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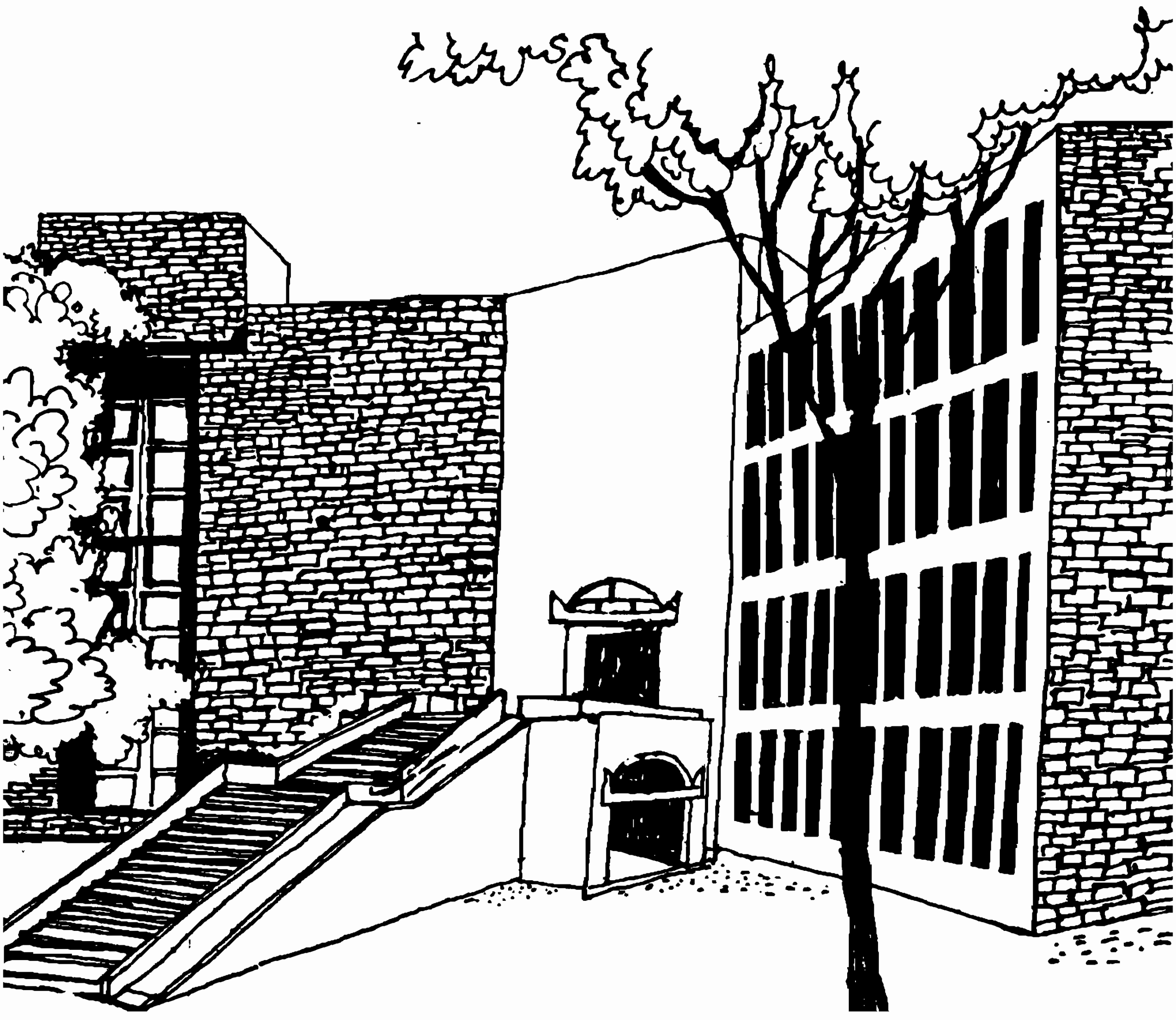

TECHNOLOGY STRATEGIES OF LARGE ENTERPRISES IN INDIAN INDUSTRY: SOME EXPLORATIONS

By

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Technology Strategies of Large Enterprises in Indian Industry: Some Explorations

Rakesh Basant

This is a revised and abridged version of a paper brought out as a working paper by the Gujarat Institute of Development Research (GIDR), Ahmedabad. It builds on research which I had initiated at the Economic Growth Center, Yale University during my tenure as the Ford Foundation Post Doctoral Fellow in Economics. The financial support for writing the paper was provided by the Ford Foundation through its Post-Doctoral Research Fellowships (Economics) Follow-up Grant. The Institute for Studies in Industrial Development (ISID), New Delhi and Brian Fikkert have provided most of the data used in this paper. The comments of Brian Fikkert and Professor G.S. Gupta have helped a great deal in revising the paper. I am extremely grateful to all these institutions and individuals. However, the responsibility of any errors of fact and interpretation rests with him alone.

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A firm's technology strategy is influenced by the 'technology regime' in which it operates. The regime is broadly defined by a combination of variables capturing industrial structure, nature of technical knowledge and the policy environment. Together, these variables determine the opportunity and appropriability conditions faced by a firm in a well defined industry. Given these broad relationships, a heuristic framework is developed to analyze firms' technology strategies across industry groups. Four firm level strategies are identified: (i) undertake R&D; (ii) purchase disembodied foreign technology; (iii) combine (i) and (ii); and (iv) remain technologically inactive, i.e., do neither (i) or (ii). The framework is translated into a multinomial logit model to empirically explore the determinants of technology choices made by Indian firms in two different industries: non-electrical machinery and chemicals. The impact of the following determinants is explored: firm size, capital and material imports, foreign equity participation, and foreign/domestic technology spillovers.

Technology Strategies of Large Enterprises in Indian Industry: Some Explorations

It is widely recognized now that a firm's technology strategy is influenced by the 'technology regime' in which it operates. The regime is broadly defined by a combination of variables capturing industrial structure, nature of technical knowledge (e.g., complexity and cumulativeness of the relevant technology) and the policy environment. Together, these variables determine the opportunity and appropriability conditions faced by a firm in a well defined industry. Given these broad relationships, firms' technology strategies may differ across industry groups. To the extent the available data permit, this paper compares some dimensions of the technology choices made by firms belonging to two different industries: **industrial (non-electrical) machinery and chemicals (excluding pharmaceutical).**

Admittedly, heterogeneity within these industry groups is enormous and, therefore, the conclusions of the empirical exercise undertaken in this paper can only be regarded as tentative. India has developed a fairly decent technological capability in the industrial machinery industry; chemicals on the other hand is a relatively new and technologically dynamic industry. The questions relating to the intellectual property rights (IPRs) are also perhaps more pertinent for the latter. More on these differences later.

The paper is divided into seven sections. The first section highlights some general technological characteristics of chemicals and industrial machinery industries. To put various relationships in perspective, Section 2 provides a broad framework of enquiry. Section 3 provides a policy background to the relationships explored in the paper by summarizing various policy measures adopted by the Indian government which could have influenced firms technology choices. On the basis of an earlier study (Basant, 1993), the literature analyzing technology choices in the Indian industrial sector is summarized in Section 4. The methodology, data and the specific relationships empirically explored in the paper are spelt out in Section 5. Section 6 discusses the empirical results and the final section explores areas for further research.

1. Some Technological Characteristics of the Chemicals and Industrial Machinery Industries

Observed sectoral patterns of technical change are often seen as a result of the interplay between various kinds of market inducement, and opportunity and appropriability combinations. Technological characteristics of industrial sectors affect opportunity and appropriability conditions and, therefore, impinge on technological strategies of firms in these sectors. Based on the review of relevant literature by Dosi (1988), this section highlights the technological specificities of chemicals and industrial machinery industries.

