USA and other leading countries[25].

1. India is a member of the European Union International Thermonuclear Experimental Reactor (ITER) nuclear fusion energy project. ITER is an international Tokamak research and engineering project designed to prove the scientific and technological feasibility of a full-scale fusion power reactor. It is an experimental step between today's studies of plasma physics and future electricity-producing fusion power plants.
2. India and the European Union participate in the proposed Facility-for-Antiproton-and-Ion-Research project aimed at understanding the tiniest particles in the universe. Indian participation in this project has been in the form of experiments and accelerator components, where Indian scientists are drawing from their vast expertise in this area in collaboration with European scientists.
3. India is also a member of the satellite-based navigation system, the Galileo Project (European version of USA's global positioning system). India's National Knowledge Network is linked up to its European counterpart GÉANT, and it is also part of the Trans-Eurasia Information Network.
4. The Indo-US nuclear deal, initiated in Dr Manmohan Singh's regime between and the USA, is a big milestone in the science diplomacy. First, it removed the nuclear apartheid regime and tentacles of various roadblocks. Second, it opened the door for India to enter into nuclear agreements to promote the civil nuclear energy programme with other major countries. Third, it opened up a new high technology commerce route in drawing uranium and nuclear technology from countries such as Australia, Canada, France, Russia, Japan and South Africa.

5. India and Japan during 2006 announced the formation of a global and strategic partnership. The most significant milestone in STI in the last decade has been Japanese official development assistance in conceptualising and executing the well-known, prestigious Delhi Metro Project. This resulted in India having one of the largest metro networks in the world by 2012.

Post 2014: Mirages of Development

By the middle of 2014 in May, the government led by Narendra Modi of Bharatiya Janata Party replaced the then ruling Congress Party led by Dr Manmohan Singh. A number of changes have since taken place in the economic, political, industrial, educational and other sectors which have a bearing on science, technology and innovation (STI) activities. From the S&T policy culture perspective, the phase of the Modi government is dominated by political-bureaucratic culture in science with the powerful persona of Modi and his Prime Minister Office assuming complete dominance. The whole governance of STI agenda reflects a top-down model, rendering the market, academic and civil society policy cultures only residual space to operate in the whole system. This is indeed a dramatic turnaround, compared to previous regimes. Further, the other noticeable shift in the contemporary S&T policy culture is the specific importance given to Indian science of the ancient period, traditional concepts and some elements of *Vedic* knowledge. For instance, while speaking at the 104th session of Indian Science Congress on 4 January 2015, Modi said,

> We in India are the inheritors of a thriving tradition of Indian science and technology 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. (*The Economic Times*, 2015)

This was about linking our past scientific traditions to the present ones. However, a noticeable change in the social tone of S&T policy culture pointed towards glorification of ancient India expressed on various occasions by important people in the government and academia.[26]

Voices on innovation and development were much louder than any of the previous governments. As widely circulated in Indian and international print media,[27] optimists believe that the new government is likely to link up STI agenda with the socio-economic development spectrum. Science, Technology and Innovation Policy 2013 was endorsed. Following the tradition, the prime minister inaugurated the Indian Science Congress Association (ISCA) in January 2015. He reiterated government's commitment and support to S&T research and higher education. He stressed, '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.'[28] This optimistic STI policy discourse resonated quite well in the international print media as well.

As reported by the *Time Magazine* on 18 May 2015, Modi declared, 'My philosophy, the philosophy of my party and the philosophy of my government is what I call *Sabka saath*, *sabka vikas*' (that is to take everybody together and move towards inclusive growth).[29] During later years, the phrase *Sabka vishwas* (every one's trust) was added. Modi went on to reiterate, 'So far as the government is concerned, there is only one holy book, which is the Constitution of India. My government will not tolerate or accept any discrimination based on caste, creed and religion'.[30] On the economic front, *The Economist* on 24 May 2014 indicated a great sense of economic optimism for India with a cover page title 'Strongman. How Modi can unleash India'.[31] *The Economist* went on to observe that

> annual growth was heading towards 10%. India had the ingredients that had made East Asian countries richer: a growing population and rates of saving and investment of over 30% of GDP that would finance factories and roads, lifting the economy's potential. Unlike most East Asian counties, India has never had a strong state, but instead, optimists argued, it had brilliant entrepreneurs who could wheel and deal the country to prosperity.[32]

In 2015, at ISCA, the prime minister identified a number of sectors and projects where the government is likely to focus its policy attention. Government's commitment to S&T for development was evidently loud in the policy discourse. 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 science and technology is reduced to a question of budgets. It is important and I am confident that it will continue to grow.[33]

By 2016–2017, the government identified a number of national flagship programmes and missions,[34] which entail S&T, R&D and technological inputs and resources, including financial and human skills. During the last seven years, some important policy statements were also issued by the government, including the recent Science, Technology and Innovation Policy 2021 draft which is in the public domain for public responses.

