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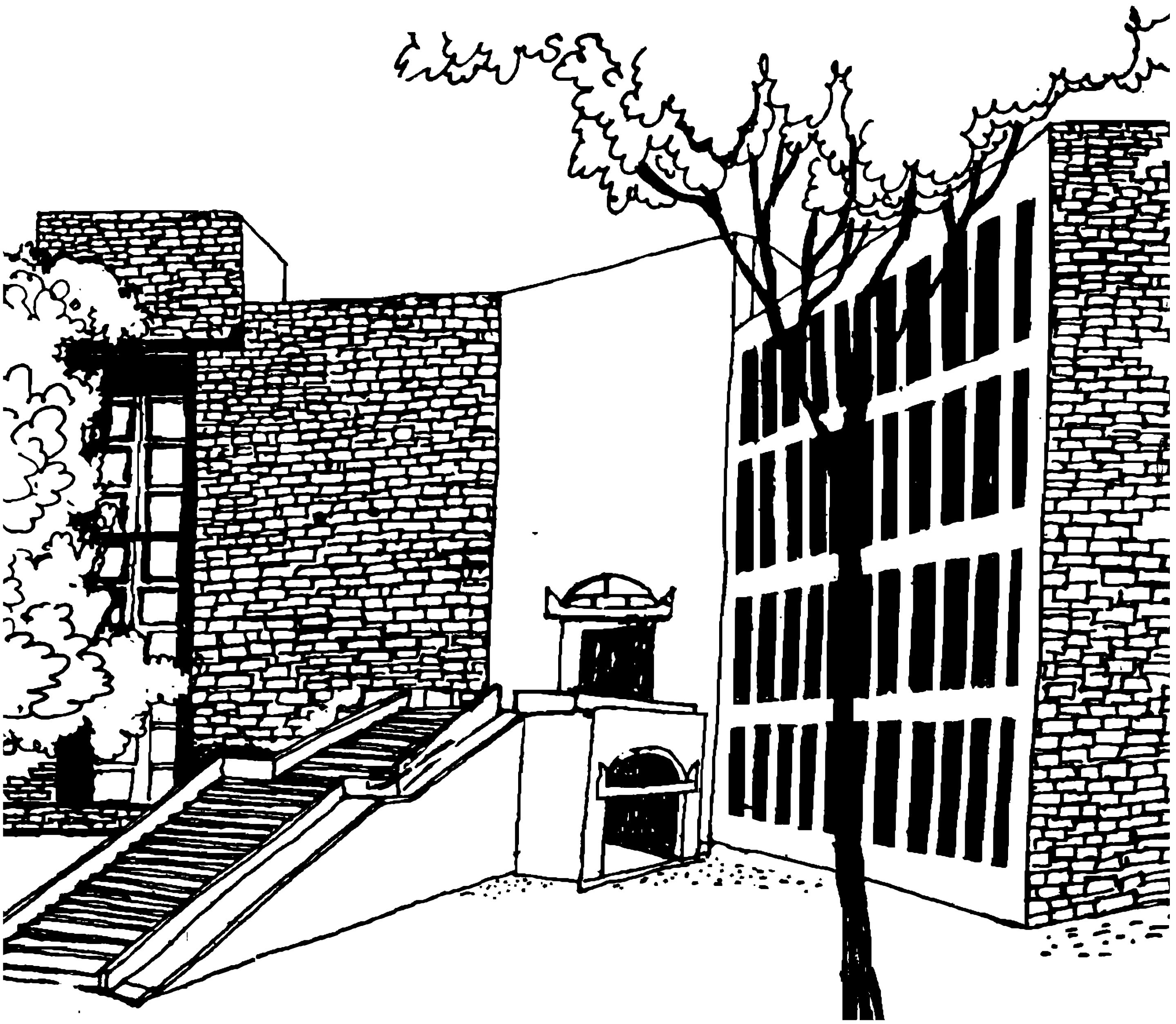

TRADE REGIMES AND PRODUCTIVITY: EXPLORING THE IMPACT OF TARIFF POLICY ON FIRM LEVEL TECHNOLOGY STRATEGIES

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ABSTRACT

The economic reforms initiated in 1991 were broadly based on the view that the strategy of state dominated industrialisation with high protective barriers was either a mistake or has outlived its usefulness. And this strategy should now be replaced by a more market oriented, open economy approach. However, there has been no consensus on the impact of economic liberalisation on total factor productivity in the Indian manufacturing sector. While the links between liberalisation and growth in total factor productivity at the aggregate level have been explored in the recent literature, the effect of liberalisation on firm level choices remains an under-explored area. It is important to analyse such linkages because it is only through such choices that changes in the firm level efficiency take place. The paper is an effort in this direction. It brings out empirically the complexity of strategic technology choices and the difficulties of analysing them. The analysis based on detailed firm-level data for the pre-reform period data clearly show that protectionism did not foster technological activity by Indian firms; in fact, it seems to have hampered technology related investments. Higher rates of protection disncouraged firms from keeping abreast of recent technological developments through the *making* or *purchasing* of technology. It is argued that an in-depth analysis of the impact of trade on firm level choices and productivity in the pre-liberalisation phase may be useful both as a benchmark for evaluating the impact of trade liberalisation as well as for providing insights to fine tune the evolving policy instruments.

TRADE REGIMES AND PRODUCTIVITY: EXPLORING THE IMPACT OF TARIFF POLICY ON FIRM LEVEL TECHNOLOGY STRATEGIES

1. Introduction

The Indian economy today is in transition. Protection and controls are being replaced by a competitive and de-regulated open economic system. Gradual removal of tariff and other trade barriers is a major part of this liberalisation process. It is important to explore whether it is possible for a country like India to adopt a "strategic" trade policy in today's world? If yes, what should be the elements of such a trade policy in order to achieve international competitiveness? It is very difficult to give unequivocal answers to such queries as there are hardly any detailed empirical studies on the impact of tariff policies on the performance of manufacturing firms in the context of developing countries. In fact, large sample firm level studies on the interface between trade, industrial and technology policies in the context of countries like India are almost non-existent.

The current dominant view is that the strategy of state dominated industrialisation with high protective barriers was either a mistake or has outlived its usefulness. And this strategy should now be replaced by a more market oriented, open economy approach. The analytical basis for this view is provided by the traditional trade theory which demonstrated that under certain conditions 'free trade' is the best policy for all countries. However, the new trade theory and the new neo-classical growth theory suggest that arguments in favour of free trade do not have unlimited validity over time and space. It is argued that in some specific cases, trade policies in the form of tariffs and technology policies in the form of research subsidies may influence aggregate economic growth or welfare by changing the factor proportions in research and/or manufacturing. In fact, under conditions of increasing returns and dynamic learning, protection may enable an industry to exploit these advantages and become internationally competitive.

