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TECHNOLOGY POLICIES AND TECHNOLOGICAL CAPABILITIES IN INDUSTRY: A COMPARATIVE ANALYSIS OF INDIA AND KOREA

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Foreword

This paper reviews the evolution of science and technology policy in India and Korea over the past fifty years in order to draw relevant lessons for India. In both countries, policies, strategies and structures of science and technology evolved under a planned development approach. However, while Korea created a strong national innovation system and acquired significant technological capabilities, policies in India failed to evolve an appropriate balance between critical ingredients of the innovation system, which weakened its performance and hence, resulted in poor R&D performance of firms. The paper recommends a more focussed but multi-dimensional integrated approach to create technological dynamism within the country. It highlights the importance, in the changing global scenario, of replacing the concept of science and technology policy by an 'innovation policy' which aims at establishing and strengthening the techno-economic network.

I have no doubt that the lessons drawn from this cooperative exercise will prove useful to the policy making community in India.

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Technology Policies and Technological Capabilities in Industry: A Comparative Analysis of India And Korea*

I. Introduction

It has long been recognised that investment in science and technology makes a vital contribution to economic growth in terms of higher growth rate of the economy's productivity (see, for instance, Shultz 1953, Abramowitz 1956, Solow 1957, Denison 1962,Griliches 1958, 1986, among others). In addition to direct returns, the externalities associated with investment in science and technology have also been found to be huge (Abramovitz 1989). Realising the importance of technology, most developing countries adopted research and development (R&D) policies in the early phases of their development. The evidence however suggests that the historical gap in technology generation between developed and developing countries has not narrowed down over the years. According to an estimate (Kumar 1998), the three most developed countries namely, US, Japan and Germany alone accounted for 65 per cent of the total R&D expenditure in 1993. Their share in US patents over 1977-1996 was 83 per cent and they controlled 71 per cent of global royalties and technology fees. It has also been observed that in most developed countries technology generation got increasingly concentrated within a few large transnational corporations (TNCs) (Tulder and June 1988). This resulted in an increasing dependence of developing countries' firms on TNCs for the transfer of new and advanced technologies. Recognising the role of TNCs in technology transfer, developing countries started liberalising their policies towards FDI in the mid-1980s. The process was further accelerated in the early 1990s. However, there are indications that though FDI has been increasing since then[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

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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 the above context, two critical questions arise: one, what were the weaknesses that resulted in the poor performance of technology policies in these countries? and two, what measures should be adopted to plug in the loopholes in these policies to make them more effective in the globalised era of the 1990s? The present paper addresses these questions in the Indian context. India provides a classic case of a developing country where despite the presence of a wide institutional infrastructure for producing trained manpower, generating new knowledge and providing science and technology (S&T) services, the industry became increasingly dependent on foreign technologies once the economy was liberalised in the 1990s. Evidence suggests that while FDI and technology purchases substantially increased, expenditures on domestic R&D declined (Jain 1998). To analyse the performance of Indian R&D, this paper reviews the evolution of India's technology policy since independence and evaluates it in a comparative framework with that of Korea. Given the phenomenal economic development in Korea (Table 1) within a short span of time, an analysis of Indian and Korean policies in a comparative mould would be useful for examining the weaknesses of the policies adopted by India and the relevant lessons that India can draw from it.

Table 1: Some indicators of development: Korea versus India

		1970	1980	1990	1997
GNP per capita (US $)	Korea	270	1750	5770	11390
	India	-	270	400	440
Industry share in GDP(per cent)	Korea	29	40	43	43
	India	20	22	27	26
Total exports as a ratio of GDP (per cent)	Korea	14	33	30	49
	India	3	6	7	11
Manufactured. exports in total exports (per cent)	Korea	-	90	87	91
	India	-	59	71	74
Adult literacy rate (per cent)	Korea	78	93	96	97
	India	33	41	49	55
Gross enrolment ratio (6-23 age) (per cent)	Korea		66	74	-
	India		40	50	-

Source: World Bank (1980), World Bank (2000)

Technology policy is an integral part of overall industrial policy framework (Barber and White 1987). While the former shapes the direction and pace of technology development, the latter determines the demand side. This paper, therefore, reviews the evolution of the technology policy in both Korea and India within the overall framework of the development strategy and industrial policy adopted by their respective governments. In each country, three different phases of growth are identified. The paper first describes the development strategy and then analyses the technology policy adopted by the government in each phase. There are two elements of technology policy: one, policies related to technology acquisition from abroad through formal modes such as FDI, technology licensing and capital goods imports; and two, technology generation policies. The paper reviews both these aspects of technology policies in the two countries.

Section II reviews the evolution of Korean policies through the three different phases of growth. Section III explains the Indian experience and evaluates it in a comparative framework of the Korean experience. Finally, Section IV concludes the analysis and draws policy implications for future technological development Indian industry.

II. Evolution of Technology Policy: the Korean Experience

The three phases of growth and evolution of technology policy in Korea are summarised in Table 2.

Table 2: Three phases in the evolution of government policies*: the Korean experience

A. Major planning objectives	B. Trade regime	C. Industrial regime	D. R&D policies	E. Technology acquisition policies
Mature industry**-based growth phase (1960-1980)	-Outward oriented for mature industries -Import substituting for new industries	-Competition promoting - Biased in favour of efficient large firms.	- Emphasis on diffusion at the production end	- Restrictive for FDI and licensing and liberal for capital goods imports
Consolidating stage (1980-1990)	- Import substituting for major import items. - Outward oriented for others	- Liberal with curbs on monopolistic powers of large firms	- Emphasis on technology and technology generation.	- Greater emphasis on licensing
Emergence stage (1990 onwards)	- Outward oriented.	- Encouragement to SMEs	--Expanding scientific base with emphasis on international cooperation - Developing innovation clusters	- Liberal for inward and outward FDI

* The first two stages are based on Kim and Dahlman (1992).

**Mature industries are the ones where technology advancement is slow and matured technologies dominate. In the 1960s, the focus had been on textile, plywood and food; in the 1970s, the focus shifted to ship building, steel, marine sciences and heavy chemicals.

II.1 Mature industry-based growth phase

Korea achieved independence in 1945 with the end of the Japanese colonial rule after the Second World War. However, the growth process could not be initiated immediately thereafter due to the division of the nation and the ensuing civil war. These developments notwithstanding, the government undertook a heavy investment in human resource development in the early years. The formal education system was strengthened at all levels, which resulted in a dramatic increase in the literacy rate. The adult literacy rate (15 years and above) reached the level of 71 by 1960. This laid an important foundation for the formation of well-trained human resources for the subsequent growth process, which was initiated in 1960 (Kim and Dahlman 1992).