The most significant development that has recently come about in 2021 is the setting up of the National Research Foundation with an allocation of ₹50 billion for five years. *Nature* in its editorial on 9 February 2021 rightly called a 'landmark science agency and the most significant development in India's research-funding policy in at least a decade.'[35] It will distribute ₹100 billion or about US$ 1.35 billion every year for research and development with a focus on universities and colleges which will enhance India's research intensity in the university sector.[36] This development certainly comes at a time when there has been a relative stagnation and even decline in the gross expenditure on research and development (GERD) against GDP. India spent 0.69% of GDP in GERD in 2020 compared to 0.84% about a decade earlier. This being the bright spot, the government allocation of research funds for more than half a dozen flagship programmes, such as Digital India, Make in India, Smart Cities and Clean India, is reported to be quite dismal in the last five years. Even though the absolute national GERD doubled over the last decade and a half, it stagnated both during the former and current political regimes at around 0.65%–0.70% of GDP.

The Digital India programme which has taken roots during the previous regime witnessed considerable success as 1,230 million Indians possess digital identities in the form of *Aadhaar* cards, while there are over 1,210 million mobile phones and 560 million internet connections. There have been some finance-related innovations in this programme.[37] The networks created begun to show some impact on development (Dahdah & Mishra, 2020). India entered in collaboration with big firms such as Google and Microsoft for digitising government services.[38] Other flagship programmes are reported to have not made any noteworthy progress in the last few years. Make in India programme was initiated with a vision of increasing manufacturing sector's growth rate of around 12% per annum, create 100 million jobs and ensure the sector's contribution to GDP to 25% by 2022.[39] As reports indicate, several targets were only partially accomplished or most unlikely to do so. Much of the public criticism is on lack of employment opportunities for young, educated classes. India's unemployment rate increased to about 12% by 2020.[40] In the case of Smart Cities programme, the government of India declared in 2015 to make 100 smart cities by 2020.[41] There are numerous reports in the media criticising the concept and targets of Smart Cities. For instance, the Parliamentary Standing Committee on Urban Development has reported that hardly 1.8% of funds allocated for the Smart Cities Mission have been used by April 2018.[42] One would be hard pressed to define, with relevant indicators, the completion of even a single smart city in country in 2021.

The Clean India programme had the main objective to eliminate open defecation completely by 2 October 2019 (150th anniversary of Mahatma Gandhi) and improve solid waste management. The government progress seems to be partially successful as 110 million toilets were constructed from 2014 to 2019.[43] The World Bank supported survey concluded that in February 2019 10% of people in India remain without access to toilets. Another survey in four northern states found that between 2014 and 2018, the non-access to toilets has come down from 70% of the population to 44%.[44] Much of the problem in toilet-building programme remained with making water availability in rural toilets and linking them up with sewage and sanitary techniques. Closely related to the Clean India mission was the National Mission for Clean Ganga which runs 2,525 km through several states of India; the mission is also known as Namami Gange. The main objectives of this mission were to 'ensure effective abatement of pollution and rejuvenation of the river Ganga'.[45] As is well known, cleaning of the Ganges River was indeed a gigantic task attempted and failed by several governments before the present regime. The major science and technical factors attributed to the failure of the mission are river flow data and its interpretation, environmental impact assessment, sludge control, and technical know-how for sewage treatment plants and its technological capabilities.[46] The biggest jolt to the way in which governance and management of the Clean Ganga Mission operate was exposed during the COVID-19 Second Wave surge during April–May 2021.[47] From science point of view, whilst wastewater-based epidemiology is well known among scientists and engineers, the field seems to be completely undeveloped or unknown in the management of the Clean Ganga Mission.[48] The Centre for Science and Environment, New Delhi, in 2018 observed, 'Even after 4 years and an allotment of ₹22,000 crore… flagship programme is far from being a success'.[49]

Liberalisation of agriculture in 2019 with the enactment of three farm laws in the Parliament posed an excessively big challenge for the government in 2020. Recommendations of the National Commission on Farmers chaired by Dr M. S. Swaminathan remained unimplemented for more than a decade since 2005. The present regime has implemented some recommendations, but the farmers are seeking full implementation of recommendations and asking to repeal three farm laws passed by the government. The optimism unleashed by the STI agenda in 2014–2015 with a promise of 'big bang' reforms somehow lost momentum by the beginning of 2021. The public disappointment became quite apparent as several flagship programmes did not bring about any visible technological innovation or progress in boosting Indian economy, particularly on the employment front. A sense of despair and frustration that has come about since the end of 2019 due to COVID-19 lockdowns and national mobility restrictions further accentuated the gloom. The relative failure on the management of COVID-19 and the public distress became a topic of debate in the Indian and international media.