The amount of flexibility the country will have in the design and implementation of trade policies during the post GATT-1984 era, is still to be ascertained. Any effort to exploit the degrees of freedom available to the member countries of GATT will have to be based on an in-depth knowledge of the impact of trade and other policies on the strategies of domestic firms. Given the inadequacy and/or non-availability of relevant data for the post 1991 period, one can only explore this linkage for the pre-reform period. An in-depth analysis of the impact of trade on firm level choices and productivity in the pre-liberalisation phase may be useful both as a benchmark for evaluating the impact of trade liberalisation as well as for providing insights to fine tune the evolving policy instruments.

The next section reviews the literature on the links between trade regimes and productivity. Section 3 provides a broad framework and the policy background for analysing such linkages in the context of India during the pre-reform period. The econometric models and the data used in this paper for empirically exploring these linkages are described in the subsequent section. Section 5 discusses the results of our estimation. The concluding section explores the usefulness of the results of this paper for analysing the trends in the Indian manufacturing sector in the 1990s.

2. Trade Regimes and Productivity

The relationship between productivity and trade regimes has been modeled in a large variety of ways. We do not make an attempt here to critically review these models or ascertain their theoretical and empirical validity in developing country contexts. The purpose of this section is only to place our explorations in the larger context of various strands in the available literature. Following Tybout (1991), four types of links between productivity and trade regimes have been identified in the literature.

Efficiency Gains: The standard `comparative-static' argument in favour of `opening up' is that it improves, through increased competition, the allocation of factors across sectors and thereby induces a one time increase in the value of domestic production. The new orthodoxy on outward orientation builds on the promise of technical efficiency. It is argued that with trade liberalisation, protected firms will have no choice but to modernise their techniques and cut their costs in order to compete with foreign producers. Some development economists, using the "X-efficiency" argument, show that trade liberalisation can change the opportunity cost of leisure in such a way that managers work harder. In other words, exposure to foreign competition can increase the returns to entrepreneurial effort, inducing managers to make an extra effort at reducing and or eliminating inefficiency. Alternatively, efficiency increases can take place when increased demand through export expansion allows firms to reap economies of scale.

Technological Catch-up: Some models (Rodrik, 1992) relate the representative firm's rate of `catch-up' to international productivity levels to its market share. Trade liberalisation, therefore, is expected to `slow down the transition to the state-of-the-art technologies in import competing sectors, and accelerate the transition among exportables'. A competing formulation is that firms may tacitly collude when protected from foreign competition by failing to modernise their plants, and trade liberalisation may induce firms to adopt new technologies and thereby result in a shift from this so-called collusive equilibrium.

The Uncertainty Dimension: It is argued that trade policy reforms are often associated with some speculation about their sustainability. Consequently, trade reforms can change entrepreneurial and managerial uncertainty regarding future economic conditions. This uncertainty may reduce firm level initiatives/efforts to increase productivity, including their decisions regarding entry and exit. Thus, unsustainable trade reforms are likely to generate relatively little change in the mix of productive capacity and capability; most output adjustment will come from changing production levels at existing facilities and technological capabilities. In contrast, reforms that establish a credible and stable regime, may induce rapid adjustments in the volume of capabilities of industrial firms.

Trade Regime and Long Run Growth: Many studies view technological change as a continous process as firms innovate, invest in and learn about existing and emerging technologies. Productivity growth, therefore, cannot be seen as an orderly shift in technology as there is no single production function (Evenson and Westphal, 1994). The process of innovation and learning is influenced by trade orientation by affecting the entrepreneurial ability to monitor new technological developments and/or by changing the expected returns from innovation (Stewart and Ghani, 1990).

Another set of studies (Grossman and Helpman: 1989, 1990) a different mechanism which links trade regimes with productivity. These studies assume that research and development (R&D) generates technology spillovers or public knowledge as well as returns which can be appropriated by the firm doing R&D. Entrepreneurs reap these returns by developing new varieties of intermediate goods. And richer the menu of intermediates available, the closer the final goods producers can get to their ideal input mix, thereby improving their levels of productivity and growth.

In this scenario, trade regime can influence rates of productivity growth in a variety of ways. The exposure to international competition and the ease with which knowledge crosses international boundaries will influence firm level decisions about product development. Easy availability of technology and presence of substitutes may reduce efforts at new product development. Availabilty of large markets, on the other hand, can be conducive for innovation. Besides, new product development and other kinds of innovation require labour and capital inputs, which are also used in the production of traded goods. Therefore, a change in the trade regime that affects relative output prices also affects returns to new product development, and thereby influence the rate of productivity growth. However, the net impact of these counter-veiling forces on productivity growth in the long run is difficult to predict.

The above summary of the literature which deals with the linkages between trade regimes and productivity growth has brought out one fact very sharply. That these linkages are crucially dependent on the technological efforts firms make as the economy `opens up'. To the best of our knowledge, all empirical studies in this area try to relate `openness' to `productivity changes'; the intermediate links between trade regimes and technology strategies/efforts have not been explored, Scherer's (1992) recent work being the only exception.

Scherer (1992: Ch. 5) argues that advantages in exporting high-technology merchandise is most likely to be sustained when domestic firms increase their own R&D in response to intensified innovative efforts by foreign rivals - that is, when they react aggressively - than when they cut back their R&D (a "submissive" reaction). He cites two studies regarding firms' R&D behaviour with respect to import competition. The first using standard Granger-Sims test on industrial R&D expenditures for the period 1967-1985 found evidence of two-way simultaneous influence; that is, U.S. and Japanese R&D outlays tended to rise and fall concurrently. A test for changes in the reaction pattern over time revealed that U.S. R&D outlays fell with increased Japanese R&D expenditure during the late 1960s, but the changes became increasingly positive and parallel by the late 1970s and early 1980s.

The second study examined the relationship between the penetration of U.S. markets by imported products and the lagged R&D spending of 26 companies specialised in seven industries - steel, machine tools, anti-friction bearings, consumer radio and television sets, semiconductors, automobiles, and photographic supplies and equipment. Statistical analysis revealed that on average, companies tended at first to reduce their R&D/sales ratios in response to increasing import inroads- that is, to react submissively to intensified foreign competition. But in the later years of the 1975-85 sample period, their reactions became increasingly aggressive. Further investigation disclosed that observed reaction patterns varied appreciably across the seven industry groups. In steel and consumer electronics, reactions were on average much more submissive than for the sample as a whole; in semiconductors and photo equipment, the reactions were palpably more aggressive. Thus no single homogeneous behaviour pattern stood out.

