SOME DIMENSIONS OF RESEARCH AND DEVELOPMENT (R &D) IN INDIAN INDUSTRIES

An Analysis With Reference to Post Liberalisation Scenario

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I, hereby affirm that the research for this dissertation titled *"Some Dimensions of Research and Development (R&D) in Indian Industry: (With Reference to Post Liberalisation Scenario)"* being submitted to Jawaharlal Nehru University for the award of the Degree of Master of Philosophy in Applied Economics, was carried out entirely by me at the Centre for Development Studies, Thiruvananthapuram.

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Certified that this dissertation is the bonafide work of Mr. Prasad. S, and has not been considered for the award of any other degree by any other university.

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Chapter 1

INTRODUCTION

1.1 The background

The economic and social development of a nation directly depends on the strength of its scientific and technological base. Since, research and development (R&D) is one of the major measures of technological activity, there is much governmental funding in this area. Government funding is divided between basic research performed mainly in university-type institutions and technical support for the provision of public goods such as health, environment, and defence (Patel and Pavitt, 1995). Besides Governments, private sector involves in R&D activity mainly in the form of in-house but with an intention of improving their competitive positions. The R&D spending can, thus, be of basic and applied in nature. Basic research is undertaken with no particular objective in view (Mansfield, 1980). On the other hand, applied research has a predetermined objective. The latter is what firms' R&D spending mainly intend. The present study attempts to examine the R&D activity of industries in India. Importance of R&D spending is being contextualised in the perspective of 'Schumpeterian innovation', which is outlined in the following discussion.

1.2 The R&D activity and innovation:

In the literature, productivity growth is stressed upon for the long run economic growth.[1] Abramovitz (1956), Kendrick (1956), and Solow (1957) have tried to identify the factors leading to growth of productivity. In Solow's formulation, the

[1] Maddison (1982) observed that countries with low productivity growth recorded low growth of per capital income between 1870 and 1979.

residual is considered as the rate of disembodied technical change. The significance of technical change, thus, lies in that it, along with other factors, influences the level of productivity.

Schumpeter (1939), in his book on Business Cycles, introduced a production function with different combinations of inputs, which tells us more about technological aspects. The Schumpeterian trilogy divides the technological change process into three stages. First is the invention process whereby new ideas are generated. Second is the innovation process encompassing the development of new ideas into marketable products and processes. And, third is the diffusion stage in which raw products and processes spread across the potential market. These stages are, however, not linear process because only some new ideas are translated into marketable products and only some innovations are successfully diffused.

He uses the term `technical development' only for innovations that involve introduction of new methods of production. Innovations must be distinguished from inventions. The application of new combinations by entrepreneur is possible without inventions, and it does not necessarily lead to innovations. Innovation itself is the independent endogenous factor that causes economic life to go through a number of cycles.

Using the wider concept of innovation, a distinction between product innovation and process innovation can be made. Product innovation relates to the generation, introduction and diffusion of a new product with production process remaining unchanged. Whereas process innovation relates to the generation, introduction and diffusion of a new production process with product remaining unchanged. In addition to changes in products and processes, innovation encompasses changes in management methods, changes in the materials and intermediate inputs used in the production processes, and changes in markets (Stoneman, 1983).

The Schumpeterian trilogy could be related to R&D process. The R&D spending is the monetary equivalent of inputs to the process of producing technological advances. It is, thus, an input to both invention and innovation. In terms of Schumpeterian view, basic research is related to invention process, and applied R&D is related to innovation process. As commercial R&D is directed more towards development, it is concerned with innovation rather than invention (Stoneman, 1983). The research expenditure of firms may yield process or product improvements. It follows that most of the inventions are generated outside commercial sphere, being undertaken in universities and scientific institutes (Stoneman, 1995).

A firm may develop its own technology through R&D. It may also generate technological advance by learning, reverse engineering and imitation. Arrow (1962) shows that there is greater economic incentive for R&D and innovation, when industries are competitive rather than monopolised. Dasgupta and Stiglitz (1980) criticise Arrow's model on the ground that he takes market structures as given or exogenous, and that he fails to take into account the innovation possibility frontier open to firms in an industry. They show that high research intensity and a high level of market concentration go hand in hand. That is, industrial concentration and research intensity are simultaneously determined. They assumed that market structure could, to a large extent, be determined by scientific and technological successes, and by the environment for innovations.

It is, thus, increasingly viewed that technical change is the product of deliberate R&D activity (Griliches, 1971). The R&D activity contributes to economic growth by innovating methods, which either improves quality of factor inputs, labour and capital or increases the efficiency with which these factors are used.

1.3 Review of empirical studies:

The theoretical propositions, thus, point to a positive relationship between productivity and R&D activity and this has been verified by a number of studies. Griliches and Mairesse (1984) fitted a production function to analyse the impact of past cumulated R&D expenditures on the output of hundred large US firms, covering the period from 1966 to 1977. They found a strong relationship between a firm's productivity and the level of its past R&D investments. Cuneo and Mairesse (1984) obtained a similar result for French manufacturing industries for the period from 1966 to 1977. In both these studies, results of cross sectional analysis were more robust than time series analysis. Clark and Grilliches (1984) further reinforced the relationship in the case of US manufacturing firms in the 1970s.

Mansfield (1980) had observed a significant relationship between productivity growth and basic research undertaken in the case of ten petroleum and six chemical firms in the 1970s. Grilliches and Lichlenberg (1984) examined the issue of a possible secular decline in the productivity of R&D for the period 1969-1977, and did not find evidence for the same. They noted that an overall decline in productivity growth during this period affected the R&D intensive industries as well, but to a lesser extent. Sterlacchini (1989) presented a cross-sectional study for the British manufacturing in which, inter-industry total factor productivity growth is associated with different indicators of innovative activity. The paper explored the relationship between innovative activities and productivity advances in the light of the inter-industrial character of technical change. The study showed that the productivity slow down over 1973-79 was significantly associated with a declining propensity to perform R&D activities.

Studies were also undertaken to test the relationship between R&D intensity and market structure. Levin and Reiss (1984), using simultaneous equation model with data for twenty manufacturing industries for three years (1963,1967, and 1972), obtained a significant positive effect of R&D on industry concentration but a negative effect of concentration on R&D intensity. The latter, however becomes positive for industries with a high share of product rather than process R&D.

These studies, thus, underscore the positive relationship between R&D activity and productivity and its growth; and R&D activity and market concentration. These studies are related to firms of developed countries. In what follows, a review of some empirical studies pertaining to R&D activities in Indian industry is made.

1.4 Review of some studies in the Indian Context:

It will be shown in the following chapter that the role of Science & Technology (S&T) in national development was recognised by the planners and government played an active promotional and developmental role. Various policy measures and organisational structures have been evolved from time to time to meet the changing industrial and technological requirements of the country.

Subrahmanian (1971) examined the relevance of the Schumpeterian hypothesis in Indian economy and the role of market structure in technological progress and, therefore, in economic growth. The proposition examined included whether size of firm (absolute and relative) was an essential determinant of R&D activity on an effective scale in Indian industry. The proposition was split into the following testable hypotheses:

a. that R&D effort is greater in large firms than in small or medium firms; and,
b. those firms with higher market power (relative size) spend relatively a higher proportion of their turnover on R&D.

He tested these hypotheses for chemical industry using the Indian Chemical manufactures' Association (ICMA) survey data on R&D expenditure of individual firms. He proposed to seek empirical evidences by examining variations in R&D expenditure among sample firms. He found that small and medium firms had greater R&D intensity than large firms. He concluded that the size of the firm, absolutely or relatively, was not an important determinant of corporate R&D or progressiveness. On the other hand, case studies of Kathuria (1989) intended to analyse Schumpeterian hypotheses, concluded a positive relationship between firm size and market structure, on the one hand, and R&D activity on the other.

Pillai (1979) examined R&D activity of Indian firms in the context of adaptation and assimilation of imported technology. He observed that those units with weak R&D base had a tendency to depend more on foreign technology for updating their technology. With the empirical analysis of automotive sector, he concluded that foreign collaborated companies demonstrated a lag in adaptation and assimilation of imported technology, which was largely due to weak R&D base.

On the influence of the mode of technology imports, Kumar (1987) examined the influences of technology imports on levels of in-house R&D spending of 43 Indian manufacturing industries. In doing so, a distinction was made between two parallel modes of disembodied technology acquisition, namely, FDI and licensing. It was argued that these modes had differential influence on local R&D activity, which was confirmed by the findings. The FDI had a negative association with R&D intensity implying that, other things being same, industries dominated by foreign-controlled firms had lower R&D intensity than the rest. On the other hand, licensing was found to be positively related to R&D intensity implying a complementary relationship between this mode of technology imports and local level R&D spending.

Swaminathan (1988), based on a case study of TVS Business Group, concluded that import of technology constrains domestic R&D effort. The study revealed that the group's R&D activity has been oriented more towards material substitution to suit local conditions. There has been no economic compulsion to direct R&D activities to innovate as the liberal policy has removed the need factor.

Katrak (1985) empirically analysed two questions relevant to the R&D. He sought to examine whether `import and adapt' technology strategy had a significant simulative effect on local R&D, and whether adaptive R&D activity differ between certain types of enterprises, namely, large and small, indigenous and foreign-owned, and private and public. Using industry-level data, published by RBI for the years 1964-65 to 1969-70, he found that imports of technology stimulated R&D although the magnitude was rather limited. The R&D expenditure was observed to have increased with size, but larger firms had less R&D intensity than smaller ones.

Katrak (1989) examined whether imports of technology by Indian enterprises encourage or inhibit their in-house R&D effort. It was tested by studying R&D expenditure of technology importers as against that of non-importers. In addition, he examined if the level of R&D activity was related to firms' expenditure on imported technologies or whether firms undertake mainly adaptive activity.[2] The analysis showed that R&D activity was positively associated with its import of technology, suggesting that the imports of technology promotes in-house R&D, but the stimulative impact of the former on the latter was found to be rather limited. It was also found that R&D expenditure was higher among technology importers than non- importers, and larger enterprises have proportionately lower R&D expenditure.

Katrak (1990) examined whether imports of technology discourage or enhance firms' technological effort, and whether the private benefits of the imported technologies differ from the social benefits.[3] For the analysis, three aspects of imports were considered. They are, types of technologies imported, whether the importers had an exclusive right of sale, and the number of technologies imported. The results showed that the technological effort, measured by R&D expenditures, is higher in enterprises whose technology imports include those intended to strengthen their in-house capabilities, but lower in the enterprises, that have negotiated an exclusive right of sale (ERS) in the home market. The results for the ERS and for the types of technologies imported also suggested that the social benefits of the imported technologies are either likely to fall short of the private benefits, or that, at best, the former would be not greater than the latter. He found that increase in the number of collaboration agreements and enterprise size induce only an equi-proportionate increase in the level of technological effort.

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[2] These questions posed in terms of bahavioural analysis. To this end, two sets of questionnaires were framed to collect information. One set was collected by the Economic and Scientific Research Foundation (ESRF) and the other by the National Council for Applied Economic Research (NCAER). The former data are reported in ESRF (1979) and pertained to the period from 1966 to 1971, while the latter was collected covering the years 1980-84.

[3] The data for the analysis were collected by questionnaire, which were sent to technology importing enterprises in the electrical (including electronics) and industrial machinery industries.

Katrak (1994) examined whether Indian firms' output of R&D based product was affected by their imports of technology and their size.[4] The analysis revealed that the output and share of R&D based products were lower in the case of large firms and higher if firms R&D intensity was higher. The output of R&D based products were higher for the enterprises whose R&D and production units were located in different places, but were not affected by enterprises' imports of technology. The R&D intensity was, however, positively associated with technology imports.

Deolalikar and Evenson (1989) in their paper attempted an econometric analysis of the decisions of Indian firms to invest in their own R&D and to purchase technology (through licensing agreements). These decisions are treated as being jointly determined by characteristics of Indian industries, Indian prices, and the supply of purchasable foreign technology. The study revealed that industrial structure, firm size, and public and private ownership influence the mix of own R&D and technology purchase.

Basant (1993) showed that foreign technology licensing expenses, capital goods imports and other imports; and, R&D embodied domestic imports were negatively related to R&D expenditures of the firm. He also found that the domestic technology spillovers, multinational companies participation and the industrial licensing policy of the Indian government are all positively related to the R&D expenditure of the firm.

Kumar and Saqib (1994) analysed the determinants of probability of undertaking R&D activity and the intensity of R&D expenditures. The findings suggested that

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[4] The data for the empirical tests were obtained from the Department of Scientific and Industrial Research (DSIR) (1988) compendium on the chemical and allied industries. This publication covers all of the 200 enterprises whose Research & Development units have been recognised by the government and the data pertain to 1987.

determinants of R&D intensity, which had a negative relationship with technology import and a weak relationship with profits in the in the post reform period as compared to the pre-reform period.

From the studies reviewed above, it is difficult to draw any firm conclusion regarding the technological strategy of Indian firm. Most of the studies have suggested that imports of technology may help R&D and other technological effort. The studies show that there has been a continuum between imitation, modification, improvement, variation, adaptation of technology and innovation by importing firm, leading in some cases to productivity gains. Obviously the process has not been a smooth one, most of them constrained by bottlenecks, either technological or organisational. In fact, gains through adaptive efforts enable an enterprise to respond to other needs of R&D. For instance, Alam (1985) notes that of late the R&D of some Indian enterprises has been influenced by the need to indigenise production and to become competitive. This may suggest that the import of technology might lead to successive stages of technological development.

1.5 The Need for and objective of the study

Most of the studies reviewed above related to pre liberalisation period, where government policy framework influenced firms' decision. Interventions like import of technology and subsidy on R&D would have affected firms' decision on R&D spending and subsequent technological developments. These interventions and technology import must have led to learning from imported technology by domestic R&D as pointed out by some studies.

In the liberalisation milieu, market forces play a vital role in influencing the decisions of firms. Productivity becomes the main conduit through which inter-firm competitive position could be improved. Adaptation of technology, thus, becomes crucial. Policy changes since 1991 have provided firms in India to import or develop technology on its own. Import of technology does not undermine the role of R&D because the latter plays a vital role in the further improvement and local adaptation of technology. Competitive environment opens up the technical search processes, available foreign techniques as well as those new ideas seem technically feasible to implement so that industry may be able to balance between innovation and imitations. The new situation thus calls for greater improvement in domestic R&D efforts. In this context, an examination of factors that influence R&D efforts at the firm level assumes greater significance. As R&D is linked to productivity growth, it is important to examine the influence of firms' R&D activity on their productivity. Since liberalisation is seen as a watershed in R&D effort, it calls for examining the relationship for both pre and post liberalisation periods.

More specifically, the study attempts

1 to review the promotional and developmental role of the State in R&D activity in the economy;

2. to analyse the aggregate, sector-wise and industry-wise trends in R&D expenditure over the period of time;

3 to examine the R&D intensity of manufacturing firms in India and its determinants; and,

4 to assess the contribution of R&D spending by firms to their productivity performance.

1.6 Data Sources and methodology

This study relies on secondary sources of data. The major source of data is the 'Research & Development Statistics', published annually by Department of Science and Technology, Government of India. This is complemented by an electronic database (Prowess) provided by the Center For Monitoring Indian Economy (CMIE). The methodology followed are simple ratios, Ordinary Least Square, and Panel Data Analysis. Specification of the models are presented in the relevant text.

