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India

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India is now counted among the leading emerging economies of the world with a vast network of science and technology (S&T) and research and development (R&D) institutional structure. It is among the top ten nations of the world for Science Citation Index (SCI)–based scientific publications for the decade 1996–2006 and second among BRICS countries. The total number of papers almost doubled from 20,514 in 1996 to 40,062 in 2006. India spent around 1.13 per cent of GDP for R&D as a whole in 2007. India's national aggregate gross expenditure on research and development (GERD) was about INR 413 billion (US$ 29.5 billion) in 2007–2008. A dominant proportion of GERD, around 68 per cent, is met by the government sources and 30 per cent from the business enterprise sector. In purchasing power parity (PPP) terms it works out to be about INR 1,660 billion. India ranks higher as compared to countries such as Brazil, Mexico and South Africa but is behind China which spent US$ 110 billion in R&D in PPP terms in 2006, and the United States at almost US$ 291 billion in 2006.

India has been experiencing a high growth rate of GDP which was 9 and 9.2 per cent for the two years 2005–2006 and 2006–2007, respectively, with an average of 6.9 per cent for the seven-year period from 2000–2001 to 2006–2007. Much of India's recent growth is driven by innovations in high technology manufacturing in drugs and pharmaceuticals, in skill-intensive services in software, telecommunications, engineering, automotive, gems and jewellery sectors, and to a lesser extent in medical services. Science and technology developments in space technology with capabilities to launch commercial satellites and un-manned missions to the moon, nuclear technology, pharma research capabilities in drug discovery and commercialisation, information and communications technology (ICT) software, biotechnology in health and agriculture, and the emerging capabilities in automotive research and telecommunications have contributed to the country's emergence as an important 'knowledge power' from Asia.

India's national system of innovation (NSI) is constituted by: (*a*) public research system of national laboratories under major science agencies and in-house laboratories in public sector enterprises; (*b*) institutions of higher learning and universities; (*c*) business enterprises both local and foreign; (*d*) civil society agencies and bodies; and (*e*) institutions and policies of government which formulate and implement social, economic, monetary and science, technology and innovation policies among others.

The current structure of India's NSI as we see it today has evolved from the post-independence period after 1947. State mediation and the role of government support in the development of science, technology and higher education has been a crucial aspect of India's current NSI. It has its roots in the 1950s when political leadership led by Jawaharlal Nehru had given top priority to science and technology institution building. The Scientific Policy Resolution (SPR) of 1958, India's first S&T Plan of 1974; and Science and Technology Policy Statements in 1983 and 2003 recurrently emphasised building national and local capacities in science and technology and attaining self-reliance in some crucial sectors of the economy.

This chapter on the role of the state in the evolution of India's NSI is specifically conceptualised and structured from a historical perspective covering three different phases from 1947 to the current era. In approaching the role of the state in the evolution of NSI in India, the theoretical framework outlined here selectively draws on three sets of literature, namely, on NSI, S&T policies and those that specifically deal with state mediation through S&T policies. As noted, this chapter on the role of the state in the evolution of NSI in India adopts a historical perspective. Since India underwent a long period of British colonialism, much of modern India's policy of state mediation in science and technology for industrialisation and development is shaped from the roots of its colonial struggle for not only political independence but technological independence. For this reason, we begin looking into the role of state mediation from this perspective in the upcoming section.

Role of State and NSI: Evolution in Three Phases[1]

> Establishing a Sanskrit School under Hindu pundits . . . can only be expected to load the minds of youth with grammatical niceties and metaphysical distinction of little or no practical use . . . But as the improvement of the native population is the object of the government, it will consequently promote a more liberal and enlightened system of instruction, embracing Mathematics, Natural Philosophy, Chemistry, Anatomy, with other useful sciences, which may be accomplished with the sum proposed by employing a few gentlemen of talent and learning, educated in Europe, and providing a college furnished with necessary books, instruments and other apparatus (*Raja Rammohan Roy's Letter to the Governor General, 1823*).

> Indians are incapable of any original work in natural science . . . If indeed it exists as yet in this variety of human race . . . so let us exercise a little discretion with our weaker brethren and not expect them to run before they can walk (*H. B. Medlicott, Head, Geological Survey of India, 1880*).

The role played by the state in the evolution of science, technology and innovation policies and institution building is intimately connected with the colonial context. As is well-known, India was under colonial rule for over three centuries. British colonialism is generally seen by Indian historians to have impacted on Indian politics, economy and society in both constructive as well as destructive or dysfunctional ways and manifestations. In the domain of language and teaching of science and technology, Indian intellectual elite argued for modern science and technology courses to be introduced in colleges with an emphasis on English rather than Indian classical languages as argued by Raja Rammohan Roy from as early as the 1830s (see earlier quote). In several ways Indians were successful in higher education and in the introduction of science and technology courses.

The first modern universities in India which introduced English language teaching were established as early as 1857 in Madras, Calcutta and Bombay. In the domain of science and industry, whilst the British created over a dozen colonial scientific enterprises such as railways, geology, trigonometry, surveys, public works, botanical gardens, among other sectors, the structure and functions of these scientific enterprises came to be defined in terms of 'colonial science'. There was a division of labour between centre (Britain) and periphery (colony). While the former was assigned the role of scientific synthesis, the latter was relegated more towards survey research and data gathering rather than professionalisation of science and technology. Above all, there was considerable discrimination in the organisation and recruitment of scientists to high positions as the quote of H. B. Medlicott, head of the Geological Survey in the 1880s reflects.

As argued elsewhere, the period from the late 19th century marks a break with colonial science (Krishna 1997a). This period is associated with the creation of a series of support structures in science and technology. Parallel to colonial science, there emerged a stream of early science policy efforts and its role in nation-building in the form of 'national science' during the 1880s and 1940s. This was a phase where elite Indian scientists such as M. N. Saha, P. C. Ray, J. C. Bose, Mahenderlal Sircar, among others, forged a close alliance with political elite (Jawaharlal Nehru and M. K. Gandhi, etc.) towards formulating science policies for nation-building, creating a local national science and technology institutional base including educational institutions in parallel to colonial science enterprises. A number of basic research–oriented science institutions and academic groups in universities and colleges, which were established outside colonial science enterprises, gave an identity to Indian science in the international scientific domain during the 1920s and 1940s. The most significant were the two Nobel Prizes given to Indians in literature and physics by the 1930s.

National or independence movements against colonial powers have taken root in various other Latin American and African countries. However, the specificity of the Indian case is that the intellectual struggle against colonial science policies led to the creation of a local and national base in science institutions that worked towards the formation of an Indian science community which became an integral part of the political struggle as well (Krishna 1997a). Thus even before independence in 1947, the struggle against colonialism and colonial science led to a number of conceptual frameworks and views such as the role of science and technology in nation-building, self-reliance in science and technology, and above all, the importance of modern science and technology institutions in the development of the country.[2] All these views and frameworks on science policy for development, which were the result of the pre-independence struggle, came to play a central part in the state policies which made science and technology important factors for development led by Jawaharlal Nehru — India's first Prime Minister — in 1947 (Krishna 1997a).

We will explore the role of the state in the evolution of the NIS in three phases. The first phase is conceptualised to begin with India's independence in 1947 lasting up to 1970. The second phase began in the early 1970s and lasted until the late 1980s. The third begins with new economic reforms and the liberalisation era in 1991 and continues into the 21st century.

1947–1970: Policy for the sciences and self-reliance

This is the phase in which the role of Nehru and his initiatives in science policies dominated and has left a lasting impression on the development of science and technology in the country, which even reverberates currently in its various manifestations. From the perspective of a science policy framework, this period reflects a phase of 'policy for the sciences' during which the main emphasis was on creating a basic infrastructure for science and technology in the country including the expansion of the university sector for the supply of required S&T human resources. Nehru's views and a framework on science policy with its roots in the pre-independence period resonated unbounded optimism over science and development and assigned a major role for state mediation even before independence which is evident from two important observations cited here. Speaking at the Indian Science Congress in 1938 he stressed (Krishna 1997a: 237):

> It is science alone that could solve these problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running waste of a rich country inhabited by starving people.

The Congress Party's manifesto which was issued for the first national government declared in 1945 underlined the prime role of the state in science and the development of the country (Krishna 1997a: 237):

> Science in its instrumental fields of activity has played an ever increasing part in influencing and moulding human life . . . 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.

While Nehru obtained the party's legitimation for assigning an important role of state mediation and governance of science and technology development, the government led by him after 1947 further legitimised the role of the state as it accepted the recommendations of the A. V. Hill Committee Report submitted in 1944. According to this report and the model of science advocated, all science and technology institutions and science agencies including national laboratories were to be placed under the overall control of a government body or ministry.[3] Nehru created the Ministry of Scientific Research and Cultural Affairs in 1948 and took on the portfolio himself. The building of S&T infrastructure with new universities, science agencies and national laboratories came under the control of this ministry. Towards establishing infrastructure and building institutions in S&T, Nehru deemed it very important to bring scientific elite and science leadership closer to the government. He used his annual full-day attendance at the Indian Science Congress every year after 1947 to strengthen his association with the scientific elite and science community where he issued major science and technology policy statements and intentions of the government.[4] As early as 1948, addressing the annual Indian Science Congress, he called upon scientists by observing that, 'in India there is a growing realisation of this fact that the politician and the scientist should work in close cooperation'.

In contrast to Gandhi's religious and rural focus on development, Nehru's modern, liberal image and his explicit support and orientation towards modern science and technology development made him a 'messiah' of Indian science and the science community right from the beginning. The Gandhian model did have some influence in this phase but could not gain legitimacy as an alternative. This close 'alliance between science and politics', inaugurated by Nehru, which is in a large measure relevant even today, played an important part in building science and technology institutions. Nehru's close alliance with the science elite extended to S. S. Bhatnagar in industrial research, Homi Bhabha in atomic energy establishment, P. C.

Mahalanobis in the Planning Commission and D. S. Kothari in the defence establishment.

The period between 1948 and the 1960s, during the development phase of a policy for the sciences, witnessed rapid expansion of major science agencies such as the Council of Scientific and Industrial Research (CSIR) which has a network of 38 national laboratories currently in physical, biological, mechanical, and chemical sciences.[5] Department of Atomic Energy (DAE), Defence Research and Development Organisation (DRDO), Indian Council of Agriculture Research (ICAR), and Indian Council of Medical Research (ICMR) are some of the other major science agencies created during this phase. In the higher education sector, from 30 universities in the late 1940s, about 95 universities including specialised institutions such as the five Indian Institutes of Technology (IITs) were established in this phase.

