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TECHNOLOGY PRODUCTION AND TECHNOLOGY PURCHASE IN INDIAN INDUSTRY: AN ECONOMETRIC ANALYSIS

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1. INTRODUCTION

While there is a large literature on the determinants of technological innovation (Kamien and Schwartz, 1975; Scherer, 1980), most of it has been in the context of developed countries, particularly the United States. There is little systematic study of the determinants of inventive activity in the manufacturing sectors of the less-developed countries. Yet in these countries inventive activity, although at a low level, appears to be growing rapidly. It is also possible that the returns to innovative effort are much greater in the less-developed countries than in the developed countries because of the scope for complementarity between invention and imitation of existing technology.

An attempt is made in this paper to study the determinants of innovation in the manufacturing sector of India, using industry-level data over the period 1960 to 1970. Our approach differs from earlier approaches in that we embed the demand for inventive activity in a conventional system of factor demand equations. Since foreign technology purchase, either outright or on a licensing basis, is an alternative (possibly complementary) to in-house research and development for a firm in a less-developed country, the demand for foreign technology is also included in the demand system. This allows us to look at the substitutability/complementarity relationships, say, between production labor and local innovation activity or between non-production labor and foreign technology use. We also include several policy variables, such as the presence of multinationals, the level of international inventive activity, the size of the public sector, and average firm size in an industry, as fixed factors in the system, and are able to observe the reduced-form effect of these factors on inventive activity and on foreign technology use within the framework of the demand system.

The empirical results suggest that inventive activity as well as foreign technology purchase are not strongly related to average firm size in the Indian context. International inventive activity, on the other hand, has strong positive effects on both local innovation and foreign technology purchase, which suggests that it increases the pool of inventions that can be both imitated and produced within India as well as licensed or sold to India. The presence of the foreign sector within an industry is associated with less local innovation, while that of the public sector is associated with more local innovation. All of these findings have important policy implications which are discussed later in the paper.

2. LOCAL INNOVATION AND THE USE OF FOREIGN TECHNOLOGY IN INDIA

Although the level of inventive activity in India is low relative to the developed countries and the semi-industrialized countries (e.g., Brazil and South Korea), it has been growing quite rapidly over time. Table 1 shows the expenditures on research and development (R&D) and on foreign technology purchase by all private and public sector companies in India from 1964-65 to 1969-70. R&D expenditure is observed to have grown at a trend rate of 26.0 per cent per annum over this short period. In contrast, expenditure on foreign technology purchase increased at a rate of 16.2 per cent per annum.[1]

In Table 2, the number of patents granted to Indian nationals -- a crude measure of inventive output -- are shown for the period 1954-57 to 1967-70 for each of 15 major industries. In no industry did the level of patenting fall over this period. Further, patents grew at a trend rate of over 10 per cent per annum in almost half of these industries, viz., food processing, textile products, chemicals, basic metals, metal products, machinery, and transport equipment. The average rate of growth of patenting by nationals was 8.4 per cent per annum over the period. There has thus been a rapid growth of inventive activity in Indian manufacturing at least during the decade of the 1960s. At the same time, the use of foreign technology has also grown at a rapid rate.

Table 1

R & D Expenditures and Payments for Foreign Technology: Indian Industries, 1964-1965 to 1969-1970

(In Millions of Rupees)

Year	R & D Expenditure on Current and Capital Account	Royalty and Technical Fee Payments for Foreign Technology
1964-65	105.1	76.9
1965-66	143.7	101.6
1966-67	178.2	142.4
1967-68	261.7	133.3
1968-69	310.7	162.2
1969-70	378.5	183.1
Trend rate of growth over the period	26.0	16.2

Source: Reserve Bank of India, Foreign Collaboration in Indian Industry: Second Survey Report, 1974, Bombay (India), pp. 25 and 138.

