Liberalisation, Technology Policies and Acquisition of Technological Capabilities : A Study of Indian Industry

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1. Introduction

In this era of globalisation and intensely competitive environment when technology has emerged as a vital source of competitiveness, policies to promote technological advance might be expected to play a pivotal role in the economic growth strategies of developing countries. The evidence however suggests that funds allocated to R&D are abysmally low in these countries. According to an estimate (Human Development Report 2003), current gross expenditure on R&D in the developing countries was 0.6 % of their GNP during 1996-2002. The comparable figure in the developed world was 2.6%. On a per capital basis, R&D expenditure per year in developing countries amount to US $20 ; in North America it is about US $ 500 (World Science Report, UNESCO).

Table 1
Selected technology indicators in the developed and developing countries

	Receipt of royalties and fee (US $ per person) 2002	R&D expenditure (% of GDP) 1996-2002	Researchers in R&D (Per million people) 1990-2001
Developing	0.3	0.6	384
OECD	85.6	2.6	3485
World	12.9	2.5	1096

Source: Human Development Report, 2003

In a global perspective, only 15% of total R&D expenditure takes place in the developing countries while developed countries account for 85% of this expenditure. Furthermore, it has been observed that within developed countries technology generation got increasingly concentrated within a few large transnational corporations (Tulder and Junne 1988). Given the fact that R&D funds are extremely low in developing countries, this means an increasing dependence of these countries on TNCs for the transfer of new and advanced technologies. However, there are indications that though FDI has been increasing[1], technology transfers have actually been declining (Kumar 1998) [2]. Besides, there is little evidence of the transfer of sophisticated technologies by TNCs to developing countries (Urata 1998). The adoption of the Agreement on Trade Related Intellectual Property Rights (TRIPs) under WTO, at the same time, is likely to restrict the imitative and adaptive R&D that most firms in developing countries carry out (see Kumar and Siddharthan 1997 on R&D activities in developing countries). Under such conditions, the neglect of R&D in developing countries will have serious repercussion on firms' ability to absorb and evolve new technologies and participate in their development. This may have long-term implication for the developmental efforts of these countries. In that context, two critical questions arise: one, what weaknesses resulted in the poor performance of technology policies in these countries? Two, what measures may be adopted to plug-in the loopholes in these policies to make them more effective in this globalised era? The present paper addresses these questions in the Indian context. While doing so, it focuses only on industrial R&D.

Section II examines whether the evolving competitive scenario and industrial restructuring due to increasing global competition in the post 1990 period affected the R&D efforts in Indian industry. Section III discusses the analytical framework for analyzing the role of government policies in determining the national innovation systems, which in turn explains the domestic technological efforts. Section IV then reviews the evolution of technology policy through three different phases of growth and analyses its impact on technology activity in the industry. Finally, Section V concludes the analysis and draws policy implications for future technological development in the Indian industry.

2. Liberalisation and R&D Efforts : The Indian Experience

India opened its economy in July 1991 by announcing a new industrial policy. These reforms brought in a "silent revolution". More than 80% of the industrial sector was delicensed; the number of industries reserved for the public sector reduced from 17 in 1990 to 6 and plans were chalked out for the dis-investment of the public sector undertakings. Beside fostering domestic competition, the economy was open to external competition as well. The economic reforms saw the progressive removal of import licensing and the phased reduction of tariffs through the 1990s. In 1990-91, the highest tariff rate stood at 355 percent, simple average of all tariff rates at 113 percent and the import-weighted average of tariff rates at 87 percent. These rates were lowered substantially during the early 1990s. The peak rate fell to 85 percent in 1993-94 and to 65 percent in 1994-95. Import weighted average of tariff rate also declined to 56.65 percent in 1994-95 (Mehta 2003). Import weighted average tariff rate in the industrial sector, which stood at 56 per cent was not significantly different from the overall tariff rate average.

The implementation of the Uruguay Round (UR) accelerated the process of the tariff reduction . At the Uruguay Round India committed to bind tariff lines for 62 per cent of its industrial products. These tariff commitments at the UR led to an increase in import coverage under bound rates from 9 per cent in the pre-UR to 68 per cent in the post-UR era (Mehta and Aggarwal 2003). Applied tariff rates are however lower than the bound rates. Analysis for the year 2001 shows that applied rates in that year were lower than the binding rates in more than two-thirds of the tariff lines[1] (Mehta 2003). Table 2 documents the average, weighted and peak tariff rates in India. It shows that the peak rate and average and import weighted rates continued to decline sharply even after 2001. In the year 2004, the maximum

Table 2

Average Applied (MFN) rates of the Indian Industry 1993-94 to 2001-02

[1] At 6-digit level

Year	Simple average tariff rate	Import weighted tariff rates	Peak tariff rates
1993-94		83.72	85
1994-95		55.83	65
1995-96	51.75	46.96	50
1996-97	40.39	35.89	42
1997-98	35.44	31.41	45
1998-99	35.91	28.31	45
1999-00	36.49	30.41	44
200001	34.08	29.36	38.5
2001-02	30.82	27.09	35
2004-05	n.a.	n.a.	20

Source : Mehta (2003)

applied tariff rate for non-agricultural products stands at 20 percent. The Special Additional Duty (SAD) that could rise up to 4 percent is also eliminated by 2004. Thus, starting 2004-05, the top tariff rate on industrial goods will be 20 percent[2] and there will be no other additional custom duties such as SAD on top of this rate.

Table 3 documents the estimates of ERP for 45 broad industry groups classified into three user-based sectors. The estimates are based on the Corden methodology and are documented for four time periods. It shows that the ERP increased during the 1980s. A number of items during the 1980s were freed of import licensing. In order to turn quota rents into tariff revenue, the government of India raised tariff rates substantially. During the 1990s, however, protection rates declined across all industry groups. The decline was sharp during the late 1990s**.**

Table 3
Effective Rate of Protection in Indian industry (%) : 1980-00

	1980-85	1986-90	1991-95	1996-00
Intermediate Goods	147.03	149.18	87.58	40.13
Capital Goods	62.77	78.45	54.23	33.3
Consumer Goods	101.51	111.55	80.55	48.28
All - Industries	115.11	125.93	80.18	40.43

Source : Das (2003)

Non tariff barriers have also been progressively liberalised. Quantitative restrictions imposed on the products in India could be categorised into four groups : (1) prohibited, (2) restricted (3) canalised through state trading enterprises and (4) special import licenses. Table 4 indicates that 61% of the tariff lines were free to import as on 1.4.1996. The share of free lines increased sharply and by 2001, QRs were completely eliminated. One may note here that 5% of the tariff lines that are

[2] Some mega tariff lines are in addition to this peak rate.

currently maintained under QRs are permissible under the Article XX and XXI of the GATT on grounds of health, safety and moral conduct.

Table 4
NTBs imposed on India's imports 1996-97 to 2000-2001 (% of lines, at 10 digit level)

	1.4.1996	1.4.1997	1.4.1998	1.4.1999	1.4.2000	1.4.2001
Prohibited	0.6	0.6	0.6	0.6	0.6	0.6
Restricted	29.6	22.8	22.7	11.6	9.5	4.7
Canalised	1.3	1.3	1.3	0.4	0.3	0.0
SIL	7.6	10.2	9.0	8.7	2.2	0.0
Free	61.0	65.2	66.5	78.8	87.3	94.7
Total	100	100	100	100	100	100

Source : Economic Survey, Government of India, 2001-2002

Reduction in both tariff and NTBs led to an improvement in the import penetration ratios[3] in the manufacturing sector. Table 5 shows that import penetration ratios were higher across all the four categories of industries during 1996-00 as compared with 1980-85.