Table 4.1: *Growth of Major S&T Institutions in Terms of Funding and Manpower in India*

	R&D Budget (US$ PPP)			*S&T Manpower*			*No. Lab./ Ins.*
Scientific Agency	*1958–59*	*1965–66*	*1972–73*	*1958–59*	*1969–70*	*1972–73*	*1970*
DAE	16.3	42.1	33.5	1067	7441	7910	4
CSIR	10.7	29.7	32.8	3512	9515	8979	34
DRDO	3.1	20.4	33.8	1500	7003	9691	37
ICAR	7.8	13.4	39.8	1500	8400	5023	24
ICMR	1.07	2.2	3.2	1001	1585	1021	8
Space (DoS)	-	-	24.3	-	-	3694	
Subtotal	38.97	107.8	1257.2	8580	33944	36318	107

Source: Rahman et al. (1973: 44, 116–17); Department of Science and Technology (1975: 5).

Note: DAE: Department of Atomic Energy; CSIR: Council of Scientific and Industrial Research; DRDO: Defence Research and Development Organisation; ICAR: India Council of Agriculture Research; ICMR: Indian Council of Medical Research; and DoS: Department of Space.

Compared to the main locus of Indian science in the academic settings during the 1920–1940s, the expansion and locus of science in the post-independence period shifted to these mission-oriented science agencies under government control. The post-war 'science push' or innovation chain model triggered considerable optimism in the organisation of science under the leadership of Nehru and closely associated elite scientists like Homi Bhabha, S. S. Bhatnagar, Mahalanobis, J. C. Ghosh, among others. The spirit of policy for the sciences perspective was clearly reflected in the Scientific Policy Resolution (SPR) passed in the Parliament in 1958 which in fact provided legitimation for the expansion of public sciences in India for the next three decades or so. The aims of the scientific policy were:[6]

- to foster, promote, and sustain, by all appropriate means, the cultivation of science, and scientific research in all its aspects — pure, applied and educational;
- to ensure an adequate supply, within the country, of research scientists of the highest quality, and to recognise their work as an important component of the strength of the nation;
- to encourage, and initiate, with all possible speed, programmes for the training of scientific and technical personnel, on a scale adequate to fulfil the country's needs in science and education, agriculture and industry, and defence;
- to ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity;
- to encourage individual initiative for the acquisition and dissemination of knowledge, and for the discovery of new knowledge, in an atmosphere of academic freedom; and,
- in general, to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge.

The SPR clearly reflected the perspective of the policy for the sciences. Implicit in it was the view that once the infrastructure for modern S&T and congenial conditions for R&D are created, personnel trained and institutionalisation of science is completed, the S&T system will feed into solving the developmental problems of India and tackling poverty. What was also stressed was the need to develop indigenous technological capabilities. As the explanatory note of SPR drew attention, building science and technology infrastructure can make up for shortages in raw materials by technology-based alternatives and by providing skills which can generate revenues in exports. The vision contained in the SPR clearly pointed out that a country of India's dimensions aspiring to become industrialised will have to pay a heavy price for importing science and technology in the form of plant and machinery, professional personnel and technical consultants. Hence, the SPR argued for building infrastructure in S&T which can greatly reduce the drain on outward capital flow during the early and critical stages of industrialisation. The perspective of self-reliance resonated quite forcefully in the Third and Fourth Five Year Plans stretching from 1961–1966 and 1967–1974, respectively:

> a basic objective in the strategy of development is to create the conditions in which dependence on external assistance will disappear as early as possible (and) replacement of imports is essentially a question of developing the necessary capacity for production within the country (Planning Commission 1961: 26–27).

> the (Fourth Plan) seeks to enlarge the area of self-reliance in terms of financial resources and technological *inputs* (Planning Commission 1972: vi–vii).

In all its ramifications, the policy for the sciences, which mainly focused on building infrastructure and strengthening state control, existed in relative isolation to economic and industrial policies in this phase up to 1970. These policies mainly emphasised a thrust towards self-reliance and import-substitution and highly regulated controls on import of technology and private foreign investment. The 1962 conflict with China and subsequent conflicts in 1965 and 1971 with Pakistan further reinforced the state commitment towards self-reliance in technology, and the state's aversion of import dependence basically meant a further thrust to import-substitution in industry as well as its technological requirements. The Fourth Five Year Plan, referred to earlier, had specific directions for the expansion of public sector enterprises:

> [T]he public sector should increasingly base itself on domestic know-how. The public and private sector have both been ready to look for foreign collaboration and not only for financial but for technological resources. We should rely more and more on our own machinery and technical know-how even though it may entail some initial risks and difficulties.
>
> Self-reliance in the technological sense implies the existence and effective functioning of indigenous organization for design, construction and engineering projects as well as capability for design and development of machinery, equipment and instruments indigenously manufactured (Government of India 1972: vi–vii and 48).

The command public sector enterprises in railways, fertilisers, steel, pharmaceuticals, among other industries, followed these import-substitution and self-reliance policies and made efforts to develop technology through promoting in-house R&D units. India had to depend on technology transfer from abroad for a range of industrial sectors in the 1940s and 1950s but by the mid-1960s onwards the policies turned towards tightening import of technology in favour of developing indigenous technological capabilities in these sectors. Almost all these sectors established in-house R&D units or laboratories towards this end but India did not evolve any national science and technology plan until the early 1970s and only in the early 1980s did India issue her first technology policy statement. Arguably, these two documents also reiterated India's commitment to the long-standing 'inward looking' policies of import-substitution and self-reliance. In large measure, these economic and industrial policies de-emphasised export promotion and the liberal import of technology. The government created the Monopolies and Restrictive Trade Practices (MRTP) in 1969 and the Foreign Exchange Regulation Act (FERA) in 1973 to control foreign inflow of firms and liberal financing. Banks were nationalised in 1969 which were directed by the state to focus on and support small-scale industry; within a short period of 10 years from the 1960s to 1970s items reserved for small firms increased from 51 to 147 (Sridharan 1995). Among the various policy measures introduced in this phase, the most significant one, which was designed to strengthen India's technological capabilities while fostering import-substitution and self-reliance, was the 1970 Patent Act. It was amended in 1970 which then reduced the duration of patents from 16 to 14 years, and seven years for food- and drug-related patents. For over three-and-a-half decades, India was able to increase her pharmaceutical technological base and capabilities through reverse engineering in drug development and commercialisation.

1970s to 1990s: Science and technology in policy and redefining self-reliance

The efforts invested in building infrastructure in science and technology institutions and higher education continued in this phase with renewed emphasis. The second layer of science agencies such as the Department of Space (DoS), Department of Electronics (DoE), Department of Environment (DoEn), Department of Biotechnology (DBT), and Department of Ocean Development (DoD) were created in this phase (see Table 4.3). In higher education, another 55 universities were established bringing the tally of total universities to around 145 by the end of this phase in 1990. Compared to China, India had a much larger visibility in the international scientific world of publications throughout from 1980 to the early 1990s. For instance, in 1990 India published 10,103 science publications measured in SCI, whereas, China published 6,509.[7] As Table 4.2 shows, India's stock of human resources increased more than four times between 1970 and 1990 from 1.147 to 4.811 million.

Table 4.2: *Growth of the Total Scientific and Technical Manpower, 1950–2000*

Category of Personnel	*Stock (Thousand)*							
	1950	*1955*	*1960*	*1965*	*1970*	*1980*	*1991*	*2000*
Engineering Degree Holders	21.6	37.5	62.2	106.7	185.4	221.4	546.7	969.5
Engineering Diploma Holders	31.5	46.8	75.0	138.9	244.4	329.4	873.9	1456.0
Science Postgraduates	16.0	28.0	47.7	85.7	139.2	217.5	482.0	767.1
Science Degree Holders	60.0	102.9	165.6	261.5	420.0	750.5	2430.3	3837.7
Agriculture Postgraduates	1.0	2.0	3.7	7.7	13.5	96.5*	168.4*	231.2*
Agriculture Degree Holders	6.9	11.5	20.2	39.4	47.2	–	–	–
Medicine Degree Holders	18.0	29.0	41.6	60.6	97.8	165.4	310.3	403.4
Total	155.0	257.7	416.0	700.5	1147.5	1780.7	4811.6	7664.9

Source: Department of Science and Technology (1999, 2002).
Note: *Including graduates.

Table 4.3: *Public R&D Expenditure of Major Science Agencies, 1990–1991, 1998–1999 and 2000–2001*

Figures in US$ (PPP)

Science Agency	*1990–1991*	*1998–1999*	*2000–2001*	*2004*
DRDO (Defence)	756,66.0	2421.2	2129.26	1952.85
DOS (Space)	429.1	1595.2	1728.73	1691.42
DAE (Atomic Energy)	306.1	880.7	NA	2715.00
ICAR (Agriculture)	306.8	888.4	1577.68	1079.28
CSIR (Industrial Research)	276.7	750.8	924.00	811.42
MOEF (Environment & Forest)	180.0	397.89	894.73	NA
DST (All S&T)	133.1	314.7	769.89	840.00
DBT (Biotechnology)	45.8	99.47	148.94	195.00
DOD (Ocean)	30.8	89.26	177.68	142.14
ICMR (Medical)	49.4	90.73	154.73	705.71
MIT (ICT)	36.6	65.36	80.00	358.51
MNES (Non-Conventional Energy)	17.7	9.47	NA	NA

Source: Department of Science and Technology (2002, 2004), R&D Statistics; for 2004 see India's Emergence as Global R&D Centre, Working Paper R2007:012, Swedish Institute of Growth Policy Studies, Sweden.

This phase characterises a trend of science and technology policy and redefining self-reliance. The former clearly reflected the inputs of science and technology and its expectations in the policy as well as political and economic processes of development. Various processes of S&T planning beginning with the creation of the National Commission on Science and Technology (NCST) in 1972 and the launching of India's first Science and Technology Plan (1974–1979) which made explicit reference to attaining indigenous technology capacities in various sectors differentiate the earlier phase of science policy. For the first time after independence, planning in S&T came into policy discourse and action. Having established a good deal of infrastructure in S&T, political and economic expectations of science and development increased, together with some visible impacts justifying science and technology policy. India entered the nuclear and space 'clubs' by the 1980s and notwithstanding various criticisms, experienced relative success in the 'Green Revolution' and 'White Revolution'. Having established technological capabilities in some high technology areas such as space, nuclear, pharmaceuticals and green revolution technologies, the government realised that a 'water tight' compartmentalised framework on self-reliance and import-substitution of the previous phase was no more tenable for the 1980s and beyond. The old policy regime which was often referred to as 'nationalist technological policies' of the 1960s was out of date in the 1980s as India had already initiated the indigenisation programmes from defence, space and military industrial projects to pharmaceuticals and the whole public sector enterprises in power, steel, fertiliser, railways, among others. There prevailed a serious concern of the increasing technological gap with industrialised countries and the need for 'catching up' within a perspective of endogenous technological capability. As far as India could maintain the balance of her endogenous technological base, it was thought wise to liberalise import of technology and open up to export regimes. This was important as India's dependence on foreign technology increased as the era of the 1980s came into sharp policy focus over new technologies such as micro electronics, information technologies and biotechnology.