Table 2

Number of Patents Granted to Nationals in India, by Industry and Year, 1954-57 to 1967-70

Industry	Year 1954-57	1958-61	1962-66	1967-70	Trend rate of Growth over 1954-57/1967-70
Food Processing	26	69	123	132	12.4
Textile Manufacturing	52	76	92	86	3.8
Jute Manufacturing	1	2	4	3	8.9
Textile Products	4	6	9	19	11.9
Wood Products	4	5	7	8	5.6
Paper and Printing	21	28	54	50	7.4
Leather	22	13	18	23	1.2
Rubber and Plastics	18	33	55	59	9.3
Chemicals	46	92	137	251	12.7
Non-Metallic Mineral Products	25	54	72	85	9.0
Basic Metals	1	2	12	7	17.2
Metal Products	2	7	9	14	14.0
Machinery	10	37	48	74	14.4
Electrical Equipment	4	26	13	16	7.8
Transport Equipment	8	36	34	47	12.0
All Industries	244	486	687	742	8.4

3. THE MODEL

The framework we use to study the twin decisions of inventive activity and foreign technology purchase is the standard demand system framework. We incorporate the two firm decisions within a conventional system of factor demand equations arising out of cost-minimizing behavior by the firm. Using the duality theorems of Uzawa (1964), Shephard (1970), and McFadden (1978), it is possible to completely describe the nature of the production technology from the cost function. In what follows, we shall assume that firms minimize the costs of producing a given output subject to a production function which includes own inventive activity and foreign technology as factor inputs.

Duality theory imposes strict restrictions on the specification and estimation of factor demand equations. For instance, symmetry restrictions across equations arising out of cost-minimizing or profit-maximizing behavior on the part of economic agents, as well as homogeneity restrictions derived from the underlying production technology, have to be generally imposed in the estimation of a factor demand system. These restrictions are not too difficult to implement when estimating a conventional and complete demand system, i.e., one in which quantity and price data are available for all inputs. In this paper, the presence of two inputs, innovation activity and foreign technology use, for which price data are not readily available

-- in fact, both factors have unobserved shadow prices -- requires a relaxation of this specification requirement. The choice of an appropriate functional form for the demand system will also depend to a large extent on this limitation in the data. Our approach in this paper is to estimate a system of demand equations which is easily estimable given the available data, with a minimum of prior restrictions imposed.

Among the three most common flexible functional forms for a cost function -- the generalized Leontief, the translog, and generalized quadratic -- only the latter yields a system of factor demand equations that is estimable even in the absence of data for some prices in the system. We thus assume that the underlying technology is characterized by the cost function:

$$
\begin{aligned}
(1) \qquad C = {} & \sum_i a_i p_i + \sum_i \sum_j^{n-1} b_{ij} p_i (p_j/p_n) + \\
& c_1 Q + c_2 Q^2 + \sum_i d_i p_i Q + \\
& \sum_k e_{1k} Z_k + \sum_k e_{2k} Z_k^2 + \sum_i \sum_k f_{ik} p_i Z_k + \sum_i \sum_k g_{ik} p_i Z_k^2,
\end{aligned}
$$

$$b_{ij} = b_{ji} \quad \forall \quad i,j=1,n-1;\ i \neq j;$$

where C = total costs, Q = total output, p_i = price of the ith variable input, and Z_k = level of the kth fixed factor.

Equation (1) represents a generalized quadratic cost function (Fuss et.al., 1978; Lau, 1978) which is linear homogenous in input prices. The symmetry restrictions inherent in equation (1), viz., $b_{ij} = b_{ji}$ $\forall$

i,j=1,n-1; $i \neq j$, should be imposed for efficiency in estimating the factor demand equations corresponding to the cost function.

Using Shephard's lemma and differentiating (1) with respect to p_i, we obtain the individual factor demand equations:

$$(2) \qquad X_i = \partial C/\partial p_i = a_i + \sum_{j}^{n-1} b_{ij}(p_j/p_n) + d_i Q + \sum_k f_{ik}Z_k + \sum_k g_{ik}Z_k^2, \quad \forall\, i,$$

$$b_{ij} = b_{ji}, \quad \forall\ i,j=1,n-1;\ i \neq j;$$

where X_i = quantity of the ith variable input. It is the system in equation (2) that is estimated in this paper.

In estimating a system of industry demand equations derived from a cost function, two important assumptions have been maintained. First, by using industry-level data for our analysis, we assume that the average firm in an industry is representative of all the firms in that industry. Although this is a restrictive assumption, it has been made before in the literature (Griliches, 1967; Zarembka, 1970; Dennis and Smith, 1978) and is necessitated by the unavailability of firm-level data at this time.[2] Second, it is assumed that input prices and output are exogenous variables at the industry level. This is not not an unreasonable assumption in the Indian context, where government intervention in the form of capacity licensing and price setting has been very common at least during the decade of the 1960s (Bhagwati and Desai, 1970). It is, therefore, not unrealistic to characterize Indian firm behavior as that of minimizing costs for given levels of input prices and output.