1.7 Chapter scheme:

The study is organised into five chapters including the introduction. The promotional and developmental role of the State in improving R&D effort in the economy is reviewed in Chapter 2. This chapter also examines the trends in R&D expenditure. In Chapter 3, we analyse the R&D intensity of Indian manufacturing firms and its determinants. The link between R&D spending and productivity is explored in Chapter 4. Chapter 5 sums up main findings of the study.

Chapter 2

TRENDS IN RESEARCH AND DEVELOPMENT IN INDIA

In this chapter, an attempt is made to examine the R & D efforts made in India. The government has been playing an active role in promoting the R & D activities. In the first section(Section 2.1), a review of the promotional and the developmental role of governmental efforts will be s attempted. In Section 2.2, trend in the R & D expenditure is examined at the national and sectoral level. Attempt is also made to examine the relationship between public sector and private sector R & D. In Section 2.3, trends in industrial R & D is analysed.

Section 2.1

2.1(A) Scientific Technological Development in India:

Before independence, the scientific and technological infrastructure in the country was limited to a few scientific institutions established by the British administration.[1] With the outbreak of Second World War, industrial research received attention of the State, though mainly for military purposes. Consequently, the Council of Scientific and Industrial Research (CSIR) was set up in 1942, with a chain of laboratories. Prof. A.V. Hill, in his report titled `Scientific Research in India' submitted in 1945, recommended to the then British Administration to promote organised scientific research in India. As regards the organisation of scientific research, he suggested a complete transplantation of the

[1] They are Survey of India in 1767, Geological Survey of India in 1851, Indian Meteorological Department in 1875, Haffkins Institute in 1899, Imperial Agricultural Research Institute (IARI) in 1903, Forest Research Institute in 1906, India Research Fund Association in 1911, now Indian Council of Medical Research (ICMR), Imperial Council of Agricultural Research in 1929, now Indian Council of Agricultural Research ICAR).

British model in India

Scientific research continued to receive attention during the post independence period. The role scientific research was seen as more of developmental, which became an integral part of overall development strategy. The science and technology were developed in a conscious way as a major force for accelerating social and economic change. In his *Discovery of India,* (1969) Nehru expressed his conviction in these words: " It was science alone that could solve the problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhibited by starving people". The enthusiastic efforts of Sir Shanti Swarup Bhatnagar led to the expansion of the CSIR into a chain of national laboratories spanning a wide spectrum of science, technology, engineering and bio medical sciences. The vision of Homi. J. Bhabha led to advanced research in nuclear energy and other fundamental areas through the creation of the Tata Institute of Fundamental Research (TIFR) and Bhabha Atomic Research Centre (BARC). The space programme envisioned by Vikram Sarabhai has grown into a self- confident and dynamic area of Indian science.

In 1948, Ministry of Scientific Research and Cultural Affairs was set up with the objective of developing R&D infrastructure in the country. Consequently, large number of specialised laboratories and institutions were set up mainly under the aegis of the CSIR. In 1954, Department of Atomic Energy (DAE) was set up as the executive arm of the Atomic Energy Commission (AEC). The University Grants Commission (UGC) and the Ministry of Education provide major support for scientific and technological activities in the educational institutions. A large number of in-house R&D units has been set up by various private and public sector undertakings largely to meet their own needs. An important development has been the rapid growth of consultancy organisations providing engineering designs, erection and consultancy services, which act as a bridge between R&D institutions and industry. In addition, a significant amount of basic research is carried out in institutions of higher learning in the country; the universities, Agricultural Universities, Indian Institute of Technology (IIT), Indian Institute of Science (IIS), Bangalore, medical institutes such as, the All India Institutes of Medical Science (AIIMS), Delhi, Post Graduate Institute of Medical Education and Research, Chandigarh, Sree Chitra Tirunal Medical Centre, Thiruvananthapuram, National Institute of Mental Health and Neurological Science, Bangalore etc.

There was a simultaneous conscious effort to expand facilities for the training of scientific and technical manpower. All India Council of Technical Education (AICTE) was constituted in 1945 and a decision was taken to establish a number of technological institutes (IITs), so that the out tern of scientists and engineers from there would meet the demand for technical man power.

In March 1958, parliament approved the `Scientific Policy Resolution (SPR)'. It was envisaged to give substantial support to science and to ensure that the nation would secure the benefits of science for its social, cultural and economic development. The First Five-Year Plan (1951-1956) did not have a working group on scientific research. It recommended that national laboratories should promote the development of small scale and cottage industries. It also proposed establishment of `National Research and Development Corporation of India (NRDC)' to act as a conduit between the research laboratories and the industry. Scientific Advisory Committee of the Cabinet (SACC) was set up in 1956 to advise the Cabinet in the formulation and implementation of schemes of scientific research. In the Second Plan (1956-60) and the Third Plan (1961-65), only one panel was set up for formulating schemes for the research activities of the CSIR and the scientific organisations associated with the Ministry of Education. The first significant step towards institutionalising science policy was taken in 1968, when Committee on Science and Technology (COST) replaced SACC. It had a three fold responsibility: to determine the quantum of investment in scientific and technological research; to work out priorities, distribute resources to meet various demands and correlate allocations with the policy of industrial development; and to build up a suitable network for evaluation to assess the utilisation of resources and the degree of attainments of various goals. At the beginning of the Fourth Plan (1969-74), Committee on Science and Technology (COST) brought out a Report on Science and Technology. In 1970, COST convened a Conference of Scientists, Technologists, and Educationists. The conference strongly recommended preparation of a national plan for the promotion of science and technology and their application to development. Subsequently further development along these lines led to a well-defined policy of self-reliance. A clear-cut exposition of this policy was reflected in a document prepared by the National Committee on Science & Technology in 1980 entitled, `Approach to Science & Technology Plan'. It provided the basis for the formulation of the Fifth Rive Year Plan. It was during this period that, new dimensions to the objectives of S&T have emerged. At the instance of the then Prime Minister, the Indian Science Congress Association at Waltair was devoted to the theme of `rural technology'. This manifested in the need for long-term and basic research in national and social sciences. In particular, three new dimensions were incorporated into the S&T policy:

(1) The problem of safe guarding the environment,

(2) Factors arising out of interaction of science and technology with society and

(3) Development of an information system and its use in decision making.

Another important landmark was the Technology Policy Statement of January 1983, twenty-five years after the `Scientific Policy Resolution'. The major aim of the policy was technological development and to draw priorities for technologies, or in other words the objectives were defined to be development of indigenous technology and efficient absorption and adaptation of imported technology appropriate to national priorities and resources. In the Sixth Plan, considerable emphasis was placed on the need to support and strengthen basic research. A scheme for granting recognition to in-house R&D units in the industrial sector and private and public funded research and development laboratories was being operated by Department of Science and Technology (DST) from 1973. The Department of Scientific and Industrial Research (DSIR) has been dealing this scheme, since 1984. One of the objectives of this scheme is to provide import facilities to recognised R&D units under Open General Licence (OGL). This has been absorbed in the liberalised trade policies announced by the Government in 1991. The in-house R&D units qualified for recognition are expected to be engaged in research and development activities related to the manufacturing activities of the company[2].

An important feature of India's industrial development since 1991 has been the phenomenal growth of foreign collaboration, the formal channel for foreign investment inflows and technology transfer into India from industrialised countries (Subrahmanian et.al, 1996). The Industrial Policy Statement of 1991 states that foreign investment and technology collaboration will be welcomed to obtain higher technology, to increase exports and to expand the production base. The in-house R&D units qualified for recognition are expected to be engaged in research and development activities related to the manufacturing activities of the company[3].

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[2] Detailed reports on incentives to such units are given later in this chapter.

[3] Detailed reports on incentives to such units are given later in this chapter.

2.1(B) R&D Organisations in India

A brief description of the major R&D organisations is given below.

Department of Scientific and Industrial Research (DSIR)

Department of Scientific and Industrial Research is the nodal Government Department of Research and Development in industry established during 1985. The Department has launched several initiatives to encourage increased utilisation of locally available R&D options through its major schemes viz., Research and Development by Industry (RDI), Programme Aimed at Technological Self Reliance (PATSER), Scheme to Enhance the Efficacy of Transfer Technology (SEETOT) and National Information System for Science and Technology (NISSAT). Several technology development, technology absorption, technology assessment and technology demonstration programmes in industry are supported by DSIR. These programmes are implemented through active involvement of National Laboratories, Universities and IITs and National Research Development Corporation[4].

Council of Scientific and Industrial Research (CSIR)

The Council of Scientific and Industrial Research was set up in 1942 with a view to develop close linkages with industry in a number of areas such as drugs and pharmaceuticals, pesticides, petroleum and petrochemicals, catalysts, leather, pollution mitigation etc. CSIR has reoriented its priorities and programmes towards undertaking globally competitive research and maximising support to the industrial base in the country. Linking CSIR research to market needs, mobilising and optimising resource base and investing in high quality science that will be

[4] National Research Development Corporation (NRDC), a public enterprise under DSIR, is engaged in the development, upscaling, licensing and commercialisation of indigenous technologies as well as export of technologies.

forerunner of future technologies have been identified as the road map to new CSIR

CSIR has also entered into MoUs with industry associations and financial institutions for forging strategic alliances. CSIR-CII (Confederation of Indian Industry) MoU is for evolving programmes to foster linkages between industry-laboratories for commercialisation and management of technology and exchange of staff; creating awareness and conducting training programmes for IPR issues; and sharing technology status information. Similar MoU has also established between CSIR and FICCI to focus at facilitating joint R&D programmes.

Department of Science and Technology (DST)

Department of Science and Technology established in 1973, is engaged in contributing to technology development and its linkages for future commercialisation or large scale applications. The department has supported a number of programmes in engineering and technology, national co-ordination of testing and calibrating facilities, instrument development and technology missions and systems. To fulfil the need for national co-ordination among various multi-disciplinary areas having inter-institutional linkage mechanism, DST has evolved certain schemes, which are specifically intended to accelerate the growth of indigenous capability.

Department of Biotechnology (DBT)

Department of Biotechnology has taken several steps to develop trained manpower, set up infrastructural facilities for research, and has organised demonstration projects for faster dissemination of research results to the industry in certain areas. The department, since its inception in 1986, has been promoting various aspects of biotechnology research and development through several agencies including industry. DBT has also set up Biotech Consortium Limited for promoting transfer and commercialisation of biotechnologies.

Department of Space (DOS)

Department of Space established during 1972, has used the development contract system effectively in the National Space Programme. The Indian Space Programme has a strong interaction with the academic institutions in the country through its Sponsored Research Programmes. To cater to the increasing demand for space products and services from various space agencies, Department of Space has set up a commercial venture, "Antrix Corporation Limited" which looks after commercial aspects of technology transfer[5].

Department of Atomic Energy (DAE)

The Department of Atomic Energy established in 1954, has been engaged in design and development of various systems for the nuclear power programme and for promoting peaceful applications of atomic energy as well as in generating technologies in related high-tech areas. They have established horizontal linkages with industry in the area of power generation equipment. They have diffused the use of radioisotopes in industry, medicine and agriculture. A number of spin-off technologies, which are not directly related to the nuclear energy programme, are transferred to many private and public sector companies for commercial exploitation.

Department of Electronics (DOE)

The Department of Electronics established in 1970 has promoted and supported Scientific Societies to implement time bound projects and programmes. These are (I) Society for Applied Microwave Electronics Engineering Research (SAMEER);

[5] "Antrix Corporation Limited", also handles consultancy services in India and export of space products and services

(ii) National Centre for Software Technology (NCST); (iii) Centre for Development of Advanced Computing (C-DAC); (iv) Electronics Research and Development Centre (ER&DC), and (v) Centre for Materials for Electronics Technology (C-MET). DOE has also set up testing and evaluation centres in electronics and supported Regional Electronics Research & Development Centres to provide technical and technological services to the industry.

Defence Research and Development Organisation (DRDO)

Defence Research and Development Organisation established in 1958 has framed out several development contracts in the area of special materials and components, controls and instrumentation, radar development, communication systems etc. They have also sponsored several programmes to the industry; such as development of thermal and other special batteries for the missile programme; successful commercialisation of low level detection transportable radar "INDRA-I" etc.

Among the above-mentioned scientific organisations, CSIR has been managing the major portion of the research in industry. The various functions assigned to the council are:

(a) The strengthening of the existing research institutions and the establishment of new ones as appropriate;
(b) The promotion, guidance and coordination of scientific and industrial research and financing of specific research schemes;
(c) The utilisation of research for the development of industry;
(d) The establishment and award of research studentships and fellowship.

Since the mid-sixties the problem of utilisation of the results of research has become an important matter of concern for the government, policy makers and planners. Scientific community has been critical of Indian industry for its lack of enthusiasm, initiative, and patience to accept Indian R&D (Valluri, 1983). The

Indian industry, on the other hand blames Indian R&D for its failure to deliver goods to industry (CSIR, 1968). Being the major agency under the Government of India, CSIR is basically responsible for conducting industrial research, and its utilisation problems since mid sixties. Scientists, technologists and engineers from related industries were nominated as members of Scientific Advisory Committees and Executive Councils of laboratories. They were expected to actively participate in the formulation of research programmes. CSIR also established a special Technology Utilisation Division (TUD) to make research available to industry and set up liaison units with major manufacturing associations. A new R&D institutional pattern, in the form of Co-operative Research Association (CRA), was introduced by CSIR. A group of industries joined CSIR in financing a research laboratory in the field of their research interest. A collaborative research effort of this kind was expected to bring research closer to user.

The CSIR now supports 30 national laboratories, two scientific and technological museums, the Indian National Scientific Documentation Centre (INSDOC), and the Publications and Information Directorate. The INSDOC and the Publications Directorate are being merged to form the Central Institute for Scientific Information and Publication. The laboratories have been categorised into six groups and there is a co-ordination council for each group to facilitate the formulation and implementation of inter-laboratory projects. These co-ordination councils comprise the directors of laboratories in each group. The CSIR Headquarters at New Delhi Co-ordinates the activities of the laboratories. After 1991, CSIR reorganisation has been stressed. The Council has also entered into bilateral agreements in the fields of pure as well as applied sciences, with scientific organisations of various countries.

We have identified in the above discussion, the major landmarks in the development of the Science and Technology institutions. However, available research in the area points out some major issues such as lack of meaningful linkages among S&T institutions, absence of proper links between research institutions and user sectors, inability to develop appropriate technology for defined economic and social goals, failure to discover the availability of technology (foreign and domestic) its transfer, diffusion and generation of technology locally, and so on (Desai 1982, Swaminathan, 1988). How far these issues got accentuated or reduced in the present environment of liberalisation is an issue that falls outside the scope of present study.

Section 2.2

Trends in R&D expenditure:

In this sub-section, some aspects of macro and micro allocation of financial research for R&D over time are examined. Collection of data on allocation to R&D activities began in 1968 with the constitution of Committee on Science and Technology (COST) in that year. With the creation of Department of Science and Technology (DST) in 1971, biennial national surveys on R&D statistics were undertaken from 1973-74. They have adopted UNESCO recommendations regarding international standardisation of statistics on science and technology. In their reports they have provided expenditure on National R&D Expenditure over the years. Along with that they also provide industry wise and sector wise R&D expenditure of central, state and private sectors.