In an effort to reformulate the framework for self-reliance and import substitution they were re-defined, which had definite implications for public research institutions and industry. These concerns were further articulated in economic policies contained in India's Sixth Five Year Plan (1980–1985) and the 1983 Technology Policy Statement. The re-defined terms of the Sixth Plan observed that 'self reliance, as should be obvious, but often is not, does not necessarily mean, self-sufficiency in all sections of the economy'. It went on to assert further, 'however, self-reliance can no longer take the form of indiscriminate import-substitution . . . export promotion is as much a part of the drive for self-reliance as efficient import-substitution'.[8] Similarly, the Technology Policy Statement of 1983[9] sought to make it clear that import of technology and foreign investment in this regard, will continue to be permitted only on a selective basis. Further, the policy document stressed that 'there shall be a firm commitment for absorption, adaptation and subsequent development of imported know-how through adequate investment in Research and Development to which importers of technology will be expected to contribute' (Technology Policy Statement 1983).[10]

As the country entered the decade of the 1980s it was entangled in a double bind situation. On the one hand, new technologies such as biotechnology and ICT and material sciences posed new challenges for their absorption and diffusion forcing the government to lift restrictions on international technology transfer. On the other hand, the critiques increasingly pointed to the failure of S&T for development and the removal of poverty. Despite a number of visible achievements, much of the 'grand optimism' over science and development of the earlier phase began to erode during this phase, also on account of the 1973 oil crises and the rise of appropriate technology and people science movements (Krishna 1997b). As the criticism from various quarters mounted to question the optimistic role of S&T for development envisaged during the earlier phase, the government geared up to formulate appropriate responses. As the basic needs agenda came into sharp focus, the government again responded, this time with the new policy agenda of 'Technology Missions' around the mid-1980s. These were time-bound regulated schemes for tackling the basic needs through redirection of science and technology inputs in water, immunisation, oil-seeds, telecommunications, leather and literacy. The period from the mid-1980s to the 1990s was one of considerable political instability coupled with the challenges of new technologies. The main industrial and S&T policy agenda towards the 1990s remained focused on how to open up and liberalise the Indian economy. Actually the process of liberal economic policies and deregulating industry began from the Rajiv Gandhi regime in 1985 when a number of restrictions on MRTP and FERA companies were lifted and a large number of products reserved for small- and medium-scale enterprises (SMEs) were taken out from the list. In this phase, globalisation became a reality which mounted considerable pressure on the political system to embark on new economic reforms from the early 1990s.

1991–2000: New economic reforms and turn to decentralised S&T policies[11]

With the coming of the new Congress government under P. V. Narasimha Rao and Dr Manmohan Singh (presently India's Prime Minister) as the finance minister, the government embarked on what has come to be known as New Economic Reforms from June 1991. The main feature of this reform process was the New Industrial

Policy (1991) with a major departure from the earlier era. Indian economic policies, compared to China's economic reforms from 1978, introduced a series of liberal economic policies with a focus on export promotion, selective privatisation, foreign direct investment and unprecedented encouragement to the private industrial sector in power, transportation, mineral exploration, electronics and telecommunication, pharmaceuticals, and ICT.

By the time the government announced a Science and Technology Policy in 2003, there had been a notable shift in the formulation and execution of S&T policies from the earlier phases. Even though the government did not abandon the concepts of self-reliance in S&T and drive towards endogenous technological capabilities, their meaning got somewhat broadened within the framework of global competitiveness and export promotion. The Ministry of Industry in 1991 declared:[12]

> [while] government would continue to follow the policy of self-reliance, there would be greater emphasis placed on building up India's ability to pay for imports through its own foreign exchange earnings. At the same time, foreign collaboration would be welcomed in investment and technology in order to increase exports and expand the production base requiring higher technology (Planning Commission 1991).

In contrast to the S&T policy statements (such as in 1958, 1986 and 2003; and the 1974 S&T Plan) which covered a range of subjects and sectors of economy in a somewhat overarching structure, the last decade witnessed a shift towards what may be characterised as a turn to decentralised S&T policies.[13] Compared to previous phases when bureaucratic-elite scientists (for example, people like Homi Bhabha, S. S. Bhatnagar, Vikram Sarabhai, M. G. K. Menon, among others) in alliance with political leadership wielded considerable power in articulating and shaping national S&T policies encompassing several sectors, the last decade witnessed a remarkable shift in the way that S&T policies were formulated and implemented at the level of different sectors. A notable change in the Indian S&T policy-making in the 1990s was the end of the domination of physicists of the 1950s to 1970s era. Technocrats such as Sam Pitroda, chemists such as R. A. Mashelkar, biologists such as P. Balram, P. M. Bhargava and S. K. Bhan, and bureaucrats-cum-strategic scholars such as K. Subrahmanyam, among others, come to influence and shape public policies in S&T. With the economic growth around the 6.9 per cent average for the period 2001 and 2006, there was a rise of private industry sectors in telecommunications, software, media and entertainment, pharmaceuticals, automotive, high technology manufacturing, among others; business enterprises came to influence decision making in policy formulation in the last decade. For instance, business captains such as Rahul Bajaj (three-wheeler auto sector); Ratan Tata and Keshub Mahindra (auto sector); Narayana Murthy and the software sector association — NASSCOM; Ambani brothers (petrochemicals and telecommunications); Mittal brothers (telecommunications); Baba Kalyani (industrial forging); representatives of private industrial houses and their associations such as FICCI and CII for instance, etc., came to influence and participate in science, technology and innovation policies as never before in contemporary history. The government at the same time created more space for private business enterprises as a part of the economic and market strategies of public–private partnerships in various infrastructure and development programmes in the last decade. Also, the civil society representatives and science and technology-based activists have all come to influence and shape the S&T policies which are formulated and implemented at the sector level. In other words, even though the government issues overall national S&T policies from time to time, there is no one 'centre of gravity'. There are multiple actors and agencies at the level of different sectors that have come to play a significant role in shaping S&T policies and the economy as a whole with respect to specific sectors. After 2003, the government did not issue any major overarching S&T policy statement and at the same time various government science and technology departments, ministries and science agencies together have issued over 20 to 25 major policy measures in about 10 sectors of the economy. Table 4.4 summarises some of the most significant policy measures and initiatives in different sectors during the last few years.

It may be noted that this shift towards a decentralised mode is mainly concerned with science, technology and innovation policies and institutional measures concerned with economic and knowledge-based growth sectors of the Indian economy. However, what is left intact without any significant change, as in the previous phases, is the mode of articulation and implementation of innovation-related policies which have societal implications such as environment, climate change, human development, national security, etc. Such

Table 4.4: *Sector-based Science, Technology and Innovation Policies: Tier Two, 1990s to 2009*

Sector	*Main Policies/Initiatives*
Pharmaceuticals	Pharmaceutical Policy 2002 2005 Patent Act (1970 Act amended)
Biotechnology	Biological Diversity Act 2002 Bioinformatics Policy 2004 Biotechnology Industry Partnership Programme (BIPP) 2007–2008 Small Business Innovation Research Initiative (SIBRI) 2008
ICT Software	Software Technology Parks (STP) Policy Initiative, DOE (1990) Creation of Ministry of Information Technology (1999) National Task Force on ICT in the Planning Commission (2006) Information Technology Act 2000; and Amendment 2008
Nuclear Energy	Indo-US Nuclear Deal 2008, Atomic Energy Commission
Space	Satellites Launch Missions, Department of Space Chandrayan Mission 2008–2009
Agriculture	Protection of Plant Varieties and Farmer's Rights Act India (2001) National Seed Policy 2002 National Agriculture Innovation Project (2006)
Telecommunications	New Telecom Policy 1999 Broadband Policy 2004
Rural Development	National Rural Employment Guarantee Scheme 2007 Jawaharlal Nehru Urban Renewal Mission National Rural Health Mission
Industry	Pharmaceutical R&D Support Programme 2004 Home Grown Technology Programme Fund for Accelerating Start-ups 2008 New Millennium India Technology Leadership Initiative 2003 National Innovation Project for Industry 2008 Programme on Cluster Development, Ministry of Industry National Automotive Testing and R&D Infrastructure Project

Source: Compiled from official websites of various government departments and ministries.

overarching policies which cut across various economic and social sectors of the economy are enacted and implemented mainly at the level of the Prime Minister's Office (PMO) and its constituent or closely networked bodies and institutional units such as the National Planning Commission, Principal Scientific Advisor to the government that advises the central cabinet of ministers led by the Prime Minister, etc. For example, India's national position and policy on climate change, skill development council, overarching trade and economic relations and energy, among others, are initiated and articulated at the PMO. Thus it is more reasonable to conceptualise the change and shift taking place in science and technology policies in the current decade after the 1991 reforms in terms of a two-tier decentralised mode. The first tier overarching mode operates at the highest level of the PMO and its closely related bodies. The second tier operates more in a decentralised mode at the levels of various sectors of economy mainly steered by relevant ministries and their respective departments.

Table 4.5: *Science, Technology and Innovation Policies: Tier One, 1990s–2009*

Overarching Policies at PMO	*Overarching Policies at National Planning Commission*	*Office of Principal Scientific Advisor to the Government*
PM Council on Climate Change	With Plan Steering Committee on S&T, energy, environment, etc.	Evolving policies, strategies and missions for generation of innovations and support systems for multiple applications
PM National Council on Skill Development; The Energy Coordination Committee	Policies on inclusive development in the 11th Plan on employment guarantee, health, urban renewal, infrastructure, education, water, irrigation, rural telephony, rural electrification, etc.	Evaluation and review studies on various science and technology-related matters; Reports on optimal use in S&T resources; development of instrumentation; utilisation of human resources, etc.
The National Knowledge Commission: Reports on reforming higher education, national innovation		Creation of missions and also undertake multi-departmental, multi-institutional projects in strategic, technology and other areas of economic/social relevance

Source: Author's elaboration.