The treatment of technology purchase as measured by payments of royalty and technical fees and localized inventive activity as variable factors of production requires more justification. These activities are normally viewed in an investment framework. Our reasons for treating them as variable inputs are twofold. First, both activities have a real element of variability. Second, the conventional investment framework has not proven to be very illuminating for the questions that we have in mind.

Technology purchase is quite variable since many of the contractual arrangements are quite short term in nature. Technical assistance, for example, is often provided only for short periods and arrangements can be changed quite rapidly. Invention by Indian firms tends also to be quite adaptive and while it has an investment component the time period over which an investment is superior is relatively short.

4. DATA AND ESTIMATION

The variables used in the analysis, and their means and standard deviations, are listed in Table 3. (See the Appendix for data sources.) A total of five variable inputs are distinguished: production labor, non-production labor, fuel, patenting in India by nationals, and royalty and technical fee payments for foreign technology. Capital is treated as a fixed factor, and not a variable input, since government capacity licensing makes capital stock exogenous to the firm's decisions, at least in the short run.

While data on production labor are available in man-hours, data on non-production labor are available only in numbers of employees. Patenting in India by nationals is used as a proxy for local inventive input (and not for inventive output, as it is the case in much of the literature), since industry-specific data on R&D expenditures or R&D personnel are not available for the period 1960-70. While patenting is a crude proxy for inventive activity, particularly in India where a system of utility models or "petty" patents (minor adaptive inventions) does not exist, almost all other quantitative measures of inventive activity, including R&D expenditures, are also likely to be crude proxies for inventive input. Most of the R&D conducted in less-developed countries is informal or 'blue-collar' R&D, which is largely conducted outside the formal R&D divisions of companies.[3] At the same time, the companies that do have R&D divisions have a strong incentive

Table 3

Variable Means: Indian Industries 1960-1970

	Light Industries[d]	Chemical Industries[e]	Engineering Industries[f]	All Industries
Production Labor[a] (in man-hours)	687,635	1,092,343	864,790	836,425
Number of Non-Production Workers[a]	32.70	112.50	252.88	122.92
Fuel Consumption (= Expenditure on Fuel ÷ Fuel Price Index)[a]	1,143	12,955	3,341	4,509
Technology Imports (Royalty and Technical Fee Payments for Foreign Know-How)[a]	33,510	57,451	948,175	339,492
Domestic Patenting (Number of Patents X 1000 Granted to Nationals in India)[a]	432	183	215	305
W_P (Hourly Wage Rate for Production Labor)	0.52	1.00	0.83	0.73
W_N (Annual Wage Rate for Non-Production Workers)	3,948	8,073	5,119	5,256
P_F (Price Index for Fuel)[b]	120.02	120.16	117.35	119.17
USPATNTS (Cum. No. of Patents Granted in USA over previous 5 years)[a]	126.80	326.77	1,389.33	586.51
FORSHARE (Share of Equity Held by Foreigners over the Period 1965-1970)[c]	26.81	13.63	23.22	22.68
PUBSHARE (Share of Production in Public-Sector Enterprises over Period 1970-1973)[c]	3.70	15.75	18.17	11.15
FIXEDCAP (Fixed Capital Stock in Rupees)[a]	1,008,852	19,517,808	4,217,698	6,241,176
OUTPUT (Gross Output in Rupees)[a]	5,150,564	25,268,988	6,224,962	10,005,713
Number of Observations	192	96	141	429

Notes: [a]Variable has been divided by the total number of firms in the industry. The means, therefore, reflect the situation of the average firm in the industry.

[b]Variable varies only with time.

[c]Time-invariant variable.

[d]Include all food manufacturing, beverage, tobacco, textile spinning and weaving, and knitting industries.

[e]Include basic industrial chemicals (including fertilizer), miscellaneous chemical products, petroleum and coal products, and cement industries.

[f]Include metal products, machinery, electrical machinery and equipment, transport equipment, railroad equipment, and automobile and cycle industries.

to overstate their R&D expenditures, since the Indian tax system allows liberal concessions for company R&D expenditure.