2.2 (A) National R&D expenditure:

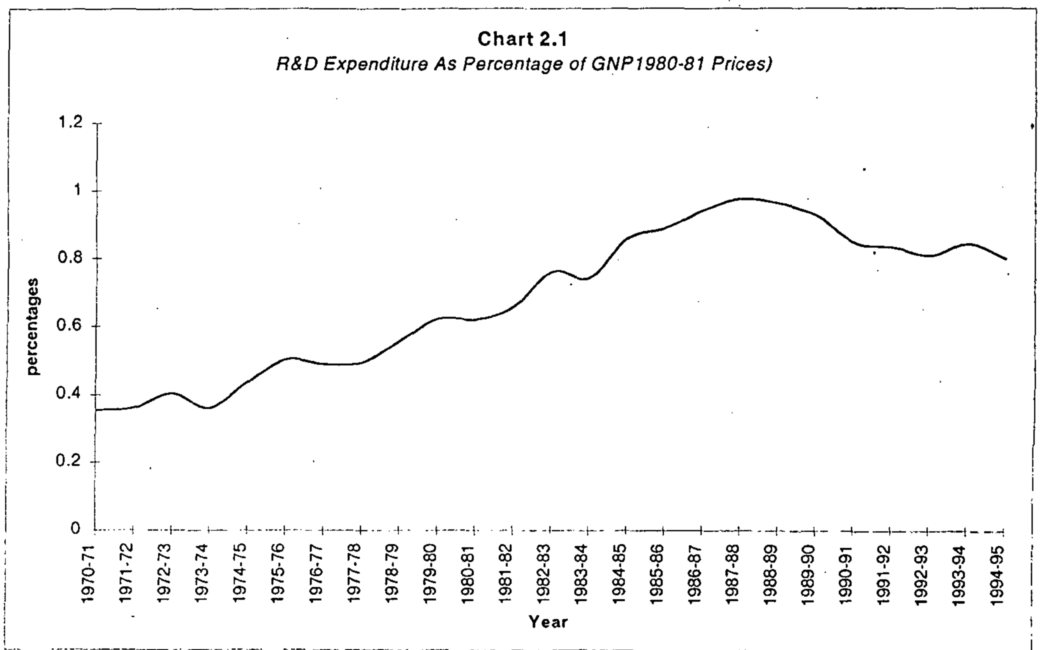
Table 2.1 : *National Expenditure on Research and Development*

Year	Current Price	Constant Price	R&D Exp as% of GNP
1950-51	4.68		
1955-56	12.14		
1958-59	22.93		
1965-66	68.39		
1968-69	107.56	255.25	
1969-70	116.62	267.97	
1970-71	139.64	316.89	0.35
1971-72	151.64	326.29	0.36
1972-73	185.76	362.09	0.40
1973-74	203.89	339.86	0.36
1974-75	291.60	418.89	0.44
1975-76	356.71	526.22	0.50
1976-77	374.16	519.76	0.49
1977-78	430.62	563.02	0.49
1978-79	520.42	668.00	0.56
1979-80	638.54	711.88	0.62
1980-81	760.52	760.52	0.62
1981-82	940.73	853.21	0.66
1982-83	1206.03	1012.61	0.76
1983-84	1381.10	1069.48	0.74
1984-85	1781.55	1283.90	0.86
1985-86	2068.78	1383.21	0.89
1986-87	2435.40	1523.49	0.94
1987-88	2853.07	1641.37	0.98
1988-89	3347.26	1780.53	0.96
1989-90	3725.74	1831.58	0.92
1990-91	3974.17	1761.84	0.85
1991-92	4512.81	1743.13	0.83
1992-93	5004.60	1782.51	0.81
1993-94	6073.02	1973.00	0.84
1994-95	6821.02	2013.08	0.81

Note: Deflated by GNP implicit deflator

Source: *Department of Science and Technology (DST)*

As seen in Table 2.1, the national expenditure on R&D has increased considerably from Rs. 255 crores to Rs. 2013 crores at constant prices. Though this amounts to a nine-fold increase, as a proportion of GNP the increase has been less pronounced (See Table 2. 1). The R&D expenditure, which was merely 0.35% of GNP in 1970-71, steadily rose to 0.62% during 1980-81. It again increased to 0.98% during 1987-88, thereafter exhibiting a declining trend, reaching 0.81 during 1994-95. The growth of national R&D expenditure as a proportion of GNP is illustrated in Chart 2.1.



A better picture of the trend in the research and development expenditure is obtained when we compute the compound annual rate of growth of R&D expenditure. The compound annual growth rates for five-year periods have been calculated (See Table 2.2.). The growth rate of R&D expenditure increased from 0.06 in 1970–75 to 0.09 during 1975–80 and again to 0.14 during 1980-85. However, in the subsequent periods, it showed a declining trend (0.07 during 1985–90 and 0.04 during 1990-95).

Table 2.2 *Compound Growth Rates of R&D Expenditure*

Year	Growth Rates
1970–75	0.06
1975–80	0.09
1980–85	0.14
1985–90	0.07
1990–95	0.04

Source: *Department of Science and Technology (DST)*

2.2 (B) Sector wise R&D Expenditure

The national R&D effort in India consisting of government (central and state) and private R&D expenditures over the period 1983-95 is explained with the help of Table 2.3.

Table 2.3 *Sector wise Research and Development Expenditure*

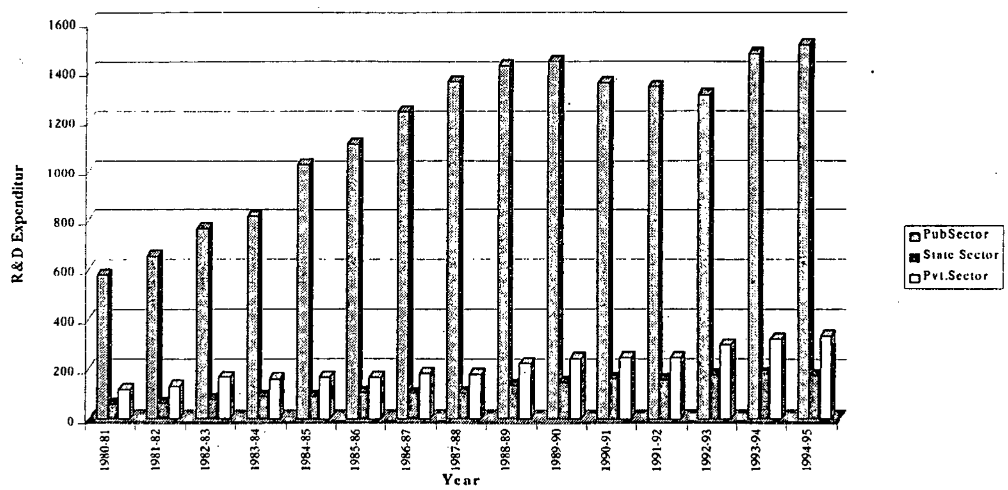
Year	Central Sector		State Sector		Pvt.Sector		Total	
1970-71	255.23	(80.54)	28.55	(9.01)	33.11	(10.45)	316.89	(100.00)
1971-72	270.97	(83.05)	20.51	(6.28)	34.82	(10.67)	326.29	(100.00)
1972-73	303.45	(83.81)	20.97	(5.79)	37.66	(10.40)	362.09	(100.00)
1973-74	279.22	(82.16)	21.45	(6.31)	39.19	(11.53)	339.86	(100.00)
1974-75	332.04	(79.27)	34.48	(8.23)	52.38	(12.50)	418.89	(100.00)
1975-76	424.31	(80.63)	39.43	(7.49)	62.47	(11.87)	526.22	(100.00)
1976-77	417.49	(80.32)	35.01	(6.74)	67.26	(12.94)	519.76	(100.00)
1977-78	449.66	(79.87)	37.26	(6.62)	76.09	(13.52)	563.02	(100.00)
1978-79	534.60	(80.03)	40.93	(6.13)	92.47	(13.84)	668.00	(100.00)
1979-80	557.83	(78.36)	51.33	(7.21)	102.72	(14.43)	711.88	(100.00)
1980-81	580.49	(76.33)	59.34	(7.80)	120.69	(15.87)	760.52	(100.00)
1981-82	654.77	(76.74)	65.11	(7.63)	133.32	(15.63)	853.21	(100.00)
1982-83	765.73	(75.62)	81.49	(8.05)	165.39	(16.33)	1012.61	(100.00)
1983-84	815.69	(76.27)	92.85	(8.68)	160.94	(15.05)	1069.48	(100.00)
1984-85	1024.96	(79.83)	90.88	(7.08)	168.05	(13.09)	1283.90	(100.00)
1985-86	1105.92	(79.95)	108.84	(7.87)	168.45	(12.18)	1383.21	(100.00)
1986-87	1238.11	(81.27)	102.94	(6.76)	182.43	(11.97)	1523.49	(100.00)
1987-88	1357.06	(82.68)	105.81	(6.45)	178.50	(10.87)	1641.37	(100.00)
1988-89	1423.25	(79.93)	135.14	(7.59)	222.15	(12.48)	1780.53	(100.00)
1989-90	1442.32	(78.75)	148.09	(8.09)	241.18	(13.17)	1831.58	(100.00)
1990-91	1355.80	(76.95)	162.22	(9.21)	243.82	(13.84)	1761.84	(100.00)
1991-92	1339.28	(76.83)	157.82	(9.05)	246.03	(14.11)	1743.13	(100.00)
1992-93	1305.32	(73.23)	179.34	(10.06)	297.85	(16.71)	1782.51	(100.00)
1993-94	1471.37	(74.58)	182.42	(9.25)	319.21	(16.18)	1973.00	(100.00)
1994-95	1509.01	(74.96)	173.65	(8.63)	330.42	(16.41)	2013.08	(100.00)
1995-96*	1564.53	(73.92)	185.93	(8.79)	365.94	(17.29)	2116.39	(100.00)

Source : *Department of Science & Technology (DST)*
Note: Figures in parenthesis are the share of total R&D Expenditure
* Projected figures

The table indicates that the central sector has been accounting for a major proportion of (more than 70%) total R&D expenditure followed by private and state sectors. However, since 1980s the share of R&D expenditure by the central sector has been declining, with that of private sector exhibiting an increasing trend. The trend in R&D expenditure of the state sector does not show a systematic pattern. In general, there has been a continuous decline in the share of public sector R&D expenditure (see Chart 2.2), owing mainly to the decline in central sector R&D expenditure.

Chart 2.2

National R&D Expenditure by Sector (Constant Price)



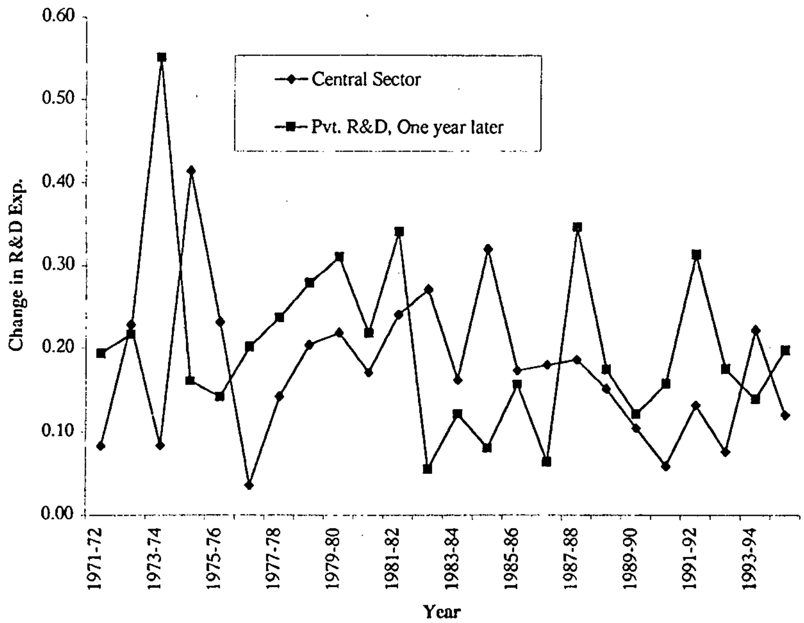
The marked decline of central share in the post 1990 period may be pointer to the lack of State initiative in sustaining R&D effort under liberalisation regime. It is, however, heartening to observe that the private sector R&D expenditure stayed at a high level during this period. The continued dominance of public sector in R&D investment coupled with the increasing trend in R&D expenditure by the private sector calls for an exploration of the link between public and private sector R&D investments. This is the subject matter of the following sub-section.

2.2 (C) Relationship between Government and Private R&D

The relationship between governmental effort in R&D and that of private is examined in terms of complementarily or susbstitutionability. State initiative is said to be complementing private initiative if the latter follows a dependent course. The argument, in the context of developed countries like US, is that as government makes more contract and R&D, finance is made available to industry, firms increase their own R&D spending in the hope of capturing more government funds (Mani, 1999). In developing countries like India, where the government R&D consists of both basic and applied, the latter may take the shape of a public good. To mop up the externalities arising on account of this, private sector is likely to engage in greater R&D activity. Thus, a complementary relationship would mean the R&D expenditure of private sector increases or decreases following the R&D expenditure of State with a lag. On the contrary, if private expenditure increases or decreases simultaneously with decrease or increase in State expenditure, it is said to be substituting State expenditure. To this end, R&D expenditure of government and private sectors is expressed in terms of their growth rate (see Chart 2.3).

Chart 2.3.

Relationship Between Central Sector R&D And Private R&D



As seen in Chart 2.3, the relationship pattern shows a mixed trend. For instance, we observe a substitutability relationship during the period 1981-88. In the subsequent period, there appears to be a complementary relationship[6]. The dichotomy is due to sudden cut back of public R&D since late eighties.

Section 2.3

R&D activities in Industrial Sector

As mentioned earlier, the Government of India has been actively encouraging industries to take up R&D activities. Out of 1375 R&D units existing in 1995, information on the year of setting up of R&D facilities is available for 1284 units. The distribution of these units according to the year of establishment is presented in Table 2.4.

Table 2.4 : *Growth of R&D Units in Industrial Sector During Different Plan Periods*

Sl. No	Plan Period	Private Sector	Public Sector	Total Number of R&D Units
1.	Before 1950	24 (92.31)	2 (7.69)	26 (100.00)
2.	First Five Year Plan (1951-56)	1 (73.33)	4 (26.67)	15 (100.00)
3.	Second Five Year Plan (1956-61)	23 (85.18)	4 (14.82)	27 (100.00)
4.	Third Five Year Plan (1961-66)	47 (97.92)	1(2.08)	48 (100.00)
5.	Annual Plans (1966-67 to 1968-69)	36 (80.00)	9 (20.00)	45 (100.00)
6.	Fourth Five Year Plan (1969 to 74)	156 (86.67)	24 (13.33)	180 (100.00)
7.	Fifth Five Year Plan (1974-79)	184 (86.38)	29 (13.62)	213 (100.00)
8.	Annual Plan (1979-80)	32 (82.05)	7 (17.95)	39 (100.00)
9.	Sixth Five Year Plan (1980-85)	253 (86.35)	40 (13.65)	293 (100.00)
10	Seventh Five Year Plan (1985-90)	233 (85.97)	38 (14.03)	271 (100.00)
11	Annual Plan(1990-91 and 1991-92)	77 (93.90)	5 (6.10)	82 (100.00)
12	Eighth Five Year Plan till 1995	39 (86.67)	6 (13.33)	45 (100.00)
	Total	1115 (86.84)	169 (13.16)	1284 (100)

Source: *Department of Science and Technology (DST)*
Note : Figures in parenthesis are percentage share
1. Information about two units in public sector units are not available.