Turn to innovation in S&T policy discourse: 2003

The post-1991 reform agenda of the government which clearly set its policy tone towards outward-looking strategy compared to previous regimes was gradually cemented in the policy discourse throughout the 1990s and particularly after the dawn of the new millennium. As Mukherjee (2009: 92) draws to our attention, Dr Manmohan Singh in 1995 clearly envisaged and underscored the changing economic context; 'India's tryst with globalization has become irreversible — no matter which government came to power after the elections of 1996'. Globalisation in India was closely associated with the country's high technology and knowledge capabilities assuming an increasing share in global software services and its exports. India's drive in export of software services as well as in non-high technology sectors such as gems and jewellery gave a new dimension of strategic economic advantages in exports and globalisation as never before. At the same time, it became clear that there are several sectors of both high technology and those that are SME based which have a high potential provided the government introduced appropriate innovation policy measures. India's relative success in ICT software, biotechnology, pharmaceuticals since the 1990s in a large measure demonstrated the importance of policies and the role of the state in injecting dynamism at the level of sectors. Even though perspectives underlying a sectoral system of innovation did not figure in the formal science, technology and innovation policies, the question of why and how certain sectors of Indian economy exhibited more dynamism and growth compared to others drew the attention of policy makers at the Planning Commission.

The year 2003 assumed considerable significance for the turn towards innovation in the S&T policy discourse. Two important developments signalled this important turn. First was the massive exercise in technology forecasting in about 20 sectors undertaken by the Technology Information Forecasting and Assessment Council (TIFAC) of the Department of Science and Technology (DST), Ministry of S&T, under A. P. J. Abdul Kalam and Y. S. Rajan. This resulted in a volume titled, *India 2020 — Vision for the New Millennium* published in 2003. They explored both the weaknesses and strengths of India, as a nation, and offered their version of how India can emerge to be among the world's first four economic powers by 2020. Inherent and central to their argument was the attention given to innovation as an important concept, tool and a strategy which had considerable policy impact since the late 1990s when the exercise on forecasting began at TIFAC. As Mr Kalam assumed the office as India's president, the volume had a radiating impact on India's S&T policies in the five years beginning 2002.

Second, the Science and Technology Policy Statement 2003 (hereafter S&T Policy 2003) which was issued by the government in 2003 clearly reflected the changing economic scenario of globalisation and underscored the importance of innovation. Part C of the document made explicit the 'strategy and implementation plan', wherein, it clearly articulated the need for 'integration of the programmes in socio-economic sectors with R&D activities' on the one hand and 'promoting close and productive interaction between private and public institutions in science and technology' on the other hand. The S&T Policy 2003 goes on to underline the importance of strengthening 'enabling mechanisms that relate to technology development, evaluation, absorption and upgradation from concept to utilization'. While the objectives outlined in the S&T Policy 2003 drew attention to strengthening infrastructure for science and technology in academic institutions, new funding mechanisms for basic research, human resource development, strengthening technology transfer mechanisms between industry and science and intellectual property, among other things, the two most important objectives of the policy clearly spelled out the turn to innovation as follows:[14]

> The transformation of new ideas into commercial successes is of vital importance to the nation's ability to achieve high economic growth and global competitiveness. Accordingly, special emphasis will be given not only to R&D and technological factors of innovation, but also to the other equally important social, institutional and market factors needed for adoption, diffusion and transfer of innovation to the productive sectors. . .
>
> Innovation will be supported in all its aspects. A comprehensive national system of innovation will be created covering science and technology as also legal, financial and other related aspects. There is a need to change the ways in which society and economy performs, if innovation has to fructify.

In continuation of the reform process initiated in 1991 by Dr Manmohan Singh as India's finance minister, the Atal Bihari Vajpayee government, in all its ramifications, continued many of those reforms until Dr Singh again assumed charge as Prime Minister in 2004. The reforms accelerated growth in various sectors of the Indian economy affecting foreign trade and investment, and fiscal reforms affecting liberalisation and foreign ownership of firms. Since 2004 the government has initiated a wide range of initiatives targeted at specific sectors such as software, telecom, biotech and pharma, automotive, among others. Since 2003, the Indian Parliament has ratified a number of laws giving protection to intellectual property rights (IPRs) and in 2005 it passed a patent regime that is compliant with the World Trade Organization (WTO) standards followed the world over.

Contemporary Structure and Organisation of India's National System of Innovation[15]

Actors and agencies of India's NSI

India's national aggregate gross expenditure on research and development was about INR 413 billion (US$ 29.5 billion) in 2007–2008. In absolute terms, Indian GERD witnessed a substantial increase of 60 per cent from INR 249 billion (US$ 17.78 billion) in 2004–2005 to INR 413 billion (US$ 29.5 billion) in 2007–2008. As a proportion of GDP, it witnessed an increase from 0.8 per cent of GDP in 1992–1993 to 1.13 per cent in 2003–2005. However, it registered a marginal decrease to 1 per cent for the period 2004–2007 as estimated by government sources. Notwithstanding the current ongoing economic downturn, the Prime Minister, Dr Manmohan Singh, announced in January 2009 that the government is committed to increase 2 per cent of GDP for R&D.

A dominant proportion of GERD, around 68 per cent, is met by government sources and 30 per cent from the business enterprise sector.

Except for making the idea of creating NSI explicit in the S&T Policy 2003 statement, India is yet to formally define her NSI as such. However, the structure and network of relationships and institutional arrangements exist both in the formal and informal sense between different actors.[16] Such a structure of an innovation system is mainly constituted by: (*a*) public research system (PRS); (*b*) private business enterprise and transnational corporations (TNCs), Indian and foreign; (*c*) higher educational institutions (HEIs); and (*d*) state mediation through public policies. We shall briefly explore various facets of the structure and organisation of India's NSI and then devote a separate section to the importance of state mediation.

Public Research System

This comprises national laboratories under a dozen science and technology agencies from the areas of space, atomic energy, agriculture, industrial research, etc. (see Table 4.1), and in-house R&D laboratories in large public sector enterprises in steel, fertilisers, railways, power, transport and aviation, chemicals, petroleum and energy, etc. The PRS is India's main actor of NSI as it accounted for 68 per cent of GERD in 2007 and 69 per cent (159,000) of the total 230,000 R&D personnel of the country in 2005.[17] Out of the total 230,000 R&D personnel, 71,300 (31 per cent) work in major science agencies such as CSIR, DAE, DBT, etc., 32,200 (14 per cent) work in universities and 55,200 (24 per cent) in government-based public sector enterprises and state government laboratories.

Private Business Enterprises and TNCs

This is the second major actor of the Indian innovation system which accounted for 30 per cent of GERD in 2007 and 31 per cent of total R&D personnel (71,300) of the country in 2005. In 1990–1991 the private sector accounted for 13.8 per cent of GERD which increased to 20.3 per cent in 2001–2002 and to 30 per cent in 2006.[18] The corresponding figure for GERD shows an increase from 2.4 billion Euros in 2002 to 5.5 billion Euros in 2005.

In recent years the business enterprise sector assumed considerable importance with the global competitive edge in pharmaceuticals, automotive, software, telecommunications, and biotechnology. Whereas the international economic crises created ripples in the US and European markets and industry insofar as the auto and IT sectors are concerned, a more optimistic market scenario emerged in the Indian case. In the midst of the crises, Tata launched the world's cheapest small car, Nano, into the Indian market on 23 March 2009 with an advanced booking for over 120,000 cars.[19] The second Indian auto firm, Mahindra and Mahindra also launched its indigenous new model of 'Scorpio' — a semi-utility vehicle. Indian automobile production from 5.3 million units in 2001–2002 grew to 10.8 million units in 2007–2008. In 2006–2007, the Indian automotive industry provided direct employment to more than 300,000 people and contributed 5 per cent of India's GDP.

The other sector which witnessed robust growth and expansion is telecommunications. The Indian telecom market was one of the fastest growing markets in the world in 2009 in terms of subscribers, a little behind China. China stands at more than 800 million telecom subscribers and India at more than 500 million.[20] This figure in 2012 stands at 900 million. In January 2009 alone India added 15 million subscribers. The third sector which witnessed a reasonable growth despite economic crises is India's IT industry which contributed to over 5.8 per cent of India's GDP in 2008–2009. The industry grew by 28 to 29 per cent in the last few years but has slowed down in 2008–2009. For instance, among the top 20 firms operating in the IT sector in India, all big Indian firms such as Tata Consultancy Services, Wipro, Infosys, HCL, and Tech Mahindra–Satyam witnessed modest growth rates between 15 to 20 per cent during 2007–2008 and 2008–2009.[21] Despite the slowdown, the Indian IT-BPO sector grew by 12 per cent in 2008–2009 to reach US$ 59.5 billion in aggregate revenue.

The trend of the global R&D flows to India is sustained and growing in the situation of an economic downslide. About 260 global TNCs operate their R&D centres or laboratories in India in the Bangalore, Hyderabad, Delhi, Pune, and Chennai regions. Bangalore is the most preferred destination for foreign R&D centres which accounts for 45 per cent of the firms, followed by NCR (Delhi) with 22 per cent.

The rise of the business enterprise sector as an important actor of NSI is also evident from various Indian firms which followed the Tatas who acquired the UK steel firm Corus, and Mittal's acquisition of the Belgian-French firm Arcelor.

Higher Educational Institutions

With over 400 universities with 18,000 affiliated colleges, much of the recent dynamism witnessed in the knowledge-based and high technology sectors of the Indian economy is the result of human resources, skills and the vast institutional base already created in the higher educational sector. In an effort to sustain this dynamism the government increased the higher education budget by three times in 2009–2010. However, R&D in HEIs in India is a weak link in India's NSI which accounts for a mere 14 per cent of R&D personnel compared to 55 per cent of total R&D personnel of the country in PRS. Higher education R&D is less than 8 per cent of GERD. However, universities accounted for over 52.2 per cent of

India's total 28,603 SCI-based publications in 2005 which makes the sector a very important actor of the innovation system.[22] In 2006 the government set up the National Knowledge Commission to assess, plan and recommend the knowledge challenges of the 21st century. Three major developments in the higher educational sector are: (*a*) increase India's competitive advantage in the fields of knowledge by expanding the existing 400 universities to 1,500 by 2015; (*b*) 15-year career support programme through scholarships from high school to Ph.D. level; and (*c*) promote university–industry links and partnerships. The Knowledge Commission's tenure continued with the new government in 2009 and its operations are being expanded.