In the initial phase of the growth process, the government shaped the development strategy on the Japanese model and adopted a two-pronged strategy. It followed rigorous export-oriented policies in mature industries, such as food, textiles (in the 1960s), metal, shipbuilding and chemicals (in the 1970s) and an import substituting strategy in the consumer goods sector. Exports were promoted through threats and promises (Kim 1991). In order to bring about the economies of scale and compete on the basis of cost advantage in mature industries, the government intentionally promoted large firms (c*haebols*). In the pursuit of this policy, however, a distinction was made between good performers and bad performers. While efficient firms were given preferential treatment in the allocation of foreign exchange, industrial licenses, capital (through low interest rates) and technology import facilities, bad performers were penalised and in many such cases their management was handed over to the selected efficient large firms (Kim and Dahlman 1992). For import substitution in consumer goods industries also, major responsibility was assigned to c*haebols*. The government gave large import substituting projects to c*haebols*, provided them low interest loans and helped them in importing technologies.

Since the country's own technological capabilities were limited, the dual trade policy placed a continuous pressure on firms for acquiring foreign technologies. To meet the industry demand, the government encouraged the transfer of foreign technology embodied in capital goods and turnkey plants by assigning low protection to the capital goods industry. Highly restrictive policies were adopted towards FDI and technology licensing. Technical agreements were allowed only in the cases where technical assistance was needed to run the turnkey projects. Capital goods imports were given preference over the alternative modes of technology acquisition for two reasons. One, light industries required simple and standardised technologies that could easily be transferred through capital goods imports. Two, it was felt that given the training and entrepreneurship of Koreans, it would be easy to assimilate and adapt foreign technologies embodied in capital goods through reverse engineering at the production end. Though the policy led to massive imports of foreign capital goods and owing to low protection retarded the growth of the local capital goods industries, it did facilitate a rapid acquisition of technology during this phase. The process of assimilating and adapting foreign technologies was pushed by the need to attain international competitiveness and was facilitated by a massive investment in education undertaken by the government in the initial years of independence.

There was nearly a total absence of demand for formal local R&D. The government took initiatives in indigenous R&D efforts by creating public institutes. In 1966, the government established the Korea Institute of Science and Technology (KIST). It attempted to draw back Korean scientists and engineers overseas by offering very attractive salaries to reverse brain drain ((Nam 1995). It also carried out a number of studies on Korea's technology development potential. These studies served as a basis for the formulation of national policies in later years. In 1967, a separate full-fledged Ministry of Science and Technology (MOST) was created. In the 1970s, a number of other specialised research institutes were set up and by the end of 1970s, there were 16 R&D institutions (Lall 1998). These institutes were staffed with overseas trained academicians and scientists. In 1973, the 'Daeduk Science Town' was constructed to serve as a linkage between research institutes, universities and industries. However, since the industry tackled mature technology and the *chaebols* aggressively performed imitative reverse engineering, there was little demand for institutional R&D and the contribution of the R&D infrastructure in technology generation was negligible. As a result, these institutes took upon a consultative role in identifying technology and facilitating technology acquisition by Korean firms. They also provided services in solving simple problems of technology transfers and absorption (Kim and Dahlman 1992, Nam 1995). They attracted the best talents and served as a think tank for the government in assessing the needs and potentials of the country. To promote in-house R&D in the private sector, the government offered various tax incentives and preferential financing schemes (loans and subsidies) for R&D activities to entrepreneurs (see, Kim 1995 for details)[3] but given the relatively easy means of acquiring embodied foreign technology and assimilating it through shop floor R&D, they faltered. As a result, formal R&D expenditures accounted for only 0.39 per cent of GNP in 1970 and the government share in total R&D expenditure remained 70 per cent (Kim and Dahlman 1992).

In sum, the continuous inflow of foreign technologies through capital goods imports together with the shop floor R&D helped in learning, mastering and accumulating technological capabilities, which determined the process of technological development and high growth rate in Korea (Kim 1987). Between 1960-77, the average annual growth in GNP was over 9 per cent. Production in the manufacturing sectors and exports of goods and services increased at the rate of 18 per cent and 28 per cent, respectively. The share of manufacturing in GDP increased from 11.5 per cent during the period 1950-60 to over 23 per cent by 1970-77 and that of exports increased 30 times from 3 per cent to 30 per cent over the same period (World Tables 1980).

II.2 The consolidation stage

By the 1980s, the industrial base of Korea had broadened. But a rise in wages and the entry of low-waged countries in the export markets had eroded its price competitiveness in mature industries. Besides, there had been an increasing international pressure on the Korean government to discourage reverse engineering. In view of these developments, the industrial policy was geared to transforming the industrial structure into one based on comparative advantage and to expanding technology-intensive industries, such as machinery and electronics. In this context, capital goods sector, which had been subject to low protection till the late 1970s also came under import substitution. Thus, the focus shifted from light industries with generic technologies to high-tech industries.

With change in the industrial policy, a need was felt to reorient the technology policy approach, as well. The two major changes introduced in this policy were: one, reversal of the government policy on foreign technology licensing; and two, rigorous promotion of domestic R&D. The foreign licensing policy was completely relaxed for all industries and for all terms and conditions, marking a shift in the preference from the acquisition of embodied technology to disembodied technologies. This shift reflected the need for progressively more sophisticated technologies. The government established a technology transfer centre, which provided industries with information regarding alternative technologies available abroad and their suppliers. It assisted firms in preparing contractual documents as well. Besides, three technical information centres were set up to collect and disseminate technical information. Public institutes helped the private firms in identifying foreign technologies and in negotiating technology transfers by undertaking joint research with them. Technology payments that were $96.5 million during the period 1972-76 increased to $2130.3 million by 1987-89. The policy towards FDI - another important source of foreign technologies - was also relaxed comparatively during this period. However, to provide protection to the domestic industry, it was kept selective. FDI was channelled into industries supplying critical intermediate inputs or complex technologies; it was prohibited for consumer durables. Besides, joint ventures were encouraged under local majority ownership to facilitate technology transfers and the development of managerial skills. To maximise spillovers from FDI, the government enforced local content requirements and showed direct preference for the desired kind of technology.

While technology licensing was liberalised, the government undertook massive efforts to promote domestic R&D efforts also. The objective was to strengthen the absorptive, learning and technology generating capacity of firms. In 1982, the *National R&D Programme* was initiated. Under the programme, a series of *national R&D projects (NRPs)* were launched. These projects covered high-risk activities, such as semi-conductors, computers, machinery and fine chemicals. The programme began with two categories of research projects: one, 'government-initiated and government-funded projects'; and two, 'company-initiated and company-government co-funded projects'. Later, the scope of the programme was widened and more categories, such as basic research projects, venture technology projects etc. were also added (see, Lim 1995 for details). The objective was to develop core technologies in those fields where Korea had potential advantages. The total expenditure on these projects during 1982-91 was $1205 million. Of this, 59.4 per cent was spent by the government and around 40 per cent investment was incurred by industry (Ministry of Science and Technology, Korea). Thus, in line with the industrial policy of creating comparative advantages in selected high-tech industries, the R&D policy focused on directing the limited R&D resources to these industries through NRPs. To pursue the policy rigorously, the government abolished all industry-specific promotion acts and legislated a new 'Industrial Promotion Act' that tied all incentives with specific industrial activities, such as the promotion of R&D and the development of human resources. Various programmes including tax incentives, preferential financing and exemption from compulsory military service were offered to the industry to increase R&D activities. Some of the policy measures adopted by the government to promote R&D are as follows:

Supply side measures

- *Reorientation of the administrative infrastructure*: The President's Science and Technology Advisory Council was instituted to provide coordination between various ministries involved in science and technology on a regular basis.