[6] Hill (1995) found a complementary relationship between Federal R&D and private sector R&D in U.S

2. Out of 1115 private sector units 151 units SIRO units
3. The Number of public sector units shown in this table also includes
4. the joint sector companies mostly under the State Governments.

As seen in Table 2.4 there were only 26 R&D units till 1950. During the Third Plan, 48 units were newly set up. The period coincides with the enactment of Income Tax Act, 1961, which provided liberal tax incentives for R&D. During the Fourth Plan, the number of such units rose to 180. As mentioned earlier, in1973, the Government of India started a scheme of registration of R&D establishments with DST, which became mandatory for availing fiscal incentives and tariff concessions. This may perhaps explain the substantial increase in the establishment of new units during the Fifth plan. But in the post 1990-91, the establishment of R&D units in industrial sector has declined considerably. It is observed that in the nineties private sector has substantially reduced setting up new R&D units. This may suggest that in the new scenario characterised by decontrolling and delicensing, domestic innovation efforts of firms are being substituted by import of technology. Having seen the trend in the reestablishment of new R&D units, we now examine sector wise R&D expenditure (see Table 2.5)

Table 2.5 *Expenditure on R&D by Sector* (Crores in Rupees)

Year	Public Sector Industry	Private sector Industry	Total
1976-77	31.76 (39.61)	48.42 (60.39)	80.18 (100)
1980-81	86.37 (41.71)	120.69 (58.29)	207.06 (100)
1985-86	198.62 (44.08)	251.94 (55.92)	450.56 (100)
1989-90	412.90 (45.70)	490.59 (54.30)	903.49 (100)
1990-91	414.53 (42.98)	549.98 (57.02)	964.51 (100)
1991-92	484.39 (43.20)	636.94 (56.80)	1121.33 (100)
1992-93	513.95 (38.06)	836.25 (61.94)	1350.20 (100)
1993-94	542.81 (35.59)	982.54 (64.41)	1525.35 (100)
1994-95	685.33 (37.97)	1119.57 (62.03)	1804.90 (100)

Source: Department of Science and Technology (DST)
Notes: Figures in parenthesis are shares of total industrial R&D.

Though the number of R&D units established by public sector manufacturing units cannot be compared to private sector units for, the manufacturing enterprises under its control is numerically low compared to private sector although its size is high. The industrial R&D expenditure of public sector manufacturing units amounts to more than forty per cent of total industrial R&D expenditure implying that R&D intensity is relatively high. However we did not get firm wise R&D sales ratio to make any definite commitment regarding this behavioural pattern over time. By 1990s, its relative share has come down, which is in line with the overall decline in its share in the national R&D expenditure. The increased share of private sector overtime could be due to combined effects of various factors including:

(a) increased awareness of the importance of the R&D activities

(b) increase in the number of R&D units

(c) introduction of several incentives for R&D by the Government

(d) liberalised economic policies and

(e) international industrial competitiveness.

Of these factors, the incentives offered by Government to lure private sector into R&D activity needs to be highlighted.

2.3 (A) Incentives and Support Measures

Government has evolved, from time to time, fiscal incentives and support measures to encourage R&D in industry and increased utilisation of locally available R&D options for industrial development. The incentives change from time to time. Some of the incentives like weighted tax deduction under section 35(2B) and enhanced investment allowance under section 32A(2B) of the I.T. Act have been discontinued. Similarly preferential treatment in licensing, delicensing of industrial set-ups and commercialisation of indigenous technologies by MRTP companies have been further liberalised and absorbed in the new Industrial Policy.

Major Fiscal incentives and support measures:

(a) Income tax relief on R&D expenditure;

Under section 35(I)(I) of the Income Tax act 1961, the revenue expenditure laid out or expended on scientific research, by the In-house R&D units on activities related to the business of the company is allowed as full deduction. Under section 35(2) of the I.T. Act 1961, expenditure of capital nature on scientific research related to business carried on could be deducted totally from the income of the year in which this expenditure is incurred. Also contributions and donations made to Scientific and Industrial Research Organisations (SIROs) approved by DSIR and notified u/s 35(1)(ii)/(iii) of the I.T. Act 1961 qualify for exemption from Income Tax

(b) Weighted Tax Deduction for sponsored research;

Under section 35(2AA) of I.T. Act 1961, a weighted tax deduction of 125% for sponsored research programmes in approved National Laboratories functioning under the aegis of the Indian Council of Agricultural Research (ICAR), Indian Council of Medical Research (ICMR), Council of Scientific and Industrial Research (CSIR), Defence Research & Development organisation (DRDO), DOE, Department of Biotechnology, Department of Atomic Energy, Universities and IITS are available to the sponsor. During the past three years, DSIR has approved 8 sponsored research programmes valued at Rs. 196.15 lakhs. Projects approved by DSIR are notified by the Director General of Income Tax (Exemption), Calcutta[7].

(c) Incentives to promote indigenously developed technology

The Technology Policy of January 1983 proposes, suitable financial mechanisms will be established to facilitate investment on pilot plants, process demonstration units and proto-type development in order to enable rapid commercial exploitation of technologies developed in laboratories. Linkages between scientific and technological institutions and development banks will be strengthened. Gaps in technology will be identified and suitable corrective measures taken with adequate allocation of resources. Fiscal incentives will be provided in particular to promoted inventions; increase the use of indigenously developed technology; enhance in-house Research and Development in industry and efforts directed to absorb and adapt imported technology.

(d) Allowance in Modvat

There have been requests from trade and industry for liberalisation and simplification of Modvat scheme. So the union budget for 1995-96 proposed modvat credit for specified quality control, testing pollution control and R&D equipment.

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[7] The Union Budget for 1996-97 deleted the requirement of approval of program by the aforesaid prescribed authority and the requisite approval of the program can be given by the Head of the concerned

(e) Customs Duty Exemption;

The Union Budget for 1996-97 introduced rationalisation of customs duty exemption on import of equipment, spares and accessories and consumables for research purposes by public funded research institutions, universities, IITs etc for availing the customs duty exemption. The ceiling on the value of goods imported for R&D is also removed and the head of the public funded research institutions/organisations can certify the R&D goods for duty free import[8].

The Scientific and Industrial Research Organisations (SIROs) recognised by DSIR are eligible for Customs Duty Exemption for import of essential items relating to capital equipment, spares, accessories, raw materials and consumables for their R&D work based essentiality certificate issued by the DSIR[9].

The Union budget for 1996-97 introduced the provision of customs duty exemption on specific goods imported for use in R&D projects funded partly by any Department of the Central Government and undertaken by a company in their in-house R&D unit recognised by DSIR.

(f) Five year tax holiday for commercial R&D companies;

In order to promote research and development activities in and by industry, and also to attract talented scientists and technologists to set up commercial

[8] Notification No. 51/96-Customs dated 23 July 1996

[9] A pass book issued by DSIR is to be maintained by the SIRO (Notification No.51/96-Customs dated 23 July 1996)

R&D companies, the Union Budget for 1996-97 introduced a provision of a 5-year tax holiday Sec. 80-IA of Income Tax Act, 1961 to approved companies engaged in scientific and industrial research and development activities on commercial lines.

(g) Excise duty waiver

The Union budget for 1996-97 introduced the provision of exemption of all goods falling under the Schedule to the Central Excise Tariff 1985 (5 of 1986) from the whole of the duty of excise leviable thereon provided such goods are manufactured by a wholly Indian owned company, such goods are designed and developed by such Indian company, the goods so designed and developed are patented by such Indian company in India and in any one or more of the countries of the European Union and in USA or Japan or in both.

(h) Accelerated Depreciation Allowance

Under Rule 5(2) of the Income Tax Rules, Third Amendment vide Notification No. 133/342/86-TPL dated 1 April 1987, depreciation allowance on plant and machinery set-up based on indigenous technology developed in recognised In-house R&D units, SIROs, Government R&D Institutions and National Laboratories.

(i) Price Control exemption on domestic R&D based bulk drugs

Being one of the thrust areas for exports, the drug industry is recognised as a highly R&D oriented sector. With a view to encouraging larger investments in R&D in the area of bulk drugs, Government have exempted the bulk drugs produced from the basic stage based on indigenous R&D from price control.

(j) International R&D collaborations

The Government has approved a scheme for promoting international R&D collaborations at the enterprise/institutional levels. The scheme is implemented by DSIR for giving clearances to proposals for R&D collaborations between companies/institutions in India and those in other countries. Recognised In-house R&D units and SIROs are eligible to apply for permission for such international R&D collaborations.

(k) Technology Development Fund

To accelerate the development and application of indigenous technology to production process, the Union Budget for 1994-95 introduced a provision to credit the 5% cess on payments of royalty on imported technologies which was hitherto collected under the Research and Development Cess Act 1986, into a new Fund for Technology Development and Application.

(l) National Awards for Outstanding In-house R&D achievements and commercialisation of public funded R&D.

In order to provide recognition to the efforts of the industry towards innovative research and technological development and also for increased utilisation of public funded R&D by industry, National Awards for R&D efforts in Industry were instituted in 1987 by the Department of Scientific & Industrial Research and implemented since 1988.

2.3 (B) R&D Manpower

There has been a steady increase in R&D manpower employed by In-house R&D units over the years. The relevant data are produced in the following Table 2.6

Table2.6 R&D *Manpower Employed by In- house R&D units*

Year	R&D Manpower	No. of units
1875 – 76	12000	400
1981 – 82	30000	750
1995 – 96	50000	1284

Source: *DSIR*

The estimated manpower of 1284 recognised In-house R&D units is over 50,000 out of which around 35% R&D personnel are employed in the public sector In-house R&D units and around 65% are employed in private sector In-house R&D units. The private sector being a larger employer of manpower only substantiates the dominant role of this sector in industrial in-house R&D.

2.3 (D) Production based on In-house R&D Efforts

The essence of successful In-house R&D is that it must lead to generation of useful technology and its successful commercialisation. A preliminary survey of a limited number of In-house R&D units carried out in 1988 by DSIR revealed that each rupee spent on R&D contributed to production of Rs.12 in the company (DSIR, 1996). The commercialisation factor i.e., the ratio of R&D expenditure incurred by a company to that of the annual turnover attributed to goods produced based on In-house R&D is given in Table 2.7.

Table 2.7 *Commercialisation factor of In-house R&D units in different sectors (1995-96)*

Sectors	Commercialisation factor
Public Sector	1:17
Private Sector	1:33
Small Scale Units	1:18
Total 1000 In-house R&D units	1:25

Source: *DSIR*

As seen in Table 2.8, the commercialisation factor is very high in private sector as compared to public sector and other small-scale units. Using the commercialisation factor, DSIR has estimated that an investment of Rs. 1575 crores on R&D by industry has contributed to industrial production of the order of Rs. 40,000 crores during 1995-96. The higher factor of private sector indicates that it contributes more to industrial production by virtue of in-house R&D. DSIR has not given the details of the methodology about the calculations and therefore we cannot comment upon the authenticity of these calculations.

2.4 Summing up:

In this chapter, an attempt has been made to document strides made in R&D in India. It has been noticed that State played a promotional and developmental role. This is reflected in the establishment of institutions promoting R&D and dominant share of State in the overall R&D expenditure, albeit a decline in the post 1980 period. To draw in private initiative, the State has been offering incentives in different forms. A review of these incentives has revealed that in-house R&D has been focussed, particularly in industrial sector. Analysis reveals that the progress made in in-house R&D has responded positively. The analysis carried out at macro level though indicated spread there may be firm specific factors, which induces a firm to involve in industrial R&D. To the extent, industrial R&D is focussed in the policy framework, analysis at a micro level assumes significance. The following chapter examines the determinants of industrial R&D at a micro level.

Chapter 3

DETERMINANTS OF INDUSTRIAL R&D

In this chapter, an attempt is made to explore factors, which are postulated to influence R&D activity at the firm level. For the purpose of analysis, R&D intensity, defined as R&D expenditure to sales, is considered as key word. While juxtaposing R&D expenditure with other variables at a firm level, one encounters problems related to data. Section 3.1 delineates how these data problems are overcome for the purpose of our analysis. The R&D intensity is studied for the manufacturing sector on the whole and for some selected industries in Section 3.2. The determinants are examined in Section 3.3.

Section 3.1

3.1 (A) Sources of data and the sample:

In the subsequent section R&D intensity is related to other firm specific variables that requires firm wise data. The firm wise data is made available by CMIE, in its electronic database called `PROWESS'. Firm wise R&D expenditure is reported along with other information. As pointed out by Shanta and Rajkumar (1999), one of the main problems of `Prowess' is incomplete reporting of R&D expenditure for all firms. Thus firms which are reported to have `0' R&D expenditure in `Prowess' database could not be considered as zero R&D firms. The DST in its annual publication titled `Research & Development Statistics in Industry' provide R&D expenditure of firms with more than Rs.100 Lakhs. According to the DST's report relating to the year 1994-95, there were 263 firms belonging to both public and private sector. And, some of these firms were engaged in non-manufacturing activities too. These 263 firms were considered as major R&D firms for the study. All other required firm specific information was collected from Prowess. Using information as given in the Prowess, these firms were identified as manufacturing and non-manufacturing. It was also possible to identify their ownership.

Accordingly, they were classified into public sector, Indian private sector and foreign sector. The market share is one of the crucial variables, but firm wise market share is not available in Prowess. The CMIE's document titled "Market Share and Market Size" gives market share of firms at a very disaggregated industry group. Having identified the main activities of the sample using Prowess information, it is possible to trace their respective market share from the CMIE's document. Those firms for which information could not be obtained were omitted from the sample along with non-manufacturing firms. This gave a sample of 204 firms.

The firm wise R&D expenditure as reported in Prowess is however, considered for carrying out analysis of R&D intensity for the period 1992-93 to 1996-97, covering the post liberalisation period. Since the DST data source is not available for all years of post liberalisation period, we could not employ this source for time series analysis.[1] About 114 firms were found having R&D expenditure in Prowess for the entire period. The time series analysis was, therefore, restricted to such sample size.

For industry-wise analysis, we made use of DST data on R&D expenditure and R&D intensity, which are available in more desegregated industry group level. Using this information, it was possible to arrive at sales turnover of all these groups, which were then aggregated into five major industry groups. They are chemicals & chemical products, nonmetallic mineral products, basic metals, alloys and mineral products, machinery and machine tools, and transport equipment & parts. It is to be noted that they are considered as high R&D intensive industries.

[1] The latest DST is related to the year 1994/95.

Section 3.2

3.2 (A) Trends in R&D Intensity

To begin with an attempt is made to understand firms' R&D intensity behaviour for the period from 1992/93 to 1996/97. For the purpose analysis, as mentioned in the previous section, a common sample of 114 firms in manufacturing sector is considered. These firms were classified according different ranges of R&D intensity (See Table 3.1).