India was able to put together her scientific and technological capabilities in developing two indigenous vaccines and manufacturing two COVID-19 vaccines in a record period of time.[50] However, health-related criticism was directed on the hospital infrastructure, delivery of essential medical supplies and drugs, particularly in the rural areas. The way in which primary public healthcare systems operate and function in India was thoroughly exposed during the pandemic for not meeting basic health needs. The media, which lauded the Modi government earlier in 2014, criticised the government for its handling of COVID-19 crisis in India.[51] *Lancet*, the British medical journal which made critical remarks on the USA for its handling COVID-19, also made similar critical remarks on 'India's complacency over COVID-19'.[52] As Ambassador Satish Chandra, the Vice Chair of Vivekananda International Foundation, a pro-government think tank in New Delhi, observed, 'As the nation reels under the impact of the monstrous second wave of the COVID-19 pandemic Prime Minister Modi has been the focus of much criticism, some justified and some unjustified, for the failure to avert it and to mitigate its adverse impact'.[53]

Concluding Remarks

In 1947, India's life expectancy at birth was around 35–37 years which increased to 69 years in 2020. Under 5 mortality rate was 260 per thousand in 1950, and it came down to 35.53 in 2020. Even though the gulf between rich and poor increased over the years according to Piketty (2020), more than 150 million people were lifted out of poverty during two decades till the onset of COVID-19 crisis. This is where we find the impact of S&T touching the lives of people. With a huge population of nearly 1.35 billion people, India is not dependent on food on outside countries since the 1960s. Notwithstanding criticisms, Green and White Revolutions and our agriculture science community have made immense contribution to develop scientific and technical capacities in agriculture. This is no mean achievement by any standards. However, as M. S. Swaminathan constantly reminds us, India is yet to accomplish the Second Green Revolution and sustainable basis of agricultural systems. Besides, as agriculture productivity improves and labour gets displaced, there is the challenge of finding employment in the industrial sector. Though we lag several developing countries in attaining human development indicators and lot more deserves to be achieved (Dreze & Sen, 2013),[54] there is indeed some positive impact from S&T institutions in the post-Independence period.

India's public research and innovation system including higher education has given her some comparative advantage in 'human capital' in areas such as information technology, biotechnology, pharmaceuticals, automobiles and several other sectors of economy. The IIT brand image became globally noticeable through its alumni impact in the Silicon Valley since the 1990s. There are more than 11,000 IITians who played an important role in the Silicon Valley. This has certainly radiated Indian Software industry (Saxenian, 2005, 2006). India's mission-oriented science agencies in space and atomic energy have earned international recognition, particularly in satellite launches to place India among the few top nations in the world. The same cannot be said about export promotion and economic competitiveness in 'high' technology and 'advanced' technology-based industries, with some exceptions such as software and biopharma. Government protective policies coupled with the long gestation period of import-substitution policies did not contribute to new technological innovation in several industries, particularly 'new technologies', to aid the technological competitiveness of Indian R&D. As Rosenberg (1990, pp. 149–150) comment on reviewing various models of industrialisation refers to Indian situation. This holds good for the present times as well.

> India represents what appears to be a case of low pay-offs from a relatively well-developed and extensive scientific and technological infrastructure. Specifically, it is widely accepted that by comparison with her agriculture research, which enabled India to approach self-sufficiency in food grain production in the late 1970s and early 1980s, industrial research in India has been distinctly disappointing. I believe that this has a lot to do with the extremely tenuous links between the various public and private institutions that are involved in the process.

In the last few years, the 4th Industrial Revolution and its associated technologies have come to play a significant part both in industry- and service-oriented economic spheres. There is a formidable challenge both in strengthening the institutional base to take advantage of these new technologies and at the same time regulating them in sectors where labour force is not severely hit. Major problems of STI policies in the last couple of decades has been on five issues or fronts. There is nothing wrong in the content, assessment of problems or goals glaringly proclaimed. All the successive STI policies were finalised after a lot of official and public deliberations. Our hindsight clearly demonstrates the gap between 'making and implementation' or between theory and practice of science policy in India. India's GERD as proportion of GDP remained relatively stagnant and, in fact, receded from 0.8 in the 1990s to 0.7 in 2020. The gulf between theory and practice can be understood from the fact that successive governments since 2000 have reiterated their financial commitment to spend 2% of GDP for GERD, but it was never implemented. There is a big gap between what governments said *they will do* and what they *actually did* in the past.

