Science, Technology and Industry Network: India's Policies & Strategies

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Contents

1. **Introduction**
2. **Frame work for Analysis (The S&T and Industry Trajectory)**
3. **Designing an Effective National Strategy and Policy for S&T and Industry: Broad Contours**
4. **S&T & Industry Trajectory: India's Experience**
5. **Technology Import Substitution**
6. **Economic Liberalization**
7. **Summing Up**
8. **Some Lessons from India's Experience**
9. **Acknowledgements**
10. **References and Notes**

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Abstract

National Policies and Strategies for Science, Technology and Industrial development are viewed as a process of establishing a network that over time interconnects S &T, innovation, and industrial activities. India's policies and strategies as they have evolved over time since Independence in 1947 have been examined in this framework to draw a few lessons. Policies and strategies adopted during successive five-year economic and industrial development plans are shown to have evolved through five phases characterized as, Phase I*: Infrastructure building,* Phase II*: Reorientation,* Phase III*: Promotion of indigenous capabilities,* Phase IV*: Moving towards economic liberalization and* Phase V*: Facing a liberalized globally connected economic environment.*

Keywords

India, Science, Technology, Industry, Policy & Strategies, Innovation Network, Development Trajectory, Globalization, Liberalization

1. Introduction

Soon after independence in 1947 from years of British rule, recognising the strategic importance of Science and Technology (S &T) in transforming the structure of economy based primarily on agriculture and raw materials to a modern industrial economy[2], the Government of India initiated programmes to develop indigenous scientific, technological & industrial capabilities. An extensive infrastructure of research and development (R&D), educational and engineering institutions were established and simultaneously to kick start industrialization, technologies were imported from industrialized countries. After a few years, under a protective economic environment, strategies for S &T and industry were changed to provide opportunities for linkages between R&D laboratories and industry. Since the eighties, the thrust of economic, industrial, and S &T policies and strategies have been towards for an open, globally connected and competitive economic

[2] The term 'Industry' at that point of time referred to manufacturing but we shall in this report also include the now growing IT service industry.

environment finally adopted in 1991. Since then Indian S & T and Industry along with public private partnership has been strengthening its international linkages in several sectors including IT and Biotechnology.

The paper examines changing policies and strategies of S &T, Innovation, and Industry adopted by India since 1947 to draw some lessons from it. The paper deals with only industrial technology- agriculture, atomic energy, space, and defence sectors have not been covered.

2. Framework for Analysis (The S &T and Industry Linked Trajectory)

Strategies and policies for S &T, Innovation, and Industry are examined as interacting policy regimes and not as independent regimes. For this a framework of interactive three broad segments as shown in Fig 1 adapted from 'Dynamics of S &T Cycle' of Niwa et al is used [1]. The three segments are:

- S &T capability building activities (lower segment)
- Technology development and innovation activities (middle segment)
- Industrial and other economic activities (upper segment).

The middle segment essentially represents the overlap between the activities of the lower and the upper segments.

The segments are inter-linked, policies and strategies in one segment impacting on the activities of the other segments (represented as linking arrows in Fig 1).