Table 5
Import Penetration Rates in Indian manufacturing sector (percent)

	1980-85	1996-00
Intermediate Goods	0.11	0.18
Capital Goods	0.12	0.19
Consumer Goods	0.04	0.10
All - Industries	0.1	0.16

Source : Das (2003)

Evidently, the protection levels for Indian manufacturing declined substantially during the 1990s when the government of India introduced a systematic and comprehensive package of liberalisation.

Major policy initiatives were announced by the government to promote FDI also. At present, foreign participation is allowed in almost all sectors (not reserved for the government). Upto 51 percent foreign equity is permitted in most industries. In the areas of sophisticated technology and /or export oriented ventures upto 100% equity is permitted. Under certain conditions, automatic approval is given to 100% equity participation, as well. As a result of these policy initiatives, the annual flow of FDI rose from a paltry USD 0.1 billion in 1991 to USD 4.28 billion in 2001 (see Table 6 also). FDI in 2001 accounted for 1 percent of GDP and 4.3 percent of domestic investment, the corresponding figures for 1991 being 0.07 and 0.12 respectively.

Table 6

[3] It is calculated as the ratio of industry imports to domestic availability.

FDI inflows in India : Approved and actual (1970-2005)

Year	FDI Approvals (Number)	FDI approved (US $ million)	FDI inflows (US $ million)
1970-1980	41	7.018849	na
1981-1985	140	86.66962	na
1986-1990	243	132.1513	na
1991-1995	841	3662.34	789.9428
1995-2000	1577	9135.6	3645.8
2000-2005		2537.0	3707.0

Source : Economic Survey, various issues

This shift from policy regulation to market orientation thus exposed the business enterprises to market competition. But in an increasingly globalizing and knowledge-based world economy markets are becoming more and more competitive. The combined effect of these developments was that technology upgradation became a fundamental force in shaping international competitiveness. One might therefore hope that technological efforts also increased in the Indian industry during the 1990s. Contrary to the expectations, however the rate of growth of R&D expenditure in industry declined in the 1990s compared to the 1980s. R&D expenditure in real terms has fallen in 12 out of 28 broad industries in the 1990s and even where it has risen, the R&D to sales ratios have either stagnated or declined (see Basant, 2000. Mani and Bhaskar, 1998, have also observed a similar trend). The patterns in R&D expenditure as a proportion of their turnover for a sample of over 3500 companies across various industries are summarized in Table 7. It shows that compared to the early 1990s the average R&D intensity has gone down in the late 1990s from 0.868 per cent to 0.823 per cent. In the engineering and chemical industries, it improved slightly/ remained constant, while in other all industries it declined.

Table 7
R&D intensities of sample enterprises across industries

Engineering and chemical industries			
	1992-95	1996-99	1992-99
Automobiles	1.05 (.0146) 139	1.10 (.012) 206	1.08 (.0149) 404
Non-Electrical Machinery	.936 (.009) 131	1.00 (.01) 167	.923 (.009) 341
Electrical Machinery	1.08 (.017) 236	1.20 (.019) 305	1.08 (.018) 658
Drugs and pharmaceuticals	1.57 (.021) 176	1.60 (.019) 219	1.55 (.020) 476
Personal Care Products	1.15 (.019) 29	2.0 (.033) 28	1.54 (.026) 72

Other Chemicals	.78 (.011) 259	.70 (.011) 375	.78 (.001) 753
Sub-group	1.07	1.09	1.08
Other industries			
Food, beverages & tobacco	.33 (.006) 70	.30 (.007) 137	.38 (.008) 254
Textiles	.43 (.009) 98	.40 (.008) 169	.36 (.007) 323
Metal and metal products	.58 (.015) 145	.40 (.008) 162	.475 (.011) 360
Cement and glass	.77 (.0167) 62	.70 (.019) 119	.60 (.017) 215
Rubber & rubber products	.53 (.007) 31	.40 (.005) 53	.44 (.005) 100
Paper and wood	.23 (.003) 45	.21 (.002) 66	.10 (.002) 128
Miscellaneous Products and Diversified	.403 (.005) 42	.30 (.005) 65	.397 (.0052) 125
Sub-group	0.49	.40	0.41
Full Sample	.868 (.014) 1463	.823 (.014) 2071	.846 (.0145) 3534

Parentheses () show standard deviation, the last row in each bracket shows the number of sample firms

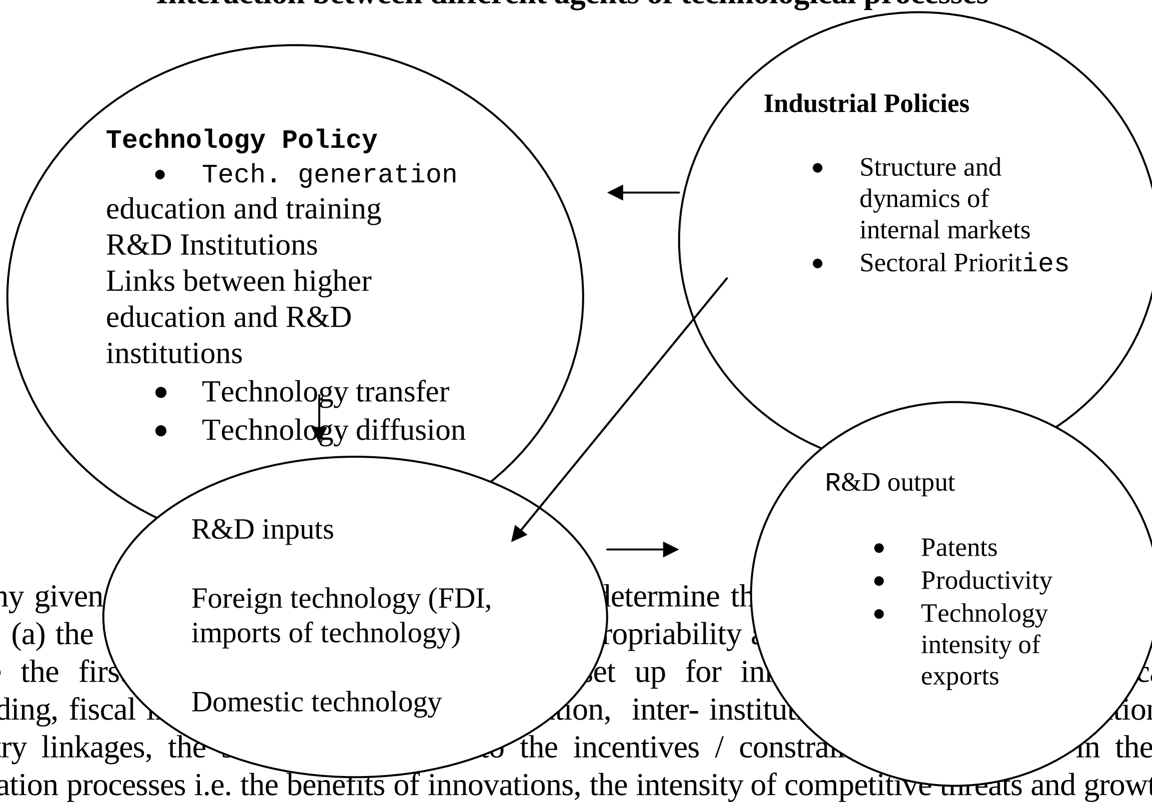
Source : Kumar and Aggarwal (2005)

India possesses numerous institutions of higher learning and an impressive institutional infrastructure for producing trained manpower, generating new knowledge and providing S&T services. The country has the largest pool of qualified engineers in the world, the seventh largest pool of R&D personnel and large cadre of expatriate scientists, technologists and entrepreneurs. Yet, funds allocations to R&D did not show any perceptible increase once the business sector was exposed to rigorous market competition. This is paradoxical. It could be that dependence on foreign technologies has been increasing in the country. But this is a matter of serious concern. Nelson (1993) talks about "Technonationalism. There is strong belief that technological capabilities of a nation's firms are a key source of their competitive prowess and that these capabilities are in a sense national, and need to be built by national action (Nelson 1993, p.3). It is therefore important to review the technology policy and its impact on the evolution of the national innovation systems in Indian industry. "National Innovation Systems" is the network of public and private institutions within an economy that fund and perform R&D, translate the results of R&D into commercial innovations, and affect the diffusion of new technologies (Freeman 1988, Nelson 1988 among many others).