Many studies have emphasized the existence of significant inter-sectoral differences in the nature, sources, determinants and objectives of innovative activities and resulting innovations. On the basis of sectoral specificities observed in developed countries, certain categories of these sectors have been identified (See, for details Pavitt, 1984 and Pavitt, Robson and Townsend,1989. Dosi,1988 provides a summary). Table 1 summarizes some salient characteristics of the sectors identified.

The industrial machinery firms in our sample will be part of the group of **Specialized Suppliers** firms. Innovative activities in among these firms relate primarily to product innovations that enter other sectors as capital goods. Opportunities for innovation are generally abundant, but are often exploited through "informal" activities of design improvements. Thus, formal R&D is often rather low or non-existent. Idiosyncratic and cumulative skills make for a relatively high appropriability of innovations.

The chemical firms in the sample will belong to the **Science Based Sector**, where also the innovations are generated endogenously but in R&D laboratories, exploiting rapid developments of the underlying sciences and science based techniques. Technological opportunity is very high; innovative activities are formalized in R&D laboratories, investments in innovative search are quite high; a high proportion of their product innovations enters a wide number of sectors as capital or intermediate inputs.

Broadly, as compared to other sectors, technological opportunities are higher in science based firms (given munificence in underlying technologies) and in specialized suppliers (given continuous pressures to improve production efficiency in user sectors). Firms in these sectors also emphasize more on product innovations vis-a-vis process innovations. Besides, the threat of technology based entry by suppliers is low in these two sectors. Otherwise, the greatest threat of technology based entry is to science based firms i.e., horizontally from other science based firms. Finally, innovating firms are relatively large when they are science based (given the appropriation of munificent technological opportunities) but small amongst specialized suppliers (given low technological barriers to entry by numerous users). (Pavitt, Robson and Townsend, 1989: 86-87).

Irrespective of the statistical proxy for innovativeness (R&D expenditure, patents etc), and after allowing for the effect of firm size, most studies observe a substantial unexplained inter-firm (intra-sectoral) variance in innovative activities. Besides, a significant proportion of firms in each industry do not report R&D expenditures and do not produce significant innovations. (Dosi, 1988:1152)

There are three obvious caveats for the interpretation of these results. The first relates to the fact that the statistical proxies for innovativeness cannot capture those aspects of technical change that are based on "informal" learning (thus, independent of measured R&D investment) and/or yielding incremental innovations (hence, unrecorded in patents or discrete innovation counts). The second is that some (generally undetermined) part of the intra-sectoral variance in innovative performance must be attributed to differences in the actual lines of business (and, thus in opportunity, appropriability) which are, nevertheless, statistically classified within the same industry. Third, some firms may not patent or innovate but still engage in substantial R&D which is simply devoted to keeping up and adapting to what other competitors are doing. Often such adaptive R&D investments also remain unrecorded.

These caveats are relevant for our analysis as well, especially because different technological paradigms relate to different modes of innovative search: in electronics, chemicals etc. innovations involve laboratory research and/or complex development and testing of proto-types; in other technologies (including several kinds of non-electrical machinery) innovation is often "informal" and embodied in incremental improvements in design, and as such neither recorded nor, often, perceived as the result of an "investment" in R&D (Dosi, 1988:1138). It also needs to be emphasized that industrial machinery related innovations cut across conventional industrial sectors as a significant proportion of innovations originating in other industry groups relate to industrial machinery (Patel and Pavitt, 1993).

Given these "technological specificities" of the two industry groups under study, we now move on to discussing a more general framework for analyzing technological strategies of firms.

2. Analyzing Technology Strategies: A Heuristic Framework [1]

A firm's technology choices can be analyzed in a variety of ways. At one extreme is the simple neo-classical model, where frictionless functioning of the market permits the use of best practice technology at every point in time on the basis of current investments. The efficient functioning of the firm in this scenario only requires that we "get the prices right". This model is of limited validity because it ignores the slow and cumulative nature of skill acquisition and development of capabilities that allow a firm to employ efficiently the best practice technologies. The evolutionary perspective provides the other extreme where firm behavior is closely linked to firm competence and it co-evolves during the development of an industry along with technology, demand and institutions (Malerba and Orsenigo, 1992:1). Thus, firm specific capabilities, which are often tacit in nature and have evolved over a period of time (path dependent), guide a firm's strategic choices. In the evolutionary framework, differences in strategies across firms reflect 'different individual histories of development of competencies and different institutional environments' (Malerba and Orsenigo, 1992:2).

It is very difficult to empirically operationalise the insights of the evolutionary perspective. Besides, acquisition of technological capability (competence) requires that the firm make co-ordinated efforts on several fronts. Such nuances of firms strategies are also very difficult to capture in empirical exercises based on large firm level data sets. These dimension are more easily analyzed in case studies. The framework outlined below needs to be viewed in this context, although we do include some of these insights in the hypotheses discussed here.

Some Broad Relationships

A firm's technology strategy is influenced by a variety of factors. The overall market structure in which the firm operates influences its innovation strategy, which in turn determines the methods used for acquiring/developing/modifying technology. The firm has two broad (but not mutually exclusive) choices: it can internalize the innovation process by pursuing specific activities, generally characterized under the rubric of R&D, or it can use existing markets to purchase technology. For optimizing firms with requisite information, the decision to do indigenous R&D or purchase technology is influenced by benefit-cost comparisons which have to take account of factors like technology spillovers, possibilities and costs of imitation etc. Obviously, the policy regime influences this decision significantly.

Broadly, the technical knowledge available to a firm can be divided in terms of three alternative sources of acquisition:

T_o: knowledge generated by firm on its own;

T_p: knowledge purchased by the firm; and

T_s: spillovers created by knowledge generation of other firms.

T_o can be assumed to be closely related to firm's R&D efforts, while the other two can be further subdivided by sources. However, R&D is not a homogenous activity. The most common categories of spending are: basic research, applied research and development. Although it is common practice to associate R&D with innovative or technological activity, many other activities in the firm contribute to this process.(Mansfield et.al.,1971)

The purchased knowledge (T_p) can be disembodied in the form of technology licenses or embodied in the inputs (including new vintages of capital) the firm purchases. Besides, licenses and inputs can either be acquired domestically (within the country) or from foreign sources. Thus, T_p can take the following four forms:

T_{pld}: T_p acquired through domestic licenses;

T_{plf}: T_p acquired through foreign licenses;

T_{pid}: T_p acquired through purchase of domestic inputs; and

T_{pif}: T_p acquired through purchase of foreign inputs.

It might also be useful to distinguish between technical knowledge embodied in (i) capital inputs (T_{pidk},T_{pifk}) and (ii) other inputs like materials (T_{pido},T_{pifo}) purchased by the firm from domestic and foreign sources. We shall return to this distinction later.

In the same vein, technology spillovers (T_s) can be created from knowledge generation of domestic agencies (firms, government and private research institutions, individual researchers etc.) and from knowledge generation abroad. These can be termed as T_{sd} and T_{sf} respectively.

A firm chooses an optimal amount of T_o and T_p (including its variants), in the presence of spillovers and a given public policy, to maximize the present discounted value of the stream of future profits. Therefore, the decisions about the sources of technology acquisition are taken simultaneously. The industrial organization literature suggests various firm and industry characteristics which determine opportunity and appropriability conditions, influence this choice.(See, for a review, Cohen and Levin, 1989 and Dosi, 1988). These include the technological conditions discussed in the last section.