- *In-house R&D units:* Under the Industrial Technology Development Law, private firms establishing research centres were extended tax privileges and financial supports. SMEs that were not able to set up R&D centres were encouraged to form research unions with other firms. As a result, the number of such institutes and unions substantially increased in the 1980s. In 1989, there were 749 research institutes and 50 research unions (with 1102 firms).

- *Financial incentives*: Massive financial support package was offered to firms undertaking research in core areas. The government funded up to 50 per cent of R&D costs of large firms and up to 80 per cent for SMEs. Under the Industrial Technology Development Programme, up to two-thirds of the R&D costs of joint projects between private firms and research institutes was subsidised. Several tax incentive programmes were also offered to the industry. To provide loan and investment services for new technology, several venture capital corporations were established (see, Kim 1995 for details). A highly systematic approach was evolved in providing these supports and is currently in practice. At the earliest stages of the R&D process, the Korean government usually supports the private sector activities with direct subsidies while in the subsequent production and marketing stages the main supports are preferential taxes, venture capital funds and government procurement (Kim 1995). Since basic research is highly risky with very low probability of success, the objective of the policy of subsidising these processes at the earliest stages is to cover the maximum risk and encourage firms to undertake research. Another important feature of these government support measures in Korea since the beginning has been that these incentives are performance linked and are monitored effectively through mandatory and legal mechanisms (Hyung-Sup Choi 1986, Kim 1995).

- *Promotion of higher education to increase scientists and engineers*: To promote high-quality higher education, the government established new institutions such as, science high schools, Korea Institute of Technology (KIT) and company training colleges. Various ministries also started supporting university research. As a result, enrolment ratios in higher education increased by over 70 per cent in six years between 1980 and 1986 (Kim and Dahlman 1992). University grants were, however, tied with their research performance. Besides, Korea Science and Engineering Foundation started its overseas programme to support Korean scientists and engineers for overseas study.

- *Tightening of patent laws to protect IPR :* Patent protection was provided not only to foreign technologies but also to indigenously developed technology from local imitation for the period from one year to four years.

- *Restructuring of existing public research institutes and setting up of new institutes*: The existing institutes were restructured and their operation was rationalised. Science Research Centres (SRCs), Engineering Research Centres (ERCs) and Regional Research Centres (RRCs) were set up at universities to support R&D. These institutes played an important role both in innovative and adaptive R&D. With the government launching the NRP and *chaebols* undertaking R&D aggressively, the public institutes started forging closer ties with the industry. For every joint research project, public institutes served the role of nucleus because of their diverse experience in technological development and project management (Nam 1995).

Demand side measures

- *Introduction of the Fair Trade Act:* Industrial policies were geared to maintain competitive pressures within the economy. The ‘Fair Trade Act’ was introduced to counter the increasing economic power of *chaebols* and the resulting monopolistic practices.

- *Promotion of SMEs:* The government began promoting small and medium enterprises (SMEs) in, particular, technology-based industries. A number of SME clusters were promoted by the government to sustain the competitive structure of the economy (Kim 1988).

- *Public procurement policy*: Under the scheme, public agencies procured capital goods and other items from local producers. The selection criteria were based not only on price but also on a quality index. This induced quality-based competition among bidders and encouraged R&D efforts among them.

A well - balanced approach adopted by the government on the demand and supply side resulted in a tremendous increase in R&D efforts during this phase. The total R&D expenditure increased exponentially from 280 billion won in 1980 to 3335 billion won in 1990 that is, an increase by 12 times within 10 years. The proportion of GNP on R&D increased from 0.89 per cent in 1981 to 2.2 per cent in 1990 (MOST, Korea). Besides, the share of industrial R&D in total R&D expenditure increased from 27 per cent to 69.6 per cent during the same period. R&D in the private sector increased much faster than that in the government sector. As a result, the share of the government sector in total R&D declined from 64 per cent in 1976 to mere 18 per cent by 1988 (Kim and Dahlman 1992). The output indicators suggest that technology exports increased from $9 million in 1988 to $35 million by 1990 (Kumar 1998). The US patent ownership data shows that the patents granted to Korea were 70 during 1977-82; this number increased to 580 during 1983-90 (ibid.).

To recapitulate, Korea witnessed a shift in policy paradigm during the 1980s when the focus of industrial policy shifted from the light and mature industries to innovation-based industries. In order to build and develop comparative advantages in priority industries, technology acquisition was liberalised and at the same time, domestic R&D was aggressively promoted. Carefully crafted policy measures ensured that imported technologies were assimilated, absorbed, mastered and upgraded through domestic R&D efforts. Limited R&D resources were directed at promoting R&D in the priority industries. The National Research Programme (NRP) was launched in 1982. It facilitated research in core technologies and helped in building close links between firms, academia and public institutes. Legal mandatory mechanisms were devised to monitor the use of tax incentives and other fiscal supports. Grants to universities and public institutes were linked with their research performance to ensure the optimal use of R&D resources. On the demand side, competitive pressures were maintained on firms to force them improve their competitiveness. The government continued an aggressive export drive and at the same time encouraged SMEs to ensure the competitive structure of the markets. This strategy paid off. In the highly motivated and competitive environment, firms intensely pursued R&D activities. The well-developed human resources and the presence of large firms were some of the factors that helped in the transformation of the economy.

II.3 The emergence stage

Korea has emerged as a highly industrialised country with massive technological capabilities during the 1990s. The ratio of R&D expenditure to GDP has increased to around 2.8 per cent and is higher than that in many developed countries including the USA (DST 1999a). The number of in-house R&D units increased from 966 in 1990 to 2270 by 1995 with the number of researchers going up from around 27,000 to over 63,000. The research unions formed by SMEs increased from 54 (with 1181 firms) to 63 (covering 1346 firms) over the same period. The number of US patents granted to Korea were 5970 during 1990-96 as compared with 580 during 1983-89. However, the neglect of scientific education and scientific base has come up as a serious bottleneck in sustaining growth. To overcome the bottleneck, the government has focused its attention during this phase on expanding the scientific base. Itmhas used a multi-pronged policy with especial emphasis on international cooperation.. Some of the features of the current policy are as follows:

1. *The promotion of scientific education:* The government has been promoting basic science and placing special emphasis on the training of the creative scientists and high-calibre technological manpower. SRCs, ERCs and RRCs are being expanded to promote

basic scientific research. Planned investment in basic scientific research at universities increased from US $ 581 million in 1993 to $1843 million and is expected to go up to $4490 million by 2001. For the promotion of basic science, there are plans to increase R&D investment in universities and colleges to 12 per cent of the total R&D by the year 2001. In parallel with these measures, the government is investing heavily on the upgradation of the quality of education and research facilities in the university system. Two new institutions, namely Korea Institute for Advanced Study and Asia-Pacific Center for Theoretical Physics, have been set up by the ministry as centres of excellence for attracting first-rate scientists from advanced countries. Finally, Korean students and researchers are sent abroad to acquire advanced degrees or study specific fields of knowledge. Between 1982 and 1995, the Korea Science and Engineering Foundation has supported 2117 scientists and engineers (Ph.Ds) for overseas study.