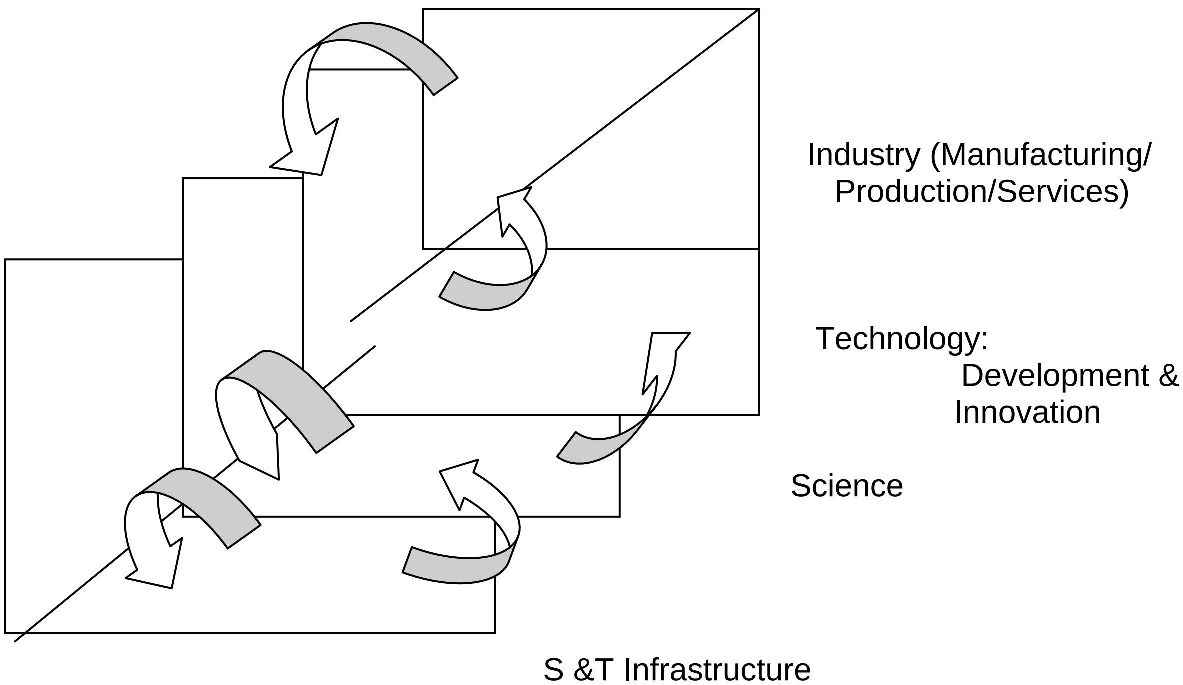

Fig. 1 S & T, Innovation, & Industry Trajectory

The objective or purpose of activities and institutions involved in each of the three segments are different and so are their policies and strategies. This is briefly indicated below: -

- S &T capability building (lower segment)

The objective is to generate human resource capabilities in science and engineering. Involved research is usually open ended. Universities, engineering and technology institutions (academic institutions) and R&D laboratories outside the industrial units are the main players.

- Technology & innovation (middle segment)

The objective of R&D is to support industry in absorption as also technological innovation that can then go into production (the upper segment). Involved institutions are, R&D laboratories with industry partnership and selected projects in academic institutions.

- Manufacturing /Services (upper segment)

In addition to production of goods and services, this involves adaptation & modification of technology (incremental innovations, material substitutions, design activities, optimisation of processes etc) with the objective of wider diffusion of products and services into the market. Main actors are in Industry

What are the different agencies/ministries in India for policies and strategies in different segments?

Briefly:

- Lower segment: The Ministry of Human Resource Development and its agencies, the University Grants Commission and also by the departments and agencies in the Ministry of Science & Technology that provide grants for research.

- Upper most segments: Ministries responsible for economic and industrial development, their R& D laboratories and in-house R & D units of Industry.

- The middle segment: This is an overlap between the lower and the upper segments. Technology development and innovation is influenced by policies and strategies for linking the upper and the lower segments. In addition the venture capital financial institutions and issues of intellectual property rights, WTO, trade and commerce etc adopted by concerned agencies also come into play.

Clearly the segments get inter- linked, policies and strategies in one segment impacting on activities of the other segments (represented as linking arrows in Fig 1).

3. Designing an Effective National Strategy and Policy for S &T, Innovation, and Industry: Broad Contours

At the face of it, with so many strategies and policies and different ministries involved, designing an effective National Strategy and Policy for S &T and Industry, may appear extremely complex.

However, irrespective of the details, (given for India in the subsequent sections), key macro or generic features of national strategy and polices are clearly manifest in policy differences that have influenced the historical development of S &T, Innovation, and Industry in three Asian countries- Japan, Republic of Korea and India as shown below: -

- Japan and Republic of Korea (ROK)

Starting focus of S &T & Industry policies in Japan during forties and in ROK during the sixties was on the upper and middle segments for export led mainly chemical and mechanical technology based industries. Capabilities in Science were derived from immediate requirements of industry for materials substitution, process optimisation, reverse engineering and like. It was in only in subsequent years (mid sixties) that these countries diversified into electronics industry and also paid attention to the lower segment. Capabilities in the middle segments were established early within private sector supported by government. Gradually over the last decades these two nations have reached a stage where the lower segment and its linkages with innovative activities (middle segment) for development of new technologies has been receiving attention. Net result: Strengths in all the segments of Fig 1 are in place.

- India:

During the fifties in India, unlike Japan and ROK, policy focus in S & T (lower segment of Fig 1) was on creating basic scientific capacities. The industrial policy (upper segment) focussed on acquiring industry operational experience on imported to meet mainly domestic requirements. It is to be noted that the lower and upper segments grew independently under different ministries and agencies without any functional linkages between the two. Subsequently especially from eighties, policy moved towards open economy and linkages of Science infrastructure with private industry for an open international competition environment and - innovation (middle segment) received attention. Ministries and agencies in the lower segment responded by providing facilities for training human resource in areas required by emerging industries like IT and Biotechnology.

We thus note that strategies and policies of S & T in India have grown with starting focus on independent basic capabilities in the lower segment whereas in Japan and Republic of Korea the initial policy focus of S & T was in areas that linked to industry. Nevertheless over the years all the three countries have reached a stage of capabilities in all the three segments though adopting initial S & T strategies in reverse order - India moving from lower to upper segment, Japan and ROK from upper to lower.

Malaysia's case is closer to that of ROK and Japan whereas that of China appears closer to that of India. Perhaps the time evolution of the S& T policy strategy is dependent on the size of the country.

4. S &T & Industry Trajectory: Details of India's Experience

After independence in 1947, India adopted a five-year planned development approach- first plan being 1950 to 1955. Changes in policy & strategies of S &T &

Industry can be examined from 1950 during the successive five-year plans mainly in 5 phases [2].