Further, the nature of technology acquired and the mode of acquisition can significantly influence the relationship between the components of T_o, T_p and T_s. For example, acquisition of new technologies by purchasing newer vintages of capital equipment, purchase of process or product technology through licensing or pure imitation can have differential influence on indigenous technological effort. T_p can stimulate T_o if the purchased technology needs to be adapted to local firm and country specific conditions. At the same time there can be components of purchased technology which the firm did not have to develop through its own R&D. In this sense, T_p acts as a substitute for firms own technological efforts. The process of adaptation has been emphasized in the literature, but which process dominates is essentially an empirical issue. Some recent empirical studies in the context of India suggest that on balance this relationship is that of substitution (Basant and Fikkert, 1996; Basant, 1993; Fikkert, 1993).

The relationship between T_s and T_o is equally complex. It is widely recognized now that even within an R&D unit, the knowledge brought to bear on research projects comes from numerous sources. These include marketing and manufacturing groups within the firm, equipment suppliers, customers, professional and informal interaction with peers outside the firm, universities, governmental and non-governmental technical agencies, reverse engineering and new employees previously working for competitors or related firms.[2] Obviously, these knowledge flows take place among firms in the same industry and across industries. It is extremely difficult to capture these processes in aggregative statistics. Stocks of technology spillovers constructed in a variety of ways are viewed as proxies for such externalities.

Early empirical efforts to quantify the extent of technology flows other than through a more accurate measure of vintage capital, were made by Schmookler (1966) and Terleckyj (1980). More recently, many others (e.g., Scherer, 1982,1984; Link, 1983) have made efforts to quantify the impact of R&D related technology originating in industry i on measured productivity growth rates in industry j.[3] Two types of R&D 'spillovers' have been distinguished in the literature: (i) R&D intensive inputs are purchased by firms of an industry from firms in the same industry and from other industries at less than their full 'quality' price; and (ii) ideas borrowed by research teams of industry i from the research results of industry j (or by one firm from the other within the same industry). Conceptually, as Griliches (1991) points out, the former are consequences of problems of measuring capital, materials and their prices correctly and not really a case of pure knowledge spillovers. According to him, it is not clear that the latter type of borrowing is particularly related to input purchase flows.

Broadly then, spillovers emerge from less than full appropriation of social returns of T_o undertaken by any economic unit. A much smaller proportion of non-pecuniary externality of T_o, which is not embodied in any product or services, can be appropriated than of the embodied T_o (see Griliches, 1991 for a discussion on this issue). It has been argued that the imperfect appropriability of the output of technological efforts results in firms under-investing in such activities (Arrow,1962; Nelson,1959; Spence,1984). Recently, Cohen and Levinthal (1989) have shown theoretically that the spillovers associated with imperfect appropriability may actually increase R&D in the industry equilibrium. They argue that there is a positive effect of spillovers on the marginal productivity of the firm's R&D as the firm's own technological effort improves its ability to assimilate the technological developments of others. Therefore, if this effect is sufficiently strong it can overcome the disincentive of imperfect appropriability, resulting in an aggregate R&D higher than the level it would have reached in the case of perfect appropriability.

Very few studies empirically estimate the impact of spillovers on technological effort; most estimate the effect of spillovers on productivity (see Griliches,1991 for a review). Besides, most of these studies refer to developed countries, Fikkert (1993) and Basant (1993) being a recent exceptions. Besides, the available studies have provided contradictory results: some find that spillovers complement firm's R&D, while others show them to be substitutes (See, Basant, 1993, and Fikkert, 1993 for reviews). It is very difficult to adequately compare and assess the results of these studies because of different methodologies and differences in the measurement of spillovers.

The main purpose of the paragraphs above was to bring out the complexities involved in analyzing technological strategies of firms and provide a rudimentary outline of the various processes at work. As emphasized earlier, it is not always possible to empirically distinguish between various influences-especially when one is dealing with large firm level data sets. It is even more difficult to ascertain the relative costs of different technology options a firm faces. An attempt is made in that direction in a later part of this paper.

3. Policies Relating to Industrial Technology in India

A variety of policies relating to the industrial development in India influence the nature of technological growth in the sector. Many studies have reviewed and analyzed these policies in detail. In what follows we only indicate, for the period 1974-83, those dimensions of the policies which influence technological development.[4]

Industrial Licensing and Import of Inputs: Restrictions on capacity creation and expansion, import of capital and other inputs (import substitution/indigenization) and technical collaborations, combined together to reduce the reliance of Indian industry on embodied foreign technology and probably induced indigenous R&D to adapt imported inputs to local circumstances.

Technology Licensing and Foreign Direct Investment: Over the years, several restrictions on foreign equity participation, with or without technical collaboration have been placed. (See, Mani, 1992). Besides, policies prescribed low royalty ceilings, reduced permitted duration of technology agreements, discouraged renewals, disallowed restrictions on exports (in most cases) and sub-licensing and curtailed use of the technology suppliers trade-mark for domestic sales. Also, Foreign Exchange Regulation Act (FERA) of 1974 restricted the foreign shareholding to 40 per cent of the firm's total equity except in the 'high technology' and 'wholly exporting' firms.

Weak Patent Regime: In 1972, India adopted a weak patent regime which (a) **reduced the scope of coverage for each patent, making it easier to invent around patented inventions**; (b) introduced a system of compulsory licensing; (c) reduced the maximum length of patent life from 16 to 14 years for most patents and to only 7 years for patents related to drugs, food and medicines; (d) **did away with product patents in drugs, food and chemicals**; (e) increased the fees for application and renewal; and (f) made the application procedures more stringent with international search etc..[5]

Recognized R&D Units: In 1973, the Indian Government initiated a scheme of granting recognition to in-house R&D units of industrial firms. Apart from tax and other fiscal benefits, the scheme provides liberalized import facilities to recognized R&D units for purchase of equipment, components, raw material etc. necessary for carrying out R&D work.

The technology strategies adopted by the firms in India would have been influenced by the prevailing policy regime. With the exception of the patent legislation, these policies were not specific to any industry groups. In its implementation over time, certain industry specific patterns may have emerged. For our empirical analysis we have developed a variable to control for some of these differences which may have existed between the two industry groups under study. In the following section we summarize the results of some studies on India which have analyzed technology choices. The discussion is mainly based on Basant (1993) and Fikkert (1993).

4. TECHNOLOGY OPTIONS: THE LITERATURE ON INDIA

Both descriptive and econometric studies on India have analyzed the relationships between 'making' and 'buying' of technologies. The evidence on the acquisition of technologies from indigenous sources outside the firm is almost non-existent. This section briefly reviews the available studies to pool together evidence on the various relationships outlined in Section 2. The studies bring out the rich complexity of the relationship between technology purchase and indigenous effort and highlight various dimensions of the processes at work. Some of these dimensions are summarized below.

(a) Adaptation v/s substitution stories

Most studies emphasize that adaptation of foreign technology to suit local conditions constitutes a major component of indigenous technological effort in India. Such adaptation is necessary due to differences between firms in developed and less developed countries in scales of production, raw materials, intermediate inputs, factor costs, income levels etc.. But these processes were not identical across industry groups or even firms. Desai (1984:305) suggests the problem of scaling down varies with the degree of integration of the plant. In process (chemical and metallurgical) industries, considerations of speed, energy efficiency or logistics demand that a number of operations be undertaken in a rigid sequence. Here scaling down was applied to every operation and often resulted in a plant that had to be custom made. In the modular industries (chiefly engineering industries), where the scale and sequence of operations are not rigidly inter-connected, there was more scope for the use of slower or more manual machines in individual operations. In the latter industries, the technologies were not imported readily scaled down; instead product designs were imported and small scale production technologies were worked out with the help of less automatic machines than those in use in industrial countries. Thus, in the two industries chosen for study, different types of technology acquisition processes may be at work. As compared to chemicals, adaptive R&D undertaken indigenously may have been more dominant in the industrial machinery industry. We have not been able to adequately capture these differences with the available data.