2. *Encouragement to international cooperation for basic research:* The government has been supporting international R&D cooperation. STEPI, a public research institute, is planning to create joint institutes with 10 developed countries; MOST provides subsidies for joint international research programmes; and public institutes have been signing research contracts with foreign firms and universities. The public sector 'Electronic and Telecommunications Research Institute', for instance, has teamed up with Stanford University for the joint development of an operating system for an indigenous multimedia workstation. The technologies will be transferred to LG, Samsung and Daewoo for commercialisation. Between 1985 and 1995, MOST supported 750 joint projects involving US $55 million In 1990 the number of projects was 76, and by 1995 it increased to 125. The *cheabols* have also formed international industry-academic cooperative associations with foreign universities to undertake joint research in advanced technology. LG electronics, for instance, has put together a $10 million joint research cooperative structure involving 32 foreign universities. Samsung is carrying out a number of joint international R&D projects in semi - conductors and LCDs with foreign universities. Besides, the *chaebols* are forging direct cooperative agreements with foreign companies to develop new technologies. A number of such agreements have been forged by LG. These involve giants, such as Motorola, Phillips and Xerox.

The Korean firms have also been directly purchasing patents. They have been acquiring low-cost patents from Russia, on the one hand, and patent portfolio from the US patent brokers, on the other.

3. *Employing foreign nationals*: Hiring foreign experts for an indirect technology transfer is widely practised by Korean companies. It is recommended and facilitated by the government. The government and the industry operate systems to identify and recruit qualified employees who they believe may transfer new technologies. Highly attractive salary packages are offered to them. Besides, Korean companies regularly send employees abroad for on-site training at overseas companies. The practice exposes Korean technicians to the technology, operations and practices of a foreign company.

4. *Liberalisation of FDI policies:* To attract the complex and advanced technologies and infuse competitive pressures, Korea has substantially liberalised the economy for FDI during the 1990s. Now most manufacturing and service sectors are open to 100 per cent foreign ownership on the basis of a simple notification. FDI in Korea has increased from an annual average of $ 863 million during 1986-1991 to $2341 million in 1997 (UNCTAD 1998).

5. *Encouragement to outward FDI for acquiring local knowledge base:* A number of incentives have been offered to *chaebols* to invest in overseas activities to claim markets and take advantage of local expertise. Direct investment abroad has increased rapidly from $923 million during 1986-91 to $4287 million in 1997 (UNCTAD 1999). For starting production facilities in developed countries, *cheabols* are pursuing the policy of acquisition and mergers. The objective is to acquire latest science, technology and know how of the acquired companies. LG Electronics secured patented HDTV technology by acquiring Zenith and dominated the huge HDTV markets; Samsung acquired Harris Microwave Conductor to secure world class technological capability in non memory semi-conductor; Hyundai purchased controlling stakes in the US firm Maxtor to obtain patents on HDD components and ASIC technology; Hyundai also acquired NCR's Microelectronic Product division and secured rights to 690 patents and trademarks.

6. *Locating research centres abroad*: The Korean government and the *chaebols* are locating research centres in advanced countries to acquire and generate new technologies using the local expertise. The major Korean firms -owned US-based research facilities include - Samsung Electronics: San Jose Research Institute, Image Quest Technology in Silicon Valley; LG Electronics : San Jose Institute and LG North American Operations in Chicago; Hyundai Electronics : SEMR Research Institute in San Jose. Besides, Daewoo Electronics is setting up a worldwide research network that includes 12 R&D centres in eight foreign countries.

7. *Launching of Highly Advanced National (HAN) R&D projects*: In 1992, the Korean government launched the HAN project called G-7 with the aim to turning Korea into one of the top seven technologically advanced countries. It is a large-scale project with the estimated cost of $5069 million. It coveRs17 strategic fields that are essential for advancing the economy in high-tech sectors. Various R&D organisations such as universities, industries, public institutes are participating in this project. International cooperation is also being pursued for the projects. After the first phase (1992-94), its performance was evaluated to decide whether to continue the programme further. It revealed that in the first phase 2500 patents were applied and 550 patents were granted, and 2100 papers were presented in seminars of which 1900 were published in journals. It was therefore decided to continue the projects.

8. *Creation of innovation clusters:* In an important development during the 1990s, the government started pursuing the policy of creating innovation clusters. The objective is to develop clusters with R&D labs, technology parks and government regional research centres where companies are vertically and horizontally integrated from R&D to production through networks. In that context, the government is planning to construct five more science towns along the lines of the Daeduk Science Town as centres of science and technology. Besides, regional research centres (RRCs) are being set up to establish a regional research network among research agents. RRC is a research

consortium to undertake research associated with regional development, involving local firms, universities and research institutes (Lee, forthcoming).

Finally, the government is supporting the establishment of S&T forums and organisations of techno-marts for acquiring technologies from foreign firms. A nationwide data network has also been created. It is periodically upgraded. It provides on-line access to information on advanced industrial technology in foreign and domestic database.

In sum, the Korean government adopted a highly focused industrial policy during each phase of growth and evolved S&T policies within an overall framework of industrial policy. This resulted in a well-balanced S&T approach during each phase. On the demand side, competitive pressures were maintained by aggressively pushing exports and by maintaining the competitive structure of the domestic industries through well-crafted industrial policies. On the supply side, technology accumulation was encouraged using an appropriate mix of technology acquisition and technology generation. While during the first phase, technology capabilities were accumulated through reverse engineering of imported machinery at the production level, the second phase, technology licensing was combined with a rigorous promotion of domestic R&D. Specific technologies were identified and the National Research Programme was launched to develop them. This helped in evolving close links between universities, research institutes and industry. A systematic approach was adopted in designing support measures and a legal mechanism was evolved to monitor their use. In the final stage, recognising the importance of international cooperation in science and technology in expanding the scientific base, the government has been aggressively promoting such cooperation. The government has established formal cooperative relationships in S&T with foreign countries in the form of agreements and other arrangements. Such arrangements facilitate the exchange of scientists, exchange of information, joint research, direct and joint investment and other cooperative activities. Thus, starting from reverse engineering during the initial phase of growth, Korea moved to technology generation in high-tech industries by the 1990. During the 1990s, it emerged as a major S&T power of the world. During each phase, it developed a systematic and integrated strategy that harnessed the strength of its private sector, academia and government, and developed a strong National System of Innovation[4]. To further strengthen the system, in recent years the Korean government is adopting policy measures to develop innovation clusters in which firms and related supporting institutes have close networks to share knowledge and information. Though they are at the early stage at present, they are likely to contribute substantially to the innovation system in future (Lee, forthcoming).