3. Technological and Economic Dynamism: The role of Policies

Market processes are generally rather weak in directing the emergence and selection of technological change. Government policies are of paramount importance in determining the rate and direction of technological advances. Technology policy concerns the development, application and diffusion of technical and scientific knowledge in the economy. One of the most important characteristics of technology policy is that it cannot stand alone. It cannot be separated from the overall development strategy (Barber and White 1987). Technology policy therefore is interdependently enmeshed with agriculture, environment, health and industrial policies. In the industry sector, it is an integral part of the industrial policies. While the technology policy shapes the direction and the pace of technology development, the latter determine the demand side. Figure 1 summarises interactions between policies and industrial dynamics of technological change.

Figure 1
Interaction between different agents of technological processes



For any given ... determine th ... o kinds: (a) the ... ropriability ... e. While the firs ... et up for in ... cal upgrading, fiscal ... tion, inter- institu ... tion-industry linkages, the ... the incentives / constra ... in their innovation processes i.e. the benefits of innovations, the intensity of competitive threats and growth opportunities.

Technological policies are instrumental in creating and shaping technological opportunities. There are three critical elements of technology policy namely technology acquisition, technology generation and technology diffusion. They act on

- the capabilities of the scientific /technological system of providing major innovative processes;
- the capabilities of the economic agents in terms of effectiveness and speed with which they search for new technologies (including through foreign sources); and
- the capabilities of the system in promoting technology diffusion.

Industrial policies/ development strategy on the other hand signal (at the macro level) approriability from technological changes. They shape context conditions under which economic mechanisms operate. They regulate

- the intensity of competition;
- patterns of economic signals (including relative prices and relative profitabilities);
- distortions of market mechanisms;
- direction of technological progress (by setting sectoral priorities)

Technology policies which influence a nation's ability to create and apply new technological knowledge together with development strategies and industries policies which direct country's economic, social and political environment provide a comprehensive framework of knowledge that can be used to govern a nation's competitive environment. Technology policies can be effective only when the three major aspects of the policy - technology acquisition, technology generation and technology diffusion are well balanced and are consistent with the industrial and macro-economic policies. Any inconsistency or the neglect of any of these aspects of the policies may hinder the technological development process.

In what follows we review the evolution of the technology policy within the overall framework of the development strategy and industrial policies. Three different phases of growth are identified. We shall describe the development strategy and then analyses the technology policy adopted by the government in each phase

4. Evolution of the Technology Policy

India has also had three stages in the evolution of government policies. These phases are summarized in table 8.

Table 8
Three phases in the evolution of government policies: the Indian experience

A. Major Planning Objectives	B. Trade Regime	C. Industrial Regime	D.R&D Policies	E. Foreign Collaboration Policies
Heavy industrialisation	Import substituting	Regulated	Setting up of R&D	Liberal

based growth (1948-1968)			infrastructure for creating scientific base	
Growth with self reliance and social justice (1969-1980)	Progressively import substituting	Tightly regulated	Emphasis on technology and technology development	Restrictive
Growth with efficiency and competitiveness (1980 onwards)	Progressively deregulated	Progressively deregulated	Emphasis on the performance of R&D institutions and their linkages with industry	Increasingly liberal

6.1 The initial growth phase

India initiated the process of industrial growth in 1948, when it announced its first Industrial Policy Resolution, IPR 1948. The country adopted the import-substitution strategy across all sectors. The labour-intensive products in mature industries in which the country had comparative advantages in the world markets were considered to have low elasticities with little scope of providing boost to industrialization. Therefore, a particular emphasis was placed on the basic and heavy industries. An accelerated growth rate in the productive capacity of the capital-goods industries was seen as important for raising saving and investment rates; diversifying the industrial sector and promoting manufactured exports. However, given the negligible R&D base, the industrialization process required inflows of foreign technologies. To meet the industry demand, therefore, FDI and technology licensing were encouraged. Foreign collaborations, both financial and technical, were allowed over a wide range of industries. The three basic principles that governed the official policies with regard to transnational corporations (TNCs) till 1968 were the principles of (i) non-discrimination between foreign and Indian enterprises; (ii) full freedom to remit profit and to repatriate capital and; (iii) compensation on a fair and equitable basis in the event of nationalization. In the late 1950s, the requirement of majority Indian ownership of joint ventures under the so-called 51% rule was also relaxed. A series of tax concessions to foreign firms were made affecting salaries, wealth tax, and corporate tax. Technical collaborations were also allowed over a wide range of industries. Though the government approval was necessary, there were no fixed criteria for approving these collaborations. Each case was considered on merit having regard to plan priorities. Tax concessions were granted on technical fees to encourage imports of technology. Besides, special tax rebates were given to foreign technicians.

The industrial boom in India started in the late 1950s. The policy of import substitution created demand for foreign technologies. The average annual number of foreign collaborations increased from mere 35 during 1948-55 to 210 during 1964-70. The actual net inflows of foreign direct investment also increased continuously over the period. The stock of FDI which stood at Rs. 2560 million in 1948 more than doubled to Rs. 5660 million in 1964. The technology-related payments jumped from mere Rs 12 million in 1956-57 to Rs 190 million in 1967-68 (RBI 1992).

The building up of the industrial capacity of the country proceeded almost totally on the basis of the imported technology (Parthasarthi 1987; Desai 1980). Foreign technology acquisition was regarded essential for initiating production and not for accumulating competitiveness capabilities, which is the crucial aspect of technological process. Given the low industrial base and import substituting policy regime, there was no thrust on exports. Therefore, there was little need to improve competitiveness and incentive to learn, absorb, assimilate and upgrade the foreign technologies to create R&D capabilities.

The process of industrialization had little connection with the building up of R&D capabilities. While industrialisation proceeded on the basis of foreign technologies, R&D promotion policies focused on creating scientific and research base. As early as in 1948, the Ministry of Scientific Research and Cultural Affairs was created. In 1958, the Scientific Policy Resolution was announced that served as a basis for the government policy on domestic R&D. The Resolution considered the creation of scientific base as a pre-requisite for developing domestic R&D capacity on the premise that technology grows out of the study of science and its application. The policy aimed at ensuring an adequate supply of research scientists and promoting scientific research for expanding the scientific base within the country. This required establishing and supporting educational and R&D infrastructure. The university and professional education institutions were expanded to generate scientific, engineering and technical manpower. From about 25 universities in 1947, the number increased to 80 in 1969 (Krishna, 2001). The number of engineering colleges increased from 38 (with 2940 seats) to 138 in 1970 with the capacity of 25000 seats. In 1968, IITs modeled on the MIT were set up to provide high-quality engineering education to gifted students (ibid.). Besides, there was a rapid expansion of the science base through agencies like Council of Scientific Research (CSIR), Department of Atomic Energy and Defence Research and Development Organisation. The CSIR had no independent lab in 1942, by the late1950s, 15 such labs were created (see Krishna,2001 for details). Between 1950 and 1970, Rs. 1500 millions were invested in the Council for Scientific and Industrial Research (CSIR) laboratories. The S&T infrastructure scenario during this phase also included the establishment of consulting, engineering and design organizations. There were forty-two such organizations in the private and eight in the public sector by 1970. These efforts resulted into four-fold increase in science and engineering personnel per million of population between 1950-70.