India and China in the early 1990s were at similar levels of R&D investment at around 0.7% of GDP. Interestingly, India's science output based on the Institute for Scientific Information database indicated nearly 10,000 papers per year in 1992 compared to less than 6,000 by China (Gaillard et al., 1997, p. 44). In 2020, China overtook India by three times in science output measured by the Science Citation Index database. How did this happen? During these years, Chinese R&D/GDP scaled up from 0.7% to 2.2%. The decade-long goal of scaling up education budget from 3% to 6% of GDP is still a big dream for India. In the HEI sector, even though 65%-70% of total national science output is accounted by universities, they are allocated about 5%-6% of GERD, which however is cornered by some 30 universities. What has come to be known as the *Humboldtian* goal remains to be accomplished. Two decades of relative stagnation in the national R&D and S&T investments, particularly in universities, have drastically aborted their ability to compete at the international level in the World Class University rankings. Whereas China been able to place about a half-dozen universities in the top 100, none of Indian universities figure in this bracket of rankings. Only two universities figure in the bracket of 300-400. The recent initiative in the setting up of the National Research Foundation is yet to be fully implemented:

> The Constitution puts in aspirations for science, but no government over the years in the country has put in 2.4 per cent of the GDP into their budget for R&D. Until India tries to put in the same amount of money as China and other countries are doing, it's simply not going to be competitive. (Ramakrishnan 2020)

Second, India is yet to establish a full-fledged dynamic national innovation system. Different actors and agencies in the S&T system operate in relative isolation to each other with only minimal or sub-critical interaction and networking. President of India in 2010 declared (2010-2020) as the Decade of Innovation, but we have not heard any special schemes or activities after this official pronouncement. In fact, the term innovation came into official STI policy statements only in 2013. After allocating more than 55% of GERD budget to three strategic sectors of space, defence and atomic energy, the remaining 45% of the budget is dispersed to civilian R&D sectors including universities. There is little disagreement among experts that lack of adequate R&D funds has prevented both the input and diffusion end of the R&D spectrum. For instance, about a half-dozen innovation policy measures administered through Technology Development Programs, Technology Missions, National Innovation Foundation, Small Business Innovation Research, among others, from Department of Science and Technology or Department of Biotechnology operate with 'shoestring' budgets compared to other emerging countries. Further, the whole spectrum of incubation and start-up ventures in the academic and university sector also operate at a very sub-critical level of funding. The research and innovation ecosystems, except for the software sector, are underdeveloped. This being the recurring scenario in the last two decades, the situation has begun to improve in the last five years. The business enterprise or private sector has witnessed only a marginal increase from 25% GERD in 2004 to about 36% 2020. R&D tax offsets and saving schemes which operate to promote R&D in the private sector have no penal underpinning to penalise firms which draw tax incentives for R&D but mostly do quality control or calibrations.

Third, small- and medium-sized enterprises, which are an integral part of 60% of India's rural population, yet to receive the attention they deserve from the formal S&T and R&D institutions and relevant policy regimes. The current phase of globalisation demands a new 'rural innovation system' which places the knowledge institutions (i.e., all educational and S&T institutions) at centre stage of rural industrialisation at the district and village levels. Cheap labour and natural resource endowments are unlikely to give us comparative advantage in future. It is only through value addition by means of innovation and technological change that we are likely to sustain the challenges of liberalisation and globalisation. India needs a new paradigm shift of regional and rural innovation systems, wherein universities, colleges and ITIs could play an important role. The social reality of India's informal sector poses a formidable challenge with more than 95% of the total labour force, about 550 million, with the sub-critical level of skills. Ninety per cent of this population is young, but they are 8th class dropouts. How vulnerable this segment of Indian society was is clearly evident from lockdown mobility of migrant labour walking from metropolis regions to their respective villages. Their economic situation will also determine how India shapes up economically in the coming decades. Given the technological and skill challenges, time has come for reinventing the Gandhian 'model' of decentralised technology to unleash the potential of this sector through the agency of grassroots, frugal innovation and inclusive innovation actors (Bhaduri, 2016; Gupta, 2013). Most successful models such as Barefoot College, Honeybee Network and SEWA, among others, deserve scaling up to all India level. Gandhian economic ideas and philosophy seem as much relevant today, in its reformed perspective, as it was in the 1950s (Krishna 2017a, 2017b; Prahalad & Mashelkar, 2010).