Such differences may exist even with regard to the adaptation processes associated with imported material/intermediate inputs. The indigenization or import substitution policies adopted by the Indian government played a very important role in the adaptation process. Imported inputs had to be used in conjunction with locally acquired inputs which induced adaptive R&D.

Imports of Inputs: Technical collaboration between Indian and foreign firms did not always imply imports of inputs and vice versa. Still, over half of the agreements covered in a recent study involved supply of equipment and over 40 per cent involved supply of materials (Desai, 1985: Table 6, 1092). Therefore, while technology purchase through import of inputs (T_{pIr}) can induce adaptive R&D (T_a) on its own, its impact will be confounded with that of technology purchase through licensing (T_{pIr}) if they are combined as sources of technology. But, as argued earlier, there were severe restrictions on import of inputs, especially capital goods. Not only were direct imports of finished capital goods low for India, the import content of locally produced capital goods has also been very small. There is some evidence to suggest that in most of the cases where technology contracts involved purchase of machinery and materials, such purchases were insignificant.

Product v/s Process Technology: Certain components of imported process technology may not need any modification to suit Indian conditions. Besides, some studies suggest that firms mainly use technology purchase to obtain basic know-how to introduce new and improved products. Although such purchases sometimes involved setting up of new processes, very few of the contracts were meant to introduce new processes for the firms' existing products. Thus, while components of the technology contracts (inputs, products etc.) need to be adapted to Indian conditions, the substantive portion of these contracts involved details about basic design and know-how. The need to indigenize foreign technology promotes R&D, while the import of basic design and know-how substitutes for the firms' need to develop such knowledge (e.g., product) on their own. There is no evidence to suggest if product or process technology import dominated either of the two industries under study.

For most firms resources available for technological development are limited. Case studies suggest that if the technology is available on license (i.e., supplier is willing and there are no government restrictions) a firm will import technology if: (a) it is outside the experience of its technologists; (b) its development involves substantial increase in R&D resources; (c) it reduces the lags involved in product introduction; and (d) its not costly.

(b) Foreign Ownership and Technological Effort

The general argument is that firms with foreign equity participation do not develop indigenous R&D capabilities because they have ready access to the technology developed by their foreign partners. There is evidence to suggest that as compared to local private enterprises, firms with foreign equity, on average, spent more on purchase of foreign technology. The evidence also suggests that the share of foreign equity firms in total technology payments (license fees, royalties etc.) was higher than their

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Given the evidence that transfer of technology from parent companies to their subsidiaries also entails significant costs (Teece,1977), it is difficult to predict the direction in which foreign equity participation will influence technology choices of firms. Foreign participation may enhance the inflow of the tacit component of technology without necessarily changing the level of expenditure on R&D and technology purchase. It is even more difficult to hypothesize about technology strategies of firms with foreign participation in different industry groups. The existence of a weak patent regime may encourage MNEs to undertake to transfer part of their process technology through licenses and undertake related adaptive R&D in the host country. Such inducement may be more relevant for chemicals as compared to industrial machinery industry.

(c) Technology Spillovers

The reliance on foreign technology is not restricted to purchase; there is evidence to show that firms engage in copying the products manufactured abroad and adapting them to local conditions.(See, Basant,1993 for details). These technology spillovers take a variety of forms: cases of reverse engineering have been identified; some machine manufacturers even keep a stock of different foreign machines to assist them with their own product development; and many firms acquire technology, legally or clandestinely, from firms which had imported it. Some survey evidence also suggests the possibility that many illegal technology purchase contracts exist.

The extent of inter-firm technology transfers (including legal sales) within India is unknown but is considered to be substantial. This is facilitated by the Government's policy of not allowing any restrictions on the technology importers rights to sell or sub-license the technology. Such transfers of technology are not captured in official data. Overall, the available anecdotal evidence suggests that benefits of spillovers exist for a firm from foreign technologies and from indigenous technological effort both within and outside the industry to which the firm belongs. How these spillovers can be empirically captured on an aggregate basis is discussed in the next section.

5. Empirical Explorations

In the model discussed below we analyze indigenous technology effort (T_o) and T_{plr} as two distinct choices which a firm makes. Given severe restrictions on the import of equipment and other inputs discussed earlier. T_{plr} is considered to be exogenous to the firm's decisions. The literature suggests that it was relatively easier to license technology than import capital and other inputs during the 1970s and early 1980s, the period for which the empirical exercise is undertaken. Other technology flow variables are defined at the industry level (see below) and hence are considered exogenous to the firm. The discussion in sections 2 and 4 suggests that technology choices of firms in terms of T_o and T_{plr} can be influenced by a variety of factors all of which cannot be captured in an empirical exercise. In what follows we outline a model to capture some of these processes.

(a) The Multinomial Logit Model of Technology Choice

We analyze the firm's strategy in the discrete choice framework and assume the decisions regarding T_o and T_{plr} to be taken simultaneously. Four explicit choices can be considered:

(1) Neither T_o nor T_{plr} (technologically passive/inactive);

(2) Only T_o;

(3) Only T_{plr}; and

(4) Both T_o and T_{plr}.

It is argued that the utility of these choices depends on some firm and industry level characteristics outlined below. First we provide some details of the formal model.

The reduced form of the technology choice equation for firm i can be derived from an indirect profit function (V_i) which is obtained from a constrained maximization of the profit function. V_{ij} is the maximum profit attainable for firm i if it chooses the j^{th} technological status. This indirect profit function can be decomposed into a non-stochastic component (X) and a stochastic component (ε).

$$V_{ij} = \beta_j X_i + \varepsilon_{ij} \qquad (1)$$

where X is a vector of firm and industry characteristics. The probability that the i^{th} firm will choose the j^{th} technological status is given by,

$$P_{ij} = \Pr(V_{ij} > V_{ik} \text{ for k not equal to j}) \qquad (2)$$

If the stochastic components have independent and Weibull distributions, the choice model is a multinomial logit. The probability that the i^{th} individual chooses the j^{th} technological status reduces to,

$$P_{ij} = \exp(\beta_j X_i) / \Sigma_{k \in J} \exp(\beta_k X_i) \quad (3)$$

The multinomial logit model makes the choice probabilities dependent on individual characteristics of the agent (Maddala, 1983). The weakness of the multinomial logit model is that the probability of any pair of states depends exclusively on characteristics of the two states concerned, and is independent of the number and nature of all other states that are simultaneously considered. The odds ratio is, therefore, not affected by the addition or deletion of an alternative. This property is known as independence from irrelevant alternatives (IIA) (Cramer, 1991).

For comparison of the empirical results the marginal effects or partial derivatives are computed and then converted into quasi-elasticities. The partial derivative indicates the impact of the independent variable **X** on the probability of choice j. To make this independent of the unit of measurement, the quasi-elasticities (η_{jk}) are evaluated at the sample means (Cramer, 1991).

$$\eta_{jk} = X_k (\delta P_j / \delta X_k) \quad (4)$$

where **j** indicates the technology choices and **k** the elements of the independent variable vector **X**. η_{jk} indicates the percentage point change in P_j upon a one percent increase in X_k. These measures satisfy,

$$\Sigma_j \eta_{jk} = 0 \quad (5)$$

Quasi-elasticities are superior to the β coefficients and to derivatives by their ease of interpretation, but like their derivatives they too, may change sign as well as value when they are evaluated at different points.

A likelihood ratio index or a coefficient of determination can be defined which is analogous to the least squares multiple correlation coefficient,

$$\rho^2 = 1 - [L(\beta)/L(\beta_0)] \quad (6)$$

The model briefly outlined above essentially computes the probability of a firm choosing a particular technology status or strategy, given the levels of any of the independent variables. The results of this model are discussed in the next section. The rest of this section discusses the details of the variables and the data used in the estimation and construction of the variables.