Table 3.1 *R&D Intensity of Manufacturing firms in different ranges*

Ranges in %	1993	1994	1995	1996	1997
0.01 – 0.15	19	21	20	24	25
0.16 – 0.3	16	17	17	16	16
0.31 – 1.00	54	51	51	46	50
1.01 – 2.00	14	10	14	17	14
2.01 – 5.00	11	13	10	10	8
5.00 <	0	2	2	1	1
Total No.firms	114	114	114	114	114

Source :*CMIE*

As many as 19 firms had R&D intensity ranging from 0.00 to 0.15 per cent in 1992-93, which was then increased to 24 in 1996-97. It implies that firms increasingly spend low proportions of sales turnover on R&D. If firms with R&D intensity of more than one per cent is considered as high in the Indian context, there is some progress as the number of firms under these ranges has not come down over the years until 1995/96. The fact that the year 1996/97 witnessed a fall in the number firms belonging to these ranges implies that the impulse of R&D is fading. The inter-temporal movements of the average intensity of these firms are analysed. To this end, the distribution of firms in 1992/93 is considered as the base (see Table 3.2.

Table 3.2: *Average R&D Intensity according to 1993 classification*

R&D intensity	No. of firms	1993	1994	1995	1996	1997
0.01 – 0.15	19	0.07	0.09	0.16	0.17	0.16
0.16 – 0.3	16	0.22	0.27	0.31	0.36	0.28
0.31 – 1.00	54	0.56	0.66	0.92	0.67	0.75
1.01 – 2.00	14	1.32	1.87	1.50	1.68	1.39
2.01 – 5.00	11	2.00	2.90	2.09	1.85	1.83
All firms	114	0.72	0.88	0.89	0.78	0.77

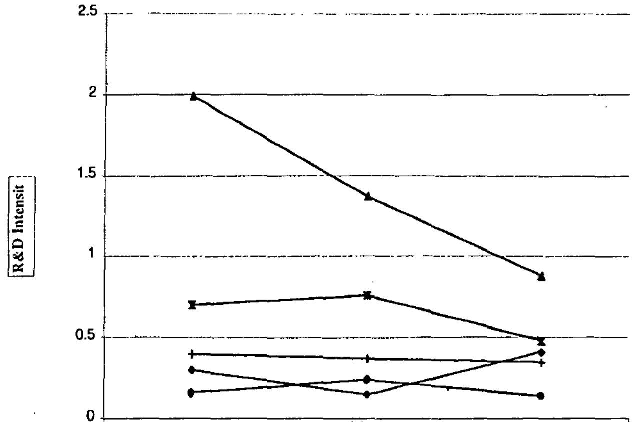
Source: *CMIE*

Those firms, which belonged to lower category of R&D intensity of less than .3 per cent, had improved their R&D until 1995/96. Firms belonging to higher category of more than 2 per cent improved their R&D intensity very substantially in 1993/94, which got reduced to a level that is lower than 1992/93. On the whole, R&D intensity had improved until 1994-95 and subsequently it diminished. The trend, thus, suggests that impulse of R&D that set immediately after liberalisation has diminished in the recent years.

3.2 (B) Industry wise R&D intensity:

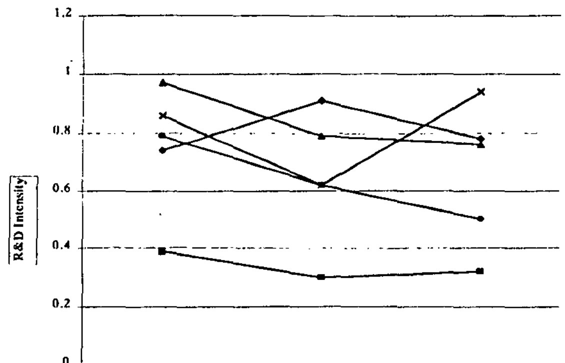
To understand R&D intensity across industries, we have classified R&D intensive industries into 5 major industry groups, namely, chemicals & chemical products, non-metallic mineral product basic metals, alloys and mineral products, machinery and machine tools, and transport equipment & parts. For the sake of convenience, we have calculated average R&D intensity for short intervals of five-year periods. The patterns are presented in Chart 3.1 and Chart 3.2.

Chart 3.1 R&D Intensity (Public Sector)



	1980-1985	1985-1990	1990-1995
Chemicals & Chemical Products	0.7	0.76	0.48
Non metallic mineral products	0.16	0.24	0.14
Basic metals, alloys & metal products	0.4	0.37	0.35
Machinery & Machine tools	1.99	1.37	0.88
Transport equipment & parts	0.3	0.15	0.41

Chart 3.2 R&D Intensity (Pvt.Sector)



	1980-85	1985-90	1990-1995
Chemicals & Chemical Products	0.74	0.91	0.78
Non metallic mineral products	0.79	0.62	0.5
Basic metals, alloys & metal products	0.39	0.3	0.32
Machinery & Machine tools	0.97	0.79	0.76
Transport equipment & parts	0.86	0.62	0.94

As seen in Chart 3.1 and 3.2, there is an overall decline in R&D intensity of industries in public sector in recent years. This needs to be viewed against context of the withdrawal of the State from R&D effort on the whole, as observed in the previous chapter. The R&D intensity of transport and equipment's & parts has improved in the 1990s. The average R&D intensity of machinery & machine tools of public sector was high in the 1980s, which declined subsequently. As machine and machine tools is a major constituent of capital goods sector, the higher R&D intensity of public sector in this industry is suggestive of its dominant role in leading capital formation process of the economy. The R&D intensity of the same industry in private sector has also registered a marginal decline in the 1990s. The higher R&D intensity in this industry in the 1980s could be a fallout of the import substitution strategy that was followed over the years. The decline of the same in the 1990s that coincides with the periods of liberalisation needs to be viewed against the decline in public sector research noted in earlier sections. The rise in the R&D intensity of transport and equipment perhaps is an outcome of the rise in the demand for automobiles in the 1990s. The higher R&D intensity of chemicals and chemical products, particularly those belonging to private sector, is to be seen against the growth of drugs and pharmaceutical and consumer industries in the 1980s as well as 1990s (Nagaraj 1991 and Kumar 1990).

The above discussion brought out certain tendencies in respect of R&D intensity of manufacturing sector as well as of major industries. As argued earlier, there may be some specific factors at work, which determines R&D effort at micro level. In what follows, first we identify the determinants of R&D based on existing literature and then study the distribution of firms by juxtaposing R&D intensity against the identified variables.

Section 3.3

Determinants of R&D Intensity

From the available literature[2], we have identified the following variables as the main determinants of R&D. They are

a. size of the firm (measured by sales),
b. market share,
c. capital intensity (measured by capital employed to total value of production),
d. import intensity (measured by total imports to sales),
e. technology imports (measured royalty and technical fees to total sales turnover),
f. export intensity (measured by total value of export to sales), and .
g. vertical integration (proportion of value added to total value of production),
h. profit margin (measured by profits before tax to sales).

In order to understand the relationship between R&D intensity and these identified determinants, firms were distributed according to different ranges of R&D intensity and the explanatory variables in a cross tabulation format. And, we have also conducted chi-square[3] test for each cross tabs. Selection of samples is already discussed in section 3.1. As mentioned, 204 firms formed the sample. In order to construct cross tabs, firms with zero observations against the relevant variables are omitted. The number of firms, thus, varies while studying R&D intensity against each of these determinants. The sample firms are also studied in terms of their ownership, namely, public sector (Central and State Government undertakings),

[2] Goldar and Ranganathan,1997; Sidharthan, 1988; Kumar,1987; Kumar and Saquib, 1996;,Kathuria, 1989, Katrak, 1985and 1989

[3] Chi-square (Cross-tabs) statistic used to test the hypothesis that the row and column variables are independent. The Pearson chi-square is the most widely used form, and we also followed the same in our analysis.

Indian private firms, foreign firms. The cross tabs for these ownership groups are presented in the Appendix 3.A

3.3 (A) Cross tab Analysis

R&D intensity and market structure:

In Schumpeterian hypothesis, market structure is an essential determinant of R&D activity. While testing the validity of the hypothesis, Subramanian (1971) expected R&D efforts of firms to be linearly related to size and market power. To operationalize this proposition, size was defined in terms of sales and market power was defined in terms of market share. The Table 3.3 depicts the relationship of R&D intensity and size.

Table 3.3 *Distribution of Companies by R&D Intensity to Sales*

R&D intensity	Sales (Rs. crores.)					
	< 50	50 to 100	100 to 1000	1000 to 5000	5000 & above	Total
Below 0.5	6	8	36	16	7	73
0.5-1.0	3		34	8		45
1.0-3.0	6	13	31	4	1	55
3 &above	11	6	12	2		31
Total	26	27	113	30	8	204

Chi-square : 48.12(0.01)
R = 0..35(.01)
Note: Figures in parenthesis are level of significance
r is the Pearson's correlation coefficient

In Table 3.3, we see a significant relationship between R&D intensity and size of the firm as indicted by Chi-square but the relationship is negative as indicated by

r. A close look reveals that firms having higher sales turnover accounted relatively low R&D intensity. Out of 204 firms, 166 firms had more than 100 crores of sales turnover, but only 79 of them had more than 3 per cent of R&D intensity. The overall results hold good for the sample of public sector and Indian private sector and not for foreign sector (see Table 3.1.A in Appendix 3 A)

The Table 3.4 provides its relationship to market share. To test whether firms with larger market share spend more on R&D, we expect a positive relationship between R&D intensity and firms market share. We have classified the sample firms into four categories according to their market share[4]. They are, 75 per cent and above which is considered as high, 60 to 75 percent treated as medium, 50 to 60 per cent low, and less than 50 representing very low.

Table 3.4: *Distribution of Companies by R&D Intensity & Market Share*

R&D intensity	Market share				
	below 50	50-60	60-75	75 &above	Total
Below 0.5	20	6	28	14	68
0.5-1.0	8	9	10	12	39
1.0-3.0	22	5	7	10	44
3 &above	14	1	4	2	21
Total	64	21	49	38	172

Chi Square: 26.22 (.01)
r = -0.227 (0.01)
Note: Figures in parenthesis are level of significance
r is the Pearson's correlation coefficient

[4] Following the studies by Sankar (1981), and Vijayabaskar (1992)

As seen in Table 3.4, R&D intensity is significantly related to market share. Out of 38 firms with high market share (more than 75%) only 2 of them had more than 3 per cent of R&D intensity. And, out of 49 firms, having medium market share (60-75%), only 11 firms had more than 1 per cent R&D intensity. Whereas out of 64 firm with very low market share (less than 50 per cent), 28 firm had less than 1 per cent R&D intensity. Analysis by types of ownership, however, reveals that it is only Indian private sector that has such significant relationship (see Table 3.1.B).

R&D Intensity and Capital intensity

A positive relationship between R&D intensity and capital intensity is expected because R&D intensity should be very high in capital intensive industries. The Table 3.5 gives distribution of firms by R&D intensity and capital intensity.

Table 3.5: *Distribution of Companies by R&D Intensity & Capital Intensity*

R&D intensity	Capital intensity				
	Below 0	0-50	50-50	150 &above	Total
below 0.5	8	24	31	10	73
0.5-1.0		26	17	2	45
1.0-3.0	4	19	28	3	54
3 &above	1	9	15	5	30
Total	13	78	91	20	202

Chi Square : 17.58 (0.04)
r : 0.078 (0.27)
Note: Figures in parenthesis are level of significance
r is the Pearson's correlation coefficient

As seen in Table 3.5, there is a significant relationship between R&D intensity and capital intensity across firms. Firms with less than 3 per cent of R&D intensity had less than 150 per cent of capital intensity. Out of 20 firms with more than 150 per cent of capital intensity, only 5 of then had R&D intensity of more than 3 per cent. Thus, it is not surprising that r is positive but not significant. Here again, Indian private sector confirms to the overall result (See Table 3.1C in Appendix 3 A).

R&D intensity to Import of Intensity and technology imports

A number of studies have examined the relationship between R&D intensity and import of technology. As seen in the review, empirical studies did not have a common consensus on the relationship. Here, we try to figure out the relationship of R&D intensity to total imports as well as to technology imports (see Table 3.6).

Table 3.6 *Distribution of Companies by R&D Intensity & Import Intensity*

R&D intensity	Import Intensity				
	Below 5	5-10	10-20	20 &above	Total
Below 0.5	21	14	18	12	65
0.5-1.0	5	16	17	6	44
1.0-3.0	16	13	15	9	53
3 &above	3	7	8	12	30
Total	45	50	58	39	192

Chi-square : 19.15 (0.02)
R : 0.14 (0.05)
Note: Figures in parenthesis are level of significance
r is the Pearson's correlation coefficient

In Table 3.6, we observe a significant relationship between R&D intensity and import intensity. But firms belonging to public sector and foreign sector did not have similar results (see Table 3.1.D in Appendix 3 A).

Import includes technology. The nature of relationship between R&D intensity and import of technology assumes significance in the wake of liberalisation of import policies with regard to import of technology. While Pillai (1979) and Swaminathan (1988) found that import of technology substituted domestic R&D effort, Katrak (1985, 1989 and 1990), Deolalikar and Evenson (1989), Bassant and Fikkert (1996) found that R&D effort improves along with import of technology. Sidharthan, (1988) found a mild complementary relationship. However, Kumar (1987) argued that technology import via foreign direct investment has negative influence on R&D efforts, whereas licensing mode has positive association. The relationship as observed by these studies is mixed. We also try to find a relationship between technology imports and R&D intensity (see Table 3.7).

Table 3.7 *Distribution of Companies by R&D Intensity & Technology Imports*

R&D intensity	Technology Import to Sales				
	0-0.1	0.1-0.5	0.5-2	2 & above	Total
< 0.5	10	16	10	4	40
0.5-1.0	9	20	5		34
1.0-3.0	8	11	8	1	28
3 &Above	1	2	4	2	9
Total	28	49	27	7	111

Chi Square: 13.76 (0.13)
R: 0.079 (0.41)

In Table 3.7, we cannot find a significant relation between technology import intensity and R&D intensity. As many as 76 firms out of 111 have less than 2 per cent of technology import intensity but only 51 firms have less than 1 per cent of

R&D intensity. A significant relationship is, however, observed in the case of firms belonging to Indian private sector (see Table 3.1 E in Appendix 3 A).

R&D intensity and export intensity

Another aspect that assumes equal importance is the relationship between export intensity and R&D intensity. While Siddharthan and Agarwal (1992) and Goldar and Ranganathan (1997) found a significant relationship in the pre liberalisation period. The latter, however, observed a negative association in the post liberalisation period. In Table 3.8, we present the findings of our analysis.

Table 3.8 *Distribution of Companies by R&D Intensity & Export Intensity*

R&D intensity	Export Intensity				
	Below 5	5-10	10-20	20 &above	Total
Below 0.5	42	9	9	2	62
0.5-1.0	20	8	8	6	42
1.0-3.0	25	7	9	8	49
3 &above	10	6	3	3	22
Total	97	30	29	19	175

Chi Square: 10.42 (0.32)
R: 0.17 (0.02)
Note: Figures in parenthesis are level of significance
r is the Pearson's correlation coefficient

In our analysis, we find an insignificant chi-square with r showing a significant positive association. Out of 97 firms with export intensity of less than 5 per cent, 62 firms have less than 1 per cent of R&D intensity. That means firms that cater to export market tend to increase their R&D intensity. A similar result is noticed only in the case of firms belonging to Indian private sector (see Table 3.1.F in Appendix 3 A).