Fourth, as Price (1965) reminds us, the science and government relationship in an advisory system and consultative mechanisms is based on checks and balances and at the same time maintaining certain degree of relative freedom and autonomy. This is so important for the scientific elite to stand up and express their objective opinion on various issues and decisions taken by successive governments on S&T policies, setting priorities, budget allocations and so on. Scientific leaders rise to elite positions in the government science agencies because of their contribution within the science community. Our experience suggests that once they rise to elite positions and join government, their status as elite is no more legitimised by their contribution to the advancement of knowledge but by their proximity and nexus to the corridors of power and political authority. This has serious implications for social responsibility of scientists and science–society relations. This is not a recent development, but the democratic space for elite as well as citizen science has certainly shrunken. Critical discourse, particularly counter-viewpoints, dissent, debates and closure through consensus are essential ingredients at the very heart of making STI policies. Disappointing to note that we are losing this democratic space. As Nobel Laureate Ramkrishnan (2020) points out, 'I personally believe that science flourishes where there is a real freedom of thought, opinion and minimal ideological interference. Although the autonomy of science remains an open question'.[55] It is high time that that top scientific elites should be exempted from civil service rules which bind and curtail their freedom of speech and scientific autonomy. Different types of problems we have seen in the case of elite science academies. As leading Indian scientists such as S. Bhagavantam, P. Balram and Gautam Desiraju pointed out at different times, these academies maintain neutral and muted stance over serious science and society problems.

Our fifth issue led us to introspect research culture, excellence and autonomy in research laboratories and universities. As reported in media, journals and by various commentators, there is a sense of despair, some sort of fear and lack of commitment in our research institutions. Problems of social exclusion in some leading universities begun to disrupt academic cultures (Subramanian, 2015). These are very serious problems which deserve attention both by our scientific elite in the government and the ministers in education and science departments before it is too late to repair. The degree of political interference seems to have increased over the years in these institutions which will prove counterproductive to creativity and advancement of knowledge. We need to look back into some of our excellent institutions such as TIFR, BARC and space research labs to understand how talents and excellence are maintained. True to his philosophy of building excellence in research groups around outstanding scientists, Homi Bhabha executed his vision of building talents at TIFR. Similar benchmarks seem to prevail in some of our space research labs and defence labs.

Interestingly, Dr A. P. J. Abdul Kalam drew attention to 'cultural of excellence' to produce high-quality innovation. His notion of culture invariably included autonomy and creativity in carrying out research with a commitment. No other criteria other than the merit and contribution to knowledge mattered in these excellent institutions. When we examine the Indian research landscape from a macro-sociological lens, one feature that stands out to research observers is few islands of excellence and vast 'hinterlands' of research with mediocrity. India demonstrates a case of underutilisation of her scientific potential and even a relative failure to scale up and expand excellent institutions and laboratories. No society can progress with these stumbling blocks. China with centralised administrative control has given considerable autonomy to universities and Chinese Academy of Science laboratories in the last 15 years. The 'Thousand Talents Program' has immensely benefited that country in cultivating talents through brain gain and brain circulation. Promoting collegial culture, international collaboration and congenial research climate within research groups and universities led China to emerging as a leading science nation in 2020 (Yi et al., 2021).

At 75, when a country introspects and looks back, it certainly needs some benchmarks. What better than China with a similar population size, as both had their beginning as agrarian economies in the 1940s. As we enter the third decade of the 21st century, the rise of China at the global level should not be construed merely as an economic powerhouse but is intimately intertwined with its rise as a hegemonic power. China's GDP grew at an average of around 9% in the three decades after 1979 reforms, whereas the world's GDP grew at around 2.5%-3%. Comparative figures for the Indian growth rate for the same period average between 4.5% and 5.5%.[56] China's GDP has more than quadrupled over a period of 15 years, touching about 15 trillion US$, next after USA, compared to less than 3 trillion US$ of India in 2020. Chinese economy is about five times Indian economy by various counts. India stands at US$ 2,000 per capita compared to China's US$10,000. Its foreign currency reserves are more than 3 trillion US$ compared to 1.3 trillion US$ of Japan and mere 500 billion US$ of India in 2020. In fact, China's economic hegemony and military clout and its overtones, in the last few years, have been possible due to S&T capacities it has developed. How did this happen? STI policies played a very significant role in strengthening the Chinese national innovation system that enabled the rise of China. It is currently the second highest investor in the global R&D, after the USA, and it has emerged as the world's leading knowledge producer. Sadly, there is no more a discourse of 'India catching up' as the rise of China left us far behind. It is here that India can draw a lesson or two in the art of theory and practice of science policy.