4.1 ***Phase I: Infrastructure Building***: Laying the foundation for S &T & Industry (1950s- end 60s)

Science & S &T Infrastructure Segment:

Referring to Fig. 1, S & T policy during this period focussed on setting up of infrastructure and human resource development for basic science and engineering capabilities with much needed government support.

Government made a strong commitment to science and scientific research, the Prime Minister Nehru himself taking direct interest in laying down the foundations of infrastructure for R&D. The Parliament adopted a Scientific Policy Resolution [3] as an expression of its conviction in future contribution of science and scientific research to county's industrial, economic and social development.

The university system and engineering education were expanded to generate scientific, engineering and technical manpower. Scientific research was given a big push based on the immense faith the planners had in its future.

Simultaneously under a separate strategy and policy of commerce and industry, industrial units were set up many in the public sector especially in capital-intensive heavy industries to modernise economy from primarily agriculture to industrialised economy (at the time of independence 70 % of population was occupied in agriculture & related activities).

As industry was in its infancy it was not in a position to invest in R&D and the government took direct responsibility of carrying out even industrial R&D in its own laboratories under the Council of Scientific and Industrial Research (CSIR) initially set up in 1942. The main functions assigned to the CSIR in the First five-year Plan (1951-55) were [4]:

- To look for knowledge fundamental or applied
- To examine existing industrial processes with the objective of introducing improved techniques of manufacture and production of standard materials wherever possible at reduced rates.
- To evolve new processes and new products preferably from indigenous raw materials and assist in starting of new industries.

Although CSIR was assigned the responsibility for industrial R&D, areas of CSIR's R&D were derived from frontier areas in Physical, Chemical and Engineering Sciences and not from technology requirements of industry. With the Prime Minister as President of CSIR, scientists had the freedom to chose their R & D agenda without justifying their work to any other ministry such as that for industry and commerce. Need for correcting this was noted in the Second five-year Plan (1956-60) as [5]: -

> *"In every field of development there are pressing problems which call for scientific study and investigations and the application of the results of research. It is therefore especially important to co-ordinate programmes of research in national laboratories and in universities and other institutions with the requirements of national planning".*

In 1956 a conventional forum - Scientific Advisory Committee to Cabinet (SACC) was set up to introduce required coordination but in actual practice movement towards linking R & D (lower segment) to industry (the upper segments) was negligible – R & D infrastructure was reluctant to change its priorities from basic research to research to meet the immediate requirements of industry.

The Industry Segment:

Industry strategy & policy gave priority to capital goods and heavy industries. The importance of participation of foreign capital and technology was recognised and commensurate Industrial Policy Resolution of 1948 [6] and the Foreign Investment Policy of 1949 were put in place. Conditions of foreign participation were framed such that major interest in ownership and effective control of industry remained in Indian hands; this policy instrument was to strengthen Indian capabilities in search and selection of technology and its subsequent assimilation. The policy also enunciated that no technology could be imported in areas where adequate local technological know-how was available. Examples of technology introduced through foreign investment route are: -

- Foreign ownership companies in fields pharmaceutical and fertilizers;
- Joint ventures in sectors of polyethylene, nylon, automobiles, detergents, cement plants, etc.

Although the policy allowed foreign ownership also in petroleum exploration and refining, and several other capital-intensive sectors, foreign investors considered ownership investments in capital-intensive industries too risky: apprehensions were availability of technical manpower, future growth prospects and economic viability[7]. Under the circumstances, in 1956, the first Industrial Policy Resolution announced in 1948 was revised [8] and the State took on direct responsibility for sectors specified in Schedule A by setting up public sector undertakings with 90-100% shares in areas such as mining and quarrying (government share 94%), petroleum exploration, electricity, gas and water supply (91%), Railways (100%), communication (99.9%), banking and insurance (82%). Other strategies for industrial Sectors specified in Schedules B consisted of new undertakings that the State would set up in co-operation with the private sector but would gradually owned by the State. Yet another set comprised Schedule C for industries to be set up by private sector with development of necessary infrastructure by the State.

The policy enabled emergence of State owned corporations (public sector undertakings) to emerge for example in steel, fertilizers, locomotives, petrochemicals, oil and gas exploration and refining, heavy machinery etc.

Technology acquisition from abroad (in the form of machinery imports etc) was possible as the sterling balance left behind by the British provided the country much-needed foreign currency for such imports without constraint [7]. The industry felt no need to use R & D infrastructure of the lower segment.

In summary, by the end of this phase: -

Infrastructure for carrying out R & D activities had been laid

Simultaneously opportunities for learning production technologies had been created.

Thus activities in both the S & T infrastructure and the industry segments (lower and upper most of segments of Fig. 1 got initiated but the two activities grew under two distinctly different organizational set-ups of the government each with its own policies and strategies- the S & T agencies for lower segment of Fig 1 and the Socio-economic ministries for the upper segment.

The planning process recognized the need for linkages between the activities of the two segments however; R & D activity and economic activity grew with their own constituencies of supporters, institutions and strategies; supporters and actors in each cherishing their independence rather than interaction with those in the other segment [9] - linkages were unlikely to emerge.