According to various estimates and data from authentic sources, India produces about 2.5 million graduates every year, of which 300,000 are engineers and 150,000 IT professionals. This is in contrast to 70,000 engineers in USA, 33,000 in Germany and 600,000 in China. However, according to Farrel et al. (2005), with 14 million young university graduates (with seven years or less of work experience) India's talent pool is estimated to be the largest in the world, overlapping the Chinese talent pool by 50 per cent and that of USA by 100 per cent.[23]

Innovation governance system

The innovation governance structure in India mainly comprises three main actors or agencies which are hierarchically interconnected and networked. The top most body is the Indian Parliament which consists of the upper house (*Rajya Sabha*) and lower house (*Lok Sabha*). The former is constituted based on political party representation which in a way is an indirect representation of the people in Parliament. The latter is a directly elected body of the people's representatives every five years. All acts and policies of innovation need the ratification of Parliament which generally operates through a committee system. Committees are of two kinds — standing committees and ad hoc committees. The former are elected or appointed every year or periodically and their work goes on, more or less, on a continuous basis. The latter are appointed on an ad-hoc basis as need arises and they cease to exist as soon as they complete the task assigned to them. Much of the work on science and technology-related issues including innovation is first examined by the standing committees and then taken up for ratification by the Parliament. For example, currently an innovation-related bill namely, 'The Protection and Utilisation of Public Funded Intellectual Property Bill, 2008' is pending for the ratification of Parliament in 2012.

At the second level, the PMO, in consultation with the Planning Commission and other concerned ministries and departments formulates, initiates and implements various innovation-related policies. For example, the initiative to launch policies on climate change which seek to implement eight national missions from solar energy to green technologies in the manufacturing sector originated in the PMO's office. This office is supported by the Principal Scientific Advisor, the Science Advisory Council to the Prime Minister. In 2006–2007 the PMO also constituted a National Knowledge Commission in the advisory role. At this level, the Planning Commission plays an important role as it formulates and creates a framework for innovation policies and related aspects. For instance, the Steering Committee on S&T for the 11th Plan played an important role which was chaired by the head of the Scientific Advisor Council to the PMO.

At the third level various ministries from science and technology to industry, human resource development and other sectors have the legal mandate to launch and implement various programmes and schemes on innovation based on the broad framework on innovation and related matters given by higher bodies. The Ministry of S&T has two important bodies, the Department of Science and Technology and the Department of Scientific and Industrial Research, which mainly administered and implemented innovation programmes and schemes on behalf of the government. The ministry-level bodies also coordinate and co-opt various business enterprises, industries and NGOs and their representative associations in a range of innovation policy-related matters.

Main objectives

There is no formal national innovation policy or statement announced by the Indian government so far but various other policy documents on science and technology for development and on economic growth have made reference to innovation policies. The policy documents which are important from a national perspective and relevant to the coming five years are listed in Table 4.4. The term innovation has become an important concept and more often is used in a generic reference to various aspects of development and implementation of economic and industrial policies in the country. The most formal usage of the term is found in two draft policy documents being circulated by the Ministry of Science and Technology.[24]

The term innovation is referred to as *a pro*cess for incremental or significant technical advance or change, which provides enhancement of measurable economic value, and shall include: (*a*) introducing new or improved goods or services; (*b*) implementing new or improved operational processes; and (*c*) implementing new or improved organisational or managerial processes. Measurable value enhancement or economic significance may include one or more of the following: (*i*) increase in market share; (*ii*) competitive advantage; (*iii*) improvement in the quality of products or services; (*iv*) reduction of costs.[25]

Other policy documents refer to innovation in a somewhat similar meaning but stress is laid on the aspect of new knowledge or inventions or advances in knowledge from national laboratories and the way in which it gets commercialised or used by society, industry or any clients. The policy documents listed in Table 4.6 underline objectives which form a basis or a broad framework of India's innovation policies. It must be noted that much of the policy discourse in these documents focuses more on creating an enabling ecosystem for innovation or what can be termed as an innovation potential or capacity in various institutions and organisational structures.

The major objectives which relate to creating this innovation potential or capacity are as follows:

- Prime Minister Manmohan Singh has set the goal of attaining 2 per cent of GDP for R&D from the current level of 1.3 per cent.[26] The objective here is to encourage the business enterprise to double its contribution to GERD from the current proportion of 30 per cent GERD.
- Use 'technology foresight' to make the right technology choices and introduce 'coherent synergy' in our S&T efforts. Technology foresight helps in the selection of critical technologies for development at any point of time.
- In an effort to accomplish the goal of a knowledge-based society and economy, the government has given top priority to both elementary and school-level education as well as higher

education. The goal is to attain 6 per cent of GDP for education in the 11th Five Year Plan period. This plan has earmarked a four times increase in education in the plan period. In terms of pragmatic goals, the aim is to increase the enrolment ratio in higher education from the current level of 11 per cent to 15 per cent in the coming five years. The National Knowledge Commission set this goal for 2015.

- To create a total of 1,500 universities by 2015 by reconstituting 18,000 existing under-graduate and post-graduate colleges; reform higher education to infuse quality, excellence and accountability.
- To effectively implement an education budget of INR 3 trillion (or US$ 214 billion) in the 11th Five Year Plan Period (2007–2012); this is a fivefold increase over the 10th Plan. To increase the share of education from 7.7 per cent to 20 per cent by the end of the plan period.
- To strengthen the human resource skill base, particularly in nuclear, space and new technologies such as biotechnology and genetics, nanotechnology and ICT, in universities and other institutions in higher education.
- To strengthen vocational education, a new Skill Development Mission under the supervision of the Prime Minister with an outlay of 4,509 million Euros or INR 31,2000 million. To aim at opening 1,600 new Industrial Training Institutes (ITIs) and polytechnics, 10,000 new vocational schools and 50,000 new Skill Development Centres. A Skill Development Corporation will also be created by the government with the active participation of the private sector to give special training to young men and women, workers and technicians.
- To enhance India's competitiveness in micro, small-and medium-scale enterprises by making R&D in national laboratories relevant to the needs and demands of this sector. The government goal is to expand some novel R&D and innovation schemes (in DBT, DST, DSIR and other science agencies) to achieve this important goal. The overarching goal is, however, to realise the aim of inclusive development through appropriate research policies.
- To foster research and innovation policies to accomplish the goal of a Second Green Revolution through national

agriculture innovation policy and introduce a systemic basis of research and innovation in agriculture and its extension.

- To strengthen India's intellectual property, particularly in public research institutions and the higher educational sector. The overall aim is to boost entrepreneurship and innovation potential dormant in universities and national laboratories.
- To promote international science and technology collaboration by participating in international 'mega projects' as an 'equal partner' to enhance India's international reputation in big science.
- The Prime Minister's pronouncement on climate change is that India is committed not to exceed the per capita emission levels of developed countries. The objective is to establish an effective, cooperative and equitable global approach based on the principles of common but differentiated responsibilities and capacities in the United Nations Framework Convention on Climate Change (UNFCCC). The national action plan on climate change hinges on the development of institutional mechanisms. The objective is to establish eight national missions (solar energy, enhanced energy efficiency, sustainable habitat, water mission, sustaining Himalayan ecosystem, Green India, sustainable agriculture, and strategic knowledge on climate change).

Main challenges confronting India's NSI

Enhancing Innovation Potential in New Technologies

Sustaining the success achieved so far and extending its scope for the coming decade depends on developing innovation potential with public–private partnerships. Here, the challenge is to create an environment enabling R&D in the public–private research systems including higher education and manage public–private partnerships which determine the effectiveness of innovation in new technologies.

Second, university–industry partnerships assume considerable importance given the nature of science-based innovation in sectors such as aerospace, bio-pharma, automotive, and material sciences. The most important challenge is the introduction of an IPR regime common to universities and public research systems. It also entails reorganisation of research teams to foster networks between universities and other important actors. Third, India has a vast higher educational structure in science and engineering but the main challenge is to make science and engineering more attractive to students.

Building Technological Capabilities and Competitiveness of the Manufacturing Sector

As India's manufacturing sector is growing and expanding into high technology sectors such as bio-pharmaceutical and automotive sectors, its ability to compete both at the domestic and international level is dependent on the firms and their enabling environment. Challenges facing the sector concern training, infusion of skills and upgrading techniques to enhance technological capabilities, maintaining quality and institutionalising international standards in manufacturing.

Second, technological capabilities of firms are related to their R&D and technological intensities. The proportion of business R&D in the national GERD is quite low compared to other countries. A closely associated problem has been the slow diffusion of existing technology from the public research systems to the manufacturing industry as a whole.

Reconfiguration of Formal and Informal Sectors via Inclusive Innovation

Inclusive innovation concerns primarily 80 per cent of the total workforce in the informal sector dominated by house-based micro, small- and medium-scale enterprises ranging from handicrafts to a range of manufacturing goods.

A multipronged approach to reconfigure the formal and informal sectors of economy and manage the transition from rural-based agriculture to an urban and semi-urban industrial-based economy with appropriate strategies of inclusive innovation is the overarching challenge facing the country in the coming decade. Imparting skills to participate in the industrial economy, promoting and diffusing local grassroots innovations and making new technologies such as ICT and telecommunications appropriate to the needs of this sector are some of the current major challenges. The future of India's development and economic progress of the country depends on the challenges of innovation in the rural and semi-urban sectors.

Government Initiatives in Strengthening NSI, 1990s–2009

New research policy developments: Supply side-1

The thrust of new research policies in contrast to innovation policy measures is to leverage the strengths of the public research system (national laboratories and higher educational institutions) to enhance capacities for science-based innovation in new technologies (such as nanotechnology, biotechnology and telecommunications and information technology) with appropriate measures to increase the human resource supply in higher educational institutions. It may also be pointed out that India's NSI till about recently in the 1990s was dominated by supply-side research policies. It is only in the last decade with the emergence of innovation as an important feature in the S&T policy discourse after Science and Technology Policy, 2003, that the government became proactive to promote innovation policy measures.

Further, the strategies of new research policies are also directed to what is known as 'inclusive innovation strategies' which are geared to enhance the competitiveness of small- and medium-scale enterprises and build appropriate linkages between the formal (or modern) S&T systems and rural sectors of economy. India's 11th Plan (2007–2012) finalised by the Planning Commission indicated an increase in the education budget by four times and the science and technology, including R&D, budget by three times the level of 2006–2007 during the plan period. However, the annual budget statement of the finance ministry increased the education and science and technology budget by only 25 per cent for the year 2008–2009. Some important elements of these policies may be specified as follows.

National Science and Engineering Research Board (NSERB)

In an effort to keep the scientific knowledge base up-to-date, a globally competitive basic research environment is essential to maintain a healthy innovation ecosystem in the country. This is given high priority by the government as it set up a NSERB in December 2008 to enhance the level of basic research. As the Prime Minister underlined recently, 'the Board will be an autonomous body and would have freedom to establish modalities of funding research as well as for creating facilities and structures that would help improve the quantity and quality of scientific research in the country'.[27] NSERB is expected to control a budget of INR 10 billion annually to open a new window for funding to researchers in public research institutions and industrial enterprises (Jayaraman 2008).