(b) Data and Independent Variables

The firm level data used here relates to firms manufacturing industrial machinery (438 observations) and chemicals (651 observations) for the period 1974-1984. The data were compiled from the annual reports of public limited companies. The details of the data and the adjustments are provided in Appendix I.

The aggregate R&D data for the two manufacturing industry groups was compiled from various volumes of the **R&D Statistics** published by the Department of Science and Technology (DST). Data on the number of foreign technology contracts in each of the 38 industry groups was also collected for the period under study. The data on patents granted in India were compiled from the documents of the Indian Patent Office. These patents were further classified into foreign and domestic patents. These data also required various adjustments which are discussed in Appendix I.

Using the data sets described above, the following variables have been constructed to capture the effects described in the heuristic framework. In parentheses we provide the variable names used.

Firm Size (SALES): Annual sales turnover is used as a proxy for the size of the firm.

Firm's Technological Effort (T_o): The firm's R&D expenditures are used to capture this process.

Foreign Technology Purchase (T_{pif}): The expenditures incurred by the firm on disembodied technology purchase from foreign firms. The expenditures include license fees, consultancy and royalties.

Technology Purchase through Capital Import (T_{pifk}): A dummy variable is used to capture if the firm imported capital goods. The variable takes the value 1 if it had and 0 if it had not.

Technology Purchase through Other Imports (T_{pifo}): A dummy variable taking the value 1 if the firm imported materials or any other input, 0 otherwise.

Foreign Equity Participation (MNP): A dummy indicator taking value 1 if the firm has foreign equity participation of more than 10 percent, 0 otherwise.

Technology Embodied in Domestic Inputs (T_{pld}): The Yale-Canada Technology Concordance (YTC) and the estimates of industry level R&D expenditures for India were used to construct stocks of R&D embodied in inputs purchased by industry j from industry k (j not equal to k) within the country. If the firm belongs to industry j then these stocks can be used as a proxy for R&D embodied in the inputs which the firm uses but does not produce. Appendix II provides the details of these computations.

Foreign Technology Spillovers (T_{sf}): The foreign patents taken in India were assigned to industries of origin. The number of patents (an aggregate of three years) taken out in the industry to which the firm belongs then constitute the relevant foreign technology spillover stock for that firm. The assumption is that patenting by foreign companies implies that the embodied technology is relevant in India and there is some scope for the sale of the patented technology in the country. Obviously, the value of patents and/or their R&D intensities can vary considerably across industries, and within each industry. The spillover variable used here gives equal weight to each patent.

There is another dimension of foreign technology spillovers which is not being captured directly; the spillovers from foreign technologies licensed in India. The industrial distributions of foreign collaborations and foreign patents in India are positively and significantly correlated (r = 0.73, Basant,1992). Inclusion of foreign collaborations in an industry as a separate spillover variable, therefore, creates problems of multicollinearity. Besides, the number of collaborations has been used to construct another variable (see below) which can create additional problems of multicollinearity.

Domestic Technology Spillovers (T_{sd}): This captures the spillovers from R&D performed by other firms in the industry to which the firm belongs. The R&D estimates (three year aggregates) of the relevant industry group are used as spillover stocks to capture this effect. The R&D performed by other domestic agencies including government agencies is ignored because dis-aggregated data on their R&D expenditures are not available (Basant,1992).

Technology Licensing Policy/Price (TLP): It is extremely difficult to find a proxy for the policy relating to foreign technology licensing in a particular industry. The industry groups added or deleted from the 'priority or banned' lists for technology licensing from time to time do not easily fit into well defined industry groups. Similarly, the price of technology licensing a firm faces in a particular industry is almost impossible to estimate. However, there is considerable variation across industry groups in their share of the total number of foreign technology licenses granted during a year.

Obviously, an industry's share in the total number of contracts will be a function of the government's policy regarding foreign technology licensing in that industry and the price at which such technology is available. One can argue that higher an industry's share in the total licenses (after controlling for the size of the industry), cheaper (in terms of price 'per unit of technical knowledge') it is to get a license for a firm belonging to that industry. The share of an industry in the total number of licenses granted (three year aggregates) divided by its share in the value added of the manufacturing sector is, therefore, used to capture this 'price'. **It should be noted that this ratio is an inverse of the 'price'.**

The last four variables capturing domestic embodied technology flows, technology spillovers and licensing policy are defined at the industry level. They are common to all the firms in each industry group and are not expected to change very significantly over short periods of time. Since we have used panel data, we have included these variables. Therefore, in principle, we capture the changes in these variables during the period 1974-84 for which we have data. As we shall see below, low variability in these variables gets reflected in their insignificant impact on the probability of various technology choices. There are, however, some important exceptions to this rule which we shall highlight in the next section.

6. The Results

We have used each year's observation in the panel data as an independent observation. If a firm's technology choices in one year influence the technology choices in the next year, the model enumerated above will not capture these effects. As Fikkert (1993) points out, these problems will be most severe if a firm purchases technology this year and spent its entire effort on performing adaptive R&D next year. In such a case, technology purchase and R&D will be complements but would appear as substitutes in the econometric exercise. Fortunately, he finds no such shifts from one corner solution to the other in the data. In fact the Markov transition probabilities show that most firms remain in the same 'state' (technology choice) year after year (Fikkert, 1993).

Tables 2 and 3 report, for the two industry groups, the means and standard deviations of the variables used in the empirical analysis. The estimates are provided separately for different technology choices. It can be seen that in a large number of cases, 32 per cent in Chemicals and 40 per cent in Industrial machinery, the firms decided neither to undertake R&D nor license foreign technology. The proportion of firms relying only on their own R&D (T_o) was significantly higher in Chemicals industry (49 per cent) than in Non-electrical machinery (16 per cent). The reliance on foreign technology purchase, with or without one's own R&D was significantly lower among firms in the Chemicals than among firms engaged in the manufacture of industrial machinery. Besides, while the average size of the firm in the two industry groups is comparable, industrial machinery manufacturing firms spend significantly more on foreign technology purchase than chemical firms in the sample. The expenditure on R&D is marginally higher among industrial machinery firms than chemical firms.

Multinomial Logit Estimates

Tables 4 to 7 report the estimated results of the multinomial logit model described earlier. According to the discrete choice argument each column of coefficients shows the effect of the regressors on the utility of the state (strategy/ choice) under consideration, relative to the utility of the reference state. This reference state in our case is the one in which the firms choose neither R&D (T_o) nor technology licensing (T_{plr}). Estimates not significantly different from zero indicate that the regressor concerned does not affect the utility (nor the probability) of the state to which it applies, relative to the reference state. Tables 4 and 5 report these coefficients for industrial machinery and chemical firms respectively. To assess the simultaneous effect of the regressor variables on the probabilities of the four distinct strategies, one should turn to the marginal effects (Equation 6, Section 5). The marginals are reported in Tables 6 and 7 for the respective industry groups. In what follows we summarize the empirical results. Because they are easier to interpret, we rely more on the quasi-elasticities (Tables 6 and 7) than on the coefficients.

Firm Size: A large firm size improves the profitability/ utility of being technologically active (undertake T_o, T_{plr} or both) relative to the reference state of not doing anything. This is true of both industry groups. The elasticities bring out some interesting differences between the two industry groups. The probability of undertaking only R&D (T_o) is significantly affected by firm size in chemicals but not in industrial machinery; the opposite is the case with technology licensing (T_{plr}). While for both industry groups, the choice of doing both (T_o and T_{plr}) is positively affected by firm size. Thus, as firm size increases, ceteris paribus, the probability of being technologically dynamic also grows. In chemical industry the choice of performing only R&D is positively affected by firm size, while in industrial machinery it is not.