In another exhaustive study undertaken by Scherer (See Scherer, 1992), Census data for 308 companies covering the years 1971 through 1987 was utilised to determine how the R&D spending of U.S. companies reacts to technological challenges from abroad, manifested primarily in imports of high-technology goods into U.S. markets. It is found that most year-to-year changes in company R&D/sales ratios were unsystematic, related neither to import competition movements nor to other plausible explanatory variables. There is considerable idiosyncrasy in companies competitive reactions. But import competition does appear to have made a difference. The short-run reaction to increased imports (or declining net exports) was on average submissive; that is, R&D/sales ratios fell. However, large, diversified firms occupying concentrated markets reacted more aggressively than their smaller, less diversified counterparts. Multinationals reacted more heterogenously to rising imports and less submissively to net exports declines. Insulation from import competition through trade barriers blunted firms' short-run reactions. Over the longer run, there appears to have been a reversal of the average reaction pattern from submissive to aggressive, although the evidence on this point remains weak.

These studies sharply bring out the possibility that there can be significant variations in R&D reactions of firms across sectors and among firms of various types (e.g., MNC versus others). Moreover, short term reactions can differ from long term strategies. Given this background, an empirical analysis of the impact of tariff structure on technological effort at the firm level should provide some insights into the processes through which the trade regime-productivity links come about. The present paper, using detailed firm level data for the pre-reform period in India, makes an effort in this direction.

3. Trade Regimes and Technology Strategies of Firms

A firm's technology strategy is influenced by the `technology regime' in which it operates. The regime is broadly defined by industrial structure, nature of technical knowledge (e.g., complexity and cumulativeness of the relevant technology) and the policy environment. These determine the opportunity and appropriability conditions faced by firms in various industry groups. Given these broad relationships, firms' technology strategies may differ across industry groups. Therefore, if rates of protection differ significantly across industry groups, it may influence firms' technology strategies across these groups.

Apart from this, there are other factors which influences a firm's technology strategy. 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 internalise the innovation process by pursuing specific activities, generally characterised under the rubric of R&D, or it can use existing markets to purchase technology. For optimising 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. The brief review above indicated how spillover or imitation potential may expand once economy opens up. However, the changing rules of the game for intellectual property rights can significantly hamper the exploitation this potentially potent source of indigenous technology development.

Rates of Protection

Various policy instruments protect domestic industries. These can be broadly classified into `price' and non-price' measures. The former include ad valorem and specific tariffs, import surcharges, advance deposits for imports and multiple exchange rates. The latter include quotas, licensing and exchange controls. ***The estimates of effective rates of protection used in this paper are based on tariff rates*** (See, Appendix II).

Tariff rates or rates of protection broadly define `openness' faced by different industry groups. Low rates of protection expose firms to foreign competition. Alternatively, negative rates of protection may put domestic firms at an unfair dis-advantage vis-a-vis their foreign counterparts. The Effective Rate of Protection (ERP) is defined as the percentage excess of domestic value-added due to the imposition of tariffs and other protective measures on the product and its inputs over foreign or world market value added. It indicates joint effects on the production process of tariffs, on the product itself and on its inputs, and it influences the producer's choice (Goldar and Saleem, 1992).

The joint effect of tariffs on output and on intermediate inputs, captured by ERP determines the incentive structure created by tariff rates. This incentive structure has an important influence on the allocation of resources among various production related activities, including the `acquisition or production of knowledge'. *This study uses estimates of ERP to capture the extent of protection firms enjoyed in different industries.*

Apart from effective rates of protection applicable to different industry groups, a variety of policies impinged on the `openness' of the Indian economy during the period under study, 1974-75 to 1983-84. These in turn would have influenced the technological strategies of the firms. Based on Basant (1993), some of these policies are summarised below.

Industrial Licensing and Import of Inputs

In general, there were restrictions on capacity creation and expansion, import of capital and other inputs and technical collaborations. A trade policy which emphasised *import substitution* and an industrial policy which not only required *essentiality* and *indigenous non-availability* for import of inputs but also emphasised *gradual `indigenisation'* of imported inputs, combined together to reduce the reliance of Indian industry on embodied foreign technology (see Srinivasan, 1992). These together with other components of what can be broadly referred as technology import policy adopted in the late 1960s changed the pattern of technology imports in India. In general, it is expected that import substitution and indigenisation policies will induce indigenous R&D to adapt imported inputs to local circumstances.

Technology Licensing and Foreign Direct Investment

Apart from prescribing limits on foreign equity participation, the government at various points of time (beginning 1969) published four lists of industry groups specifying the roles allotted to foreign capital and technology in each group (see Mani, 1992): the first list enumerated industries where foreign investment would be permitted with or without technical collaboration; the second consisted of those industries where only foreign technical collaboration and not investment was to be permitted; the third comprised of those industries where no foreign participation, neither financial nor technical, would be permitted: and the fourth mainly provided the exceptions to the above categories, consisting of a list of 19 priority industries in basic and intermediate goods where foreign investment above 40 percent was permitted.

Besides, various policy changes were initiated in the 1960s which were in effect, almost unchanged, till the early 1980s. These policies (i) prescribed low royalty ceilings (ranging from 3-5%); (ii) reduced the standard permitted duration of technology agreements from 10 to 5 years. (Renewals were not allowed unless they involved more advanced or different technology); (iii) disallowed export restrictions except in countries where the technology exporter had subsidiaries, affiliates or licensees; (iv) disallowed the use of the technology suppliers trade-mark for domestic sales; (v) significantly reduced in the early 1970s the protection granted to patents; (vi) did not allow any restrictions on the technology importer's right to sell or sublicense the imported technology; and (vii) passed Foreign Exchange Regulation Act (FERA) in 1974 whereby the foreign shareholding could not exceed 40% of the firm's total equity unless the firm was producing a `high technology' product or wholly engaged in exporting.

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 (Nayar, 1983; Encarnation, 1989). The evidence also suggests that the share of foreign equity firms in total technology payments (license fees, royalties etc.) was higher than their share in the total number of technical collaborations. That is, they were paying more per contract than their wholly indigenous counterparts. This was probably due to the fact that the quality of the technology being transferred was significantly better in the case of firms with foreign equity as compared to other firms. This was reflected in higher participation of foreign technicians (Encarnation, 1989; Nayar, 1983) and greater interest of foreign partners in tailoring the transferred technology to Indian conditions (Davies, 1977; Desai, 1985).