4.2 ***Phase II: Reorientation***: Creating protected environment for Linked Network (1960s-70s)

During the early part of sixties several events took place that had a significant impact on policy towards indigenisation of technology. The country faced a severe food shortage. Military conflicts with countries across the borders forced increased defence expenditure. Foreign exchange reserves so far used for importing technology become scarce.

Expansion of basic industry was still necessary but self-sufficiency in food got added as one of the principal objectives of the Third Plan (1961-65) [10]. Foreign exchange reserves had come under strain, liberal policy towards technology import and the outflow on account of remittances of dividends profits, royalties, and technical fees could no longer be sustained. Consequently the fourth five-year plan (1966-79), reviewing the experience of the past fifty years noted [11]:

> *"Recent experience also underlines the need to take quick strides towards self-reliance. Increase in the total burden of foreign obligation has highlighted the heavy cost of servicing and repayment*"

Policies for industrialization and for science and technology were reoriented. A restrictive attitude towards foreign collaboration was adopted and the strategy was to encourage all efforts that would find substitutes for imported items and technology. In other words a **Technology Import Substitution (TIS)** strategy was adopted. This was an inward looking policy regime.

Industrial policy changes yet again to scrutinised and disaggregate foreign investments into Category A: Industries where no foreign collaboration was considered necessary, Category B: Industries where only technical collaboration was permitted and Category C: Industries where foreign investment might be permitted.

Another guideline was for strengthening indigenous technology consultancy capacities – wherever Indian industry-consultants were available, their services were to be utilized exclusively. Even where a foreign consultant became unavoidable an Indian consultant was to be given a primary role.

These changes in Industry policy had significant impact on the R&D infrastructure that had grown substantially during the previous plans. By the end of Third FYP (1961-66), 26 research laboratories under CSIR and 81 other research institutes had been established, S &T manpower had risen from 0.188 million in

1950 to 0.732 million in 1965 and national expenditure on R&D had grown from Rs. 46.8 million to Rs. 683.9 million; funds coming mainly from government sources (96%).

Under the new economic policy both the S & T infrastructure and industrial infrastructure were forced to change. The R & D institutions had thus far determined their research priorities based on scientific merit, but now they had to set R&D priority towards substitution of imported know how and products. Industry, especially in category A, also had no option but to use results from indigenous science and technology; technology know how import option was no longer available. Restrictions on imports provided exclusively reserved avenues for indigenous research and development activities and industry to get linked

This phase created a policy environment for the nucleation of network between the production and S &T infrastructure segments of Fig. 1 and for the emergence of innovation segment.

The important point to note is that change in S &T strategies was pushed by changes in the economic and industrial strategies and not by Science Policy. We therefore examine impact of this change in some detail.

5. Technology Import Substitution (TIS) & S & T Capabilities

The Governing Body of CSIR reformulated research projects and pilot plant activities of the national laboratories to meet the requirements of (1) Defence, (2) Substitution/elimination of imported products and technologies, (3) Development of other Industrial technologies, (4) Food and Agricultural Products, and (5) Objective Basic Research[12]. Even a laboratory like National Chemical Laboratory known for basic research changed the balance between basic and applied from earlier 50:50 to 20:80 in favour of applied research [13]. Savings in foreign exchange as a result of import substitution were estimated as significant [14].

This reorientation had a significant impact on industrialization and on R & D. In industry, significant technological capacity accrued in sectors such as heavy machines and electrical industries and mining machinery; public sector undertakings for example Heavy Engineering Corporation, Bharat Heavy Electrical Limited and Mining and Allied Machinery Corporation, emerged as important repositories of such technological capacity. The entire rolling stock requirements of railway and road transport could be met indigenously, and railway wagons were even exported. By 1965-66, the foreign content in various commodities reduced substantially from what it was in 1950-51; for example in bicycle from 62 to 0 %, in production of textile machinery from 67 to 57%, in sugar machinery from 100 to 1 %, in iron and steel from 25 to 17%, and in aluminium from 73 to 25 [15]. Overall, as a result of the massive TIS programmed a diversified, technology industrial structure came into existence under the second and third five-year Plans. This phase established the wherewithal in India to develop many industrial sectors with its own resources [16]. The S &T infrastructure also got coupled to industry in those areas where import of technology was not allowed; innovation networks got nucleated.

5.1 ***Phase III: Promotion of Indigenous Technologies*** (1970s-80s)

This period covers mainly the 4^{th} and the 5^{th} Five-Year Plans. The decade beginning 1970 had demonstrated that Indian S and T infrastructure had reached a level where, given congenial environment, it could contribute directly to economy However to realize S & T infrastructure's full potential, protection from foreign technologies was still considered necessary. The policy view was that: -

- Unrestricted import of technology was still one of the deterrents to generation and utilization of indigenous technology.
- A large number of know-how developed at a laboratory or pilot plant level had to be taken to commercial production levels, and the resulting product required a brand image.

Based on these considerations, Industrial and S &T policies were re-examined reorientation further.

Changes in the S &T policy

The following key issues were addressed to [2]:

(1) Foreign technologies had contributed little to the enhancement of "Technological Capacity". The importation had been, by and large, in packaged form with little or no scope for unpacking.