Innovation in Science Pursuit for Inspired Research (INSPIRE)

A second major recent initiative by the government has been the launching of a new scheme, INSPIRE, through DST which provides scholarships to attract talents to science. It is said to establish a vertical link between different stages in the pursuit of a career in science. It targets the whole learning pyramid from young learners to senior researchers. It is a very significant programme which aims to cover one million young learners. The government allocated INR 21,000 million in the 11th Plan (2007–2012).

Widening Higher Education and Research Base

Given the importance of the emerging knowledge base economy and future demand for highly skilled human resources, the government gave a major boost to widening the higher education and research base in 2009. A fourfold increase in the budget of higher education and scientific research in the 11th Plan period will establish a range of higher educational institutions and national research laboratories.[28]

The 11th Five Year plan's focus on giving special emphasis to education is reflected in the 2009–2010 budget for higher education to implement four new IITs, six Indian Institutes of Management and 14 Central Universities. INR 21,300 million (US$1521.4 million) was allocated for this expansion in the 2009–2010 budget in addition to INR 20,100 million (US$ 1,435.7 million) to higher education.

Promotion of University Research and Scientific Excellence (PURSE)

In an effort to strengthen the scientific research base in universities and further encourage performing universities, the government announced the PURSE scheme which grants INR 100 million to universities over their normal budget for three years. The special grants are based on the competitive basis of the university's publications in SCI-based journals with high impact factors.

Public–Private Partnerships in Science Education for Innovation and Excellence in Research

The Ministry of Science and Technology launched a special fellowship programme in doctoral research in computer sciences and medical electronics in association with the software companies association in 2008.

Biotechnology Industry Partnership Programme (BIPP)

The Department of Biotechnology has launched a public–private partnership (BIPP) programme for high risk discovery and innovation and accelerated technology development especially for futuristic technologies. The scheme is aimed at enhancing global competitiveness in new technologies in agriculture, energy, environment, and human health. The government provides 30 to 50 per cent funding and the rest is met by the industry partner.

The Protection and Utilisation of Public Funded Intellectual Property Bill, 2008

After the Cabinet approval in October 2008, the Ministry for S&T introduced this Bill in the upper house of the Parliament in December 2008. The Bill gives right of ownership to public research institutions and universities for R&D output leading to intellectual property and authorises these institutions to institute technology transfer and innovation units for R&D commercialisation. Researcher(s) who created intellectual property, the research group or department involved and the funder are entitled for one-third each of the rents and royalties generated out of the intellectual property commercialisation under this Bill. Scientists and faculty will be allowed to set up centres for entrepreneurship and innovation from the intellectual property developed.[29]

The New Millennium Indian Technology Leadership Initiative (NMITLI)

This scheme is meant for fostering partnerships between public research systems and industry and at the same time to enable these partnerships to attain global leadership positions in a few selected niche areas. CSIR evolved 57 projects in which 80 industry partners and 270 R&D groups from different institutions are involved with a budget of over INR 5,000 million (US$ 357.14).[30]

Launching of Nano Mission

The nano mission as an initiative launched in May 2007 came into operation in 2008. It is an umbrella programme with a budget of INR 1,000 million (US$ 71.42 million) for five years for developing research capacities in nano science and technology in training, human resource skills, basic research, international cooperation, and innovation. Under this initiative, close to 130 research projects have been funded in 2007 to 2008.

The national Nano Science and Technology Mission created in 2007 with INR 10 billion continued to draw support in 2009 for its implementation to enhance innovation potential. Six new R&D centres in the public–private partnership mode have come up with a budget of INR 1 billion. About 50–60 science and technology institutions, including existing IITs and NITs will be involved in building nano clusters across the country to create the ecosystem for undertaking extensive research in nanoscience and applied nanotechnology to develop applications for industrial products, agriculture, health care and safe drinking water, among others. Eleven centres of excellence have already been established in 2008–2009 in different specialised departments of universities in India. Six major public–private partnership programmes have already been instituted with leading Indian and foreign firms.

India–EU Partnerships in S&T

At the international level India has forged international cooperation in nuclear energy, physics, space and communication technologies with USA and the European Union since 2006. India has become a partner in the Framework 7 of EU since 2007 in the following projects:

(*a*) India is member of the European Union's International Thermonuclear Experimental Reactor (ITER) nuclear fusion energy project.

(*b*) India recently joined the satellite-based navigation system, Galileo Project (European version of USA's Global Positioning System) and is a member of Framework Programmes FP7 for 2007–2012.

(*c*) India and the European Union also decided to embark on joint scientific projects, including those in strategic fields, after holding their first ministerial science conference in the

Indian capital, New Delhi, on 10 February 2007. India also signed a pact with the EU to participate in the proposed Facility-for-Antiproton-and-Ion-Research (FAIR) project aimed at understanding the tiniest particles in the universe.

(*d*) Indian S&T international cooperation has a budget of over 48 million Euros. Much of this budget is being spent on EU-related programmes in S&T.

Innovation policy measures 1997–2009: Supply side-2

Indian science and technology policies for a long period have relied more on input-oriented research policies leaving the R&D downstream connectivity to either enterprises which interacted directly with research institutions or a centralised body called National Research Development Corporation (NRDC). This body was a sort of depository for technologies and R&D results developed in national laboratories which had the mandate to commercialise technologies. The NRDC did not play any significant role either in start-ups or R&D commercialisation. Over 70 to 75 per cent of technologies deposited in NRDC lie idle on its shelves. Second, the role of S&T policies was confined to the 'supply side' of training highly skilled human resources in higher educational and specialised institutions who found their way into industries and business enterprises.

Since the 1990s, a series of initiatives and programmes were introduced by DST, DSIR, CSIR, and other governmental science agencies beginning with the creation of software technology parks of India (STPIs). India has taken a number of steps in the last few years to promote various policies and programmes for innovative start-ups both at the federal government and state government regional levels. From the point of view of sectors, ICT software and biotechnology are the two main areas which have attracted considerable attention. Market failure perspective to fund and support new innovative firms fits well to the Indian context. Hence, the role of government- and public-supported financial institutions has become significant.

Start-ups, spin-offs and early stage technology development (ESTD) all fall into more or less the same category. Ministry of S&T through DST and DSIR has initiated a number of such schemes and programmes as shown in Table 4.6.

Table 4.6: *Ministry of S&T Main Initiatives and Programmes, 1990–2008*

No.	*Scheme/Programme/Initiative*	*Launched by Govt./Private & Organisation*	*Area/Sector*
1	Small Business Innovation Research Initiative (SBIRI) (2007–2008)	Govt./ Department of Biotechnology	Biotechnology and related fields
2	NASSCOM-ICICI Knowledge Park Fund (2008)	Private	ICT software
3	Fund for Accelerating Start-ups in Technology (FAST) (2008)	DSIR	All areas
4	Lockheed Martin India Innovation Growth Programme (2008)	Private/FICCI	All areas
5	Pharmaceuticals R&D Support Programme (PRDSF) (2004)	Govt./DST	Pharma and drug development
6	Techno-entrepreneur Promotion Programme (TePP) (1998)	Govt./DSIR, TIFAC	All areas
7	Technology Development and Demonstration Programme (TDDP) (1993) & Technology Development Board (1996)	Govt./DSIR	All areas
8	Home Grown Technology (HGT) Programme (1992)	Govt./DST, TIFAC	All areas
9	Sponsored Research and Development (SPREAD) (1989)	Govt./DST	All areas–research-industry links
10	Technology Development & Utilization Programme for Women (2007)	Govt./DST	All areas for women
11	New Millennium Indian Technology Leadership Initiative (NMITLI) (2003)	CSIR–Public–Private Partnership	All areas
12	Innovation and Entrepreneurship Programme (from 1990s)	All IITs and UGC	All areas
13	Encouraging and Development of Commercialisation of Inventions and Innovations: A New Impetus	Govt./DSIR	All areas for start-ups
14	The Protection and Utilisation of Public Funded IPR Bill (2008)	Govt./Ministry of S&T	All areas/ public research institutions

(*Cont.*)

(*Cont.*)

No.	*Scheme/Programme/Initiative*	*Launched by Govt./Private & Organisation*	*Area/Sector*
15	Encouraging and Development of Commercialisation of Inventions and Innovations: A New Impetus	Support to Innovative Start-ups Incl. Gazelles	Department of Scientific and Industrial Research, Ministry of S&T
16	The Protection and Utilisation of Public Funded Intellectual Property Bill (2008)	Knowledge Transfer and IPR issues in public/academic/non-profit institutes	Department of Science and Technology & Department of Biotechnology, Ministry of S&T
17	Biotechnology Industry Partnership Programme	Strategic research policies	Department of Biotechnology, Ministry of S&T
18	National Rural Employment Guarantee Scheme (NRGES)	Support to the creation of favourable innovative climate & horizontal measure in support of financing	Ministry of Rural Development
19	National Rural Health Mission (NRH)	Support to the creation of favourable innovative climate & horizontal measure in support of financing	Ministry of Health and Family Welfare

Source: Compiled from formal websites of various science and technology ministries and departments.

Impact of public support to innovation: Demand side

India's economic growth during the last decade-and-a-half is associated with the dynamic growth of various sectors of economy ranging from aerospace industries, ICT software, pharmaceuticals, auto, petrochemicals, and high technology services. India's GDP grew at an average of 4.5 to 5 per cent for the decade 1993–2004 and accelerated to over 8.8 per cent for the succeeding five years from 2003–2004 to 2007–2008. Growth has also been associated with a jump in exports in skill-intensive manufacturing and services which in turn can be related to a spurt in innovative activities in these sectors. This has resulted in some visible quantifiable gains in reducing poverty and raising the living standards of the middle class in the country. While the poverty level according to the Planning Commission has fallen from 36 per cent to 27.8 per cent in 2004–2005, there has been a tremendous rise in the purchasing power of the Indian middle-class population triggering manufacturing industries and consumer goods. From a macro national perspective it may be said that there has been a combination of research, educational, industrial, fiscal policies and innovation policies contributing to growth and dynamism. Impact of these policies on macroeconomic indicators has certainly taken a long time in the Indian case.