The R&D policies thus focused on expanding scientific base and research capabilities by creating R&D infrastructure . As a result, this phase is termed as the 'Infrastructure Phase' (Jain et al. 1989). Though R&D expenditures increased significantly both in the private and public sector in India during this period[3], the accent was on R&D with a short pay off (Desai 1980). R&D activities centred on, (1) scaling down of plants based on foreign technology to suit to small Indian markets; (2) adapting foreign processes to Indian conditions and local materials; and (3) tackling on-the-spot production problems and quality control. The expansion and diversification in the industrial base[4] achieved during this period was mainly due to increasing factor inputs, particularly increasing public investment ; factor productivity, which grew at the negligible rate of 0.2 percent did not contribute significantly to the industrial growth (Ahluwalia 1991).

The above observations notwithstanding, it is noteworthy that India built up a relatively substantial research- base compared to many other developing countries, in this phase.

4.2 The restrictive phase

By the late 1960s, the focus in national planning shifted from merely growth to growth- with-self-reliance and social justice. With the structuralists' views gaining ground, growth philosophy had undergone changes with considerable emphasis on distribution aspects of growth. The foreign exchange crisis that the country was facing induced the government to pursue the goal of self –reliance also. The government sought to secure increasing controls on the domestic economy through various measures to ensure growth with equity and self-reliance. The industrial licensing system was tightened; the import substitution drive was accelerated and; the foreign trade sector was tightened progressively. Besides, the Monopolistic and Restrictive Trade Practices (MRTP) Act was devised to regulate the expansion of large firms; the reservation policy was introduced to protect the small-scale sector and banks and other financial institutions were nationalized to ensure the flow of credit to the designated sectors. India thus set to attain conflicting goals through a package of inconsistent policies which had disastrous implications for technological development not only in this phase but also in the later period. A highly protected and regulated economic environment was created with no industry-specific priorities.

Since the R&D base had broadened and the industrial structure was diversified, the issue of technological self-reliance also became important. There arose a viewpoint that technology should not be imported to the detriment of local development efforts. The view was expressed that the R&D structures created and nurtured in the earlier period should contribute to the industrial demand for technologies (Sandhya et al. 1990). Major policy measures were introduced which marked a distinct shift in the emphasis from science and scientific development to technology and technological development[5]. To generate the demand for domestic technologies, the government reversed its policies on foreign technology acquisition. Numerous restrictions were imposed on foreign collaborations. The government through three lists separated areas (a) where no foreign collaboration was considered necessary, (b) where only foreign technical collaboration was permissible and, (c) where both financial and technical collaborations could be considered. FDI was allowed only in core industries in which little technological progress had been made in the country. The Foreign Exchange Regulation Act (FERA 1973) imposed numerous restrictions on the entry and growth of foreign companies. The transfer of technology through licensing was also restricted. Limits were imposed on the maximum royalty payment, duration of agreement and renewals and extensions of technical collaborations and, tax rates on royalty, technical fees and lump sum payments were raised to discourage imports of technology. Thus, attempts were made to promote domestic R&D by restricting the foreign technology inflows at the time when not only technology generation capabilities were limited and most R&D was adaptive in nature[6] but R&D resources were also scarce.

In view of the restrictions on technology acquisition, R&D policies were re-examined and reoriented. A separate 'Department of Science' was created with a three tier structure : cabinet subcommittee on S&T, scientific advisory committee to the cabinet and committee secretaries on S&T. Besides, S&T planning was made a part of overall planning process in India in the early 1970s with the creation of the National Commission on Science and Technology and a separate chapter on S&T was included in the fifth Plan document (1974-1979). Three major policy measures adopted for R&D promotion in the industry are as follows :

- *Introduction of the Patent Act (1970):* This act virtually abolished product patents and relaxed terms of process patents in sectors like food, medicine, drugs and pharmaceuticals with a view to encourage local R&D through imitation and adaptations.

- *Introduction of the scheme of recognizing in-house R&D units* : The government introduced the scheme of giving recognition to in-house R&D units. Various policy incentives like tax exemptions, relaxation in import licensing to R&D units[7] and relaxation in industrial licensing for using results of R&D units[8], were provided to firms for setting up in-house R&D units. The government set up various facilities like Technical Consultancy Organizations (1973), Risk Capital Foundation (1975) and Technology Development Fund (1976) with the objective of providing financial support for modernization or setting up of a unit based on new indigenous technologies.

- *Promotion of industry-institution linkages :* The National Research and Development Corporation (NRDC) that was set up in the early 1950s, was geared up to transfer the R&D results of research institutes to industrial units. Besides, the National Information System for Science and Technology (NISSAT) was started in 1977 with the objective of organizing information support facilities for people engaged in research and academics. Under the scheme, sectoral information centres were set up to offer selective dissemination of information, current awareness services, industrial and technical enquiry services, technical translation and other similar services. Network Service Centers for linking participating institutions and library Networks for promoting resource-sharing activities were also set up under the scheme.

The technology policy of the government resulted in a drastic decline in foreign technology transfers between 1968 and 1980. Average annual foreign investment approved declined from Rs. 44.6 million in the early 1970s (1974-76) to around 34 million by the late 1970s. In the late 1970s, there had been net outflow of FDI. Growth in technology payments also slowed down. Average annual growth rate in royalty payments declined from 22.3 percent during 1970-76 to 15.2 percent during 1977-85. However, local R&D did step up. R&D expenditures of the private companies increased more than eight times from Rs 146 million in 1970-71 to Rs 1207 million in 1980-81. The number of registered R&D units in the private sector increased from 156 in 1969 to 516 in 1979. The R&D expenditure of CSIR, which may be taken as a proxy for the institutional industrial R&D expenditures, increased more than three time from Rs. 215 million in 1970-71 to Rs. 690 million in 1980-81. India achieved near self-sufficiency in standard techniques and began exporting technology. Technology receipts on account of lump sum payments and royalties jumped from Rs. 2 million in 1968-69 to Rs. 20 millions by 1979-80 (RBI, 1992).

Technological dynamism however did not take firm roots in the Indian industry. The industrial production growth rates stagnated. Exports increased at a slow pace with the result that by the late 1970s, the balance of payment situation became a matter of serious concern[9]. Patterns of trade in technology-intensive products also became adverse with increase in the share of technology intensive imports in total imports from 63 percent in 1970-71 to 80 percent in 1980-81 and decline in the high-tech exports in total exports from 17.2 percent to 16.9 percent over the same period. Though India achieved self- reliance in technologies for local production and consumption due to the policy of import-substitution and self-reliance; it could not build capacity to create internationally competitive technologies to produce for international markets. As a result, export competitiveness capabilities could not be acquired (Lall 1987). While analyzing the causes of decline in the manufactured exports during this period, Tondon Committee, set up by the government of India to review exports, observed that the international competitiveness of Indian goods declined because of the growing technological obsolescence, inferior quality, limited range and high costs. Besides, it was also observed that though India mastered standard techniques it remained dependent for highly expensive and complicated technologies (Bhagwan 1995). Almost all the studies for this period showed that the total factor productivity that was already very low declined further and became negative (see, ICICI 1994, for references). Chandra and Shukla (1994), in their study on the competitiveness of the Indian industry, found the labour productivity in Indian manufacturing to be the lowest in comparison with other newly developing countries. Capital productivity did not improve either. The contribution of total factor productivity in the growth rate of 3 percent during 1970-80 was as low as 0.2 percent (UNCTAD 1992). The results were poor export performance, stagnating growth rates and declining productivity.