Capital Imports: Imports of capital goods also increase the possibility of doing R&D, licensing foreign technology or both among firms in both industry groups. The choice of doing both is more significantly affected than the other two choices. Once again the elasticities bring out some interesting differences. Among industrial machinery firms, capital imports significantly improve the probability of doing R&D alone or combining it with technology licensing but reduce the chances of only licensing technology. Among chemical firms, on the other hand, capital imports improve the possibility of only licensing technology or combining it with R&D, while having no significant impact on doing R&D alone. For both sets of firms such imports significantly reduce the utility and probability of technological inactivity.

Other Imports: The utility of being technologically inactive also declines with other imports, especially for firms engaged in industrial machinery production. The elasticities, however, show that such imports significantly reduce the probability of relying on technology licensing alone (T_{plr}) among chemical firms without significantly affecting the probability of this choice for industrial machinery firms. The non-capital imports improve the chances of doing both R&D and licensing technology for both sets of firms but improves the probability of relying on R&D alone only in the case of industrial machinery firms.

It has already been suggested that imports of inputs, especially capital may induce adaptive R&D. The positive relationship between foreign technology licensing and import of input requires some more elaboration. To the extent that some of the licensing contracts entail import of inputs as well, such a relationship is expected. However, as noted earlier, such tying was not encouraged by policy and is in fact not widely prevalent. Access to foreign inputs may also induce technology licensing to produce those inputs within the firm, especially under a policy regime which encourages 'import substitution' and 'indigenization'. There is also evidence to suggest that technology licensing often follows imports of goods (see discussion above and Desai,1984). Our results show that, such imports have not encouraged reliance on technology licensing alone, except in the case of capital imports among chemical firms.

Multinational Participation: Foreign equity participation encourages firms in chemical industry to be technologically active, the positive impact being most significant on the choice of combining indigenous effort with foreign technology licensing. The impact of such participation on the probability of relying only on one's own R&D is, however, not very significant; the probability of the other two technologically active choices are more positively affected. Interestingly, multinational participation has a negative, but generally insignificant, impact on the probability of being technologically active for industrial machinery firms; only the chances of relying on R&D alone are significantly reduced with such participation. This is an interesting result and needs to be explored further.

Technology Flows Through Domestic Input Purchases: The coefficients suggest that availability of R&D intensive inputs in the domestic market, have no significant effect on the profitability/utility of technology choices for both sets of firms. The marginals suggest that an increase in the R&D embodied in locally acquired inputs will significantly reduce the probability of doing only technology purchase for industrial machinery firms without having any significant impact on the probability of any other technology choices. As noted earlier, intra-industry variations in such technology flows are not very significant which may be partly responsible for the insignificance of their impact.

Technology Spillovers: Domestic and foreign technology spillovers do not significantly affect the utility of any of the technology choices for both industry groups. Once again, this is partly due to low variance of the variables capturing such spillovers. In an inter-industry exercise such flows encouraged technological dynamism presumably to assimilate the technology available for imitation (Basant,1993). At the margin, however, foreign technology spillovers seem to significantly improve the probability of doing both R&D and purchasing technology among chemical firms. Other choices for chemical firms and none of the technology choices for industrial machinery firms are significantly affected by technology spillovers.

Licensing Policy: With a cross-section of firms across industries, the licensing policy/price variable showed a significant and negative impact on the choice of undertaking only R&D; while technology licensing with or without R&D was positively affected. That is, an increase in the possibility of licensing technology and/or a decrease the costs of licensing, reduced the probability of doing only R&D but increased the probability of licensing foreign technology and combining it with indigenous effort (Basant, 1993). Again, perhaps due to insignificant changes in licensing policies during the period under study, this variable did not show any effect on the technology choices for firms belonging to both industries.

7. In Lieu of a Conclusion

On the whole, a few interesting results emerge from the consideration of significance of the coefficients and the marginals for various alternative technology strategies. A few highlights of Logit results may now be summarized. These tentative results provide good hypotheses which need to be tested when better data become available.

(1) R&D and foreign technology licensing are neither perfect complements nor perfect substitutes of each other. If the circumstances permit, the firms may choose one than the other. The results discussed above bring out the complexity of the relationship between these two technology choices.

(2) Large firm size increases the probability of doing R&D, licensing foreign technology or both relative to being technologically inactive. The firm size has the most significant impact on the choice of doing only R&D for chemical firms and relying only on technology purchase for industrial machinery firms. Besides, both sets of firms are also likely to combine indigenous effort with licensing of foreign technology than being technologically inactive with increases in firm size. This implies that the utility of relying only on R&D increases with increases in firm size for chemical firms and that of relying only on technology licensing for industrial machinery firms. We need to understand whether these strategies are policy induced or reliance on one's own R&D efforts is not adequate for large firms in industrial machinery industry. This may also be linked to the type of technology sought; larger industrial machinery firms probably seek product technology from abroad which requires relatively less local adaptation. Besides, given the technological capabilities in this industry, local adaptation may also be more feasible in this industry. (As mentioned earlier such adaptive R&D may not get reported). Therefore, relying on foreign technology licensing alone is possible in many cases. Such processes were, however, not dominant among chemical firms.

(3) Capital imports improve the probability of relying on technology licensing alone among chemical firms and on R&D alone for industrial machinery firms. Of course, for both sets of firms, the probability of combining the two also improves with capital imports. Adaptation to suit local conditions seems to be more important for industrial machinery firms, while tying of capital imports with technology licensing was perhaps more prevalent among chemical firms.

(4) Other imports seem to significantly reduce the need to license technologies to produce them domestically by chemical firms while such a process was not significant among industrial machinery firms. Once again, adaptive R&D induced by such imports is perhaps more significant among industrial machinery than chemical firms.

(5) Foreign equity participation improves the utility of technological dynamism only among chemical firms and not among firms engaged in producing industrial machinery. In fact, such participation significantly decreases the chances of relying on R&D alone among industrial machinery firms. It improves the probability of licensing foreign technology and combining it with their R&D efforts

among chemical firms. Apparently, foreign equity participation influenced technology strategies in the two sets of firms differently. It may have harmed the development of technological capability among industrial machinery firms but its impact on the technological capability of chemical firms is uncertain. As mentioned earlier, the peculiarities of the patent regime and the importance of formal R&D may have induced chemical firms with foreign equity participation to undertake more R&D indigenously. It needs to be emphasized that we did not have adequate data to ascertain the relation between technology strategies and the level of foreign firms equity holdings and therefore used a dummy to distinguish firms with or without such participation.

(6) Technology flow and spillover variables did not show any significant effect on technology choices. The same was true of the technology licensing policy variable. As indicated earlier, this was partly because of low variance in these variables during the period under study. To adequately analyze the impact of such variables at the industry level we either need data for a longer time period or more dis-aggregated data to construct these variables for sub-groups within each industry.

Despite limited variability, the results show that increases in foreign technology spillovers will significantly increase the probability of chemical firms combing indigenous R&D efforts with technology licensing as a technology strategy. Chemicals is a science based technologically dynamic industry and foreign spillovers are particularly useful for firms engaged in this industry. Besides, a weak patent regime enhanced imitation potential of foreign technologies, especially in the chemical industry. In the presence of significant technology spillovers it is understandable that firms in this industry will try to exploit the possibilities of imitation and/or assimilation. Evidently, a combination of technology licensing and firm level R&D is most appropriate for this purpose. Evidently, such spillovers are less important for industrial machinery firms.