The phase after 1991 is marked by liberal economic policies and opening up of a number of sectors such as pharma, ICT software, chemicals, aerospace, among others, for international competition. Export promotion and developing technological capabilities associated with it were channelled to take advantage of globalisation. Much of the innovation strategy in this phase during the last 15 years was invested in creating an enabling innovation ecosystem. This includes expansion of higher education, R&D base and creating a host of programmes and schemes to foster technology transfer and commercialisation of R&D from public labs to industry. There are various sectors which have witnessed dynamic growth and one can see a combination of the pre-1991 and post-1991 impacts of research, educational and innovation policies.

In the case of pharmaceuticals and drugs, India's patent policies of the 1970s which had protected patents for only seven years enabled technological capabilities in reverse engineering in drugs and chemicals together with the oriented basic research inputs.[31] However, these capabilities have taken a long time since the 1970s–1990s to have some visible impact. By 2000 India became the fifth largest drug producer in the world and in the last five years India's drug industry has certainly progressed from reverse engineering to the drug discovery path. Most importantly, 80 per cent of the essential drugs required by the country and parts of South Asia are produced in India. Between 1981 and 1995, CSIR, India's major R&D organisation with 38 national labs registered only nine US patents in drugs, but during the decade after 1995 to 2005 it obtained nearly 280 US patents in pharma and related fields. Similarly, five leading private Indian pharma firms did not obtain any US patents till 1995, but during 1996 and 2005 each one of them obtained 15 to 20 US patents per year. The Department of Science and Technology's half dozen innovation policy measures certainly contributed to this growth of the pharma sector which is now aiming towards global networking and a global competitive edge in pharma. A good example is the DST technology commercialisation grant to Shanta Biotech, Hyderabad for the development of Hepatitis-B and A vaccines which reduced the cost per dose by 70 to 80 per cent.

Similar is the case with India's growth in the software sector. Virtually starting from scratch in the 1980s the sector became dynamic by the late 1990s. Currently, over three million professionals work in this sector contributing to 6 per cent of India's GDP. The Ministry of Communication and Information Technology is the lead agency for formulating policies in the ICT sector. However, given the dominant role of the business enterprise in software exports, its association, NASSCOM, also plays a lead role in the formulation of research and innovation policies in ICT. The government, through its generic policies, has focused on developing skilled human resources with the expansion of the higher education sector.

Policies to build software technology parks in Bangalore, Hyderabad, Pune, Chennai, Delhi, and Gurgoan and other parts paid off very well. In 2008, 70 per cent of the software exports were from these five major software parks.[32] In a large measure the public–private partnerships in higher education, software technology parks and in e-governance and e-commerce contributed to the growth and dynamism of this sector.

In the auto sector, as already noted, Tata launched Nano in India with 120,000 bookings and the Mahindras launched their new model, UTE 'Scorpio' in the midst of the international auto crisis. Both have benefited from the government's tax incentives of the R&D scheme. In the case of telecommunications, there are currently about 500 million subscribers expanding at the rate of 6 to 10 per cent per month. This is again the result of the government creating an enabling environment and satellite connectivity for convergence technologies and the market's expansion.

The aerospace sector of India which is dominated by the dynamic growth of space technology and innovation has witnessed remarkable progress and world recognition in the capabilities to design and launch satellites.[33] In 2008 the space sector opened up for public–private partnerships in R&D and innovation. The success of launching *Chandrayan-1* for landing experimental instruments on and around the orbit of the Moon led to the high priority being given to space science and technology development.

The case of innovation in the manufacturing sector is revealed by two important surveys. The first is from the World Bank, 'The India 2006 Enterprise Survey', and the second is the innovation study undertaken by India's National Knowledge Commission. The World Bank Survey of 2006 in about 4,000 firms reveals some interesting features of innovation in the manufacturing sector which are as follows (Dutz 2007):

- In India 40 per cent of firms had developed a major new product, while 62 per cent had upgraded an existing product line. The criteria suggest that Indian firms have more innovation outputs than firms in China, but less those in Brazil, South Korea and Russia. The report comments that China's low scores are due to active copying than developing new products;
- Creation-oriented enterprises are concentrated in drugs and pharma, auto components and garments;
- Absorption of knowledge is likely to enable productivity rather than creation of new knowledge. The most important channel for absorbing existing knowledge is through the use of new machinery and equipment, followed by hiring key professionals;
- For most enterprises in India, the acquisition of global knowledge is expected to be more important for productivity than is the creation of domestic knowledge.

India's National Knowledge Commission survey report on innovation has come out with the following four important sets of findings for large enterprises and SMEs in India (National Knowledge Commission 2007).

Increase in Growth and Innovation

(*a*) 'Innovation Intensity' (i.e., the percentage of revenue derived from products/ services which are less than three years old) has increased for large firms and SMEs, with SMEs registering a greater increase in innovation intensity than large firms. Forty-two per cent of the large firms and 17 per cent of the SMEs are also 'Highly Innovative' firms (i.e., firms that have introduced 'new to world' innovations during the course of business in the last five years).

(*b*) Nearly half of the large firms and SMEs attribute more than 25 per cent of change in the following factors to innovation: increase in competitiveness, increase in profitability, reduction in costs and increase in market share. For large firms innovation has the most significant impact on competitiveness, while for SMEs, innovation has the most significant impact on an increase in market share.

(*c*) Seventeen per cent of the large firms rank innovation as the top strategic priority and 75 per cent rank it among the top three priorities. All the large firms in our sample agree (of which 81 per cent strongly agree) that innovation has gained importance as being critical to growth and competitiveness since the start of economic liberalisation in India. All the large firms agree (of which nearly half strongly agree) that they cannot survive and grow without investment in innovation. An overwhelming 96 per cent of large firms in our sample see innovation spending increasing over the next three–five years.

(*d*) Breakthrough and incremental: 37.3 per cent of large firms have introduced breakthrough innovation, while 76.4 per cent have introduced incremental innovation, which may be an indication that large firms in India are still in the mindset of incremental innovation as opposed to breakthrough innovation.

Concluding Remarks

The evolution of the current structure of India's NSI explored in this chapter clearly demonstrates the important part played by the state and governing political leadership in laying foundations and chalking out a goal direction over the last six decades. State mediation through initiating public science, technology and innovation policies has been a determining factor in building a national science and technology system and creating national innovation capacities. The Indian case clearly demonstrates that these endowments and capacities take long periods of time to establish and require sustained state support and public legitimation from time to time. It is here that the role of governing political leadership comes in to play a crucial part. State mediation is very crucial for giving a goal direction but at the same time it is also important to draw relative autonomy in research policies and a space for an autonomous science and technology system. Indian NSI, throughout its evolution, was rather fortunate on both these counts. What is also of significance in the Indian case is the fact that in various sectors of the economy, the country was able to build a reasonable innovation system followed only by a strong base of a science and technology system. In other words, it is rather problematic to build innovation systems without a strong base in science and technology systems which create appropriate innovation capacities. The dynamic growth of reasonable sectoral systems of innovation such as in space, agriculture and food security (Green Revolution), pharmaceuticals, biotechnology, ICT software and telecommunications, are good examples.

The science and technology policies in India for almost five decades till the 1990s were in a large measure tilted in favour of strengthening the input or supply side rather than the demand side of innovation. This has resulted in building a large science and technology system as well as a reasonable R&D base across a range of sectors and fields both in 'big science' (space, defence and atomic energy) and high technology such as chemicals and pharmaceuticals, biotechnology, ICT software, among other areas.

As we are dealing with a relatively long historical period of three phases in the development of India's NSI, it is important to qualify the nature and character of state mediation in building national scientific and technological capacities in the Indian case. As dealt with in this chapter, the most central feature of the nature of state mediation has been sustaining the overarching goal of self-reliance over long periods of time after 1947. In fact this concept of self-reliance has its roots in India's freedom movement, drawing from politics into economic policies. Both economic and science and technology policies were governed by the concept of self-reliance and its associated strategy of import substitution from the 1940s to 1980s. As Sridharan (1995:184) argued, 'the import-substituting technology policy regime has created a state of growing technological backwardness over the past two decades and made Indian industry so uncompetitive that India was threatened . . . at the start of the 1990s'.

Such critiques are justified in their own right to an extent because of the lack of technological dynamism in various manufacturing sectors on account of such inward-looking policies.

However, what is generally seen in the literature in the Indian case is the glossing over or bypassing of the important factor of under-utilisation of scientific and technological capacities created as part of the strategies and perspectives followed in the decades around the 1970s and 1980s (Krishna 1997a). There is a need to make a distinction between becoming uncompetitive due to the lack of, or underdevelopment of, technological capabilities, and under-utilisation of existing scientific and technological capacities or potential. India was able to establish a good reservoir of these capacities in various sectors but the problems remained somewhere else on the demand side of the innovation spectrum. As Rosenberg (1990: 149) observed on reviewing various models of industrialisation:

> 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.

The disappointment which is expressed, in my view, is not so much due to lack of technological capabilities but on account of under-utilisation and lack of enabling innovation measures. Rosenberg was quite right in pointing towards the lack of enabling innovation policy measures which link science and technology capacities established with the growing industrial needs and demands. The turn to innovation in S&T policies and appropriate innovation policy measures which were introduced since the mid-1990s in the third phase as also the shift to decentralised S&T policies around the 1990s gave a new meaning to the policies. As India progressed from the 1990s into the new millennium, the results of long-standing policies of self-reliance in building a national science and technology system and innovation capacities became quite apparent as argued earlier based on the study of three sectors, namely ICT software, pharmaceuticals and biotechnology (Krishna 2007). For instance, in the case of pharmaceuticals, India's 1970 Patent Act led to varying degrees of technological capabilities in both public and private business enterprises throughout the 1980s and 1990s, and in the last decade (2000–2010), India began to progress from a phase of reverse engineering onto the drug discovery path. It is widely known that India produces over 75 per cent of essential drug requirements for the South Asian region.[34]

However, given the dominant proportion of R&D being performed in publicly funded national laboratories and universities, the problems of the supply side and the under-utilisation of the R&D capacity continue to persist. A major weakness of the current system is the lack of an innovation ecosystem with risk capital and intermediary mechanisms to foster and promote technology transfer and commercialisation of public R&D. It is only since the last few years that the government has begun to focus on the demand side of innovation and a serious attempt has been made to build an innovation ecosystem through a series of policy measures and programmes.

India has not yet articulated her national innovation policy or defined her NSI in the formal sense. Science, technology and innovation policies in the Indian context are to be understood in terms of decentralised sector-based (for instance, space, atomic energy, pharmaceuticals, ICT software, etc.) and problem-based (for instance, climate change, disaster management, drought and floods, etc.) policies. Hence the problem is that of innovation policies which are rather very fragmented in ministries and elite bodies such as the Planning Commission and the PMO, lacking coordination and networking with various actors and agencies in the system as a whole. The return of the Congress Party-led government with Dr Manmohan Singh as Prime Minister in May 2009 infused a renewed sense of optimism over science, technology and innovation policies for development and inclusive economic growth. However, a number of challenges and problems confront India's NSI.