(2) Interaction between research institutions and industry was still not been extensive.

(3) Research institutions had mostly confined their activities to invention and innovation without taking much initiative in activities required for improving manufacturing aspects.

Several remedial steps were taken. In 1971 a committee named National Committee on Science and Technology (NCST) replaced earlier Science Advisory Committee. NCST's mandate was to promote inter-departmental co-operation and to co-ordinate scientific research activities with economic and industrial plans. For the first time the S &T Plan (1974-79) identifying R &D requirements of 24 sectors of development to take a system view of science and technology [17]. Basic sciences were also emphasized but it was stressed that support to it be provided in higher educational institutions (academic institutions in the lower segment).[3]

To implement the plans and policies of NCST, for the first time since independence, a separate government department, Department of Science & Technology (DST) was set-up. The Director of Indian Institute of Technology, Madras (since called Chennai) was brought over to head the Department as a full-

[3] For a critical review of support to the education sectors see Dhruv Raina and Ashok Jain [18].

fledged Secretary to the Government of India[4]. People experienced in research and development activities were recruited to man DST. Through DST several initiatives identified by NCST got implemented. For example new S &T programmes were launched in areas such as non-conventional sources of energy, ocean development, testing and calibration, weather forecasting, rural development and environmental pollution. A Science and Engineering Research Council was established along the lines of National Science Foundation of US and the UK Science Research Council to provide project funding to academic institutions for research in frontier areas of science.

During the period following changes in the industry related policies that had a direct bearing on S &T plans and programmes were: -

- In 1970, Patent Law was enacted to provide for patenting of process and putting restrictions on product patents [19]. This enabled the local industry to manufacture products already marketed by foreign companies using alternate processes developed through indigenous R & D without violating the Patent Law.

- Technology import policy was made more restrictive and selective [20]. Wherever import was considered necessary, preferred mode was outright purchase of the 'best' available technology.

- In 1976 a 'Technical Development Fund Scheme' was created to provide foreign exchange for import of machinery, technical know how, consultants services and drawing and designs [21].

- Rather than import of completely assembled products, their import in the form of semi-knocked-down components was promoted. For example, for an electron gun to manufacture picture tubes the import duty was 60%, whereas

[4] Secretary is the highest ranked government official

it fell down to 40% for the import of its semi-knocked-down (SKD) components [22].

- Foreign Investment was permitted only in selected industries but was generally restricted to 40% of the equity capital. The multinational corporations operating in India were directed to bring down their foreign equity. Higher foreign equity capital was considered only in export-oriented industries that required sophisticated technologies [23].

- Companies importing technologies were required to establish in-house R&D facilities to effectively absorb these technologies. As an encouragement, a package of extraordinary incentives in the form of tax concessions was introduced; companies could write-off 100 percent investment made on in-house R&D and 133 percent on expenditure on research sponsored to Indian R & D laboratories and academic institutions.

- In order to stimulate utilization of indigenous research, industrial licensing regulations were liberalized for industry using R & D developed in-house or by national laboratories. A number of industrial units established in-house R&D facilities. Contribution of private sector to national industrial R&D expenditure increased from 3.5% in 1965 to 16% in 1980

The above changes introduced during the 1970s had a strong influence on S &T structure in India. In several areas, indigenous research moved up to production, for example, in electronics, drugs and pharmaceutical, pesticides, chemicals, power generating equipment, agriculture and food processing. Several processes and products developed by CSIR laboratories, from low horsepower tractor to infant baby food to a number of pesticides and catalysts, went into production. For example in the case of pesticides, CSIR had selected around 40 pesticides out of 80 identified by the Ministry of Chemicals and Fertilizers for accelerated technology development and It succeeded in developing 25 technologies, 20 of these going into production yielding an annual turnover of around Rs. 750 million. A public sector corporation, National Research Development Corporation: NRDC, established in sixties for commercialisation of technologies developed in India was able to increase the umber of indigenous technologies in its portfolio going into production from 15.4% in 1970 to 19% in 1980.

In general under a protected economic environment, by the beginning of 1980's, linkages between S & T and production segments of Fig. 1 became functional. Innovation segment was further strengthened, and seeds for innovative activities had been sown albeit in a protected sectors.

6. Economic Liberalization

This period covers 1980s to 1990s (6th, 7th & 8th fie year plans). During this period policies gradually moved from somewhat closed and inward to an open internationally connected economy; from import substitution strategy to international competitiveness.

6.1 ***Phase IV: Moving towards economic liberalization*** (1980s-90).

The Sixth five-year plan was formulated against the background of a perspective covering the period of 15 years from 1980-95 [24]. While during the previous fifth five-year (1974-79), removal of poverty and self-reliance were stated to be the twin objectives, the subsequent plans witnessed an increasing re-emphasis on modernization. Economic liberalization implied opening up of the country’s economy to external connectivity and consequently reinterpretation of self-reliance in the context of global competition. This move to modernity, implicit in the Sixth five-year plan, accelerated immediately after Rajiv Gandhi became the Prime Minister on January 1, 1985 and by the Eighth plan in 1991 had become an explicit policy of the government.