The paper, therefore, brings out empirically the complexity of strategic technology choices and the difficulties of analyzing them. The differences in the technology choices made by firms in chemicals and industrial machinery industries which could be ascertained with the limited data set available with us should be explored further. Case studies and more detailed secondary data are necessary to adequately capture differences in industrial organization and technology related characteristics discussed earlier.

End Notes

1. This section builds on Link (1987), pp. 46-50.
2. See Link 1987, Table IX for some estimates on the relative importance of these sources.
3. See Griliches,1991 for a detailed review of studies on R&D spillovers.
4. This section is based on Basant (1993).
5. It is widely believed that this legislation slowed down the rate of patenting activity in India, especially by foreign firms, which picked up only in the early 1980s (Basant,1992).

Table 1: Proposed Patterns of Technological Opportunities and Threats

	Opportunities		Threats		Appropriability	
Category of firm	Number of innovations	Percentage Product Innovations	Ratio of Innovations Purchased to those Produced	Percentage of Innovation made by firms from other 3 Digits	Average Size of Innovating Firm (Employment)	Principal Activity of Firms fitting These Characteristics
Science Based	High	High	Low	High	High	Chemicals Electrical-Electronic
Specialized Suppliers	High to Medium	High	Low	Medium to High	Low to Medium	Mechanical Engineering Instruments Rubber & Plastic Products
Scale Intensive	Medium	Medium	Medium	Low	High to Medium	Mining Food Vehicles Metals Utilities
Supplier Dominated	Low	Low	High	Medium	Low to Medium	Textile Agri. Paper Construction Printing

Source: Pavitt, Robson and Townsend (1989): Table 1, p.86.

Table 2: Sample Means and Standard Deviations by Technology Strategy (Choice) Status, Industrial Machinery

Variables	All Cases	Technology Strategy Status			
		None	Only T_e	Only T_{pir}	T_e and T_{pir}
Observations	438 (100.0)	173 (39.5)	69 (15.8)	107 (24.4)	89 (20.3)
R&D Expenditure (10^6 Rs.)	0.92 (2.96)	NA	1.52 (2.36)	NA	3.36 (5.49)
Technology Purchase Expenditure	0.74 (2.13)	NA	NA	1.64 (3.29)	1.69 (2.46)
Sales (10^6 Rs.)	154.35 (193.43)	65.33 (119.19	163.24 (192.72	199.54 (206.17	266.12 (217.65
R&D Embodied in Domestic Inputs (T_{pid})	0.95 (0.362)	0.91 (0.342)	1.02 (0.41)	0.92 (0.35)	1.00 (0.41)
Domestic Technology Spillovers (T_{sd})	4.85 (3.01)	4.57 (2.83)	5.45 (3.25)	4.72 (2.97)	5.11 (3.16)
Foreign Technology Spillovers (T_{sf})	1.37 (0.06)	1.37 (0.06)	1.37 (0.05)	1.37 (0.06)	1.37 (0.06)
Licensing Policy Indicator (TLP)	5.50 (0.53)	5.48 (0.54)	5.57 (5.19)	5.49 (5.37)	5.51 (5.36)

Note: Except in the first row, where they represent percentages to total observations, figures in parentheses are standard deviations.

Table 3: Sample Means and Standard Deviations by Technology Strategy (Choice) Status, Chemicals

Variables	All Cases	Technology Strategy Status			
		None	Only T_o	Only T_{pir}	T_o and T_{pir}
Observations	651 (100.0)	211 (32.4)	318 (48.8)	42 (6.5)	80 (12.3)
R&D Expenditure (10^6 Rs.)	0.84 (1.89)	NA	1.19 (1.93)	NA	2.11 (3.18)
Technology Purchase Expenditure	0.16 (0.68)	NA	NA	0.53 (0.47)	1.02 (1.64)
Sales (10^6 Rs.)	151.32 (181.94	58.54 (68.12)	178.21 (166.50	14319 (131.12	293.41 (305.73
R&D Embodied in Domestic Inputs (T_{pid})	0.65 (0.26)	0.59 (0.22)	0.71 (0.26)	0.61 (0.26)	0.61
Domestic Technology Spillovers (T_{sd})	7.25 (2.54)	6.71 (2.49)	7.82 (2.43)	6.78 (2.55)	6.64 (2.61)
Foreign Technology Spillovers (T_{sf})	1.24 (0.23)	1.29 (0.23)	1.19 (0.23)	1.29 (0.24)	1.29 (0.24)
Licensing Policy Indicator (TLP)	1.79 (0.30)	1.82 (0.32)	1.75 (0.28)	1.84 (0.32)	1.81 (0.31)

Note: Except in the first row, where they represent percentages to total observations, figures in parentheses are standard deviations.

Table 4: Coefficients of Multinomial Technology Model-Maximum Likelihood Logit Estimates, Industrial Machinery

Regressors	Only T_o	Only T_{plf}	T_o & T_{pif}
Intercept	-10.359 (-0.70)	-12.686 (-0.93)	-7.867 (-0.52)
Sales (10^{-8})	0.513[b] (3.25)	0.800[a] (5.41)	0.874[a] (5.80)
Capital Import Dummy (T_{plfk})	1.998[a] (4.90)	0.724[d] (2.33)	2.206[a] (5.11)
Other Imports Dummy (T_{plfo})	1.551[d] (2.37)	0.797[e] (2.06)	1.911[d] (2.42)
R&D Embodied in Domestic Inputs (T_{pid},10^{-3})	-0.760 (-1.01)	-1.693 (-2.13)	-1.409 (-1.79)
Domestic Technology Spillovers (T_{sd},10^{-3})	0.001 (0.00)	-0.100 (-0.65)	0.073 (-0.46)
Foreign Technology Spillovers (T_{sf},10^{-3})	3.415 (0.49)	4.891 (0.79)	2.070 (0.30)
Multinational Participation Dummy (MNP)	-0.939c (-2.62)	-0.557 (-1.75)	-0.446 (-1.30)
Licensing Policy/Price (Inverse) Indicator (TLP)	0.000 (0.43)	0.001 (0.98)	-0.000 (0.29)
Log likelihood	-482.28		
χ^2	197.16		
ρ^2	0.17		
N	438		

Note: Figures in parentheses are t-ratios.
a- Significant at less than .1 per cent.
b- Significant at less than .2 per cent.
c- Significant at less than 1 per cent.
d- Significant at less than 2 per cent.
e- Significant at less than 5 per cent.

Table 5: Coefficients of Multinomial Technology Model-Maximum Likelihood Logit Estimates, Chemicals

Regressors	Only T_o	Only T_{plf}	T_o & T_{pf}
Intercept	-0.963 (-0.214)	-3.66 (-0.47)	-8.95 (-1.30)
Sales (10^{-8})	0.917[a] (5.60)	0.766[a] (3.72)	1.198[a] (6.89)
Capital Import Dummy (T_{plfk})	0.472[c] (2.21)	1.040[c] (2.73)	1.001[c] (2.89)
Other Imports Dummy (T_{plfo})	0.458 (1.88)	-0.203 (-0.48)	1.113 (2.12)
R&D Embodied in Domestic Inputs (T_{pld}, 10^{-3})	0.0715 (0.06)	0.227 (0.12)	0.025 (0.02)
Domestic Technology Spillovers (T_{sd}, 10^{-3})	-0.000 (-0.00)	-0.074 (-0.17)	0.081 (0.21)
Foreign Technology Spillovers (T_{sf}, 10^{-3})	-0.857 (-0.28	0.385 (0.08)	4.847 (1.06)
Multinational Participation Dummy (MNP)	0.808[b] (3.11)	1.475[a] (3.72)	1.525[a] (4.43)
Licensing Policy/Price (Inverse) Indicator (TLP)	0.000 (0.62)	0.000 (0.21)	-0.001 (-1.24)
Log likelihood	-616.54		
χ^2	263.70		
ρ^2	0.18		
N	651		

Note: Figures in parentheses are t-ratios.
a- Significant at less than .1 per cent.
b- Significant at less than .2 per cent.
c- Significant at less than 1 per cent.
d- Significant at less than 2 per cent.
e- Significant at less than 5 per cent.