It is argued, therefore, that technology import with foreign direct investment reduces indigenous R&D. A recent econometric exercise however, did not find any significant difference between the R&D intensities (expenditure on R&D as proportion of sales) of local enterprises and foreign equity firms (Kumar, 1990). Besides, nearly all foreign affiliates of any size have set-up R&D facilities in India (Lall, 1985). Because of their R&D efforts, some of them were even given permission by the Indian government to retain an equity share higher than (40%) that prescribed by FERA regulations (Encarnation, 1989).

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 hypothesis 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 industries like chemicals and pharmaceuticals as compared to other industries.

4. Empirical Explorations

Broadly, the technical knowledge available to a firm can be divided in terms of three alternative sources of acquisition: $\mathbf{T_o}$- knowledge generated by firm on its own; $\mathbf{T_p}$- knowledge purchased by the firm; and $\mathbf{T_s}$- spillovers created by knowledge generation of other firms.

$\mathbf{T_o}$ 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 but R&D costs do not account for the major share of expenses or time involved in innovation (Mansfield et al, 1971).

The purchased knowledge ($\mathbf{T_p}$) 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, $\mathbf{T_p}$ can take the following four forms: $\mathbf{T_{pld}}$- $\mathbf{T_p}$ acquired through domestic licenses; $\mathbf{T_{plf}}$- $\mathbf{T_p}$ acquired through foreign licenses; $\mathbf{T_{pid}}$- $\mathbf{T_p}$ acquired through purchase of domestic inputs; and $\mathbf{T_{pif}}$- $\mathbf{T_p}$ acquired through purchase of foreign inputs.

Similarly, technology spillovers ($\mathbf{T_s}$) can be created from knowledge generation of domestic agencies (firms, government and private research institutions, individual researchers etc.) and from knowledge generation abroad.

A firm chooses an optimal amount of $\mathbf{T_o}$ and $\mathbf{T_p}$ (including its variants), in the presence of spillovers, a given public policy and firm characteristics, to maximize the present discounted value of the stream of future profits. Therefore, the decisions about the sources of technology acquisition are taken simultaneously. Further, the nature of technology acquired and the mode of acquisition can significantly influence the relationship between the components of $\mathbf{T_o}$, $\mathbf{T_p}$ and $\mathbf{T_s}$. 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. $\mathbf{T_p}$ can stimulate $\mathbf{T_o}$ 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, $\mathbf{T_p}$ acts as a substitute for firms own technological efforts. Besides, the costs of total expenditures on innovation - the sum of $\mathbf{T_o}$ and $\mathbf{T_p}$ expenditures - may rise with the level of such expenditures due to internal costs of adjustments or increasing financing costs. In an extreme case financing constraints may imply that the firm has a fixed budget for technological improvements in a given year. Then money spent on $\mathbf{T_p}$ will necessarily reduce the amount which can be spent on $\mathbf{T_o}$ (Fikkert, 1993). The process of adaptation has been emphasised in the literature but which process dominates is essentially an empirical issue.

In the model discussed below we analyse indigenous technology effort $\mathbf{T_o}$ and $\mathbf{T_{plf}}$ as two distinct choices which a firm makes. *Given severe restrictions on the import of equipment and other inputs discussed earlier. T_{pif} 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. Given these policy restrictions, ***in one of the models, technology licensing is also considered to be exogenous***. Other variables are defined at the industry level (see below) and hence are considered exogenous to the firm. The discussion above suggests that technology choices of firms in terms of $\mathbf{T_o}$ and $\mathbf{T_{plf}}$ 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.

Further, as mentioned in the literature review, openness of the economy vis-à-vis the world markets can influence potential foreign technology spillovers. *It is therefore, assumed here that effective rates of protection will capture the effect of foreign technology spillovers on firm level technology strategies*[1].

The Multinomial Logit Model of Technology Choice

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

(1) Neither $\mathbf{T_o}$ nor $\mathbf{T_{plf}}$ (technologically passive/inactive);
(2) Only $\mathbf{T_o}$;
(3) Only $\mathbf{T_{plf}}$; and
(4) Both $\mathbf{T_o}$ and $\mathbf{T_{plf}}$.

It is argued that the utility of these choices depends on some firm and industry level characteristics (**$\mathbf{F_c}$ and $\mathbf{I_c}$**) outlined below. While the details of the formal model are provided in Appendix-I, it essentially computes the probability of a firm choosing a particular technology status or strategy, given the levels of any of the independent variables.

[1] Elsewhere, the issue of spillovers in the Indian context has been dealt with in a variety of ways. (See for details, Basant 1993; Basant, 1997; Basant & Fikkert).

The Tobit Model

While the logit model captures the technology choices and strategies of firms, it does not take into account the intensity with which a particular strategy is followed. For example, a significantly larger amounts of money may be spent on R&D than technology purchase or vice versa. To probe such differences, tobit analysis has been undertaken. The indigenous technology effort (T_o) of a firm, as reflected in its R&D expenditures, is postulated in this model as a function of embodied and disembodied foreign technology purchase (T_{pif}, T_{plf}), and some firm and industry characteristics (F_c, I_c), including effective rates of protection.

$$T_o = G\ (T_{plf}, T_{pif}, F_c, I_c)$$

Given severe restrictions on the import of equipment and inputs discussed earlier, T_{pif} is considered to be exogenous to the firm's decisions. The same policy restriction is invoked to assume the exogeneity of T_{plf}, although 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.

All firms whether undertaking R&D or not are included in the estimation of this relationship. The choice of zero expenditure on R&D, a corner solution, is accounted for by the use of tobits maximum likelihood estimation[2]. Since a simultaneous tobits model has not been estimated, the simultaneity of technology purchase and R&D expenditures has been ignored for this exploratory exercise. In the same vein, tobits on technology purchase expenditures have also been estimated:

$$T_{plf} = H\ (T_{pif}, F_c, I_c)$$

Since exogeneity of T_o is difficult to justify this variable has been excluded from this set of equations. As mentioned, this has been done for exploratory purposes knowing fully the analytical inadequacies of such a model.

Exporting v/s Non-Exporting Firms

Should trade liberalisation affect firm behaviour of exporting firms more differently than that of non-exporting firms? At one level, both exporters and non-exporters will have to respond to import competition. It is possible, however, that a significant proportion of non-exporting firms are producing non-tradables, thereby having limited exposure to import competition. Exporting firms on the other hand, by definition deal with tradables and, therefore, may have higher exposure to import competition. Moreover, exporting firms also have the option of responding to import competition through more exports. This may require technological investments to upgrade quality and so on. Of course, one can argue that exports and technology strategies have two way linkages and may be simultaneously determined.

[2] The general formulation of the tobit in the censored regression model is: $y^* = b'x+e$, where $y=0$ if y^* is less than an or equal to 0 and $y=y^*$ otherwise.