In India, the balance could not be maintained either within different components of technology policy or between technology and industrial policies. This affected the performance of the National System of Innovation and in turn, the learning, absorptive and innovative capacity. India, thus failed to evolve an appropriate mix of these critical ingredients. Macro economic policies stifled all forms of competition. The industrial licensing policies suppressed internal competition and restrictive trade and FDI policies suppressed competition from external forces. In a closed economy, there was a little incentive to improve efficiency of resources. Besides, the license regime created the market structure which was dominated by a few dominant firms and a large number of smaller firms. While the latter were too small and had limited resources to undertake R&D, the former due to lack of competition were not motivated to do so (Desai 1985). Moreover, the policies like FERA and MRTP restricted the growth of large firms . For further expansion, they had to diversify in unknown areas. The policy of discouraging the expansion of firms and the compulsion to diversify in different fields further reduced the incentive to undertake substantive R&D. These restrictions also affected the capabilities to generate R&D resources. Most R&D units remained too small to undertake innovative R&D. R&D statistics published by the Department of Science and Technology shows that in 1982-83, 55% private sector in-house units spent less than Rs 1 million on R&D per annum. Their average expenditures per annum in the private sector were Rs 0.35 million. Technology designs and innovations were beyond their capabilities and financial resources. In the absence of the necessity and resources to generate new technologies, technology was imported and adapted to suit to local needs or to replace local materials to meet import substitution requirement with little efforts at learning, assimilating and improving it.

The second important condition for creating the domestic absorptive capacity is the presence of trained workers, scientists, engineers and entrepreneurs. It is increasingly being acknowledged that without the universal primary and secondary education it is not possible to generate the process of self-sustaining development (see Lall 1992). India, however, could achieve the literacy rate of only 52 percent by 1990-91. Expenditure on education which was as low as 1.2 percent of GNP in 1950-51, increased to around 4% in the 1990s. Though an inverted educational paradigm was adopted by stressing higher-level education, according to an estimate only around 4 percent of the population of the age-group 17-23 has been in universities and colleges and only 19 percent of those enrolled in higher education have been studying science (DST 1999b). Moreover, the number of scientists and engineers per million population was 158 in 1995 (DST 2000c). Besides, it is also observed that there has been mismatch between man power requirements and the output of the higher education system. This has contributed to the problem of brain drain which is estimated at between 5500 and 6500 scientists, technical and professional; manpower annually (Jha 1994).

Technology institutes and universities play a major role in the innovation system (see, Goldman et al. 1997). However, the degree to which they provide support to the industry depend upon the environment and incentives. These institutions remained isolated from the socio-economic block and were primarily aimed at basic research with no links with the process of industrialization. Desai (1980) noted that less than half of the know how that the labs considered utilizable was actually being used. Income from sales of technologies was 2.2% of the expenditure of CSIR labs in 1974. A more recent study by NISTADS (1989), identified only 20 collaborative joint projects with industry and only 20 patent applications were filed. Highlighting poor linkages between the industry and institutes further, it found that out of 2744 scientists, only 1.9 percent visited the industry for research or consultation in 1988. It is generally suggested that since these institutes were staffed with academics, they could not develop corporate culture (see,Jain and Uberoi 1993). A necessary condition for creating demand for research-based activities of these institutes is a competitive environment where there is a concern for improving quality and generating new products (Goldman et al. 1997). This condition was not met in India resulting in the lack of motivation to strive hard. Besides, though the public institutes were directed to devote greater resources to technology development in this period, they were not given any specific guidelines to work on. In the absence of any specific policy on technology development, the scientists experienced confusion over their goal orientation (Krishna 1997). Most projects tended to be initiated by scientists themselves (Rosenberg 1990). Besides, the lack of attention to R&D supporting activities in the national laboratories prevented the possibilities for technological change (Rosenberg 1990). The culture of collaborative research involving different institutes was not promoted. As a result, links between different labs could not be developed.

Moreover, the public institutes had been funded entirely or largely by the government without any mechanism to ensure that it is serving well defined clientele. Assured salaries, and promotions of the staff were also not linked with the research performance. The absence of performance-linked incentives affected the work culture in these institutes. Bureaucratic hassles had been another major factor responsible for the poor performance of these institutes (Lall 1987; Rosenberg 1990). Furthermore, it was observed that the demand for locally developed technologies came from small firms (see also Desai 1984, 1985, 1990) which lacked technical and financial resources. In the absence of any other assistance in a packaged form, therefore, production based on local technology could not take off in many cases.

A relatively small role played by the universities was another major weakness of the system. The weak linkages between universities and institutes contributed to the decline of the academic science base (Krishna,2001). Though the number of universities tripled between 1969 and 1990 from 80 to 240 bulk of these institutions remain only teaching institutions without adequate facilities for scientific research (ibid.). Though this was realized by the Education Commission (1966), no major steps were taken to improve research oriented higher education. Ahmad and Rakesh (1991) showed that the academic science accounted for a mere 6% of total R&D funding. Nagpaul (1997) found that 207 universities published on an average 7 papers per year between 1987-89 in the SCI based journals. In another study, it is shown that only 16 academic institutions accounted for 80% of the publications (see Krishna 2001 for more details).

Finally, at the time when much of the R&D was adaptive in nature, the government of India restricted technology imports severely, violating the fourth condition for building the innovation system in developing countries. Restrictions on technology payments along with the lack of competitive compulsion prevented Indian firms from obtaining technologies in its full breadth and depth. These transfers were limited to only those aspects of the technology which were necessary for setting up and operating the plants. The aspects which were necessary for technology generation and upgradation were considered unnecessary (see Jain 1998, for details). In an empirical study, Basant and Fikkert (1996) found that the private returns of technology purchase were 44 percent in comparison with 1 percent on local R&D. They thus pointed out that the restriction of technology imports imposed heavy costs on the economy. Technology acquisition was viewed as a source of techniques necessary for initiating production and hence was considered as substituting domestic R&D. In the absence of the inflows of new and advanced technologies, however, there was little incentive, direction and capability to update the existing technologies.

Beside the failure in building a strong the national innovation system, lack of focus in industrial and R&D policies was another major factor that resulted in the poor R&D performance. The goal of total technological self reliance resulted into the distribution of scarce resources to all sectors resulting into resource constraints in all the sectors. No efforts were made to identify specific industries and specific core technologies that could be evolved, and directed the limited R&D resources to the promotion of these technologies. In sum, the disjointed policies in India with lack of focus resulted into a weak innovation system and under-utilization of research capabilities created in the first phase.

4.3 The liberalized phase

The third phase of growth initiated in India in the 1980s when, in view of the decelerating exports, worsening balance of payments situation and stagnated industrial growth rate for over 15 years, industrial and trade policies were reoriented. The focus shifted once again. This time it was from growth-with-social justice and self-reliance to growth-with-efficiency (See, the Sixth Plan Document). The IPR 1980 stressed the need for the optimum utilization of installed capacity and for achieving higher productivity and, towards that end, proposed liberalization of the industrial licensing policies by introducing de-licensing, regularization of excess capacity and the capacity re-indorsement scheme. However, it was in 1990 that a massive dose of liberalization was administered.

With shifts in plan priorities, technology has acquired a stronger focus. Restrictions on technology imports and foreign equity participation are being relaxed.. In the case of technical agreements, automatic approvals are granted to all those agreements where lump sum payments do not exceed Rs. ten million and royalty does not exceed five percent for domestic sales and eight percent for exports. Hiring of foreign technicians has been liberalized. The Ministry of Science and Technology also provides assistance in the effective transfer of technology process and efficient management of technology. The Scheme to Enhance the Efficacy of Transfer of Technology (SEETOT) was initiated to facilitate acquisition of technologies and export of technologies and services. Finally, a Memorandum of Understanding is signed between the government of India, European countries and the CII for the establishment of Technology information Centre in India to provide with information on available industrial technologies.