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NOTES

1. This long report is not meant for the comprehensive coverage of all developments in science policies or science and society relations.
2. The first attempt to develop a national plan for India came up in 1938. In that year, the Congress President Subhash Chandra Bose had set up a National Planning Committee with Jawaharlal Nehru as its president. However, the reports of the committee could not be prepared and only for the first time, in 1948-1949, some papers came out.
3. Hill to Bhatnagar, 11 May 1951, Hill papers, Cambridge AVHL II (as cited by Kumar [2001], footnote 89).
4. These quotes of Nehru have been in circulation for quite some time now in S&T study writings. For the first part of this quote, see Science Reporter (1964), *1*(7– 8), July–August. The second part is from Nehru (1958).
5. When India's first Scientific Manpower Committee was set up in 1947, another important committee set up during the end of the colonial regime—the Sarkar Committee—had submitted its report in 1946. This Committee recommended the setting up of no less than four higher technical institutions. The origins for the creation of five Indian Institutes of Technology can be traced to these events.
6. Already dozens of scientific enterprises such as the Geological Survey of India were created during the colonial period; see Anderson (2010).
7. S. S. Bhatnagar in CSIR, Homi Bhabha in atomic energy, J. C. Ghosh and P. C. Mahalanobis in the Planning Commission and D. S. Khothari in the defence-related organisation were some of the elite who were close to Nehru.
8. In fact, immediately after Independence, an Advisory Committee for Co-ordinating Scientific Work (ACCSW) was set up in 1948 with Nehru as the chairperson and S. S. Bhatnagar as the secretary. The Department of Scientific Research was set up in 1948. ACCSW lasted until 1956 when the Scientific Advisory Committee to the Cabinet (SACC) replaced it. SACC, through Homi Bhabha and Nehru, was instrumental in the 1958 Scientific Policy Resolution. SACC was reviewed by the Education Commission during 1964–1966, and later, in 1968, it was replaced by a broad-based Committee on Science and Technology (COST) under the chairmanship of Dr B. D. Nagchowdhury. This lasted until 1970 when the National Committee on Science and Technology (NCST) was set up under the chairmanship of C. Subramanian. NCST was entrusted with India's first S&T plan. Even though several of these advisory bodies were created by drawing scientists from various organisations and agencies, only a few elite scientists wielded power who were close to the political leadership both during Nehru's era and Mrs Gandhi's era until the early 1980s.
9. C. V. Raman was present at the inauguration of CSIR's Central Food Technological Laboratory in 1950 at Mysore. It is said that Raman described the rapid expansion of CSIR laboratories under S. S. Bhatnagar as the 'Nehru–Bhatnagar Effect'.
10. B. P. Pal was no ordinary scientist. He served as a director of the Indian Agricultural Research Institute in Delhi and as the first director general of the Indian Council of Agricultural Research. He was an elected fellow of the Royal Society. He did his doctoral work at Cambridge University.
11. https://www.statista.com/statistics/1169800/india-number-of-diary-cooperative-societies-by-region/
12. Despite its successes, the Green Revolution came under severe criticism during the 1970s for ecological and socioeconomic reasons. The major criticism was that the high yields could only be obtained under certain ideal conditions of irrigation, fertilisers and monocultures. The main prerequisite was a rich soil.