The direction of change was implicit in 1980 Statement on Industrial Policy. Much before official adoption of economic liberalisation, the policy statement introduced liberalization of licensing rules and a host of incentives for foreign investments and exemption from foreign equity restrictions for rapid industrialization coupled with export of products to create a favourable balance of payments [25]. Promoting competition in the domestic market, technological up-gradation and modernization was the main thrust.

Subsequently import policy was made more liberal and some twenty-five industries were de-licensed. Open General License (OGL) was given for import of raw materials and capital goods - nearly 150 items in 1984 and 200 goods in 1985 were added to OGL and tariff rates on imports on several capital goods were slashed in 1985. Restrictions on imports of designs and drawings were removed. Opening up of the economy also saw a rapid increase in total number of foreign collaboration, the number of approvals increasing from 267 in the year 1979 to 2303 in 1996. Cases of foreign investments grew from 32 in the year 1979 to 1555 in 1996 [26].

Responding to the liberalization signals, issues of innovation (activities in the middle segment of Fig 1) and competition started finding expression in Science and Technology policies. For example reviewing the S & T scenario, the Planning Commission appointed working group on S & T for the sixth-plan (1980-85) commented [27]: -

> *"It is evident that in large areas of economic activity relatively obsolete cost ineffective technology continues to be applied. The pace of scientific and technological innovation remains unimpressive and the adoption of the available scientific and technological knowledge is tardy. There are many gaps in new important fields and in the ranks of leadership and in excellence".*

After years of S & T planning and policies, for the first time concern was expressed on technology obsolescence and its cost ineffectiveness. The major thrust of the S &T policies during this period may be summarized as:

- Strengthen innovative impulse for modernization to achieve economic and technological self-reliance.

- Strengthen linkages between S &T activities, financial institutions, and development banks.

- Ensure commitment of industries to R&D. Industry should earmark an appropriate percent age of sales turnover for R&D expenditure.

Modernization of technology, it was argued, also required updating of scientific knowledge to prepare the country for emerging science based and innovation -intensive industries. The S &T chapter of the plan noted :

> *"With our occupation to foster research programmes of a highly applied nature, much attention has not been paid to the advancing frontiers of science. The successful accomplishments of basic research automatically result in the creation of manpower imbued with great intellectual quality, self confidence and the ability to find new and innovative solutions to the problems" (p 321).*

The aim was to attract the very best and young talent to contribute to scientific research and achieve originality and excellence in international terms. To create conducive environment for innovative ideas, going beyond import substitution to market relevant research with high science content and with forward and backward linkages was emphasized. The plan document noted:

> *"Science can and must establish new heights for achievement and endeavour which are big enough to provide the challenge and excitement for the country's best talent. This will generate pride and self confidence as well as new innovative ideas and solutions which go beyond import substitution".*

Significant support to frontier areas of S &T emerging in the world scene became one of the important objectives of the 1980-85 plan; areas such as microelectronics, information technology, and biotechnology amongst others were identified and wee funded by the Science Department and agencies during the subsequent seventh-plan (1985-90). New R & D institutions and centres of excellence were established in carefully identified areas of thrust and around individual scientists or groups of outstanding merit. Through the Science and Engineering Research Council (SERC) and other government programmes of the Department of Science and Technology several national R&D programmes in emerging areas such as super conductivity, molecular electronics, immunology, biotechnology, new materials, seismic studies etc were launched.

Simultaneously the technology in the S & T policy (the 'T' component) also received attention. Twenty-seven years after the Scientific Policy resolution of 1958, in 1983 a Technology Policy Statement (TPS) was issued [29] and in 1987 Technology Information, Forecasting and Assessment Council (TIFAC) was established to examine and evaluate the existing state of technology and directions for future technological developments in various sectors; technology forecast reports covering 10 or more years were prepared. Renewed efforts were made to strengthen interaction between major economic ministries and R&D organizations and Scientific Advisory Committees were established in the Ministries of Coal, Mines, Steel, Transport, Chemicals, Fertilizers, Food Processing and Industry.

Reviewing the proposals for the Seventh five-year plan (1985-99), with Rajiv Gandhi as a young Prime Minister, a new approach of **Technology Missions** for addressing major social objectives especially affecting the weaker sections of the society was introduced [30]. The mission-oriented approach required formulation and implementation of programmes that started from research and development and went up to the delivery of final products and services. Six Technology Missions were launched within a short period of three years (1985-1988s). The objectives of technology missions were:

- To make drinking water available within a specified distance around each village.

- To spread literacy.

- To enhance production of edible oils adequate to meet the county's requirement.

- To immunize every child against polio, smallpox etc.

- To provide telephone connectivity to all the villages.

- To enhance dairy production.

Technology Missions necessarily required a networking of actors and institutions responsible for R&D, manufacturing and delivery. Technology Missions may be viewed as the first open to public scrutiny programme planned and executed covering all the three segments similar to other such missions that were confined to sanitised areas of space, atomic energy and defence,

This shift during 180s to 1990s from singular focus on science in India's S & T policy to include a strong component of technology in it was significant and has since continued to influence India's S & T policy and programmes.