Further, as suggested by the technology catch-up models discussed earlier, import competing and exporting firms may react differently to trade liberalisation. Therefore, to explore the differences in the technology strategies of exporting and non-exporting firms vis-à-vis trade liberalisation, the above models have also been run separately for exporters and non-exporters. The results of these models 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.

Data and Independent Variables

The firm level panel data used here relates to about 700 manufacturing firms, the total number of observations being 5984. The data were compiled from the annual reports of public limited companies. For some of these firms data are available for six years (1974-75 to 1979-80) and for others for nine years (1974-75 to 1983-84). The details of the data and the adjustments are provided in Appendix II. While we had a panel data set at the firm level, we have not been able to utilise it for testing the kind of sequencing Scherer's work indicated; submissive reaction first and aggression in later years and so on. This is so because of the non-availability of panel data at the industry level.

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_{plf}): 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 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'.

Effective Rates of Protection (ERP): Goldar and Saleem (1992) have computed effective rates of protection for 66 industry groups for the 1980-81, 1983-84 and 1989-90. We have used these estimates for our analysis. We have assumed that the 1980-81 rates were valid for the period upto 1980-81. For the post 1981 data points, 1983-84 rates have been applied. The details of the computation of ERP are provided in Appendix II.

Except for the last two 'policy variables' (capturing licensing policy and effective rates of protection) which are defined at the industry level, all other variables vary across firms.

5. 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).

Table 1 reports the means and standard deviations of the variables used in the empirical analysis. The estimates are provided separately for different technology choices.

Multinomial Logit Estimates

Tables 2 and 3 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 (See Table 2). 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 4, Appendix I). The marginals are reported in Table 3. In what follows we summarise the empirical results. Because they are easier to interpret, we rely more on the quasi-elasticities (Table 3) than on the coefficients.

Effective Rates of Protection: Overall, the results very clearly show that high rates of protection have a negative and significant impact on technological activity of firms. With higher rates of protection, the probability of firms using the strategy of technological inactivity (neither `making' nor `buying' technology) goes up significantly. As protection declines, the utility of undertaking T_o, T_{plf} or both, relative to the reference state of not doing anything, goes up significantly. However, the profitability of doing R&D or combining it disembodied technology purchase increases more than the utility of purchasing technology alone.

Licensing Policy: The licensing policy/price variable shows a significant and negative impact on the choice of undertaking R&D or combining it with technology purchase; while technology licensing 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.

Firm Size: A large firm size improves the profitability/utility of being technologically active (undertake T_o, T_{plf} or both) relative to the reference state of not doing anything. Thus, as firm size increases, *ceteris paribus*, the probability of being technologically dynamic also grows.

Capital Imports: Imports of capital goods also increase the possibility of doing R&D, licensing foreign technology or both by the sample firms. The strategy of doing both or R&D alone is more significantly affected than the strategy of relying only on technology purchase.

Other Imports: The utility of doing R&D or combining it with technology purchase increases with imports of materials; such imports do not have any significant impact on the strategy of relying only on technology purchase.

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 capital 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, 1985). Our results show that, such imports have not encouraged reliance on technology licensing alone.

Multinational Participation: Foreign equity participation encourages firms 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 technology purchase is, however, not as significant as the impact on the probability of the other two technologically active choices.

Exporters: Introduction of the exporter dummy in the logit model (Tables 3 and 4) shows that being an exporter improves the probability of being technologically active in a significant manner. The logit model was, therefore, estimated separately for exporters and non-exporters (See Tables 6 and 7 for Exporters and Tables 8 and 9 for Non-Exporters respectively). In general, a reduction in effective rates of protection improves the probability of technological activity (R&D, technology purchase or both) in both sets of firms. This impact is, however, stronger for exporter firms than non-exporter firms. Overall, while conducting inhouse R&D or combining it with technology licensing seems to be the more preferred strategy for exporting firms, non-exporting firms opt more for technology licensing alone in the face of reduction in rates of protection.

Tobit Estimates

Table 10 reports the estimated results of the various tobit models. The impact of various exogenous variables on the R&D and technology purchase *expenditures* is in the same direction as it was on the *probability* of undertaking these activities (the logit model). We will only focus here on the impact of rates of protection and exposure to world market through exports. Columns 2 and 4 report the estimated results of a set of equations where R&D expenditure is the dependent variable, and where foreign technology licensing is assumed to be exogeneous. The remaining two columns (3 and 5) report results for equations where foreign technology purchase expenditure is the dependent variable.

Column 2 shows that high rates of protection have a negative and significant impact on firm level R&D expenditures. Subject to problems of model specification discussed earlier, the same holds true for technology purchase expenditures (column 3). Thus, both inhouse R&D and foreign technology purchase expenditures are adversely affected by higher rates of protection. Given the consistency between logit and tobit estimates, one can broadly argue that high rates of protection not only reduce the incidence (probability of undertaking technological investments), but are also likely to reduce the intensity of such investments. The inclusion of an export dummy (columns 4 and 5) does not alter this result. Exposure to world markets significantly increases technological investments. While the fact that a firm exports goods seems to increase both technology purchase and R&D expenditures, the impact is somewhat stronger for technology purchase expenditures.

6. In Lieu of a Conclusion

Some earlier studies on India (Basant and Fikkert, 1996) have shown that R&D and technology purchase expenditures (especially the latter) had a significant and positive impact on firm level productivity during the late 1970s and early 1980s, the period of our study. For the same period, it was found that in-house R&D and foreign technology purchase are substitutes, at least in the short run (Basant, 1993; Basant and Fikkert, 1996; Fikkert, 1992). The results in the paper suggest that trade liberalisation may positively affect technological activity of firms resulting in higher R&D and foreign technology purchase expenditures. If all these results are robust, recent economic reform, of which reduction in rates of protection was one of the important measures, should result in higher technology related investments and, therefore, higher growth of total factor productivity at the firm level. As a proportion of sales, technology purchase expenditures seem to have increased, but R&D expenditures have declined. In fact, R&D expenditures as a proportion of sales in the private corporate sector declined from about 0.89 per cent in 1988-89 to about 0.67 per cent in 1995-96. This is probably a (short term) result of increases in foreign technology purchase expenditures, the two being substitutes.

The evidence on productivity growth in the manufacturing sector during the post-reform period has been a period of much debate. Various studies using different methodologies have shown divergent trends in productivity growth in this period. (See Table 11) These studies, however, do not probe the underlying causes which may result in higher or lower rates of productivity growth at the firm level (See for a review, Pushpangndan and Babu, 1997). The results of this paper are a small contribution in that direction. *Ceteris paribus*, the result of our empirical explorations would be more consistent with those studies which show a faster growth of total factor productivity in the 1990s.