R&D Intensity and Profit Margin

As regards the relationship between profit margin and R&D intensity, a positive association is postulated. That is, higher in the ratio of profit margin, higher would be the allocation of funds to R&D effort. Table 3.9 gives the relationship between profit margin and R&D intensity.

Table 3.9 *Distribution of Companies by R&D Intensity & profit-margin*

R&D intensity	Profit Margin				
	Below 0	0-10	10-15	15 &above	Total
Below 0.5	16	37	13	6	72
0.5-1.0	8	29	5	3	45
1.0-3.0	7	31	12	4	54
3 &above	4	14	7	5	30
Total	35	111	37	18	201

Chi Square: 7.75 (0.56)
R: 0.12 ((0.08)
Note: Figures in parenthesis are level of significance
r is the Pearson's correlation coefficient

Here we get an insignificant Chi-square statistics but a positive and significant r. It is possible that higher profit margin induces firms to undertake R&D in order to sustain the margin. The distribution of sample firms according to ownership pattern shows that only foreign group of firms has a significant positive r (see Table 3.1.G).

R&D Intensity and Vertical Integration

Goldar and Ranganathan (1996) hypothesised that firms with a higher degree of vertical integration tends to invest more in R&D. We, thus, expect a positive relationship between R&D intensity and vertical integration. Table 3.10 gives the distribution of firms according to different ranges of R&D intensity and vertical integration.

Table 3.10: *Distribution of Companies by R&D Intensity & Vertical Integration*

	Vertical integration			
R&D intensity	0-25	25-50	50 &above	Total
Below 0.5	34	34	5	73
0.5-1.0	23	21	1	45
1.0-3.0	25	26	3	54
3 &above	7	21	1	29
Total	89	102	10	201

Chi Square: 13.41 (0.14)
R: 0.04 (0.55*4)
Note: Figures in parenthesis are level of significance
r is the Pearson's correlation coefficient

A poor relationship between R&D intensity and degree of vertical integration is noticed. A close look at the table reveals some interesting pattern. Out of 172 firms with less than 3 per cent of R&D intensity, only 9 were vertically integrated to an extent of 50 per cent and above. Whereas out of 29 firm with more than 3 per cent R&D intensity, only one had 50 per cent vertical integration. Thus, the hypothesis of positive relationship between these two variables is not supported by analysis based on distribution of firms. No ownership groups show a significant relationship (see Table 3.1.H in Appendix 3 A).

3.3 (B) Determinants of R&D: a multiple regression analysis

Following the cross tab analysis, we intend to identify the determinants of R&D intensity using OLS technique. We retained all explanatory variables. Since, total import includes import of technology we decided to consider total import intensity. The estimates of multiple regression for the period 1994-95 are provided in Table 3.11.

Table 3.11 *Regression results: Determinants of R&D intensity*

Explanatory Variables	Estimated Equation
Size	-1.004 (-4.01*)
Capital Intensity	0.003 (3.41*)
Market Share	0.012 (1.84**)
Export Intensity	0.014 (1.09)
Import Intensity	0.019 (1.80***)
Profit Margin	0.005 (1.01)
Vertical Integration	-0.600 (-1.51)
Constant	3.37 (4.8*)
F statistics	4.02*
R^2	0.17

Notes: Size: Sales Turn Over in log values
Figures in parenthesis are *t* statistics
Technology imports include payments of Technical Fee, and Royalty., etc.
*Significant at 1% level
**Significant at 5% level
***Significant at % level

The estimates show that size variable is inversly related to R&D intensity and market share is positivly related. Our results on size variable does not confirm to the findings of Goldar and Ranganathan (1997), Lall (1983), Siddharthan (1988) and Siddarthan and Aggarwal (1992), but confirms to the results obtained by Katrak (1985) and Kathuria (1989). But our results on the market share is in contrast with Kumar (1987) The positive relationship between R&D and market share indicates that firms consider R&D activity as a channel to reinforce the market power in the emerging competitive environment.

The significant positive relationship of R&D intensity with capital intensity is in harmony with Goldar and Renganathan (1997). Import intensity variable in the regression equation has also showed a significant effect on R&D intensity. Probably, firms with greater import intensity undertake more R&D to utilise the imported inputs in order to meet the specifications of the domestic demand. In our analysis, profit margin failed to explain R&D intensity, which is in confirmity with Kumar (1987)..Another variable that has been found insignificaant in influencing R&D intensity is export intensity.

3.4 Summing up

In this chapter we tried to examine the factors that influence R&D expenditure. As a prelude, the behaviour of R&D intensity has been studied for the manufacturing sector using a common sample of 114 firms for the period 1993-97. It has been observed that while the R&D intensity showed an upward trend in the initial years, a declining trend has been noticed in the latter years.

The major explanatory variables for the analysis have been identified based on a review of empirical studies. The relationship between these variable and R&D

intensity has been examined first using cross tabulation and then by running a multiple regression. Similar results have been obtained using both these methods. The coefficient of market share, however, has been found positive in the multiple regression analysis as against a negative r-value in the cross tab. The negative significance of size variable contradicts the generally held notion that large firms incur greater R&D expenditure. It thus invalidates the Schumpeterian hypothesis of a positive relation. However, the positive influence of market share on R&D intensity lends credence to the Schumpeterian hypothesis that market power stimulates R&D activity. While capital intensity and import intensity have been found to be exerting a positive influence variables such as, profit margin, vertical integration and export intensity do not show any significant influence.

As a positive relationship between capital intensity and R&D intensity is observed, it may be the case that R&D in the Indian manufacturing sector is related to productivity. Given that productivity assumes much significance in the contest of inter-firm competitive position, an examination of the link between R&D intensity and productivity appears to be pertinent. Towards this end a modest attempt has been made in the next chapter.

Appendix 3A

Table 3.1.A *Distribution of Companies by R&D Intensity and Sales*

Public Sector

	Sales (Rs. in crores)					
R&D intensity	Less than 50	50 to 100	100 to 1000	1000 to 5000	5000 and above	Total
Below 0.5	1	2	8	3	4	20(29)
0.5-1.0	2		13	2		17(24.6)
1.0-3.0	2	6	9	2	1	20(29)
3 &above	7	2	3			12(17.4)
Total	13 (18.8)	11 (15.9)	33 (47.8)	7 (10.1)	5 (7.2)	69 (100)

Chi square : 30.22 (0.01)
r :-0.43 (0.01)

Indian Private Sector

R&D intensity	*Less than 50*	*50 to 100*	*100 to 1000*	*1000 to 5000*	*5000 and above*	*Total*
Below 0.5	3	5	22	11	3	44 (41.9)
0.5-1.0	1		14	4		19 (18.1)
1.0-3.0	2	6	18			26 (24.8)
3 &above	4	3	7	2		16 (15.2)
Total	10 (9.5)	14 (13.3)	61 (58.1)	17 (16.2)	3 (2.9)	105 (100)

Chi square : 22.98(0.05)
r : -0.31(0.01)

Foreign Sector

R&D intensity	Less than 50	50 to 100	100 to 1000	1000 & 5000	5000 and above	Total
Below 0.5	1		7	2		10 (32.3)
0.5-1.0			7	2		9 (29.0)
1.0-3.0	2	1	4	2		9 (29.0)
3 &above		1	2			3 (9.7)
Total	3 (9.7)	2 (6.5)	20 (64.5)	6 (19.4)		31 (100.0)

Chi square : 9.03 (0.43)
r : -0.19 (0.3)
Figures in the parentheses indicate percentage to total

Table. 3.1.B *Distribution of Companies by R&D Intensity and Market Share*
Public Sector

R&D intensity	Market Share				
	Below 50	50-60	60-75	75 & >	Total
Below 0.5	4	2	6	5	17(32.1)
0.5-1.0	2	4	4	4	14 (26)
1.0-3.0	7	2	3	3	15(28.3)
3 &above	5		1	1	7 (13.2)
Total	18 (34)	8 (15.1)	14 (26.4)	13n(24.5)	53n(100)

Chi Square: 10.46 (0.31)
r : -0.28 (0.35)

Indian Private sector

R&D intensity	Below 50	50-60	60-75	75 &above	Total
Below 0.5	13	3	18	6	42 (45.7)
0.5-1.0	5	3	4	5	17 (18.1)
1.0-3.0	12	3	2	4	21 (22.3)
3 &above	8	1	3	1	13 (13.8)
Total	38 (40.4)	10 (10.6)	28 (29.8)	18 (19.1)	93 (100)

Chi Square: 14.3 (0.11)
r :-0.25 (0.014)

Foreign Sector

R&D intensity	*Below 50*	*50-60*	*60-75*	*75 &above*	*Total*
Below 0.5	3	1	3	2	9 (34.5)
0.5-1.0	1	2	2	3	8 (30.8)
1.0-3.0	3		2	3	8 (30.8)
3 &above	1				1 (3.8)
Total	8 (30.8)	3 (11.5)	7 (26.9)	8 (30.8)	26 (100)

Chi Square: 6.04 (0.73)
r :-0.055 (0.78)
Figures in the parentheses indicate percentage to total

Table 3.1.C *Destribution of Companies by R&D Intensity and Capital Intensity*
Public Sector

R&D intensity	Capital Intensity				
	Below 0	0-50	50-150	150 &>	Total
Below 0.5	3	7	4	5	19 (28.8)
0.5-1.0		7	8	2	17 (25.7)
1.0-3.0	2	6	9	2	19 (28.8)
3 &above	1	5	3	2	11 (16.6)
Total	6 (9)	25 (37.8)	24 (36.4)	11 (16.6)	66 (100)

Chi Square: 7.27 (0.608)
r : 0.0045(0.97)

Indian Private Sector

R&D intensity	Capital Intensity				
	below 0	0-50	50-150	150 &>	Total
Below 0.5	4	16	21	3	44 (41.9)
0.5-1.0		13	6		19 (18.1)
1.0-3.0	1	9	15		26 (24.8)
3 &above		3	11	2	16 (15.2)
Total	5 (4.8)	41 (39.0)	53 (50.5)	6 (5.7)	105 (100)

Chi Square: 14.9 (0.09)
r : 0.197 (0.04)

Foreign Sector

R&D intensity	*Capital Intensity*				
	Below 0	*0-50*	*50-150*	*150 &>*	*Total*
Below 0.5	1	1	6	2	10 (32)
0.5-1.0		6	3		9 (29)
1.0-3.0	1	4	4		9 (29)
3 &above		1	1	1	3 (9.7)
Total	2 (6.5)	12 (36.7)	14 (45.2)	3 (9.7)	31 (100)

Chi Square : 10.75(0.29)
r : -0.9257(0.62)
Figures in the parentheses indicate percentage to total

Table 3.1.D *Distribution of Companies by R&D Intensity and Import Intensity*

Public Sector

R&D intensity	*Import Intensity*				
	Below 5	*5-10*	*10-20*	*20 &>*	*Total*
Below 0.5	6	3	5	3	17 (27)
0.5-1.0	3	5	6	2	16 (25.4)
1.0-3.0	5	3	4	7	19 (30.2)
3 &above	1	2	4	4	11 (17.5)
Total	15 (23.8)	13 (20.6)	19 (30.2)	16 (25.4)	63 (100)

Chi-square: 7.26 (0.60)
r :0.21 (0.81)

Indian Private Sector

R&D intensity	*Import Intensity*				
	Below 5	*5-10*	*10-20*	*20 &>*	*Total*
Below 0.5	11	9	13	6	39 (39.4)
0.5-1.0	1	5	10	3	19 (19.6)
1.0-3.0	8	8	8	1	25 (25.2)
3 &above	2	4	3	7	16 (16.2)
Total	22 (22.2)	26 (26.3)	34 (34.3)	17 (18.5)	99 (100)

Chi-square: 17.06 (.04)
r : 0.06 (0.50)

Foreign Sector

R&D intensity	*Import Intensity*				
	Below 5	*5-10*	*10-20*	*20 &>*	*Total*
Below 0.5	4	2	1	2	9 (30)
0.5-1.0	1	6	1	1	9(30)
1.0-3.0	3	2	3	1	9 (30)
3 &above		1	1	1	3 (10)
Total	8 (26.7)	11 (36.7)	6 (20)	5 (16.7)	30 (100)

Chi-square: 8.85 (0.45)
r : 0.17 (0.34)

Figures in the parentheses indicate percentage to total

Table 3.1.E *R&D Intensity and Technology Imports*
Public Sector

R&D intensity	Technology imports to sales				
	0-0.1	0.1-0.5	0.5-2	2 & >	Total
Below 0.5	1	2	4	2	9 (28.1)
0.5-1.0	1	6	3		10 (31.3)
1.0-3.0	3	1	5	1	10 (31.3)
3 &above	1		2		3 (9.4)
Total	6 (18.6)	9 (28.1)	14 (43.6)	3 (9.4)	32 (100)

Chi Square: 11.13 (0.26)
r : -0.15 (0.42)

Indian Private Sector

R&D intensity					
	0-0.1	*0.1-0.5*	*0.5-2*	*2 & >*	*Total*
Below 0.5	7	11	7	1	26(44.1)
0.5-1.0	4	10	1		15(25.4)
1.0-3.0	3	8	2		13(22)
3 &above		2	1	2	5(8.5)
Total	14 (23.7)	31 (52.5)	11 (18.6)	3 (5)	59 (100)

Chi Square:19.12 (0.02)
r : 0.15 (0.24)

Foreign Sector

R&D intensity	*Technology Imports*				
	0-0.1	*0.1-0.5*	*0.5-2*	*2 & >*	*Total*
Below 0.5	2	3		1	6 (30)
0.5-1.0	4	3	1		8 (40)
1.0-3.0	2	2	1		5(25)
3 &above			1		1 (5)
Total	8 (40)	8 (40)	3 (15)	1 (5)	20 (100)

Chi Square: 9.40 (0.40)
r : 0.07(0.74)
Figures in the parentheses indicate percentage to total

Table 3.1.F *Distribution of Companies by R&D Intensity and Export Intensity*

Public Sector

R&D intensity	*Export Intensity*				
	below 5	*5-10*	*10-20*	*20 &>*	*Total*
Below 0.5	12	3	2	1	18(32.1)
0.5-1.0	8	1	3	3	15(26.8)
1.0-3.0	7	2	5	2	16(28.6)
3 &above	3	2	2		7(12.5)
Total	30 (53.6)	8 (14.3)	12 (21.4)	6 (10.7)	56 (100)

Chi Square: 6.97 (0.63)
r :0.15 (0.19)

Indian Private Sector

R&D intensity	*Export Intensity*				
	below 5	*5-10*	*10-20*	*20 &>*	*Total*
Below 0.5	25	5	7		37 (40.7)
0.5-1.0	9	4	4	1	18 (19.8)
1.0-3.0	13	5	2	4	24 (26.4)
3 &above	5	3	1	3	12 (13.2)
Total	52 (57.1)	17 (18.7)	14 (15.4)	8 (8.8)	91 (100.0)

Chi Square: 13.12 (0.15)
r : 0.21 (0.04)

Foreign Sector

R&D intensity	*Export Intensity*				
	below 5	*5-10*	*10-20*	*20 &>*	*Total*
Below 0.5	5	1		1	7 (25)
0.5-1.0	3	3	1	2	9 (32.1)
1.0-3.0	5		2	2	9 (32.1)
3 &above	2	1			3 (10.7)
Total	15 (53.5)	5 (17.8)	3 (10.7)	5 (17.8)	28 (100)