6.2 ***Phase V: Science and Technology in Liberalized Economy*** (1991 onwards)

In 1991, the country entered an explicit economic liberalization and globalization policy regime. The overall policy for Foreign Collaborations (FC) became much more liberal than ever before. Foreign investments and collaborations were encouraged - technology imports as also foreign equity participation increased. For example, during the year 1997-98 as many as 2,400 collaborations were approved mostly with industrially advanced countries. Foreign direct investment (FDI) also jumped from a mere Rs. 5 billion per year during 1991 to over Rs. 360 billion during 1996[31].

As a result of economic liberalization there was a strategic shift in the working of government funded R & D laboratories - commercial returns from R and D became the guiding strategy- economic accountability got added to scientific accountability of R&D, research programmes were reoriented towards ‘business plans’ with the objective to create wealth from knowledge by breaking the boundaries between science disciplines and between those of research and market institutions. To start the process, mandate was given to publicly funded R&D laboratories to supplement their financial resources received directly from government by 30% or more through consultancy and research for Industry. N addition the vision document of CSIR set up a goal of 500 foreign patents by the year 2001 up from 50 in 1996[40]. [32].

Systems for Protection of Intellectual Property were strengthened and this attracted global R&D contracts. For example in 1992 CSIR ranked first among the top patentees in the country ahead of Hoechst AG (Germany), Siemen AG (Germany), and Hindustan Lever Ltd. (India). Patents filed by CSIR laboratories within India earned US$ 240 million (US$ 50 million from abroad) in 1995-96 and this was expected to rise to US$ one billion by 2001 (US$ 500 million from abroad).

Assured of IP protection, multinationals took initiatives to set up R and D facilities in India. Cray Research, Astra Biochemicals, Roche Scientific Company and Lever Brothers were the early entrants to operate 100 per cent foreign owned R&D companies in India. IBM set up its fifth research – not R&D- facility outside the US at Indian Institute of Technology, New Delhi at a cost of US $ 35 million (the other four being in Japan, China, Israel and Switzerland). Others that followed include Bohringer and Viewlogics. Recognising the quality of manpower and the costs at which was available, not only in the fields of science but also in technical administration, India moved towards emerging as a global R&D platform [33].

It is to be noted that the liberalized policy also contained specific provisions for strengthening the technology indigenisation effort. There were obligations on technology-importing firms- for example Indian entrepreneurs must set up R&D facilities if it made payments during the period of collaboration of more than Rs. 20 million for technology imports [34].

Research and Development Cess Act 1986 continued in the form of a 5% Cess (tax) on royalty payment for imported technology. The Technology Development Board of the Department of Science & Technology (DST) uses this fund to promote indigenous development of technologies as well as to promote absorption and adaptation of imported technology [35]. The Board provides matching grant for leveraging the partnership between industry and research institutions. The Technology Absorption and Adaptation Scheme (TAAS) of the Department of Scientific and Industrial Research, New Delhi, Programme Aimed at Technological Self Reliance (PATSER) initiated by DSIR in 1988, Home Grown Technologies initiated by DST in early 1990s; and Funding of R&D in Electronics to Industry (FRIEND) initiated by Department of Electronics (since renamed as Ministry of Information Technology) are other examples of mechanisms to promote R & D interaction between technology importing company and national R&D infrastructure. A 3-Year Excise duty waiver was also given on goods designed and developed by a wholly owned Indian company and patented in any two countries out of India, USA, Japan and in any one or more of the countries of the European Union[5].

To encourage commercialisation of innovations, Risk investment mechanisms have been introduced within financial institutions. A number of financial institutions have ventured capital schemes to encourage setting up of commercial units based on indigenous technological innovations. Examples are, Industrial Development Bank of India (IDBI), Industrial Credit and Investment

[5] Notification No. 15/96-Central Excise dated 23 July 1996 amended vide Notification No. 07/98-CE dated 2 June 1998.

Corporation of India (ICICI), Technology Development and Information Company of India (TDICI), Risk Capital and Technology Finance Corporation (RCTFC) and Small Industries Development Bank of India (SIDBI).

The economic climate has triggered enterprise to build upon capabilities nucleated during the earlier phases. Note worthy examples are the emergence of globally competitive enterprises in IT, Biotechnology, Drugs and Pharmaceuticals. Another development is the emergence of new entrepreneurial sector in the form of Research and Development Service Organisations based on high end S &T and managerial expertise these areas. These developments are now reorienting the academic institutions, their R&D and human resource development programmes.

In a sense the feed back loops connecting top to bottom segments of Figure 1 became active.

7. Summing Up

The result of the evolutionary development described above from country's independence in 1947 till the end of 1990s is summarised below:

An extensive and vibrant R&D infrastructure and institutions of higher learning had been established consisting of 1348 S &T institutions in the public sector, approx. 1250 R&D units within the private sector, some 200 voluntary organizations with overriding involvement in S &T and a total of 204 universities including six Indian Institutes of Technology.