The paper brings out empirically the complexity of strategic technology choices and the difficulties of analysing them. The differences in the technology strategies adopted by firms in different industries should be analysed further. Case studies and more detailed secondary data are necessary to adequately capture differences in industrial organisation and technology related characteristics discussed earlier.

However, on the whole, the significance of the coefficients and the marginals for various alternative technology strategies, clearly show that protectionism did not foster technological activity by Indian firms; in fact, it seems to have hampered technology related investments. Higher rates of protection discouraged firms from keeping abreast of recent technological developments through the `making' or purchasing of technology. These results are consistent with the macro-experiences of most countries:

> "....the evidence overwhelmingly indicates that projectionist policies have not fostered successful technological development except, perhaps, in those few countries where they have been coupled with additional policies that effectively insure the rapid achievement of internationally competitive levels of capability, so that protection is indeed a temporary `necessity'." (Evenson and Westphal, 1994 61)

The results also justify the recent policy initiatives taken in the Indian economy But as the Indian Government continues the movement towards an `open economy', forcing Indian firms to compete with the best, it will also have to see that the effective rates of protection do not become negative. The search for `additional' policies to help Indian firms beat the international competition should also be a conscious and continuous. Probably, therein lie the ingredients of a strategic trade policy.

Table 1: Sample means and standard deviations by technology strategy (choice) status

Variables	All Cases	Technology Strategy Status			
		None	Only T_o	Only T_{pif}	T_o and T_{pif}
Observations	5984 (100.0)	3024 (50.6)	1661 (23.7)	527 (8.6)	772 (13.0)
Sales (10^6 Rs.)	213.8 (429.6)	95.13 (125.6)	279.23 (406.5)	192.5 (277.2)	552.5 (884.5)
Effective Rates of Protection (**ERP**)	101.7 (40)	106.1 (39.9)	101.2 (40.5)	90.22 (38.1)	93.4 (37.9)
Licensing Policy Indicator (**TLP**)	11.1 (16.11)	9.33 (15.42)	9.6 (14.1)	18.07 (20.42)	16.5 (16.9)

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

Table 2: Coefficients of multinomial technology model-maximum likelihood logit estimates

Regressors	Only T_o	Only T_{pif}	T_o & T_{pif}
Intercept	-1.13 (-9.67)	-2.219 (-12.17)	-3.55 (-16.99)
Sales (10^8)	0.387[a] (15.91)	0.302[a] (10.51)	0.446[a] (18.44)
Capital Import Dummy (T_{pifk})	0.617[a] (8.51)	0.57[a] (5.27)	1.32[a] (11.75)
Other Imports Dummy (T_{pifo})	0.336[a] (4.37)	0.525[a] (4.23)	1.196[a] (7.52)
Effective Rate of Protection (**ERP**)	-0.006[a] -(6.07)	-0.009[a] (-5.91)	-0.008[a] (-6.04)
Multinational Participation Dummy (**MNP**)	0.602[a] (6.83)	0.470[b] (3.87)	0.869[a] (8.15)
Licensing Policy/Price (Inverse) Indicator (**TLP**)	.63e-4 (-2.43)	0.17e-3 (6.25)	0.16e-3 (5.69)
Log likelihood		6024.225	
χ^2		2059.8	
ρ^2		0.15	
N		5984	

Note: Figures in parentheses are t-ratios.
a- Significant at less than .00001 per cent.
b- Significant at less than .0001 per cent.

Table 3: Effects of regressor variables on technology strategy status - estimated marginals from a multinomial logit model

Regressors	None	Only T_o	Only T_{pif}	T_o & T_{pif}
Sales (10^{-8})	-0.093[a] (-16.19)	0.06[a] (11.64)	0.01[a] (7.77)	0.023[a] (14.36)
Capital Import Dummy (**T_{pifk}**)	-0.182[a] (-10.03)	0.077[a] (6.69)	0.018[a] (5.22)	0.086[a] (20.54)
Other Imports Dummy (**T_{pifo}**)	-0.13[a] (-6.78)	0.019 (1.6)	0.022[a] (6.79)	0.085[a] (19.57)
Effective Rates of Protection (**ERP**)	0.002[a] (7.24)	-0.0007[a] (-4.66)	-0.0005[a] (-10.71)	-0.0004[a] (-9.91)
Multinational Participation Dummy (**MNP**)	-0.155[a] (-7.7)	0.091[a] (6.38)	0.014 (3.31)	0.050[a] (11.8)
Licensing Policy/Price (Inverse) (**TLP**)	-.52e-5 (-0.82)	-.25e-4[a] (-6.29)	.16e-4[a] (11.84)	.13e-4[a] (11.35)

Note: Figures in parentheses are t-ratios.

a- Significant at less than .00001 per cent.

Table 4: Coefficients of multinomial technology model with exporter dummy maximum likelihood logit estimates

Regressors	Only T_o	Only T_{plf}	T_o & T_{plf}
Intercept	-1.21 (-10.14)	-2.33 (-12.48)	-3.82 (-17.42)
Sales (10^8)	0.36[a] (15.33)	0.28[a] (9.84)	0.423[a] (17.5)
Capital Import Dummy (**T_{pifk}**)	0.57[a] (7.8)	0.50[a] (4.64)	1.21[a] (10.7)
Other Imports Dummy (**T_{pifo}**)	0.27[a] (3.4)	0.421[a] (3.32)	1.03[a] (6.4)
Effective Rate of Protection (**ERP**)	-0.006[a] (-6.19)	-0.009[a] (-6.06)	-0.008[a] (-6.29)
Multinational Participation Dummy (**MNP**)	0.57[a] (6.45)	0.430[b] (3.55)	0.828[a] (7.76)
Licensing Policy/Price (Inverse) Indicator (**TLP**)	-0.65e-4 (-2.54)	0.17e-3 (6.15)	0.15e-3 (5.47)
Exporter Dummy (D)	0.298 (4.04)	0.44 (3.93)	0.78 (6.31)
Log likelihood	-5996.719		
χ^2	2114.82		
ρ^2	0.15		
N	5984		

Note: Figures in parentheses are t-ratios.
a- Significant at less than .00001 per cent.
b- Significant at less than .0001 per cent.