III. Evolution of technology policy: the Indian experience

In India there have been three stages in the evolution of government policies. These phases are summarised in Table 3.

Table 3: 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 based growth (1948-1968)	Import substitution	Regulated	Setting up of R&D infrastructure for creating scientific base.	Liberal
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

III.1 The initial growth phase

India initiated the process of industrial growth in 1948, when it announced its first Industrial Policy Resolution (IPR) 1948. Unlike the Korean approach that was a mix of export-orientation and import-substitution, India pursued 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 a boost to industrialisation. Therefore, specific emphasis was placed on basic and heavy industries. This was in contrast with the Korean growth strategy that focused on traditional and matured industries. While Korea shaped its strategy on the Japanese model, India adopted a high growth strategy based on the Russian model mixed with a capitalistic overtone. 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 industrialisation process required inflows of foreign technologies. In Korea, foreign technologies embodied in capital goods served the industry to meet the requirements of simple and matured technologies; in India, however, heavy industry-based industrialisation required complex 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: (a) non-discrimination between foreign and Indian enterprises; (b) full freedom to remit profit and to repatriate capital; and (c) compensation on a fair and equitable basis in the event of nationalisation. In the late 1950s, the requirement of majority Indian ownership of joint ventures under the so-called 51 per cent rule was also relaxed. Foreign firms were invited to participate in the state-reserved industries notably drugs, aluminium and heavy electrical equipment. 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 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 import 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 FDI also increased continuously over the period. The stock of FDI that stood at Rs2560 million in 1948 more than doubled to Rs5660 million in 1964. The technology related payments jumped from mere Rs12 million in 1956-57 to Rs190 million in 1967-68 (RBI 1992). The building up of the industrial capacity of the country proceeded almost totally on the basis of imported technology (Parthasarthi 1987; Desai 1980). However, in the absence of the need to improve competitiveness there was little incentive to learn, absorb, assimilate and upgrade the foreign technologies to create R&D capabilities. Foreign technology acquisition was regarded essential for initiating production and not for accumulating competitiveness capabilities, which was the crucial aspect of technology accumulation in Korea during this phase.

The process of industrialisation 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 a scientific and research base. As early as 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 a 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 a capacity of 25000 seats. In 1968, Indian Institutes of Technology (IITs) modelled on 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, such as Council for Scientific and Industrial Research (CSIR), Department of Atomic Energy and Defence Research and Development Organisation. The CSIR had no independent lab in 1942, by the late 1950s, 15 such labs were created (see Krishna, 2001 for details). Between 1950 and 1970, Rs1500 million 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 organisations. There were 42 such organisations in the private sector and eight in the public sector by 1970. These efforts resulted in a 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 a R&D infrastructure. As a result, this phase is termed ‘Infrastructure Phase’ (Jain et al. 1989). Though R&D expenditure increased significantly both in the private and public sectors in India during this period[5], the accent was on R&D with a short pay-off (Desai 1980). R&D activities centred on: (a) scaling down of plants based on foreign technology to suit small Indian markets; (b) adapting foreign processes to Indian conditions and local materials; and (c) tackling on-the-spot production problems and quality control. The expansion and diversification in the industrial base[6] achieved during this period was mainly owing to increasing factor inputs, particularly increasing public investment; factor productivity, which grew at a negligible rate of 0.2 per cent did not contribute significantly to industrial growth (Ahluwalia 1991).

The above observations notwithstanding, it is noteworthy that India built up a relatively substantial research base compared to the other developing countries in this phase. In Korea also, formal R&D remained at a very low level. However, a rigorous export drive and the promotion of efficient firms induced R&D within industry at the production end. This process facilitated learning from foreign technologies and resulted in accumulating technological capabilities to some extent. Thus, while traversing different paths, both countries built substantial S&T capacity in the first phase. While India built research capacity, Korea accumulated technological capabilities.

III.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, the 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 progressively tightened. 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 nationalised to ensure the flow of credit to the designated sectors. While Korea remained focused on ‘growth’ as the objective and consolidated the gains achieved during the first phase, India set to attain conflicting goals through a package of inconsistent policies which had disastrous implications for technological development not only during this phase but also during 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 during 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[7]. 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 listed these into three: (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; tax rates on royalty, technical fees and lumpsum payments were raised to discourage import 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[8] 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 : (a) cabinet subcommittee on S&T; (b) scientific advisory committee to the cabinet; (c) 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, such as food, medicine, drugs and pharmaceuticals with a view to encouraging local R&D through imitation and adaptations.

- *Introduction of the scheme of recognising in-house R&D units*: The government introduced the scheme of giving recognition to in-house R&D units. Various policy incentives, such as tax exemptions, relaxation in import licensing to R&D units[9] and relaxation in industrial licensing for using results of R&D units[10] were provided to firms for setting up in-house R&D units. The government set up various facilities, such as Technical Consultancy Organisations (1973), Risk Capital Foundation (1975) and Technology Development Fund (1976) with the objective of providing financial support for modernisation 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 organising 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 Centres 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 Rs44.6 million in the early 1970s (1974-76) to around to Rs 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 per cent during 1970-76 to 15.2 per cent during 1977-85. However, local R&D did step up. R&D expenditures of private companies increased more than eight times from Rs146 million in 1970-71 to Rs1207 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 Rs215 million in 1970-71 to Rs690 million in 1980-81. India achieved near self-sufficiency in standard techniques and began exporting technology. Technology receipts on account of lumpsum payments and royalties jumped from Rs2 million in 1968-69 to Rs20 million by 1979-80 (RBI, 1992).

The above achievements notwithstanding, there is evidence that technological dynamism did not take firm root 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[11]. Patterns of trade in technology-intensive products also became adverse with increase in the share of technology intensive imports in total imports from 63 per cent in 1970-71 to 80 per cent in 1980-81 and decline in the high-tech exports in total exports from 17.2 per cent to 16.9 per cent over the same period. Though India achieved self- reliance in technologies for local production and consumption owing 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 analysing the causes of decline in the manufactured exports during this period, the Tandon 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 per cent during 1970-80 was as low as 0.2 per cent (UNCTAD 1992). The results were poor export performance, stagnating growth rates and declining productivity.

Both Korea and India had created S&T capacity during the first phase. To harness their capabilities they focused their attention on technology generation during the second phase. While India experienced industrial stagnation, Korea emerged as a major technological power within 10 years. What went wrong with India during this phase? A comparative analysis of the policies of the two countries during this phase may provide vital clues for the failure of India in building strong technological capabilities despite having built vast research capacity during the earlier phase.