In this changing scenario, the promotion of local R&D is important not only for the effective exploitation of inward technology but also to improve bargaining power in the purchase of technology. Accountability and questions relating to returns on the investment on R&D have become important. The Technology Policy Statement of 1983, announced after 25 years of the Scientific Policy Resolution, 1958, has recognized the needs of establishing linkages between scientific, technological and financial institutions to promote effective transfer of technology from institutions to industry. The new S&T policy 2003 has placed further emphasis on the strengthening of the linkages between industry, R&D institutions and financial institutions for encouraging commercial exploitation of technologies developed in laboratories through involvement of design, consultancy and project implementation groups. It has recommended the development of consortium approach involving academic institutions, national labs and the user-industry for the goal-oriented programme and new product development. In view of the renewed emphasis on domestic R&D, some important policy measures have been adopted to push and reorient the industrial R&D efforts. These include :

- *Strengthening of the administrative infrastructure :* A full fledged ministry of S&T was created for the first time in 1985 with the Department of Science and Technology and a new Department of Scientific and Industrial Research (DSIR) as constituents of this Ministry. At the highest level, a post of the scientific advisor to the Prime Minister was created. In addition, the science advisory council to the Prime Minister was set up in 1986 to advise the Prime Minister on major issues facing science and technology development. Besides, in 1987, a Technology Information, Forecasting and Assessment Council (TIFAC) was established with the objective of creating a technology information system.

- *Creation of an additional institutional support :* To promote consultancy and implement programmes towards strengthening consultancy capabilities for domestic and export markets, the Consultancy Development Centre was set up in 1986. In 1988, the DSIR launched a scheme of granting recognition to Scientific and Industrial Research Organizations (SIROs) in the private sector. Higher institutes of technology and medicine have also been grouped in this category. At present, there are 534 SIROs recognized by the DSIR.

- *Introduction of the Quality System Management (QSM) :* For strengthening in-house R&D units, QSM has been made mandatory for the applicant laboratories. This provides a high degree of assurance to the validity of test results for the benefit of the users, both in India and abroad.

- *Strengthening of fiscal incentives and support measures* : Write off of 100% tax on capital investments for R&D and 133% for expenditure on sponsored research are made available to industry. In certain areas, 125 % weighted tax deduction on R&D is applicable.

- *Instituting Technology Development Fund (TDF) :* The Government of India instituted a fund called TDF to provide financial support for technology absorption and development. It is created by placing the proceeds of R & D Cess on the import of technology. The Cess increases cost competitiveness of local technologies and the fund, created through this cess is used to finance local R&D efforts.

- *Introduction of new schemes :* New schemes have been introduced to support industry for technology absorption, development and demonstration; for involving national research organizations in joint products with industry and for providing financial support to individual innovators having original ideas. Under the "Programme Aimed at Technological Self Reliance" (PATSER) the Department of Scientific and Industrial Research till 1999 supported about 85 R&D projects of Industrial units. A new scheme called `Technopreneur Promotion Programme' (TePP) which aims to support individual innovators be they be housewives, artisans, farmers, students etc., in their attempts to commercialise their innovations has been introduced by PATSER alongwith `Home Grown Technologies Assisstance' programme of TIFAC. More than 70 enquiries were received under this scheme till December 1998. Besides, the Drugs and Pharmaceuticals program was initiated in 1994-95. Under this scheme, financial support is provided to national laboratories and academic institutions for carrying out research programs conceived jointly by the industry and public funded R&D institutions.

- *Creation of Patent Information Centres :* It is proposed to set up 20 patent information centres across the country. The first such Patent Information Centre was set up in Calcutta on September 20, 1997. Such centres will create patent awareness, provide patent information and facilitate filing of patent applications, etc. in the respective regions. The IPR bulletin is brought out to provide information on patents granted in India and other countries.

- *Restructuring the public institution :* Directives have been issued to the government research institutions to generate, at least 30% of their budget from consultancy to the private sector[10]. A satellite based CSIRNET is being set up connecting CSIR headquarters and laboratories to have a fast real time access to one another as also to internet. CSIR has lauched a 'CSIR Programme for Youth Leadership in Science' (CPYLS) scheme to attract youth to science. National Research Development Corporation (NRDC) has been geared to develop and transfer of indigenous technology through Invention Promotion Programme.

- *International linkages :* The DSIR participates in the activities of international organisations such as UNCTAD, WIPO, UNIDO, ESCAP and APCTT at various levels and forums on issues related to Technology Development and Technology Transfer in coordination with other concerned Ministries and disseminates the information.

Thus, for the first time in this phase, there has been a major thrust on improving international competitiveness and hence on technological upgradation of Indian industry. In that context, the government liberalized the inflows of foreign technologies progressively on the one hand and offered a package for R&D promotion on the other. The statistics reveals that the policies adopted in the liberalized phase resulted in a tremendous increase in foreign technology inflows. The number and the magnitude of foreign collaboration approvals increased sharply (Table 9).

Table 9
Indicators of foreign technology acquisition in the 1990s in India

Year	Lump sum payments approved (Rs. Million)	Actual Technical Payments (Rs. Million)	Capital goods imports (Rs. Million)
1990	5741.4	6562.0	104660
1991	9798.2	5722.0	106550
1992	22812.7	4052.0	108390
1993	36900.2	9910.0	166630
1994	22999.9	6593.0	199900
1995	71961.5	13086.0	282890
1996	26522.1	16008.0	298680
1997	-	11256.0	280160
1998	-	-	323040

Sources : Economic Survey 2001, RBI Monthly Bulletin,April (1999), Foreign Collaboration Approvals, DSIR.
Note: - not available

International technology transfers increased substantially.
There have been several instances of achievements in R&D efforts also. Important achievements have been made in technology development in pharmaceuticals, bio-technology and engineering. The share of external cash flow in government grants and R&D expenditures of CSIR increased from 17.3 percent and 15.5 percent respectively in 1985-86 to 40 percent and over 26 percent respectively by 1993-94. The industrial production based on CSIR knowledge base touched the figure around Rs.42000 million in 1998-99. There have also been successful restructuring of some public institutes such as National Chemical Laboratories (see , Goldman et al. 1997), that are attracting international projects now. These successful cases notwithstanding, the macro level statistics are not encouraging.

Input indicators
Overall domestic R&D expenditures did not show discernible change. Industrial R&D expenditures as a proportion of total turnover increased somewhat in the late 1980s; however, it has been declining continuously in the late 1990s. Kumar and Aggarwal (2005) analyzed the R&D expenditure of ……..They found that the R&D expenditure declined in 35 firms between the two years. On comparing the R&D expenditure intensity of 154 engineering and chemical sector R&D performing firms reported in the DSIR R&D compendiums for the late 1980s and

the late 1990s, the author found that it declined in 100 firms. Evidence suggests that firms increased advertisement intensity faster than the R&D intensity during this period. This implies that firms preferred to increase advertisement expenditure to R&D expenditure to differentiate their products once the competitive pressures mounted (table 10).

Table 10
R&D indicators in India in the 1990s (%)

Year	National R&D to GDP ratio	Industrial RDS to sales turnover ratio	Advertising expenditure to sales turnover ratio	Plant and Machinery to sales turnover
88-89	.96	0.8	0.59	4.19
89-90	.92	0.78	0.6	3.33
90-91	.85	0.61	0.55	5.41
92-93	.81	0.67	0.75	6.57
94-95	.71	0.62	0.59	3.88
95-96	.69	0.65	0.57	4.16
96-97	.66	0.64	0.59	4.32

Sources: Research and Development 1999; Research and Development in Industry, 1999

Furthermore, the classification of R&D data by objectives reveals that the share of industrial development in total R&D expenditures declined sharply after 1986-87 in both the private and the public sector (table 11)

Table 11
Share of industrial promotion in total R&D in private and public sectors

Year	Private Industry	Public sector
1977-1978	71.3	26.1
1982-83	54.8	54.8
1986-87	57.9	54.2
1990-91	48.1	41.0
1996-97	33.9	23.2

Sources : Various issues of ‘R&D in Industry’ (DST)

Evidence suggests that the institutional industrial R&D expenditures also declined relatively during this period. If R&D expenditure by CSIR is used as a proxy for institutional industrial R&D expenditures, R&D employment in total industrial (organized sector) did not show any perceptible change in the private sector either. In the public sector it declined continuously (Table 12)

Table 12
R&D employment per thousand of total employment

Year	R&D employment per thousand of total employment	
	Private	Public

1990-91	17.7	10.7
1992-93	16.1	11.4
1994-95	17.1	10.4
1996-97	17.9	8.3

Sources: Various issues of ‘R&D in Industry’ (DST)

A detailed analysis of the nature of work assigned to R&D professionals reveals that only 36 percent of personnel are actually in professional R&D activities suggesting that technical manpower is not efficiently used (Table 13).