Chi Square: 8.12 (0.52)
r :0.05 (0.78)

Figures in the parentheses indicate percentage to total

Table 3.1.G *Distribution of Companies by R&D Intensity and profit margin*

Public Sector

R&D intensity	*Profit margin*				
	Below 0	*0-10*	*10-15*	*15 & >*	*Total*
Below 0.5	5	7	5	2	19(28.8)
0.5-1.0	6	7	1	3	17(25.7)
1.0-3.0	2	9	5	3	19(28.7)
3 &above	2	5	2	2	11(16.6)
Total	15 (22.7)	28 (42.4)	13 (19.6)	10 (15.1)	66 (100)

Chi Square: 5.65 (0.77)

r : 0.12 (0.38)

Indian Private Sector

R&D intensity	*Profit margin*				
	below 0	*0-10*	*10-15*	*15 & >*	*Total*
Below 0.5	6	26	7	4	43(41.3)
0.5-1.0	2	15	2		19(18.3)
1.0-3.0	4	16	5	1	26(25)
3 &above	2	7	4	3	16(15.4)
Total	14 (13.5)	64 (61.5)	18 (17.3)	8 (7.7)	104 (100)

Chi Square: 7.76(0.55)

r : 0.06(0.54)

Foreign Sector

R&D intensity	*Profit margin*				
	below 0	*0-10*	*10-15*	*15 & >*	*Total*
Below 0.5	5		4	1	10(32.3)
0.5-1.0			7	2	9(29)
1.0-3.0	1		6	2	9(19)
3 &above			2	1	3(9.7)
Total	6 (19.4)		19 (61.4)	6 (19.4)	31 (100)

Chi Square: 9.51(0.14)

r : 0.41(0.02)

Figures in the parentheses indicate percentage to total

Table 3.1.H *Distribution of Companies by R&D Intensity to Vertical Integration*

Table A.3.1H Distribution of Companies by R&D intensity and vertical integration

Public Sector

R&D intensity	*Vertical Integration*				
	Below 0	*0-25*	*25-50*	*50 &>*	*Total*
Below 0.5		10	7	3	20 (29.9)
0.5-1.0		7	9	1	17 (25.4)
1.0-3.0		9	8	2	19 (28.4)
3 &above		4	7		11 (16.4)
Total		30 (44.6)	31 (46.3)	6 (9)	67 (100)

Chi Square: 3.90 (0.68)
r : -0.01(0.93)

Indian Private Sector

R&D intensity	*Vertical Integration*				
	Below 0	*0-25*	*25-50*	*50 &>*	*Total*
Below 0.5		22	21	1	44 (42.3)
0.5-1.0		9	10		19 (18.2)
1.0-3.0		12	13	1	26 (25)
3 &above	1	3	10	1	15 (14.4)
Total	1 (1)	46 (44.23)	54 (51.92)	3 (2.8)	104 (100)

Chi Square: 10 (0.29)
r :0.08 (0.37)

Foreign Sector

R&D intensity	*Vertical Integration*				
	Below 0	*0-25*	*25-50*	*50 &>*	*Total*
Below 0.5		3	6	1	10 (32.3)
0.5-1.0		7	2		9 (29)
1.0-3.0		4	5		9 (29)
3 &above			3		3 (9.7)
Total		14 (45.2)	16 (51.6)	1 (3.2)	31 (100)

Chi Square: 9.11 (0.16) ;
r : -0.01 (0.97)

Figures in the parentheses indicate percentage to total

Chapter 4

R&D AND PRODUCTIVITY: THE NEXUS

In this chapter, we examine the nexus between R&D and productivity during the post liberalisation phase. Number of studies in TFP has been undertaken in Indian context (Goldar 1986 and 1995, Ahluwalia 1991, Balakrishnan and Pushpangadan 1994, Basant and Fikkert, 1996, Srivasthava, 1994, Rao 1996). These studies confirm the proposition that there are multiple reasons for explaining productivity. Though the impact of R&D on productivity cannot be ignored, the existing studies could not isolate the impact of R&D, except Basant and Fikkert (1996) which relates to the period 1974/75 to 1981/82 using panel data analysis. Our study of the nexus between productivity and R&D related to the period 1988/89 to 1994/95, which covers the period of liberalisation. In section 4.1, we discuss the model used and construction of variables, and in section 4.2 we discuss the results. Following this section we discuss about the limitation of the study and summing up.

Section 4.1

4.1(A) Specification of the model:

Following Griliches (1979), the simplest form of production function model is given as:

$$LogY = a(t) + \beta(logX) + \gamma(logK) + u \qquad \text{.............4.1}$$

Where Y is a measure of output at the firm, industry or national level

X is a vector of standard economic inputs such as man-hours, capital, raw materials etc;

K is a measure of cumulated research effort;

$a(t)$ is the other forces, which affect output and change systematically over time; and,

u is the random unsystematic fluctuations in output.

According to Grilliches (1979), one of the major difficulties in measuring the contribution of K *to* economic growth is that quantification of R&D efforts is ambiguous. Measuring R&D capital is too broad a concept. Grilliches (1979) has pointed out the following issues while measuring the contribution of R&D.

1. We have to make assumptions about the relevant lag structure to capture the effect of R&D on productivity.

2. Past R&D investments depreciate and become obsolete. Thus, the growth in the net `stock' of R&D capital is not equal to the gross level of current or recent resources invested in expanding it.

3. The level of knowledge in any one sector or industry is not only derived from `own' R&D but also affected by the knowledge borrowed or stolen from other sectors or industries.

In spite of these issues, it is widely accepted that increase in R&D expenditure show up its impact on increasing productivity (Griliches and Mairesse, 1984). To examine this proposition in the Indian context in the post liberalisation phase, we have fitted a simple extended Cobb-Douglas Production Function:

$$Q_{it} = Ae^{\lambda t} C^{\alpha}_{it} L^{\beta}_{it} M^{\Theta}_{it} K^{\gamma}_{it} e^{\varepsilon it} \quad \text{.............................4.2}$$

Where Q = output; C = capital; L = labour; M = material inputs; K = R&D capital

Expressing this in a log form

Or in log form

$$q_{uit} = a + \lambda t + \alpha_{cit} + \beta_{lit} + \theta M_{it} + \gamma k_{it} + e_{it} \quad \text{...........................4.3}$$

Where q_{uit} *is the variation in output*

λ *is the measurement of rate of change of disembodied technology factor*

α *is elasticity of capital*

β *is elasticity of labour*

θ *is the elasticity of material inputs*

k is the share of R&D expenditure on variation in output

e_{it} *is usual disturbance term*

In panel data, we can distinguish the usual disturbance term into two

$$\varepsilon_{it} = u_i + v_{it} \quad \text{............................4.4}$$

U_i is permanent, unobserved heterogeneity across firms in their technologies, types of output etc., individual specific effect, which is invariant of time (unobservable entrepreneurial or managerial skills of the firm) and

V_{it} is period specific shock for firm i, assumed to be independent across firms and over time, that is usual disturbance term.

One could, of course, also consider more complicated functional forms, such as the CES or Translog functions. But as Grilliches and Mairesse (1984) pointed out that, based on the past experience and also on some exploratory computations that, this will not matter as far as our main purpose of estimating the output elasticities of R&D capital.

In the estimation procedure, we have Fixed Effect (FE) and Random Effects (RE) techniques. In the case of FE model, u_is are assumed to be fixed parameters to be estimated and the remainder disturbance stochastic with $v_i t$ independent and identically distributed with mean zero and constant variance, $V_{it} \sim IID(0,\sigma^2)$. The X_{it}s, that is the explanatory variables are assumed independent of the v_{it} for all i and t. There are too many parameters in the fixed effects model and the loss of degrees of freedom can be avoided if the u_i can be assumed random. In this case $u_i \sim IID(0,\sigma_u^2)$, and $V_{it} \sim IID(0,\sigma_v^2)$ and the U_i are independent of V_{it}. In addition, the X_{it} are independent of the U_I and V_{it} for all i and t. The random effects (RE) model is an appropriate specification if we are drawing the sample from a large population. In this case number of observation N is usually large and a fixed effects model would lead to an enormous loss of degrees of freedom. Therefor FE is less efficient than RE, because it uses only variation in the data within each firm through time(Baltagi,1995). RE assumes that u_i is uncorrelated with the regressors, which rather unlikely in the present context. The random and fixed effects models yield different estimation results, especially if t is small and N is large. A specification test based on the difference between these estimates is given by Hausman, named as Hausman's test (Baltagi, 1995).

4.1 (B)Construction of the variable:

(1) Output (Q)

This is the value of output deflated by the corresponding manufactured product group of WPI (base 1981-82) at 2-digit level.

(2) Labour (L)

This is the man-hours worked. The firms report their total payments of wages and salaries. This is divided by the average wage rate of the industry to which each firm belongs in order to derive estimates for man-hours worked. The ASI data available at the 3 digit industrial classification are used to calculate the average wage rate for the relevant industry groups; the average wage rate is being total labour costs to total hours worked.

(3) Material input (Total Input) (M)

Total material input, reported by the sample firms, deflated by a composite index of industrial raw material price, which is constructed as follows. The value of primary inputs into manufacturing output was used to construct shares of individual items in total materials cost. These values were taken from "Input - Output Transaction Table (commodity into Industry Absorption matrix) for the Indian economy for 1989-90 published by the CSO. The shares of individual items were used to yield the weight assigned in the composite index. (See Appendix A)

(4) Capital (C)

Gross fixed asset reported by the sample firms' deflated by WPI of machinery and machine tools.

(5) R&D/Technical Capital (K)

Following Basant and Fikkert (1996) and Hall and Mairesse (1992), in order to construct the R&D capital stock at time *t* by firm *i* as a function of past R&D investments, we follow a perpetual inventory method as follows:

$$K_{it} = (1-\delta)\, K_{it-1} + RD_{i,t-1} \qquad \text{..................................4.5}$$

$RD_{i,t-1}$ is the expenditure on R&D at time $t-1$ and δ is the rate of depreciation to technical knowledge, assumed to be 15%. The R&D expenditures are deflated by average of WPI (1981/82=100) for machinery and machine tools and CPI for industrial workers (1981-82 =100). In order to employ the equation 4.5, we have generated the initial R&D capital stock using the following equation

$$K_{90} = RD_{89} \sum_{S=0}^{N} [(1-\delta) / (1+r)]^s \qquad \text{..................................4.6a}$$

Where N = average age of the R&D units
r = real R&D Expenditures per R&D unit in the pre 1989/90 period
δ = depreciation rate

In our analysis, we have taken only those firms which report R&D expenditure. So we do not have any non-zero R&D expenditure firm. Therefore it is necessary to know the number of years for which firm had R&D units and the rate of growth of R&D expenditures in such units. Using 'Research & Development Statistics' of DST, we calculated the real growth rate of R&D expenditure per R&D unit in the pre 1989-90 period as 12 per cent. We have also calculated the average age of the R&D units as 4.3 years. Based on this figure we can employ the above equation as;

$$K_{90} = RD_{89} \sum_{S=0}^{4} [(1-0.15) / (1+0.04)]^{s} \qquad \text{.............................4.6b}$$

4.1(C) Data source and sample description:

Data required for analysis are collected from the Prowess of CMIE. Initially we collected 918 observations. Following Hall and Mairesse (1992) and Bassant and Fikkert (1996), we removed all observations for which capital-labour ratio was outside of three times the inter-quartile range (the difference between 75 and 25 per cent value) above or below the median. This retained a sample size of 798 observations, which were used for analysis. Of the sample, 6.6 per cent of was from food products, 1.7 per cent from beverages, 20.1 per cent from chemicals and drugs, 5.6% from textiles, 6.3% from basic metals, 23% from non metallic mineral products, 18.6% from electrical and electronic machinery, 26.6% from non electrical machinery, 2.9% from paper and paper products, wood and leather industries, 4.8% from plastics and rubber industry, 3.8 % from miscellaneous products. Table 3.1 provides the means and standard deviations of all variables.

Table 4.1 *Sample Means and Standard Deviations of Variables* (All the variables except for Man-hours are in Rupees in Lakhs).

	All Firms		Scientific Firms		Other Firms	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Total observations	*797*		*440*		*357*	
Value of Output	12671.46	43436.56	7979.195	19844.16	18454.65	60599.51
Physical Capital	6699.343	38391.8	1849.225	4277.843	12677.08	56640.68
Man Hour	18597.84	74773.49	11250.03	38834.36	27653.97	102433.9
R&D Capital	222.8267	772.9456	218.7352	754.8509	227.8695	795.7182
Raw Materials	13546.07	85076.63	4234.896	10266.58	25022.02	125756.6

Note: All variables are in constant 1981-82 prices

Section 4.2

Estimation Results

The estimation was carried first for the entire sample and second by classifying the firms into two groups, namely, high and low technology, based on the degree of R&D intensity of the industry group to which the firm belongs to. The first group comprises chemical, electrical and electronic machinery, transport equipment and parts, and basis metal and metallic products. All other industries comprise of second group. Table 3.2 gives presents the estimates for the entire sample.

Table 4.2 *Production Function Estimates (Complete Sample, 464 firms. 1989/90-1994/95)*

Variables	FE without Period dummy	RE without Period dummy	FE with Period dummy	RE with Period dummy
T	0.026 (2.44)*	-0.0071 (-1.6)***	0.061(2.3)*	-0.015(-2.8)*
Capital (C)	0.35(8.45)*	0.41(19.9)*	0.35(8.5)*	0.41(20)*
Labour (L)	0.13(4.51)*	0.29(14.38)*	0.13(4.6)*	0.29(14.5)*
R&D (K)	0.0064(1.33)	0.13(1.65)*	0.0026(3.42)*	0.13(8.4)*
Material (M)	0.026(2.02)*	0.068(6.11)*	0.027(2.1)*	0.07(6.3)*
Period Dummy (d)			0.021(1.02)	0.048(2.4)*
Constant		0.85(13.7)*		0.83(13.3)*
R^2	0.97		0.97	
Hausman Statistic	112.88		108.9	

Notes: FE is fixed effects estimation
RE is random effects estimation
Figures in parenthesis are *t* values
* Significant at 1% level
** Significant at 5% level
*** Significant at 10% level
All Hausman statistics are significant at the 0.01 level.

Since all Hausman statistics are significant, RE is rejected in favour of FE specification The FE estimates shows that all explanatory variables other than R&D stock are statistically significant. The results does not support the proposition that R&D positively influences variation in output, whereas disembodied technology factor λ is significant in explaining variation in output. Since output is explained only by capital, labour, material and a secular component indicating disembodied technology change, one can conclude that R & D expenditure does not influence productivity in the sense of total factor productivity, even though TFP does not appear explicitly in the model. The estimates of elasticities of physical and R&D capital are about 0.35 and 0.06 respectively. As the period covers pre and post liberalisation, we introduce a time dummy to capture the possible impacts of the policy changes in 1991/92. The period dummy is significant implying that the policy changes in 1991 do not reflect a direct effect on productivity. The R&D stock has become significant when period dummy was introduced. It possibly indicates that the policy changes has indirect effect on productivity through R&D.

Since our sample consisted of R&D performing firms in rather diverse industries, it would be interesting to examine the influence of sectoral (industrial) differences. Table 3.3 gives our estimates separately for firms in R&D intensive firms, (under High technology industry groups) and the rest of our sample (Low technology industry groups). It needs to be pointed that such sub-classification of sample is likely to bring down the heterogeneity of sample (Girliches and Mariesse, 1984).