Table 4: Korean and Indian policies during the second phase of growth : A comparative perspective

	Korea	India
Planning objective	Growth	Growth with self-reliance and social justice
Trade strategy	Export-oriented and import-substitution	Import- substitution
Industrial strategy	Focus on innovation-based industries	Self-reliance in industrial production
Technology acquisition	Liberal technology licensing with selective approach towards FDI	Highly restrictive policies towards FDI and technology licensing
Technology promotion	Encouragement to technology learning and absorption of technology acquisition on the one hand, and promotion of innovative R&D through highly focused specific national research projects. Incentives were based on performance.	Technological self-reliance in all sectors.
Technology diffusion	Competitiveness pressures through export drives, Trade ACT and promotion of SMEs.	Highly regulated domestic markets, reserved areas for SMEs and protection from external competition.

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 macroeconomic policies. Any inconsistency or neglect of any of these aspects of the policies may hinder the technological development process. In India, the balance could not be maintained either within different components of technology policy or between technology and industrial policies (Table 4). This affected the performance of the National System of Innovation and in turn, the learning, absorptive and innovative capacity. One can suggest that a critical factor differentiating the performance of the two countries was the effectiveness of the National System of Innovation. While Korea developed a strong National System of Innovation, India had vital links missing owing to inconsistencies in policies, which weakened the performance of the system . Four conditions need to be satisfied for building a strong innovation system : (a) strong competitive pressure on domestic firms, be it from other domestic firms, importers, TNCs or export markets; (b) the presence of high-quality human capital ; (c) well-developed links between industry-institutes-academia; and (d) access to foreign technologies. Korea tailored the country's innovation system in each stage to accommodate these conditions; India, however, failed to evolve an appropriate mix of these critical ingredients. As described above, Korea maintained competitive pressures on firms on the demand side. Though the trade and FDI regimes were not liberal, rigorous export promotion and domestic competition compelled the entrepreneurs to improve international competitiveness and invest in learning and R&D. In India on the other hand, macroeconomic 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 owing 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 per cent private sector in-house units spent less than Rs one million on R&D per annum. Their average expenditures per annum in the private sector were Rs0.35 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 local needs or to replace local materials to meet import-substitution requirements with little effort at learning, assimilating and improving it.

The second important condition for creating domestic absorptive capacity is the presence of trained workers, scientists, engineers and entrepreneurs. It is increasingly being acknowledged that without universal primary and secondary education it is not possible to generate the process of self-sustaining development (see Lall 1992). Korea invested heavily in human capital formation even before launching the growth process. By 1965, it had already achieved universal primary education. During 1966-1975, its educational expenditures accounted for as high as one-third of total investment in physical capital (Kuznets 1988). India, however, could achieve a literacy rate of only 52 per cent by 1990-91. Expenditure on education, which was as low as 1.2 per cent of GNP in 1950-51, increased to around 4 per cent in the 1990s. Though an inverted educational paradigm was adopted by stressing higher-level education, according to an estimate only around 4 per cent of the population in the age-group 17-23 have been in universities and colleges and only 19 per cent of those enrolled in higher education have been studying science (DST 1999b). Moreover, the number of scientists and engineers per million population was 158 as against 2235 in Korea in 1995 (DST 2000c). Besides, it is also observed that there has been mismatch between manpower 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 depends upon the environment and incentives. The public institutes in Korea played a major role in building the absorptive capacity. During the initial phase, when the demand for domestic R&D was negligible, they provided consultative services and assisted firms in identifying and bargaining for technologies. During the later years, the government announced the NRP which helped in evolving industry-institute and university linkages and the role of public institute in innovation and invention assumed important dimensions. In India these institutions remained isolated from the socio-economic block and were primarily aimed at basic research with no links with the process of industrialisation. Desai (1980) noted that less than half of the know-how that the labs considered usable was actually being made use of. Income from sales of technologies was 2.2 per cent 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 per cent 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). However, it was the same in Korea also. But the government harnessed the capacities of these institutes through well-crafted policies. 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, (as NRP in Korea), 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. Krishna (1997, p. 269) note :

'in a small city of Mysore the DRDO and CSIR maintain two large food research laboratories but they remain in relative isolation from each other'

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. Korea, it may be recalled, evolved various mechanisms to ensure the productivity of R&D resources. 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 the bulk of these institutions remain only teaching institutions without adequate facilities for scientific research (ibid.). Though this was realised by the Education Commission (1966), no major steps were taken to improve research oriented higher education. Ahmad and Rakesh (1991) showed that academic science accounted for a mere 6 per cent of total R&D funding. Nagpaul (1997) found that 207 universities published on an average seven 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 per cent 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 per cent in comparison with one per cent on local R&D. They thus pointed out that the restriction of technology imports imposed heavy costs on the economy. In Korea, technology inflows were liberalised during the second phase when rigorous R&D promotion was planned. This was because technology acquisition was considered crucial for learning and maintaining competitive pressures. In India, however, the concept of ‘learning’ was missing at both the industry and the policy making level. 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.

Besides 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. Korea adopted a highly focused approach. It identified specific industries and specific core technologies that could be evolved, and directed the limited R&D resources to the promotion of these technologies through a well-formulated NRP. The support system was geared to ensure the channelisation of the resources to these sectors and high productivity of these resources. In India, on the other hand, the goal of total technological self-reliance resulted in the distribution of scarce resources to all sectors resulting in resource constraints in all the sectors. In sum, the disjointed policies in India with lack of focus resulted in a weak innovation system and under-utilisation of research capabilities created during the first phase.

III.3 The liberalised phase

The third phase of growth was initiated in India during the 1980s. Industrial and trade policies were reoriented in view of decelerating exports, worsening balance of payments situation and stagnating industrial growth rate for over 15 years. The focus shifted once again. This time it was from growth-with-social justice and self-reliance to growth-with-efficiency (see Sixth Plan document). The Industrial Policy Resolution 1980 stressed the need for optimum utilisation of installed capacity and for achieving higher productivity. To meet this objective it proposed liberalisation of the industrial licensing policies by introducing delicensing, regularisation of excess capacity and the capacity reendorsement scheme. In the foreign trade sector, a move was initiated to cut down import restrictions and tariffs. The process of deregulation was accelerated in the mid-1980s, when industrial licensing was abolished in a number of industries and major reforms were introduced in the foreign trade sector. However, it was in 1990 that a massive dose of liberalisation was administered. More than 80 per cent 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 disinvestment of the public sector undertakings. Besides fostering domestic competition, the economy was open to external competition as well. Maximum tariff was reduced from 300 per cent in 1991 to

65 per cent progressively by 1994-95 and the rupee was made convertible on current account. The tempo of reforms has been maintained since then with continuing liberalisation in the financial, infrastructure, information technology, telecom and foreign trade sectors.