Table 13
R&D Manpower (% of people involved and their kind)

Year	R&D		Auxiliary		Administration	
	Private	Public	Private	Public	Private	Public
1980-81	67.0	50.0	22.0	22.0	11.0	28.0
1986-87	55.1	38.9	24.0	39.8	20.9	21.3
1990-91	55.7	44.8	29.8	37.8	14.5	14.7
1996-97	34.8	49.4	43.2	34.7	22.0	15.9

Sources: Various issues of ‘R&D in Industry’ (DST)

Output Indicators

Output indicators present a similar picture. Table 14 provides information on the number of patents sealed in the name of Indians and foreigners during the last 17 years. The data is compiled by the DST on the basis of primary data and has been subject to various limitations like non-reporting or mis-reporting. However, it presents a broad picture of the over-time trend. Apparently, the patents sealed in India, whether they were in the name of foreigners or Indians, declined drastically after 1989-90.

Table 14
Patent sealed and in Force in India

Year	Patent sealed		Patent in force	
	Indian	Foreign	Indian	Foreign
1990-91	379	1112	2238	8210
1991-92	551	1125	1206	9093
1992-93	251	1021	1034	8997
1993-94	442	1304	1995	7281
1994-95	476	1283	1923	7052
1995-96	415	1118	2098	6694
1996-97	293	614	2003	7202

Source : Research and Development Statistics, DST (1999b)

Performance indicators

Industrial production has not shown any appreciable increase in the 1990s. The growth rates in basic and capital goods industries have not increased either (Table 15). There is evidence of

Table 15
Growth rates of industrial production (%)

Year	TOTAL	Basic goods	Capital goods	Int goods	Consumer goods
1990-91	8.2	4.30	21.90	5.60	6.30
1992-93	2.3	2.60	-0.10	5.40	1.80
1993-94	6.0	9.40	-4.10	11.70	4.00
1995-96	12.8	10.70	4.10	19.10	12.30
1997-98	6.6	6.50	5.30	8.10	5.70
1999-00	8.2	5.14	5.42	15.37	5.41

Sources : Economic Surveys, various issues

growth of productivity in the late 1980s[11]. Basant and Fikkert (1996), however, found that technology-induced increase in productivity did not take place in the late 1980s. Their finding is supported by the fact that the growth in productivity could not be sustained for long; it declined in the 1990s (Srivastava 2000, Balakrishnan 2000, Das (1998). Exports of technology intensive products increased in the late 1980s but again their growth could not be sustained in the 1990s. Technology-intensive imports remains substantially higher throughout the period. As a result, the ratio between technology-intensive exports and imports did not decline (Table 16).

Table 16
Technology intensive trade in India : 1990-91

Year	Technology intensive exports (% share in total)	Technology intensive imports (% share in total)	Ratio between T-I exports and imports
1990-91	5.14	9.96	0.39
1992-93	4.06	8.17	0.42
1994-95	4.72	10.68	0.41
1996-97	5.83	8.36	0.6
1997-98	6.07	9.97	0.51

Sources DST (2000c)

The poor performance of R&D in this phase has its genesis in the second phase. In the protected regime, the country could not build capacity to innovate and produce internationally competitive technologies. Substantial technology activities were undertaken but they were geared towards product/process adaptation. The national innovation system remained weak in the absence of the economic environment that nurtures it. The process of liberalization initiated in the 1980s and accelerated in the 1990s put competitive pressures on firms to modernise and upgrade their technologies. To cope up with the pressures, firms were forced to resort to technology acquisition. Despite massive institutional capabilities accumulated over the years, there is no perceptible increase in the demand for institutional R&D (with a few exceptions). This could be due to lack of confidence in domestic technology. In the absence of the internationally competitive quality and standard in technology development, industry has created demand for foreign technologies which are tested abroad and are easily available. Some major policy decisions have been taken to improve the performance of these institutes and increase their accountability. For instance, scientists have been allowed to obtain royalties from commercialization of patents developed by them in the laboratories. Besides, highly ambitious targets have been fixed by CSIR in its vision documents. CSIR Vision 2000 set the targets to increase R&D to GNP ratio to 2 percent. CSIR labs were directed to generate 30% of their budget through contracts. Vision 2001 set the targets at more ambitious level. By 2001, CSIR laboratories have to generate 50% of their budget through external contracts and consultancy and hold a patent bank of 500 foreign patents,. Despite these measures, the work culture of public institutions has not changed significantly (See Goldman et al. 1997). In a survey based industry, Alam (1993) found that a large number of firms felt that their approach to research for industry is not very positive. The financial statistics vouch for this. R&D-GNP ratio declined continuously to .66 percent instead of to increasing to 2 percent. The ratio of external cash from research contracts and consultancy to government grant declined from 42.8 percent in 1989-90 to 33.5 percent by 1998-99 (Table 14). Resources from contract research increased increased slowly from Rs. 1670 million in 1995-96 to Rs. 2040 million in 1998-99. Table 15 shows that much of the revenue is generated through government research contracts. The share of the industry remains only one-fourth against the target of 50%. Resources generated from the foreign contracts have been meager Rs. 147 million which formed only 7 percent of the total external cash flow. Fixing the targets can never succeed unless it is supported with a well formulated penal and mandatory mechanism. While good performers should be rewarded, bad performers need to be penalized. In many countries including China in recent years such measures have proved to be highly successful (see Goldman et al. 1997). In China beginning with 1989 budget of 5000 institutes were slashed and decisions were decentralized to the institutes. The results are noticeable. Some institutes have downsized, others have set up spin-off plants and some have become demand-driven by serving the industry.

Table 17
The ratio of external cash flow to government grants

Year	Cash flow/govt. grants (%)
1989-90	42.8
1993-94	40.0
1998-99	33.5

Sources : CSIR Annual Reports, various issues

Table 18

Source-wise composition of external cash flow to CSIR labs in selected years (%)

	1987-88	1992-93	1995-96	1998-99
Government	56	77	77.2	66.9
Industry	42	22	20.4	26.0
Foreign	2	1	2.4	7.1
Total	100	100	100.0	100

Sources : CSIR Annual Reports, various issues

Another vital link missing is the isolation of universities from R&D. While universities are the major research centers in almost all developed countries including Korea, in India they are isolated still from the scientific research and advancements. This has affected the quality of higher scientific education which is becoming increasingly irrelevant over the years. Though there are instances of cooperation (for instance NRDC has signed a MOU with the university of Delhi for commercialising their technologies), these are too inconsequential to make an impact. The country is still to formulate a National Innovation Scheme that can create a networking of various institutes and universities.