Table 4.3 *Production Function Estimates Separately for the High Tech and Other Firms (Complete sample, 262 and 202 firms respectively, 1989/90-1995/96)*

Variables	FE without Period dummy		RE without Period dummy		FE with Period dummy		RE with Period dummy	
	HT	LT	HT	LT	HT	LT	HT	LT
T	0.0075 (1.47)***	0.012 1.61)***	0.066 (1.96)**	0.011 (-1.5)	0.007 (1.2)	0.012 (1.18)	0.94×10^{-4} (-0.01)*	-0.022 (-2.6)*
Capital (C)	0.24 (5.31)*	0.087 (1.14)	0.30 (10.9)*	0.48 (16.2)*	0.24 (5.3)*	0.09 (1.11)	0.31 (10.9)*	0.48 (16.12)*
Labour (L)	0.597 (9.59)*	0.050 (1.5)	0.56 (16.9)*	0.19 (7.8)*	0.61 (9.5)*	0.05 (1.5)	0.56 (16.9)*	0.199 (7.9)*
R&D Capital Stock (K)	0.010 (0.28)	0.002 (0.45)	0.043 (1.96)*	0.11 (5.3)*	0.01 (0.3)	0.066 (1.9)	0.043 (1.9)*	0.102 (4.9)*
Material (M)	0.0074 (0.46)	0.034 (1.98)**	0.036 (2.56)*	0.94 (6.2)*	0.008 (0.5)	0.034 (1.95)*	0.036 (2.6)*	0.098 (6.4)*
Period Dummy (d)					0.0024 (0.114)	$.34 \times 10^{-6}$ (0.001)	0.014 (0.6)*	0.069 (2.3)*
Constant			0.43 (5.36)*	0.87 (8.9)*			0.42 (5.3)*	0.84 (8.6)*
R^2	0.97	0.98			0.98	0.97		
Hausman Statistics	16.80	119.29			18.57	113.46		

Notes: FE is fixed effects estimation
RE is random effects estimation
Figures in parenthesis are *t* values
* Significant at 1% level
** Significant at 5% level
*** Significant at 10% level
All Hausman statistics are significant at the 0.01 level.

All FE specifications are accepted on the basis of the significance of Hausman Statistics. The estimates show those results of high rather than low technology group is in broad conformity with the results of the entire sample. But with the period dummy, R&D stock variable in both the sub-groups turned to be insignificant. This leads to suspect the indirect effect of policy changes on productivity through R&D at these two sub-group levels.

Our tentative results indicate that liberalisation does not affect significantly the relationship between R&D and productivity. Our earlier finding indicated that R&D intensity in industries classified as high technology has declined over the period of our analysis. In our results, the T representing disembodied technology factor is, however, significant. This implies that firms are seeking other options to improve productivity. As seen in Table 3.4, there is an increase in the number of foreign collaborations in the 1980s and more rapidly in the first half of 1990s. In this context, we attempt to examine import of technology.

Table 4.4 *Growth Phases in Foreign Collaboration Approvals*

Phases		Average annual number of approvals		
		All Collaboration	Financial Collaboration	Co.3 as % col.2
	1	2	3	4
I	1956-65	244	n.a.	n.a.
II	1966-79	239	40	16.73
III	1980-90	724	174	24.03
IV	1991-95	1627	837	51.44

Source: Subrahmanian et.al (1996)

Generally firms seek maximum profit by tie-up with foreign manufacturers, which leads to continued technological dependence (Subramanian, 1984). Does this imply that with liberal policy in respect of import technology, the domestic R&D effort is getting increasingly substituted?

Limitations of the analysis:

With the time constraint and availability of data, we could not incorporate influence of technology purchase factor and spill over effects. There is also a possibility of improving statistical methodology. The estimates presented here are based on an extended Cobb-Douglas Production Function. And, so we have not examined explicitly the effect of R&D on productivity growth, and compute total factor productivity growth rate and its relations with R&D activity.

Summing up:

The primary objective of the chapter is to investigate the nexus between productivity and R&D capital in the Indian manufacturing industries. The estimation is carried out in the framework of extended Cobb-Douglas Production Function. The period covered was 1989/90 to 1994/95 for a sample of 464 R&D performing firms. The results, though tentative, show that the relationship between firm productivity and R&D is not very significant in the Indian context.

Appendix IV A

Table A4.1: *Weights of Raw Material inputs into industry – inter industry*

		Food Pdts	Beverages	Cotton txt.	Wool & Silks	Jute, Hemp…	Misc. textiles pdts.
1	Food Articles	22.044	3.305	0.151	7.289	0.000	0.108
2	Non Fd. Articles	60.569	52.090	37.884	0.108	54.029	1.100
3	Coal and lignite	0.554	0.949	0.859	0.413	1.090	0.087
4	Crude pertroleum, natural gas	0.151	0.056	0.000	0.000	0.000	0.079
5	Met. Minerals	0.000	0.000	0.000	0.000	0.000	0.001
6	Non Met. Minerals	0.118	0.000	0.004	0.000	0.000	0.012
7	Food Pdts.	7.955	6.871	0.319	0.051	0.012	0.042
8	Beverages	0.071	8.542	0.000	0.000	0.000	0.000
9	Textiles	0.993	1.281	34.742	51.690	19.334	79.527
10	Wood Pdts.	0.484	0.775	0.278	0.116	0.064	0.101
11	Printing	1.417	7.468	0.325	1.112	0.206	1.159
12	Leather	0.001	0.000	0.009	0.000	0.000	0.026
13	Plastic & Rubber pdts.	0.582	1.351	0.226	0.174	0.111	4.374
14	Petroleum & Coal tar pdts.	0.937	1.308	1.170	0.537	1.169	0.781
15	Chemicals	1.342	3.769	10.612	27.516	3.476	7.542
16	Non met. Mineral pdts.	0.242	1.363	0.076	0.173	0.117	0.054
17	Met. Pdts.	0.631	4.956	1.697	1.771	1.851	0.685
18	Non ele. Machineray	0.484	3.942	1.298	1.577	4.818	1.593
19	Elec & Electronics mach.	0.000	0.000	0.120	0.076	0.200	0.064
20	Transport	0.000	0.000	0.000	0.000	0.000	0.000
21	Miscellaneious manufacturing	0.043	0.136	0.118	0.132	0.101	0.368
22	Electricity	1.382	1.838	10.113	7.266	13.423	2.295
	Total	100.000	100.000	100.000	100.000	100.000	100.000

Contd…82

		Wood & wood pdts.	Paper & Paper pdts.	Leather	Rubber & plastic pdts.	Petroleum & coal tar pdts	Chemicals
1	Food Articles	0.016	0.043	22.130	0.000	0.001	2.453
2	Non Fd. Articles	74.320	6.619	1.695	10.751	0.008	6.133
3	Coal and lignite	0.241	2.914	0.125	0.898	6.100	1.347
4	Crude pertroleum, natural gas	0.000	0.000	0.000	0.000	88.518	4.055
5	Met. Minerals	0.000	0.000	0.000	0.000	0.000	0.005
6	Non Met. Minerals	0.038	0.102	0.000	0.246	0.134	3.107
7	Food Pdts.	0.033	0.534	0.037	0.000	0.000	0.799
8	Beverages	0.000	0.000	0.049	0.000	0.000	0.060
9	Textiles	0.982	2.003	4.937	7.502	0.129	2.113
10	Wood Pdts.	11.389	0.156	0.257	0.102	0.033	0.110
11	Printing	0.430	58.546	0.505	1.062	0.164	5.178
12	Leather	0.055	0.000	46.310	0.015	0.000	0.007
13	Plastic & Rubber pdts.	0.702	0.269	4.650	7.059	0.042	1.690
14	Petroleum & Coal tar pdts.	1.662	0.969	1.282	0.913	2.825	2.310
15	Chemicals	3.853	10.262	11.938	57.254	0.533	53.737
16	Non met. Mineral pdts.	0.175	0.217	0.058	0.253	0.009	0.793
17	Met. Pdts.	2.151	4.662	1.006	5.195	0.413	4.310
18	Non ele. Machineray	0.281	0.300	0.425	0.285	0.144	0.764
19	Elec & Electronics mach.	0.396	0.256	0.506	0.484	0.041	0.381
20	Transport	0.000	0.000	0.049	0.011	0.000	0.000
21	Miscellaneious manufacturing	0.935	1.973	1.148	1.533	0.040	1.292
22	Electricity	2.338	9.676	2.892	6.435	0.866	9.354
	Total	100.000	100.000	100.000	100.000	100.000	100.000

Contd...83

Table A4.1: *Weights of Raw Material inputs into industry – inter industry*

		Non met. Mineral pdts.	Non ele. Mechinery	Electrical mechinery	Met. Pdts	Electronic equipments	Transport	Miscellane -ous mfg.
1	Food Articles	0.258	0.000	0.001	0.000	0.000	0.000	3.177
2	Non Fd. Articles	0.688	0.133	0.005	0.058	0.210	0.210	3.073
3	Coal and lignite	11.502	0.307	0.069	5.077	0.001	0.157	0.079
4	Crude pertroleum, natural gas	0.001	0.172	0.206	0.160	0.000	0.000	0.000
5	Met. Minerals	0.000	0.001	0.000	2.679	0.000	0.000	0.175
6	Non Met. Minerals	25.084	0.016	0.000	1.596	0.002	0.000	1.867
7	Food Pdts.	0.030	0.000	0.000	0.003	0.000	0.000	0.005
8	Beverages	0.000	0.000	0.000	0.000	0.000	0.000	0.028
9	Textiles	5.070	0.263	0.183	0.125	0.077	0.351	1.466
10	Wood Pdts.	0.519	1.042	1.260	0.203	0.557	0.869	1.492
11	Printing	1.105	0.488	1.878	0.333	2.808	0.927	2.685
12	Leather	0.001	0.042	0.012	0.004	0.015	0.048	0.159
13	Plastic & Rubber pdts.	0.729	1.821	1.356	0.101	1.609	6.578	2.960
14	Petroleum & Coal tar pdts.	11.082	1.895	1.927	5.267	1.029	2.122	3.537
15	Chemicals	3.874	2.354	11.751	2.274	3.511	7.037	5.597
16	Non met. Mineral pdts.	11.584	0.331	1.724	0.438	0.341	0.333	1.080
17	Met. Pdts.	8.819	50.688	48.306	68.698	21.112	34.076	42.221
18	Non ele. Machineray	1.872	32.649	1.426	0.846	0.662	3.121	2.943
19	Elec & Electronics mach.	0.001	1.950	23.536	0.082	64.763	2.228	4.462
20	Transport	0.000	0.596	0.030	0.046	0.000	35.201	5.438
21	Miscellaneious manufacturing	1.430	0.467	2.416	0.467	0.552	1.741	13.166
22	Electricity	16.351	4.786	3.912	11.543	2.751	5.002	4.388
	Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000

Chapter 5

SUMMING UP

The importance of firm level technological capability in improving the competitiveness of the sector as well as the economy as a whole is well recognised. In Schumpeterian perspective, innovation is the forerunner of technical advancement, where R&D is seen as the major input. The present study has attempted to examine the R&D activities in Indian industry in Schumpetarian framework. It assumes importance in the context of liberalisation of polices, which places primacy on competitiveness of firms. More specifically, it looks into the promotional and developmental role of the State in promoting the R&D activity in the country over the years. It analyses the trends in the national R&D expenditure at the sector (public and private) and at an industry level. The study further examines firm level determinants of R&D and the nexus between R&D and productivity performance of firms during the period 1989-90 to 1994-95.

To begin with, the trend in R&D expenditure at national level has been analysed. It has been observed that there was a declining trend of R&D expenditure with respect to GNP particularly in the 1990s. In terms of growth rate too, the trend is the same. A sector-wise (Central, State and private) examination of R&D behaviour reveals that as much as 80 per cent of R&D is concentrated in public sector. It has, however, been observed that the relative share of public sector has registered a continuous declined since in the late 1990s. The decline in the share of public sector coincides with the overall policy of fiscal contraction of the government. The R&D behaviour of major industry groups shows a downward trend in the 1990s, except for transport equipment and parts and chemical and chemical products of private sector. The sharp reduction in R&D activity of industries in public sector, in particular, machinery and machine tools, is in line with the overall decline in pubic sector R&D spending. This needs to be viewed against the backdrop of ushering in of policies intended towards outwardorientation. The redefining of policy paradigm, thus, lead to reduction of public sector R&D spending, which accounted for bulk of national R&D.

As argued earlier, technology capability of firms crucially depends upon their R&D activity. In this context, a study of factor that influence R&D expenditure at the firm level becomes crucial. As a prelude, the behaviour of R&D intensity has been studied for the manufacturing sector using a common sample of 114 firms for the period 1993-97. It has been observed that while the R&D activity showed an upward trend in the initial years, a declining trend has been noticed in the latter years. An analysis of the relationship between postulated determining variables and R&D activity has been carried out first using cross tabulation and then by running a multiple regression. Similar results have been found in both these methods, excepting market share for which different significant relationship was observed. While multiple regression shows a positive relationship, the cross tab shows a negative r value. The size variable has been observed to be negatively related to R&D activity, which contradicts the generally held notion that large firms incur greater R&D expenditure. It thus invalidates the Schumpeterian hypothesis of a positive relation. However, the positive influence of market share on R&D intensity lends credence to the Schumpeterian hypothesis, that is market power stimulates R&D activity. While capital intensity and import intensity have been found to be exerting a positive influence, profit margin, vertical integration and export intensity do not show any significant influence.

Given that productivity assumes much significance in the contest of inter-firm competitive position, a modest attempt has been made to explore the nexus between R&D intensity and productivity is made. The nexus has been examined in the framework of extended Cobb-Douglas Production Function, using panel data analysis for 418 firms for the period 1989/90 to 1994/95. The estimation though tentative reveals no significant effect of R&D expenditure on productivity. It, thus, appears that R&D activity at firm level plays a very negligible role in the overall technological effort of firms. In the estimates, disembodied technology factor is, however, significant. This implies that firms are seeking other options to improve productivity. In the regime of liberal policy of import of technology, firms are likely to import technology rather than making efforts to develop indigenously. Does this imply that with liberal policy in respect of import of technology, the domestic R&D effort is getting increasingly substituted? It may, however, be noted that the robustness of the findings would require an estimation of the influence of R&D activity on total factor productivity growth. Nevertheless, we feel our findings have in creasing policy relevance in the present context.

Indian economy is being liberalised and restrictions on embodied and disembodied technology imports to Indian industries have been relaxed considerably. The long run efficacy of this policy depends on the impact of these policies on developing innovative capabilities and thereby improving the productivity performance. It appears from our analysis that instead of forging better links with research to exploit capabilities by orienting potential sources of internally generated technology, the tendency has been to rely on technology transfer agreements with foreign entities. It is high time that the policy makers evolve suitable instruments conducive to technology dynamism. One aspect of technology management which urgently needs attention in the Indian context is to design the kind of incentive structure required to perform innovative activities, exploit the available and build on the technological capabilities. An open competitive environment alone can not assure technology dynamism. Various methods of technology management to assure building technological capabilities is essentially an empirical issue which cannot be resolved without more details on innovative activities and the nature of technology transfer.

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