With shifts in plan priorities, technology has acquired a stronger focus. Restrictions on technology imports and foreign equity participation are being relaxed. The policies have been made progressively liberal since 1980. At present, foreign participation is allowed in almost all sectors (not reserved for the government). Up to 51 per cent foreign equity is permitted in most industries. In the areas of sophisticated technology and /or export-oriented ventures up to 100 per cent equity is permitted. The provision of automatic approval up to 51 per cent equity is introduced. Under certain conditions, automatic approval is given to 100 per cent equity participation, as well. In the case of technical agreements, automatic approvals are granted to all those agreements where lumpsum payments do not exceed Rs10 million and royalty does not exceed 5 per cent for domestic sales and 8 per cent for exports. Hiring of foreign technicians has been liberalised. 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 a Technology Information Centre in India to provide 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, 1983, announced after 25 years of the Scientific Policy Resolution, 1958, has recognised the need of establishing linkages between scientific, technological and financial institutions to promote effective transfer of technology from institutions to industry. A new Draft of the Technology Policy 1993 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 a 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 Science and Technology 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 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 Organisations (SIROs) in the private sector. Higher institutes of technology and medicine have also been grouped in this category. At present, there are 534 SIROs recognised 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 per cent tax on capital investments for R&D and 133 per cent for expenditure on sponsored research are made available to industry. In certain areas, 125 per cent weighted tax deduction on R&D is applicable. During the year 1998, 11 certificates involving Rs 274.4 million on cost of plant and machinery, 18 certificates for import of capital equipment and consumables/materials for R&D projects supported by DSIR, 700 essentiality certificates for claiming customs duty exemption amounting Rs 350 million, 53 essential certificates for claiming excise duty exemptions amounting Rs 15.36 million were issued by the DSIR.

- *Instituting a Technology Development Fund (TDF) :* The Government of India instituted a fund called TDF to provide financial support for technology absorption and development. It was 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 organisations 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 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 housewives, artisans, farmers, students etc., in their attempts to commercialise their innovations, has been introduced by PATSER along with `Home Grown Technologies Assistance’ programme of TIFAC. More than 70 enquiries were received under this scheme till December 1998. Besides, the drugs and pharmaceuticals programme was initiated in 1994-95. Under this scheme, financial support is provided to national laboratories and academic institutions for carrying out research programmes 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 20 September 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 per cent of their budget from consultancy services to the private sector[12]. A satellite based CSIRNET is being set up connecting CSIR headquarters and laboratories in order to have a fast real time access to one another as also to the internet. CSIR has launched a CSIR Programme for Youth Leadership in Science (CPYLS) scheme to attract youth to science. The National Research Development Corporation (NRDC) has been geared to develop and transfer indigenous technology through the 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 liberalised the inflows of foreign technologies progressively on the one hand, and offered a package for R&D promotion, on the other. The statistics reveal that the policies adopted in the liberalised phase resulted in a tremendous increase in foreign technology inflows. The number and the magnitude of foreign collaboration approvals increased sharply (Table 5).

Table 5: Indicators of foreign technology acquisition in India (1990s)

Year	Foreign collaboration approved (no.)	Foreign investment approved (Rs million)	Actual FDI (Rs million)	Lumpsum payments approved (Rs million)	Actual technical payments (Rs million)	Capital goods imports (Rs million)
1990	703	1492.2	-	5741.4	6562.0	104660
1991	976	5293.9	3510	9798.2	5722.0	106550
1992	1520	38879.0	6750	22812.7	4052.0	108390
1993	1476	88648.0	17870	36900.2	9910.0	166630
1994	1854	142073.0	32890	22999.9	6593.0	199900
1995	2337	326130.0	68200	71961.5	13086.0	282890
1996	2303	361122.0	103890	26522.1	16008.0	298680
1997	2325	548536.0	164250	-	11256.0	280160
1998	1786	306586.0	133400	-	-	323040

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

The average annual actual inflows of FDI increased from around Rs 200 million during 1970-80 to Rs 2800 million during 1985-90 (i.e. an increase of over 10 times) and further to Rs 24,000 million during 1990-95. In 1995, total FDI inflows were Rs 67,000 million, which increased to over Rs 91,000 million by 1998. Technology payments also substantially increased in the 1980s. Firms appear to have increased the acquisition of new machinery and plants as well (Table 6). As a result, capital goods imports increased sharply during the 1990s from Rs 104 billion in 1990-91 to Rs 323 billion in 1998-99. These imports declined somewhat in 1999-2000.

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. Under the PATSER scheme, 17 projects were completed by 1999 involving over 13 industrial units, resulting in the commercialisation of products and processes such as SPV Traffic Signalling System, automatic transmission control for dump trucks and detonating card for exploration. The share of external cash flow in government grants and R&D expenditures of the CSIR increased from 17.3 per cent and 15.5 per cent, respectively in 1985-86 to 40 per cent and over 26 per cent, respectively by 1993-94. The industrial production based on CSIR knowledge base touched the figure around Rs 42,000 million in 1998-99. There have also been successful restructuring of some public institutes, such as the National Chemical Laboratories (see, Goldman et al. 1997) which are attracting international projects. These successful cases notwithstanding, the macrolevel statistics are not encouraging.

Input indicators

Overall domestic R&D expenditures did not show discernible change. Industrial R&D expenditure, as a proportion of total turnover, increased somewhat in the late 1980s; however, it has been declining continuously in the late 1990s. Goldar and Ranganathan (1998) analysed the R&D expenditure of 56 largest firms reported in the Confederation of Indian Industries data for 1989-90 and 1994-95. They found that the R&D expenditure declined in 35 firms between this period. On comparing the R&D expenditure intensity of 154 firms in the engineering and chemical sector, reported in the DSIR R&D compendiums for the late 1980s and the late 1990s, the author found that it declined in the case of 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 6).

Table 6: Research and Development indicators in India in the 1990s (per cent)

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

Source: 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 sectors (Table 7)

Table 7: 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

Source: Various issues of 'R&D in Industry,' (DST)

Evidence suggests that the institutional industrial R&D expenditure also declined relatively during this period. If R&D expenditure by the CSIR is used as a proxy for institutional industrial R&D expenditures, R&D employment in total industrial (organised sector) did not show any perceptible change in the private sector either. In the public sector it continuously declined (Table 8)

Table 8: 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

Source: 'R&D in Industry', DST

A detailed analysis of the nature of work assigned to R&D professionals reveals that only 36 per cent of personnel are actually in professional R&D activities suggesting that technical manpower is not efficiently used (Table 9).

Table 9: Research and Development Manpower

(percentage 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

Source: `R&D in Industry,' DST

Output indicators

Output indicators present a similar picture. Table 10 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, such as non-reporting or misreporting. 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, drastically declined after 1989-90.

Table 10: Patent's 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 during the 1990s. The growth rates in basic and capital goods industries have not increased either (Table 11).

Table 11: Growth rates of industrial production (per cent)

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

Source: Economic Surveys

There is evidence of growth in productivity during the late 1980s[13]. Basant and Fikkert (1996), however, found that technology-induced increase in productivity did not take place during the late 1980s. Their finding is supported by the fact that the growth in productivity could not be sustained for long; it declined during the 1990s (Srivastava 2000, Balakrishnan 2000, Das 2000). Exports of technology-intensive products increased in the late 1980s but again their growth could not be sustained during the 1990s. Technology-intensive imports remained substantially higher throughout the period. As a result, the ratio between technology-intensive exports and imports did not decline (Table 12).