Table 6: Effects of Regressor Variables on Technology Strategy Status - Estimated Marginals from a Multinomial Logit Model, Industrial Machinery

Regressors	None	Only T_o	Only T_{pir}	T_o & T_{pir}
Sales (10^{-8})	-0.168[a] (-5.20)	0.004 (0.43)	0.099[a] (3.72)	0.065[a] (4.17)
Capital Import Dummy (T_{pirk})	-0.323[a] (-3.26)	0.178[a] (5.93)	-0.069 (-1.44	0.21[a] (6.38)
Other Imports Dummy (T_{piro})	-0.288 (-1.87)	0.120[b] (3.25)	-0.013 (-0.18)	0.181[a] (4.60)
R&D Embodied in Domestic Inputs (T_{pid}, 10^{-3})	0.311 (1.83)	0.025 (0.56)	-0.251[c] (-2.70)	-0.085 (-1.83)
Domestic Technology Spillovers (T_{sd}, 10^{-3})	0.015 (0.44)	0.008 (0.85)	-0.018 (-1.06)	-0.005 (-0.55)
Foreign Technology Spillovers (T_{sr}, 10^{-3})	-0.854 (-0.55)	0.157 (0.39)	0.767 (1.01)	-0.069 (-0.18)
Multinational Participation Dummy (MNP)	0.1416 (1.74)	-0.089[a] (-3.65)	-0.046 (-1.17)	-0.006 (-0.29)
Licensing Policy/Price (Inverse) (TLP)	-0.000 (-0.64)	0.000 (0.04)	0.000 (1.44)	-0.000 (-0.34)

Note: Figures in parentheses are t-ratios.
a- Significant at less than .1 per cent.
b- Significant at less than .2 per cent.
c- Significant at less than 1 per cent.

Table 7: Effects of Regressor Variables on Technology Strategy Status - Estimated Marginals from a Multinomial Logit Model, Chemicals

Regressors	None	Only T_o	Only T_{pif}	T_o & T_{pif}
Sales (10^{-8})	-0.160[a] (-7.43)	0.114[a] (4.13)	0.003 (0.93)	0.044 (7.69)
Capital Import Dummy (T_{pifk})	-0.101 (-2.71)	0.007 (0.25)	0.042[a] (9.51)	0.051[a] (9.11)
Other Imports Dummy (T_{pifo})	-0.081 (-1.90)	0.053 (1.63)	-0.042[a] (-8.51)	0.070[a] (10.66)
R&D Embodied in Domestic Inputs (T_{pid}, 10^{-3})	-0.014 (-0.07)	0.005 (0.04)	0.012 (0.68)	-0.004 (-0.16)
Domestic Technology Spillovers (T_{sd}, 10^{-3})	-0.000 (-0.01)	-0.001 (-0.04)	-0.006 (-1.36)	0.007 (1.41)
Foreign Technology Spillovers (T_{sf}, 10^{-3})	-0.009 (0.02)	-0.502 (-1.23)	0.031 (0.64)	0.462[a] (6.57)
Multinational Participation Dummy (MNP)	-0.164[a] (-3.55)	0.037 (1.06)	0.053[a] (9.66)	0.074[a] (10.04)
Licensing Policy/Price (Inverse) (TLP)	-0.000 (-0.28)	-0.000 (1.80)	0.000 (0.60)	-0.000[a] (-8.16)

Note: Figures in parentheses are t-ratios.
a- Significant at less than .1 per cent.
b- Significant at less than .2 per cent.
c- Significant at less than 1 per cent.

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Appendix I

The Details of Data

1. R&D Data: The volumes of R&D Statistics published by the Department of Science and Technology (DST) are the major source of estimates of R&D expenditures for various sectors in India. The R&D estimates relating to the industrial sector are used in this paper. The estimates of R&D expenditure in this sector are based on periodic surveys of recognized in-house R&D units and are reported separately for 38 industry groups (See, Basant,1992:Table A.3). These categories have been regrouped into 31 industry groups for our purposes. After some adjustments (see, Basant, 1993 for details),these R&D estimates were used to generate domestic spillover stocks and stocks of R&D embodied in inputs acquired by the firms locally. An aggregate of R&D in three years, two preceding years and the year for which the stocks are to be created were used for this purpose. Appendix II provides more details of these procedures.

2. Patent Data: The data on patents granted in India during the period 1972-89 were compiled from the Patent Office Journals and the Gazettes of India. For each patent granted in India during this period information was collected on the country of assignee and its international patent (technological) classification (IPC). The Yale-Technology concordance described in Appendix II was used to classify foreign patents granted in India into 31 different industry groups to generate spillover stocks for foreign technology. As in the case of R&D, three year aggregates were used for this purpose also (Basant, 1993 provides more details)

3. Industry Level Data on Foreign Technology Collaborations: Chandhok and The Policy Group(1990) provides data on the number of foreign technology collaborations approved in 38 industry groups during the period 1970-1989. These data have been used to generate the proxy variable for the 'price' of technology licensing. Estimates of three years, two preceding years and the year for which the proxy variable is to generated, were added to create this variable. In addition the share of the relevant industry group in the total value added was used to normalize this variable. For this purpose the estimates for the year 1980-81 provided in Ahluwalia (1991) Table 2.3 were used.

4. Firm Level Data: The firm level data used here was compiled by the Institute for Studies in Industrial Development (ISID), New Delhi from the annual reports of public limited companies (firms with more than 50 shareholders) with greater than Rs 500,000 of nominal paid-up capital in 1974. Industrial machinery and chemicals firms were chosen from this data set. For some of these firms, data

Appendix II

Yale-Technology Concordance and Construction of Variables

Inventions when patented are classified and assigned to technology fields in National Patent Classification Systems or the International Patent Classification (IPC) Systems or both. Unfortunately, none of these systems can be assigned easily to industry groups. Almost all economic data - e.g., sales, R&D, employment etc.- are classified by industry. Therefore, matching inventions (patents) to industry is necessary if one wants to make use of patent data in industry level studies of technological change. A concordance between patent and industrial classifications is developed for this purpose. In its simplest form, a concordance assigns some fraction of each patent class to an industry. When one knows the number of patents in each class, one can simply add up the patents assigned to an industry from each class to generate the industry total.

The relationship between an industry and invention is quite complex. At the outset, one can distinguish between: (a) the industry of manufacture (IOM), i.e., the industry manufacturing the product in which the invention is embodied; and (b) the industry of use (IOU), i.e., the industry in which the invention and the product in which it is embodied is actually used.

The present study uses the assignment system or the Yale-Technology concordance developed by Evenson et.al (1988) on the basis of information on patents granted in Canada. The Yale-Technology concordance provides a technology flow matrix whereby given the industry of manufacture of the patent, technology flows to user industries can be predicted. Probabilities generated from IPC-IOM relationships were combined with the probabilities generated from IPC-IOU relationships to generate this matrix. This technology flow matrix has been used to assign R&D to different sectors in terms of its use. This can be done by multiplying the matrix by estimates of R&D originating in different industry groups.

The foreign technology spillover stocks (T_{sf}) used in the paper were generated by mapping foreign patents granted in India with given IPC codes into industries of manufacture (IOM). The technology flow matrix was used to estimate the stock of R&D used in in industry j. By subtracting from this stock the stock of R&D produced and used in industry j the estimate for stock of R&D embodied in the inputs domestically purchased (T_{pid}) by industry j from other industries was generated.