Table 5: Effects of regressor variables on technology strategy status - estimated marginals from a multinomial logit model with exporter dummy

Regressors	None	Only T_o	Only T_{pif}	T_o & T_{pif}
Sales (10^{-8})	-0.08[a] (-15.4)	0.06[a] (11.39)	0.01[a] (7.25)	0.02[a] (13.9)
Capital Import Dummy (T_{pifk})	-0.166[a] (-9.09)	0.074[a] (6.32)	0.015[a] (4.35)	0.076[a] (19.3)
Other Imports Dummy (T_{pifo})	-0.1[a] (-5.42)	0.014 (1.18)	0.019[a] (5.23)	0.071[a] (17.61)
Effective Rates of Protection (**ERP**)	0.002[a] (7.39)	-0.0007[a] (-4.72)	-0.0005[a] (-10.91)	-0.0004[a] (-10.5)
Multinational Participation Dummy (**MNP**)	-0.14[a] (-6.64)	0.088[a] (6.08)	0.012 (2.86)	0.046[a] (11.3)
Licensing Policy/Price (Inverse) (**TLP**)	-0.43e-5 (-0.67)	-0.25e-4[a] (-6.18)	.16e-4[a] (11.66)	.131e-4[a] (10.76)
Exporter Dummy (D)	-0.101 (-5.53)	0.027 (2.35)	0.023 (6.52)	0.05 (14.51)

Note: Figures in parentheses are t-ratios.
a- Significant at less than .00001 per cent.

Table 6: Coefficients of multinomial technology model for exporting firms maximum likelihood logit estimates for exporting firms

Regressors	Only T_o	Only T_{plf}	T_o & T_{plf}
Intercept	-0.62 (-3.51)	-1.67 (-6.56)	-2.54 (-9.79)
Sales (10^8)	0.38[a] (13.47)	0.304[a] (8.99)	0.45[a] (15.61)
Capital Import Dummy (T_{pifk})	0.74[a] (8.18)	,0.49[a] (3.83)	1.24[a] (9.6)
Other Imports Dummy (T_{pifo})	0.25[a] (2.31)	0.34[a] (2.04)	0.76[a] (4.13)
Effective Rate of Protection (**ERP**)	-0.008[a] -(7.2)	-0.009[a] (-5.02)	-0.01[a] (-6.68)
Multinational Participation Dummy (**MNP**)	0.47[a] (4.65)	0.226[b] (1.61)	0.707[a] (5.97)
Licensing Policy/Price (Inverse) Indicator (**TLP**)	-0.11e-3 (-3.57)	0.13e-3 (3.6)	0.13e-3 (3.8)
Log likelihood	-4099.518		
χ^2	1254		
ρ^2	0.15		
N	3721		

Note: Figures in parentheses are t-ratios.
a- Significant at less than .00001 per cent.
b- Significant at less than .0001 per cent.

Table 7: Effects of regressor variables on technology strategy status - estimated marginals from a multinomial logit model for exporting firms

Regressors	None	Only T_o	Only T_{pif}	T_o & T_{pif}
Sales (10^{-8})	-0.084[a] (-15.9)	0.047[a] (9.78)	0.005[a] (4.05)	0.03[a] (13.08)
Capital Import Dummy (**T_{pifk}**)	-0.178[a] (-8.69)	0.074[a] (6.45)	-0.008[a] (-2.27)	0.11[a] (18.63)
Other Imports Dummy (**T_{pifo}**)	-0.08[a] (-3.54)	-0.004 (-0.33)	0.008[a] (1.98)	0.08[a] (12.75)
Effective Rates of Protection (**ERP**)	0.002[a] (7.65)	-0.0009[a] (-6.03)	-0.0003[a] (-6.27)	-0.0007[a] (-9.86)
Multinational Participation Dummy (**MNP**)	-0.106[a] (-4.7)	0.056[a] (4.37)	-0.012 (-3.16)	0.06[a] (10.55)
Licensing Policy/Price (Inverse) (**TLP**)	0.24e-5 (0.33)	-0.43e-4[a] (-10.04)	0.17e-4[a] (11.65)	.23e-4[a] (11.6)

Note: Figures in parentheses are t-ratios.

a- Significant at less than .00001 per cent.

Table 8: Coefficients of multinomial technology model- maximum likelihood logit estimates for non-exporting firms

Regressors	Only T_o	Only T_{plf}	T_o & T_{plf}
Intercept	-1.447 (-8.68)	-2.30 (-7.9)	-4.78 (-11.27)
Sales (10^8)	0.294[a] (6.36)	0.25[a] (3.9)	0.451[a] (7.75)
Capital Import Dummy (**T_{pifk}**)	0.28[a] (2.22)	0.59[a] (2.93)	1.08[a] (4.38)
Other Imports Dummy (**T_{pifo}**)	0.24[a] (2.15)	0.419[a] (2.09)	1.51[a] (4.42)
Effective Rate of Protection (**ERP**)	-0.002[a] -(1.56)	-0.01[a] (-4.28)	-0.004[a] (-1.607)
Multinational Participation Dummy (**MNP**)	0.75[a] (4.17)	0.94[b] (3.86)	1.24[a] (4.7)
Licensing Policy/Price (Inverse) Indicator (**TLP**)	-0.14e-4 (-0.34)	0.21e-3 (4.75)	0.15e-3 (2.54)
Log likelihood	-1868.62		
χ^2	428.04		
ρ^2	0.15		
N	2263		

Note: Figures in parentheses are t-ratios.

a- Significant at less than .00001 per cent.

b- Significant at less than .0001 per cent.

Table 9: Effects of Regressor Variables on Technology Strategy Status
Estimated Marginals from a Multinomial Logit Model for Non-Exporting Firms

Regressors	None	Only T_o	Only T_{plf}	T_o & T_{plf}
Sales (10^{-8})	-0.063[a] (-6.3)	0.04[a] (5.6)	0.008[a] (4.7)	0.007[a] (8.4)
Capital Import Dummy (**T_{pifk}**)	-0.084[a] (-3.1)	0.037[a] (1.8)	0.02[a] (4.9)	0.021[a] (8.4)
Other Imports Dummy (**T_{pifo}**)	-0.078[a] (-3.2)	0.03 (1.6)	0.016[a] (3.7)	0.03[a] (10.8)
Effective Rates of Protection (**ERP**)	0.0008[a] (2.9)	-0.0002[a] (-0.9)	-0.0005[a] (-8.4)	-0.68e-4[a] (-3.2)
Multinational Participation Dummy (**MNP**)	-0.175[a] (-4.5)	0.115[a] (3.8)	0.03 (5.1)	0.02[a] (6.8)
Licensing Policy/Price (Inverse) (**TLP**)	-0.81e-5 (-0.9)	-0.59e-5[a] (-0.9)	0.11e-4[a] (5.9)	.31e-4[a] (4.5)

Note: Figures in parentheses are t-ratios.

a- Significant at less than .00001 per cent.