13. For the first time since India's Independence, a party other than the Congress Party came into power for about two years between 1977 and 1979. The Janata Party had several Gandhians who emphasised small technologies and rural- based development programmes. However, it could not sustain power for a long time.
14. Some of these involve not only technological but organisational/systemic innovations. For more such examples, see Munshi (2018).
15. The Chipko movement led by Sunderlal Bahuguna and Chandi Prasad Bhatt which was very successful in mobilising people against the felling of trees in the Garhwal region is an example. Later, this movement led by Bahuguna was also successful in stalling the Tehri Dam Project on ecological grounds. The Narmada Bachao Andolan led by Medha Patkar and Baba Amte in criticising the World-Bank-funded dams is another example of civic culture, relevant to S&T policy issues, coming to the centre stage of politics.
16. See https://vidyaashram.org/patriotic-people-oriented-science-and-technology-ppst/
17. See https://rightlivelihood.org/the-change-makers/find-a-laureate/medha-patkar-and-baba-amte-narmada-bachao-andolan/
18. In five years, two elections were held, and three governments changed.
19. 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'. 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'. See Friedman (2005).
20. Currently postgraduate programmes in biotechnology are offered by 51 universities in India.
21. See https://hbr.org/2010/07/innovations-holy-grail
22. The credit for designing STIP goes to N. Vittal who played an important part in the development of India's software sector in the 1990s. He served in atomic energy, electronics departments and chaired the Telecom Commission.
23. Tata Motors in the 1990s emerged as the first auto firm to have developed and launched vehicles including engines based on indigenous technology. It entered the passenger vehicle market in 1991 with the launch of the Tata Sierra, a multi utility vehicle. Soon after it launched Tata Estate in 1992 (a station wagon) and the Tata Sumo in 1994. The famous Indian indigenous car, Indica was launched in 1998. It is the first indigenous passenger car. The firm that has mastered indigenous vehicles, particularly Jeeps is Mahindra and Mahindra company. Wiley jeep in India since late 1940s is quite famous and they have the history of defence supplies of this vehicle. Mahindra produces a number of auto vehicles, including MUVs, LCVs and three-wheelers. It has produced over 20 models of cars, including larger, multi-utility vehicles like the Scorpio and the Bolero. Mahindra launched its popular and widely advertised vehicle SUV, XUV500, code-named as W201 in September 2011.
24. See https://www.isro.gov.in/ and https://www.isro.gov.in/about-isro/antrix-corporation-limited. Also see https://www.isro.gov.in/list-of-spacecrafts. See also Pallava Bagla and Subhadra Menon (2008) for detailed developments on the Moon and Mars missions which began specifically since the 1990s.
25. The information and details of projects drawn from Krishna (2016b).
26. Hindu nationalists have for long promoted and propagated the belief and a viewpoint that many discoveries of modern science and technology were known to ancient India. However, all of a sudden on 25 October 2014 when the prime minister addressed a gathering of doctors and other professionals in Mumbai, he endorsed the Hindu nationalist viewpoint. He said,

    > We can feel proud of what our country achieved in medical science at one point of time. We all read about Karna in the Mahabharata. If we think a little more, we realise that the Mahabharata says Karna was not born from his mother's womb. This means that genetic science was present at that time. That is why Karna could be born outside his mother's womb.

    The prime minster went to further observe that, We worship Lord Ganesha. There must have been some plastic surgeon at that time who got an elephant's head on the body of a human being and began the practice of plastic surgery. There must be many areas in which our ancestors made big contributions. Some of these are well recognised. If we talk about space science, our ancestors had, at some point, displayed great strengths in space science. What people like Aryabhata had said centuries ago is being recognised by science today. What I mean to say is that we are a country which had these capabilities. We need to regain these. (see https://www.theguardian.com/world/2014/oct/28/indian-prime-minister-genetic-science-existed-ancient-times)

The change in the social tone of S&T policy culture was reflected in the Indian Science Congress sessions which are held annually in India. Speaking at the 106th session, Dr G. Nageshwar Rao, the Vice Chancellor of Andhra University, in a paper presented said, 'We had 100 Kauravas from one mother because of stem cell and test tube technology'. Dr Harsh Vardhan, the current minister of Science and Technology, claimed that scientist Stephen Hawking once said that the Hindu Vedas had a theory which trumped Einstein's theory of relativity. The minister made this remark while addressing the inaugural session at the 105th Indian Science Congress in March 2018. In January 2018, Shri Satyapal Singh, the minister of State for Human Resource Development commented that 'I have a list of around 10 to 15 great scientists of the world who have said there is no evidence to prove that the theory of evolution is correct'. He stated that school curriculums need to change to reflect this. He added, 'since man is seen on earth, he has always been a man. Nobody, including our ancestors, in written or oral, said they ever saw an ape turning into a human being'. See https://caravanmagazine.in/science/false-scientific-claims-modi-first-term.