The coupling between R&D and production was strengthened. A survey covering about 1000 In-house R&D units showed that the commercialization factor i.e. the ratio of R&D expenditure incurred by a company to that of the increased annual turnover attributed to goods produced based on In-house R&D is about 1:25. The commercialization factor for the public sector companies is about 1:17 whereas for the private sector it is about 1:33. For the small-scale units the commercialization factor is about 1:18. Thus, it has been estimated that an investment of Rs. 14 billion on R&D

by industry has contributed to enhanced industrial production of the order of Rs. 350 billion during 1994-95 [36].

In the context of contribution of indigenisation technological capability to economy, we refer to an assessment made of the technology source-wise contribution to industrial production in India. For the year 1993-94 it was assessed that the total value of industrial products was of the order of about Rs. 5000 billion. 45% of total production is attributed to foreign sources. This includes imported technology, capital goods imported during a span of 10-15 years, industrial products made by wholly owned subsidiaries and joint ventures with current liabilities of making payment to the principle by way of dividends or other repatriation obligations. The value of industrial production through indigenous technology as reported by the In-house R&D Centres in the country, acquired from CSIR and other major scientific research organizations and those, which were commercialized through agencies like the NRDC, amounted to nearly Rs.400-450 billion amounting to about 10% of total production. The remaining industrial production amounting to almost 45% of the total industrial production was thus attributed to indigenised or totally absorbed technologies with no obligation of technology payments abroad. In some sectors, for example the capital goods sector, indigenisation to the extent of 70-80% had been achieved [37].

Over the years a fairly strong entrepreneurial capacity with sensitivity to and competence in technology indigenisation also came up. We give just two illustrative examples that have been well documented. TELCO, a leading engineering company, started with only one foreign collaboration with Daimler-Benz AG in 1954. By 1991, with progressive integration of design and manufacturing capabilities introduced its indigenously designed multipurpose vehicles in the country and subsequently went on to put up its own passenger car in the domestic and international markets[38]. As an example of technological capability in technology absorption and adaptation material, the Samtel Group, manufacturers of TV picture tube, in 1982 imported all the 40 components for assembling a complete TV picture tube, but by 1990 it had attained 85% cost wise indigenisation[39].

Actors and institutions involved in matters of S& T and Industry have started combing in the middle segment. During the earlier years, from fifties to eighties segments had remained separated between scientists, R&D institutions and S&T agencies on one hand and the economic and industrial actors and institutions on the other. Subsequently and gradually the industry has started playing an active role in S& T that has become one of the important items on the agenda of industry associations like the Confederation of Indian Industries (CII) and the Federation of Indian Chambers of Commerce and Industry (FICCI).

The domain for the accountability of R&D has also undergone a process of transformation. Until about the end of seventies, despite policy pronouncements, it remained restricted to the scientific merit of R&D. However, over the years it expanded to encompass efficiency and marketability criteria.

Thus starting from a stage of infancy, the Indian S& T and Industry have over time reached a stage of maturity. Capacities nurtured initially in a policy environment insulated from global economy concentrating to domestic requirements were subsequently encouraged to go through the experience of facing a protected economic environment and finally liberalized to face an internationally open competitive environment.

Consequently by adopting evolutionary approach in policies and strategies, the country has reached a stage of a vibrant and linked S& T and Industry Trajectory, with capability in all the three segments and experience to adjust to future changing global economic scenario.

8. Some Lessons from India's Experience

Policy Framework

- S &T policies and strategies should not be viewed as independent of Industry, economic and commercial policies. National policy has to ensure strengthening of linkages between activities of three segments governed by different policies.

- A country has to have strengths in all the three segments shown in Fig 1, although depending upon stage of country's development national policies may differ in their thrust on one or the other aspects in any segment.

Components of National' Policy and Strategies

1. A Macro policy and strategy overarching policies and strategies for individual segments of science and its infrastructure, for Innovation, and for Industry. The long-term aim has to be the strengthening of linked Trajectory. This Macro policy cannot be formulated either by S &T Ministry or Department nor by Industry Ministry or Department, has to done under the head of the Nation e.g. Prime Minister by knowledgeable and experienced people with a national vision (external help may be taken if necessary). Financial allocation to different sectors of development is a subsequent and is a planning exercise distinctly different from visioning exercise.

2. Micro policies for individual segments (except for R&D in academic institutions, please see point 3) should pay attention not only to activities under its direct domain but also to how linkages with other segments are to be fostered and monitored. Strategies for linkages involve financial and other mandatory instruments (for example, publicly funded laboratories like of CSIR requiring to generate minimum 30% from industry sponsored projects

or technology importing industry required to set-up facilities for absorption and up gradation of technology etc).

3. Few projects or programmes such as India's Technology Missions with public private partnership involving government agencies and industry is a good mode for understanding and learning of how to establish a system that links to three segments of Fig 1 and generates useful innovation capabilities.

4. Differentiation is necessary between purposes of R&D, technology development and innovation. It is useful to recognise that Science

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