Table 10: Maximum likelihood tobit estimates for all firms

Regressors	RDS	TPES	RDS	TPES
Intercept	-2.628 (-15.18)	-7.168 (-18.33)	-2.76 (-15.6)	-7.4 (-18.3)
Foreign Technology Licensing Expenses (T_{plf}, 10^{-6})	-0.104 (-5.8)			
Sales (10^{-8})	0.7 (70.2)	0.242 (13.9)	0.69 (69.4)	0.23 (13.5)
Capital Imports Dummy (T_{pifk})	0.72 (6.8)	2.09 (9.95)	0.62 (5.8)	1.97 (9.2)
Other Imports Dummy (T_{pifo})	0.43 (3.6)	1.85 (7.16)	0.32 (2.62)	1.68 (6.3)
Effective Rate of Protection (ERP)	-0.011 (-8.72)	-0.014 (-5.6)	-0.011 (-8.92)	-0.015 (-5.7)
Export Dummy			0.48 (4.3)	0.72 (3.15)
Multinational Participation Dummy (**MNP**)	1.064 (9.57)	0.85 (3.95)	1.033 (9.27)	0.81 (3.79)
Licensing Policy/ Price (Inverse) Indicator (**TLP**)	.94e-4 (3.02)	0.42e-3 (7.37)	0.9e-4 (2.88)	0.42e-3 (7.3)
σ	2.95	4.95	2.95	4.96
Log Likelihood/Adj. R^2	-7588	-5237	-7579	-5232

Notes: Figures in parentheses are the t-values.

Table 11: Estimates of total factor productivity in the Indian manufacturing sector

Measure used	Time period	Data used	Result	Source
Translog	1959-60 to 1985-86	ASI	TFPG of0-4% per annum during 1959-60 to 1985-86 Turnaround from 1980-81 to 1985-86.	Ahluwalia (1991)
Translog, Cobb-Douglas	1970-71 to 1988-89	CSO, NAS	1970-80: .3% 1980-88:.65% 1970-88:.92%	Mohanty (1992)
Growth Accounting	1960-88	ASI	Deceleration in TFPG in 1980s	Balakrishna and Pushpangadan (1994)
Growth Accounting	1980-89	RBI	Decline in TFPG after 1987	Srivastava (1996)
Translog, Cobb-Douglas		ASI	Increase in TFPG after 1987	Srivastava (1996)
Growth Accounting	1973-74 to 1992-93		Decline in TFPG in the 1980s	Rao (1996)

Source: Pushpangadan and Babu (1997)

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Appendix I

The Logit 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 (e),

$$V_{ij} = b_j X_i + e_{ij} \qquad (1)$$

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,

$$P_{ij} = Pr(V_{ij} > V_{ik} \text{ for } k \neq j) \qquad (2)$$

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,

$$P_{ij} = \exp(b_j X_i) / S_{k\hat{j}} \exp(b_k X_i) \qquad (3)$$

McFadden (1974) suggested a `conditional logit model' which considers the effects of the characteristics of the choice and the individual agent in the determination of the choice probabilities. The multinomial logit model considered here makes the choice probabilities dependent on individual characteristics only (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 (**h_{jk}**) are evaluated at the sample means (Cramer, 1991).

$$h_{jk} = X_k (dP_j/dX_k) \qquad (4)$$

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

$$S_j h_{jk} = 0 \qquad (5)$$

Quasi-elasticities are superior to the b 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,

$$r^2 = 1 - [L(b)/L(b_0)] \qquad (6)$$

Appendix II

The Details of Data

1. Industry Level Data

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 normalise this variable. For this purpose the estimates for the year 1980-81 provided in Ahluwalia (1991) Table 2.3, were used.

Effective Rates of Protection: The estimates of effective rates of protection (ERP) have been compiled from Goldar and Saleem (1992).

$$\mathbf{ERP = EPC - 1}$$

EPC, the effective protection coefficient, is given as a ratio of value added evaluated at domestic prices and at world prices. That is:

$$\mathbf{EPC = (p - m) / (p / (1 + t_0) - m / (1 + t_i))}$$

where, **p** is the price of the commodity in the domestic market, m is the cost of the intermediate input at domestic prices, $\mathbf{t_o}$ is the nominal tariff rate on output and $\mathbf{t_i}$ is the average nominal tariff rate on intermediate inputs.

Estimates of ERP can also be computed on the basis of international and domestic prices. The tariff based estimates of ERP used in the paper have been criticized on theoretical and methodological grounds. Given the data and other limitations, the debate on the relative reliability of the two sets of estimates is yet to be settled. (See, Goldar and Saleem, 1992)

2. 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. I am grateful to Brian Fikkert for sharing these data with me. Industrial machinery and chemicals firrms were chosen from this data set. For some of these firms, data are available for six years (1974-75 to 1979-80) and for others for nine years (1974-75 to 1982-83). The overall sample has 5717 observations . The ISID data provides information on expenditures on R&D, technology licensing, import of capital and other inputs. It also contains data on capital stock, sales, value added, wages, foreign equity participation etc. The estimates in value terms have been inflated to constant 1980 rupees. Industry specific wholesale price indices were used for this purpose. Some other adjustments were also made in these data.

The R&D expenditures of the firms included in the sample were checked with the **Compendiums on In-house R&D Centers** published from time to time by the DST. These volumes indicate the initial year of recognition for each firm's R&D unit, its R&D expenditures and sales. This cross-checking revealed that many firms which were recognised by the DST failed to itemise their R&D expenditures in the annual reports. For such firms the R&D estimates in the ISID data set were corrected by utilising the DST information. Since the Compendiums often provide an individual firm's R&D expenditures only for years after 1980, these estimates were interpolated back to the firm's initial years of recognition. The procedure adopted was to use the average growth rate in the R&D sales ratio for the firm's industry (provided in volumes of **R&D Statistics**) to interpolate the firm's published R&D-sales ratio back on an annual basis to its initial year of recognition. Since each firm's sales are known for any given year, these R&D-sales ratios could then be converted into R&D estimates.

Unfortunately, the Compendiums do not contain detailed information about all the recognised R&D units. Besides, when patent data were matched with the ISID data many firms which had taken out patents in the relevant years did not report R&D expenditures in their annual reports. For the firms which had recognised R&D units and/or had patents assigned to them but did not report R&D expenditures, the average R&D-sales ratio for the industry was applied to generate R&D estimates.

Obviously, these adjustments are not perfect but they are likely to be a substantial improvement over previous studies which have relied exclusively on annual report data. The data on technology purchase expenditures was also checked with the information contained in the **Directory of Foreign Collaborations in India**. This cross-checking revealed no serious discrepancies (Fikkert,1993).