27. See the *Time Magazine* dated 18 May 2015 which showcased Modi on the front page with a caption 'Why Modi Matters' and 'How Narendra Modi wants to change India'; see https://time.com/magazine/us/3849941/may-18th-2015-vol-185-no-18-u-s/. See also *The Economist* dated 24 May 2015. https://www.economist.com/briefing/2014/05/24/modis-mission
28. See https://www.narendramodi.in/text-of-pm-shri-narendra-modis-address-at-the-102nd-indian-science-congress-2924
29. See https://time.com/magazine/us/3849941/may-18th-2015-vol-185-no-18-u-s/
30. ibid
31. See https://www.economist.com/weeklyedition/2014-05-24
32. See the report from Mumbai on Reviving India's Economy, Modi's mission | The Economist. https://www.economist.com/briefing/2014/05/24/modis-mission
33. See Text of PM Shri Narendra Modi's address at the 102nd Indian Science Congress (3 January 2015). https://www.narendramodi.in/text-of-pm-shri-narendra-modis-address-at-the-102nd-indian-science-congress-2924
34. Flagship programmes include Digital India, Skill India, Smart Cities and Urban Development and Clean India. Policies include the Startup India Action Plan (2016), Technology Vision 2035 (2016) and National Education Policy 2020.
35. https://www.nature.com/articles/d41586-021-00327-1
36. However, some science journalists have expressed doubts about the funding allocated to National Research Foundation as the Parliamentary Committee on S&T indicates that it will be funded from existing budgetary allocations in some science departments (Sharma, 2021).
37. Projects such as Aadhaar, Smart Cities Mission, BHIM UPI, RuPay, GSTIn, GeM (Government e-Marketplace), DigiLocker come under the aegis of the Digital India programme. See https://economictimes.indiatimes.com/small-biz/startups/newsbuzz/a-refreshed-digital-india-programme-will-play-critical-role-in-the-pursuit-of-5-trillion economy/articleshow/70067053.cms?from=mdr See also https://www.dqindia.com/5-years-of-digital-india-how-far-have-we-come/
38. 'Google Inc. collaborated with the Indian Railways to set up free Wi-Fi services at 100 major railway stations in India. Google worked in tandem with RailTel, an Indian PSU, which deals with optic-fibre networks along railway tracks in India which will be used to provide these Wi-Fi services. Microsoft Inc. has worked with the Government of India on the Digital India Initiative, with their most recent contribution being the 'Digital Governance Tech Tour'. This is a national programme

that helps deliver critical AI and intelligent cloud computing skills to government officials in charge of IT across the nation'. https://www.dqindia.com/5-years-of-digital-india-how-far-have-we-come/
39. https://www.makeinindia.com/about; https://www.thehindu.com/opinion/op-ed/why-make-in-india-has-failed/article30601269.ece; https://www.businesstoday.in/current/economy-politics/unemployment-rate-shoots-up-to-12-month-high-of-119-in-may/story/440736.html
40. https://www.businesstoday.in/current/economy-politics/unemployment-rate-shoots-up-to-12-month-high-of-119-in-may/story/440736.html
41. https://www.india.gov.in/spotlight/smart-cities-mission-step-towards-smart-india
42. https://www.business-standard.com/article/economy-policy/here-s-how-bjp-s-flagship-smart-cities-mission-echoes-failures-of-upa-govt-118040300112_1.html
43. https://edition.cnn.com/2019/10/05/asia/india-modi-open-defecation-free-intl-hnk-scli/index.html
44. https://edition.cnn.com/2019/10/05/asia/india-modi-open-defecation-free-intl-hnk-scli/index.html
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48. https://www.natureasia.com/en/nindia/article/10.1038/nindia.2021.75
49. https://www.downtoearth.org.in/coverage/pollution/namami-gange-5-reasons-why-ganga-will-not-be-clean-by-2020-61891
50. Bharat Biotech has developed indigenous vaccine in collaboration with Indian Council of Medical Research which is being administered to millions in India along with Astra-Zeneca vaccine manufactured by Serum Institute. On 21 August 2021, a *Reuters* report indicates that DBT and Zydus Cadila have come with DNA-based COVID-19 vaccine and approved by the Indian drug authority (https://www.reuters.com/business/healthcare-pharmaceuticals/india-approves-zydus-cadilas-covid-19-vaccine-emergency-use-2021-08-20/). See also Mande (2020).
51. https://www.indiatoday.in/coronavirus-outbreak/story/india-wasted-early-successes-in-managing-covid19-pm-modi-actions-inexcusable-vaccination-drive-botched-lancet-1800465-2021-05-09
52. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)00993-4/fulltext (for observations on India) and see also https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)00318-4/fulltext (for observations on the USA).
53. https://www.vifindia.org/article/2021/may/11/modi-government-an-evaluation%20%20
54. Dreze and Amartya Sen in their book at length argue how India falls behind even South Asian countries. The situation does not seem to have improved any better since this book and even worsened during the pandemic situation.
55. https://economictimes.indiatimes.com/news/science/science-flourishes-where-there-is-freedom-of-thought-says-nobel-laureate-venki-ramakrishnan/articleshow/73279136.cms?from=mdr
56. Thus, while growth averaged 4.4% a year during the 1970s and 1980s, it accelerated to 5.5% between the 1990s and the early 2000s, and further to 7.1% in the past one decade. https://www.weforum.org/agenda/2018/04/india-s-remarkably-robust-and-resilient-growth-storys

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