Table 19

Composition of R&D budget of the central government in India (% of total)

	1958-89	1970-71	1980-81	1990-91	1996-97
CSIR	27.1	24.1	15.7	10.8	9.3
DRDO	8.0	19.6	18.2	29.5	30.7
DAE	41.2	32.2	16.8	12.0	11.0
DOS	-	13.0	16.6	17.0	22.1

Source : Research and Development Statistics, 1999

Limited R&D resources is another major factor contributing the decline in R&D efforts Much of government support is in the form of soft loans and venture capital, with no substantive subsidy programme .Domestic R&D units are too small to undertake substantial R&D even in the 1990s (Table 20). Many firms use R&D units for quality control. Their main objective is to avail tax incentives. Government still constitutes around 80% of R&D expenditure in India. Under such circumstances, government budget cut on industrial R&D with no corresponding increase in the private sector is likely to reduce R&D efforts. The statistics shows that the proportion of industry in total central government R&D expenditure declined from 15.7 percent in 1980-81 to 9.3 percent by 1996-97 (DST 1999b). There has been continuous increase in defense R&D. Under such circumstances, civilian R&D institutes may be linked with the defense institutes and collaborative research may be encouraged between the two. However, the culture of collaborative research is rare and the limited resources are not pooled through networking to develop core technologies in sectors where India has potential.

In a recent study on R&D in the manufacturing sector, Kumar and Aggarwal (2005) found that R&D intensity by local firms declined in all the industries (except drugs and pharmaceuticals) in the post reform period. While analyzing their behaviour they observed that due to the competitive pressures R&D activities are more focused on improving competitiveness in the post reform period; they concluded however, that the intensities are too small to make much of an impact.

Table 20
Size-wise distribution of R&D labs in the Indian industrial sector in 1997-98

Annual R&D expenditure (Rs. Million)	R&D units (% in total number)		Average R&D expenditure (Rs. Million)	
	Public	Private	Public	Private
<10	65.0	79.0	2.89	2.7
10-50	22.0	17.0	23.8	42.7
>50	13.0	4.0	198.4	183.4

Source: Research and Development in Industry , DST (1999b).

To recapitulate, The weakness of the Indian policies lies in its failure to evolve a right mix of different policy strands, which impacted on the performance of the national innovation system. Thus the overall problem relates to the lack of appropriate linkages between different actors of the national innovation system. Though various policy measures were adopted in the 1990s to correct the imbalance in the approach, these efforts did not succeed significantly due to the half hearted approach. No innovation policy has been announced. After the Technology Policy 1983, S&T policy is announced in 2003. Schemes and policies are announced in a discretionary manner without any concrete approach. Their implementation and performance are left to the market forces. No serious evaluation is ever made of these policies and little is done to ensure their effective use . Under such policy environment no major change is perceptible in near future.

5. Policy Implications

In this era of liberalization, when technology has emerged as the most crucial factor determining competitiveness and growth, it is important to adopt a highly focused approach. A package of well formulated policies needs to be introduced that takes care of different aspects of technological development.

Given the limited resources, it is important to identify the sectors or specific activities across sectors where the country may build comparative advantages. These activities should have significant technological potential and generate beneficial externalities for other activities. Bio technology and information technology for instance are two sectors where India has potential and which cut across various sectors. Once the priorities have been decided, policies need to be formulated at the sector/ activity level. In each case, it is important to identify innovation chain which includes both technical and economic interfaces e.g., stages of innovation, skills required, institutions involved, financing of research, marketing of products and market feed backs. Having identified the innovation chains, a package of direct and indirect policies needs to be developed to promote R&D in these areas. These measures include, direct intervention in forging links between institutions and industry, between industry and universities and among firms; strengthening of the existing infrastructure and creation of new institutions that may have important links in the innovation chains. Successful restructuring of the technical institutions is important in this context. This requires reorientation of the incentive schemes and funding patterns. The government of India did take certain measures to improve the accountability of these institutions in the post 1991 period and National Chemical Laboratory is an excellent example of the structural transformation. However, the results in the case of other institutions are modest and call for more stringent steps.

University-industry-Institutions linkages also need to be developed. In this context, the concept of Science parks is a useful idea. They consist of centres of state-of-the-art research bringing together scientists from the university domain, the business world and public bodies with the aim of transferring knowledge and technology to society and promoting innovation in the bio-medical, technological and ICT (Information and Communications Technology) fields. Some parks are led by the University. The primary aim of these parks is to link university research teams to the world of business, and they spring from the need to connect academic know-how with companies so that the institutions of higher education do not lose in competitiveness once they have relinquished their monopoly of knowledge. There are other science parks where companies play a leading part in the management of knowledge. In India Software technology parks have been set up with a distinct focus on software exports from the country at the initiative of the Ministry of Communications and Information Technology. The government is providing various services including infrastructure and technology assessment. However, such parks should also be used to promote institution-university-business linkages. Besides, it is also important to promote science parks within the country to encourage participation of higher education institutions and public and private research institute. Patenting by universities is almost absent in India. It is important to harness the skills of the higher education institutions by forging links between industry-institutions and universities. Promotion of industrial clusters is another area that may be given priority to internalize deficient markets for capital, skills, information and entrepreneurship. All these measures may be supplemented with the fiscal incentives, research grants and R&D subsidies. Fiscal incentives should be given not only on R&D expenditures but also on the products developed in the process (see Kumar and Aggarwal 2005).

Human skills is a crucial aspect of the process of technological development. It needs to be treated as human capital investment and not as social service expenditure as in India. At the higher education level, emphasis should be on forging proper links between industry and technical institutions for improving the relevance of technical education, for reducing manpower imbalances and for financing of technical education in the country. It also requires periodic analysis of manpower requirements for better planning in human capital investment. AICTE (1994) recommended formation of an Education Development Bank for better financing technical education in India. Such policy measures may improve the access to technical education.

Finally, the supply side policies need to be matched by appropriate demand side policies. On the demand side, competitive pressures may be maintained by adopting a well formulated competition policy and intellectual property protection.

In sum, in the changing global scenario, the concept of science and technology policy needs to be replaced by ‘innovation policy’. The innovation policy aims at establishing and strengthening the Techno-Economic network rather than supporting science and technology activities *per se*. While Korea and other OECD countries are increasingly focusing on innovation policy, India is still in the regime of S&T policy. The country needs a transition from S&T policy regime to innovation policy regime and DST has a take a major step forward in this direction..

Notes

[1] FDI inflows in developing countries increased phenomenally at the annual rate of 24.2% during 1990-94 and the share of these countries in total flows increased from mere 16.5% in 1986-90 to around 38% by 1994. The growth in FDI inflows to developing countries slowed down and their share in total FDI flows declined somewhat thereafter ; however, it has remained higher than that in 1980s (Jain 1998).
[2]Average annual growth rate in technology transfer payments in developing countries during 1985-95 had been 17.9% compared to 19% for all countries (Kumar 1998)
[3] R&D expenditures by CSIR labs increased over four times from Rs. 51 million to 215 million between 1958-71 while that by privately-owned companies increased from 100 times from mere Rs. 1.5 million in 1958 to Rs. 146 million in 1970-71.
[4] The industrial structure diversified with the basic and capital goods industries having experienced the growth rates of 11 and 15 percent respectively between 1959-60 and 1965-66. Besides, the share of technology-intensive exports in total exports increased while that of technology-intensive imports in total imports declined.
[5] CSIR labs were asked to alter the balance between basic and applied research in favour of the latter. The concern for applied research was such that even an institution like National Chemical Laboratory with a balance of 50:509 between basic and applied research was asked to alter it to 20:80 (Sandhya et al. 1990, p. 2801)
[6] Most studies found a complementary relationship between the two during this period (see Kumar and Siddharthan 1997).
[7] R&D units could import all their requirements under `Open General License'
[8] Firms were allowed to set up capacity based on results obtained from their R&D efforts.
[9] The net BOP increased from $622 million in 1970 to $5314 million by 1980.
[10] CSIR (1996) in its draft paper has set the target of generating 50% of the resources by 2001 AD.
[11] While Ahluwalia (1991) found that there was a distinct upturn in productivity after 1982-83; ICICI(1994), Srivastava (1996) and Goldar(1995) found that the turn-about took place in the post-1985 period.

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