One of the major problems for an economy the size of India, compared to other emerging nations and the international context is the very low level of gross expenditure on R&D. India is spending just over 1.13 per cent of GDP for R&D compared to 1.2 to 1.4 per cent for Brazil and China and around 2.2 per cent in the case of the Organisation for Economic Cooperation and Development (OECD) and EU countries. The government is committed to increase the current 1.13 per cent level to 2 per cent in the coming five years.

While both public R&D and business R&D are low compared to international standards, the rate of growth in their respective levels over the last five years has been positive. From almost a very low level of less than INR 6,919 million a decade back, currently India attracts over INR 1.03 billion for R&D every year through foreign firms setting up R&D laboratories and units in India. Currently by 2009, about 250 multinational firms had already set up R&D labs or units.

In higher education the major challenge still remains the big daunting task of increasing the enrolment ratio from the current 11 per cent to 15 per cent. India has set up over 400 universities and 18,000 colleges but the research intensity in these institutions of higher learning is quite weak. Only 25 per cent of this number is research based and the rest are teaching-based universities aspiring to achieve the 'Humboltdian ideal' of teaching and research universities. In a large measure the innovation potential in the higher education sector in India is under-utilised for the lack of adoption of innovation policies by a large number of universities which foster university–industry partnerships and relations, with the possible exception of IITs and other leading universities. The major challenge is to infuse 'innovation culture' in academic institutions of higher learning. The same may be said of the industrial research system of CSIR-based laboratories. India has just articulated 'The Protection and Utilisation of Public Funded Intellectual Property Bill, 2008' — an Indian version of the US Bayh-Dole Act but it is yet to be implemented in 2012. There is a lot of expectation from this Bill for catalysing innovation and technology transfer from public research systems to industry and society.

The existing innovation policy measures routed through the Ministry of Science and Technology departments lack adequate personnel and professionals to monitor and make them more effective. The main problem is their limited sphere of influence and impact which needs at least a three- or fourfold increase in their operation compared to the present situation. For example, the Technology Development Board which is one of the major innovation agencies of the ministry gets hardly 10 to 15 per cent of the total budget collected by the government in the form of cess for import of technology. Similarly, the R&D tax incentive system operated by the S&T department lacks penal 'teeth' and legal provisions to effectively monitor the funds given to business enterprises to ensure whether they are in fact involved in quality control and analyses-related activities or R&D per se.

The government has committed a massive policy and budgetary provision to promote more than a dozen national programmes on inclusive development. India's innovation policies are still tilted in favour of high technology and global competition. What is needed is an appropriate institutional and governance structure which coordinates and networks the formal R&D structures and universities with the needs and demands of inclusive development programmes. What is also needed is a new framework and institutional networking structure on inclusive innovation, to which, these dozen development programmes are linked and connected. For instance, there is only one major institutional structure in the form of the National Innovation Foundation established by the DST, Ministry of S&T. Given the multiple challenges in health, urban renewal, employment guarantees to the poor, roads and infrastructure, among other programmes, all the major R&D agencies and laboratories and universities need to create institutional mechanisms and outreach research centres for impacting their 'near' and 'distant' neighbourhoods. In other words, these institutions must have an agenda for 'grass root innovations' along with high technology and global orientation in their research and innovation policies. India made an impressive mark in the world and is recognised for software services clusters in Bangalore, Hyderabad, Delhi, and Gurgaon and Chennai. This experience needs to be extended and replicated in the case of rural-based and district-based traditional industrial clusters. It is here that the knowledge institutions, universities and R&D agencies need to be linked to the needs and demands of half of India's population now being covered under inclusive development and growth through evolving effective inclusive innovation policy mechanisms.

Notes

1. This section is selectively drawn from Krishna (1997a).
2. Much of this discourse and concepts on nation building and self-reliance in science can be found in the various issues and pages of an important Indian journal in science and technology studies, *Science and Culture*, published from Calcutta, for the period 1938–1947. The journal was

edited by one of the eminent Indian physicists, Professor M. N. Saha, the founder of Saha Institute of Nuclear Physics and Member of Indian Parliament representing Calcutta constituency after 1947.

3. At that time in 1945 it was suggested to place all science and technology agencies under the control of Member, Planning and Development who operated under the government Department of Planning and Development.
4. Nehru inaugurated and spent a full day with the scientific community at the annual session of the Indian Science Congress from 1947 till his sad demise in the mid-1960s.
5. It was created in 1942 but was expanded rapidly during this phase under the leadership of S. S. Bhatnagar. It may also be pointed out that science organisations such as CSIR (India) which was based on the British Department of Scientific and Industrial Research (DSIR) model, created in the wake of World War I, were created in other former colonies such Australia, New Zealand, South Africa, and Canada.
6. See the website of the Department of Science and Technology, Government of India, http://www.dst.gov.in/stsysindia/spr1958.htm (accessed 2 December 2011).
7. Actually from the late 1990s China began to overtake India in science publications reaching more than double by 2005.
8. See Planning Commission (1980: xxi and 10).
9. http://www.dst.gov.in/stsysindia/sps1983.htm (accessed 2 December 2011).
10. See the website of the Department of Science and Technology, New Delhi, India for the full statement of Technology Policy Statement, 1983, http://www.dst.gov.in (accessed 8 January 2013).
11. Parts of this section are drawn from Krishna (2008).
12. See also Sridharan (1995).
13. This does not mean to suggest that there were no policy statements issued by different sectors in earlier phases. There were fewer policy statements issued by sectors compared to the current phase after 1991. Sectoral-based policies issued in the last decade basically articulated and formulated with the different stakeholders at the level of sectors in coordination with the government.
14. See http://dst.gov.in/stsysindia/stp2003.htm (accessed 2 December 2011), the website of the Department of Science and Technology, Government of India, New Delhi.
15. Parts of this section are drawn from Krishna (2008).
16. As noted earlier, NSI in the Indian context makes sense at the sectoral level of understanding rather than at the national level.
17. Different years are used for different sets of data as per their availability from reliable sources.

18. It may be noted that the figures being quoted are from the R&D statistics given by the Department of Science and Technology. However, the DST figures grossly underestimate the foreign R&D inflow that has come into India during the period ending 2005–2006. The estimates of a World Bank study (see Dutz 2007) show that total private R&D investment has risen from half a billion Euro in 2002 to 2.45 billion Euro in 2005.
19. India is attracting global auto manufacturers due to the country's large middle-class population, growing earning power, strong technological capability, and availability of trained manpower at competitive prices.
20. The launch of advance telecom services like 3G and IPTV will drive the future growth in India. The sector attracted $2,558 million FDI in the financial year 2009 as compared to the $1,261 million in financial year 2008. Telecommunications account for a 9.37 per cent share in total FDI inflow.
21. However, big foreign firms such as Microsoft, IBM, Cisco, Oracle, Intel, and Adobe witnessed only a marginal growth rate for the same period between 1 and 10 per cent. For instance, Microsoft which registered 26 per cent growth rate in 2007–8 declined to just 1 per cent in 2008–9 compared to the previous year; and Hewlett-Packard from 30 per cent to 2 per cent for the same periods.
22. However, as per the figures given by the DST, Government of India, based on their databases the total number of papers has increased from 59,315 in 2001 to 89,297 in 2005. These are non-SCI based publications which are covered in one or the other international database.
23. Some of the figures used here are taken from Herstaat et al. (2008) and compared with the data sets given by DST, Government of India. The figure of 14 million science graduates is from Farrel et al. (2005).
24. The first is the Draft National Innovation Act 2008, Department of Science and Technology, Ministry of S&T. It may be noted that this draft is being circulated only for soliciting views from interested public and intellectuals and not yet formalised; and the second is the 'The Protection and Utilisation of Public Funded Intellectual Property Bill, 2008', being circulated among government departments and public and pending ratification by the Parliament to enable it to come into operation.
25. The definition is taken from the Draft National Innovation Act 2008 document.
26. See the Prime Minister's and minister of science and technology's addresses at the 96th Indian Science Congress held at North Eastern Hill University, Shillong, Meghalaya during 3–7 January 2009. See also the Steering Committee Report on Science and Technology of the Planning Commission for the 11th Plan (2007–2012).

27. From the Prime Minister's address at the 96th Indian Science Congress held at North Eastern Hill University, Shillong, Meghalaya during 3–7 January 2009. See also http://www.dst.gov.in/scie_congrs/pmspeech09.htm (accessed 11 September 2012).
28. The government has announced the creation of 30 central universities; five new Indian Institutes of Technology; and 20 Indian Institutes of Information Technology. The government also established the Indian Institute of Space Science and Technology, Kerala; National Institute of Science Education and Research, Bhubaneswar, by the Department of Atomic Energy; Stem Cell Biology and Regenerative Medicine, Bangalore; Cancer Research Institute, Chennai; and Institute of Advanced Study in Science and Technology, Guwahati. See the Prime Minister's address at the 96th Indian Science Congress held at North Eastern Hill University, Shillong, Meghalaya during 3–7 January 2009.
29. See http://timesofindia.indiatimes.com/India/Cabinet_nod_for_bill_giving_scientists_share_in_IPRs/rssarticleshow/3659358.cms (accessed 2 December 2011).
30. See http://www.csir.res.in/csir/external/heads/collaborations/NM.pdf (accessed 2 December 2011).
31. It may be pointed out that India before 2005 WTO regulations opted for a unique Patent Policy which protected patents for seven years. This is not the case in other countries of Europe and North America which protected patents for 20 years. China came under the WTO regime only in 2005 and before that it did not have systematic patent regulation.
32. There are currently about 45 software technology parks spread all over the country. India's dynamic achievements in space research and launch of satellites helped communication and high speed connectivity to software technology parks. All these cities developed as educational and innovation hubs. Over the decades India's educational structure and system has produced a vast number of English-speaking graduates and educated professionals which is again related to the policies which led to the expansion of higher education. All these combined to infuse confidence among firms and entrepreneurs.
33. Research and innovation policies in space are enunciated by the Department of Space in coordination with the Indian Space Research Organisation (ISRO). Space R&D accounts for 22 per cent of total governmental R&D funding in 2007–2008. The main research focus in space is to accomplish high technology capabilities in designing, launching and commercialisation of satellites and manage complex system engineering and management in space technologies.
34. However, this holds good for certain sectors as noted earlier and not for the industrial spectrum across the board.

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