Table 12: Technology intensive trade in India : 1990-91

Year	Technology intensive exports (per cent share in total)	Technology intensive imports (per cent share in total)	Ratio between Technology Intensive 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

Source: DST (2000c)

Korea and India in the 1990s: Some S&T indicators

A comparative analysis of R&D indicators for Korea and India reveals that while Korea made rapid strides in technological development in the 1990s, India moved slowly widening the gap between the two countries. Korea has set the target of being one of the seven most technologically sophisticated countries. India's main concern, on the other hand, is how to check the declining trends in R&D intensities in the Indian industry.

Table 13: India and Korea : A comparative analysis of S&T indicators

Indicators	India	Korea
R&D –GNP ratio (per cent)		
1990	.85	
1996	.66	2.82
S&T personnel per million population		
1988	147	1344
1996	158	2235
Royalty and license fee (receipts $million)		
1990	1	37
1996	1	185
Royalty and licensce fee payments, $million)		
1990	72	136
1996	90	2431
FDI inflows ($ million)		
1990	162	788
1996	2587	2325
Patents (1995, number)		
Resident	1545	54249
Non-resident	5021	37308
High tech exports (1996)		
Volume ($million)	2310	44433
per cent of manufactured exports	10	39

Source: World Bank (1999)

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 liberalisation initiated during the 1980s and accelerated during 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 owing to lack of confidence in domestic technology. In the absence of the internationally competitive quality and standards in technology development, industry has created demand for foreign technologies that 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 commercialisation 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 the ratio of R&D to GNP to 2 per cent. CSIR labs were directed to generate 30 per cent of their budget through contracts. Vision 2001 set the targets at a more ambitious level. By 2001, CSIR laboratories have to generate 50 per cent 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. The R&D-GNP ratio continuously declined to 0.66 per cent instead of increasing to 2 per cent. The ratio of external cash from research contracts and consultancy to government grant declined from 42.8 per cent in 1989-90 to 33.5 per cent by 1998-99 (Table 14). Resources from contract research 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 per cent. Resources generated from foreign contracts have been a meagre Rs 147 million which formed only 7 per cent 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 penalised. In many countries including China, in recent years such measures have proved to be highly successful (see Goldman et al. 1997). In China from 1989 onwards the budget of 5000 institutes was slashed and decisions were decentralised 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 14: The ratio of external cash flow to government grants

Year	Cash flow/government grants (per cent)
1989-90	42.8
1993-94	40.0
1998-99	33.5

Source : CSIR Annual Reports.

Table 15: Source-wise composition of external cash flow to CSIR labs in selected years

(per cent)

	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

Source: CSIR Annual Reports.

Another vital link missing is the isolation of universities from R&D. While universities are the major research centres in almost all developed countries including Korea, in India they are isolated from 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 16: Composition of R&D budget of the central government in India

(percentage 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 to 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 were too small to undertake substantial R&D even in the 1990s (Table 17). Many firms use R&D units for quality control. Their main objective is to avail tax incentives. Government still constitutes around 80 per cent of R&D expenditure in India. Under such circumstances, cut in the government budget 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 per cent in 1980-81 to 9.3 per cent by 1996-97 (DST 1999b). There has been continuous increase in defence R&D. Under such circumstances, civilian R&D institutes may be linked with the defence 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 (2000) found that R&D intensity by local firms declined in all the industries (except drugs and pharmaceuticals) in the post-reform period. While analysing their behaviour, they observed that owing to 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 17: Size-wise distribution of R&D labs in the Indian industrial sector in 1997-98

Annual R&D expenditure (Rs million)	**R&D units (per cent 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, both Korea and India adopted well-defined development strategies and technology development approaches. Growth with rapid industrialisation had been the major objective for both. In the initial phase both the countries adopted an unbalanced growth strategy and initiated their development with foreign technologies. The two models of development were contrasting in nature. While Korea adopted the Japanese model of first encouraging diffusion of technology at the production end and then promoting technology generation and a scientific base, India followed a more traditional approach of promoting science first. Both the approaches have merits and demerits. The choice of technology acquisition was also different in the two cases. However, there is little evidence that the mode of technology acquisition has significant implication for the growth process. In a detailed analysis of the technology acquisition in developing countries, Mowery and Oxley (1995) concluded 'the mix of channels through which an economy obtains technology from foreign sources is less important than the overall efforts to exploit and master these technologies' (p.87). The weakness of the Indian policies lies in its failure to evolve a right mix of different policy strands that 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 during the 1990s to correct the imbalance in the approach, these efforts did not succeed significantly owing to the half hearted approach. No innovation policy has been announced. After the Technology Policy 1983, the Draft Policy 1993 was announced. However, it was never translated into a policy. 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 a policy environment no major change is perceptible in the near future.

IV. Policy Implications

In this era of liberalisation, 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 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 an innovation chain which includes both technical and economic interfaces for example, stages of innovation, skills required, institutions involved, financing of research, marketing of products and market feedback. 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 the 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 linkages also need to be developed. 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 internalise deficient markets for capital, skills, information and entrepreneurship. All these measures may be supplemented with 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 2000).

Human skill 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 the 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 a S&T policy regime to an innovation policy regime and the DST has to take a major step forward in this direction.

Notes

[1] FDI inflows in developing countries increased phenomenally at the annual rate of 24.2 per cent during 1990-94 and the share of these countries in total flows increased from mere 16.5 per cent in 1986-90 to around 38 per cent 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 per cent compared to 19 per cent for all countries (Kumar 1998)

[3] A number of schemes were launched to grant loans and subsidies. These included, Technology Development Fund, Technology commercialisation Fund, Cooperative R&D fund. Besides, tax incentives were given on training technicians, employing foreign technicians, building R&D labs etc. Under the Technology Development Reserve System firms were required to maintain a R&D fund and the amount actually spent on R&D out of this fund was subject to tax deduction.

[4] National innovation system is the set of institutions which jointly contribute to the development and diffusion of new technologies (Metcalfe 1995).

[5] 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.

[6] The industrial structure diversified with the basic and capital goods industries having experienced the growth rates of 11 and 15 per cent 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.

[7] 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)

[8] Most studies found a complementary relationship between the two during this period (see Kumar and Siddharthan 1997).

[9] R&D units could import all their requirements under `Open General License'

[10] Firms were allowed to set up capacity based on results obtained from their R&D efforts.

[11] The net BOP increased from $622 million in 1970 to $5314 million by 1980.

[12] CSIR (1996) in its draft paper has set the target of generating 50 per cent of the resources by 2000 AD.

[13] While Ahluwalia (1991) found that there was a distinct upturn in productivity after 1982-83; ICICI (1994), Srivastava (1996) and Golfer (1995) found that the turn-about took place in the post-1985 period.

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