Royalty and technical fee payments for foreign technology is used as a proxy for foreign technology input. Since the variable is expressed in terms of expenditure on foreign technology purchase, the estimated elasticities from this equation have to be interpreted as expenditure, and not quantity, elasticities. There are data problems with the foreign technology payments variable. Since there are government restrictions on profit repatriation by foreign companies based in India, there is always a strong incentive for these companies to engage in overinvoicing of foreign technology imports, especially when these originate from their parent companies abroad. While it is important to be aware of these data limitations, little can be done about them. Since we treat both patents granted to nationals and payments for foreign technology as endogenous variables, errors of measurement are part of the general error structure of this model.

Data on three prices -- the wage rate for production labor, the wage rate for non-production employees, and the price index for fuel -- are available. The latter varies only over time, not across industries. We have included a variable measuring international inventive activity which we treat as a proxy for the "price" of both domestic invention and foreign technology purchase. The price or cost of domestic invention is lowered by an increase in international inventive activity, because adaptive invention is made easier. The real price of foreign technology is also lowered by an increase in international inventive activity, since the latter shifts the supply curve of internationally-available technology. Homogeneity restrictions have,however, been applied only to the actual price terms in the estimation procedure.

Four fixed factors or Z variables have been included in the system. These are the fixed capital stock, the share of equity held by foreigners, the share of output produced in public-sector (state-owned) firms, and the cumulative number of patents granted in the United States (to nationals and foreigners) over the previous five years. The latter is a proxy for the rate of nternational innovation activity. One of the important concerns in this paper is the relationship between patenting by nationals in India and international patenting. The latter could have either a blocking effect on Indian patenting, in which case the relationship would be negative, or a disclosure effect, in which case the relationship would be positive.

The total sample includes observations on 50 three- and four-digit manufacturing industries over the period 1960-70. The sample of industries has been divided into three groups: light industries, comprising food processing, beverages and tobacco, textile spinning and weaving, and knitting industries; chemical industries, comprising basic industrial chemicals (including fertilizer), miscellaneous chemical products, petroleum and coal products, and cement industries; and engineering industries, comprising metal products, machinery, electrical machinery and equipment, transport equipment, and automobile and cycle industries. For estimation purposes, cross-sectional and time-series data have been pooled within each of the three groups. We thus assume a high degree of similarity of technologies within each of the three industry groups. A full set of three-digit industry dummies has been included in the systems to isolate industry shift effects.[4]

Since the industry-level variable are totals over a varying number of firms in each industry, all dependent and independent variables, with the exception of the output share of the public sector and the equity share of the foreign sector, have been divided by the number of firms in the industry prior to estimation. This procedure removes a potential source of heteroscedasticity in the residuals of the demand equations.

The systems shown in equation (2) have been estimated jointly by the iterative Zellner (1963) method, taking account of error interdependence and symmetry restrictions across equations. This assures us of efficient estimates for the systems. Note that since all the prices have been divided by the price of fuel (to impose homogeneity of degree zero in prices on the demand equations), the symmetry restrictions in effect apply only to the production and non-production labor demand equations.

5. SOME HYPOTHESES

The cost function model predicts the own-price effects on factor demand to be negative. Furthermore, since more output cannot be produced with less of any input (assuming that the firm is cost-minimizing), the effect of output level on factor demand will generally be positive. These are the predictions readily based on theory. We can, however, provide further plausible hypotheses.

It is unlikely that production and non-production labor are substitutes for each other, since the two types of labor perform very different (complementary) tasks. One could almost regard non-production employees as support staff for production workers in a firm, in which case the two types of labor would be strong complements. Fuel and production labor are also likely to be complements to each other, while the relationship between non-production labor and fuel is difficult to predict. If domestic inventive activity is primarily labor-saving, production labor and local patenting will be substitutes for each other. On the other hand, non-production labor, which includes technicians and scientists who are engaged in inventive activity, may well be complementary to patenting by nationals in India. In fact, however, technicians and scientists are likely to constitute such a small proportion of the non-production labor force that the complementarity between them and inventive activity is probably not going to be noticeable from the empirical results.

International inventive activity is hypothesized to have an adverse effect on labor demand, since most inventions developed in the Western countries (and subsequently imitated in or imported into India) are labor saving. International patenting (proxied by patenting in the United States) can have two opposite effects on Indian patenting. If U.S. patents are primarily used by international companies for blocking purposes, they will have an adverse effect on Indian patenting. However, U.S. patenting can also have a disclosure effect whereby Indian companies can learn of an invention which they would otherwise not have known about, modify it, and patent an adapted invention in India. By increasing the pool of knowledge from which to learn, imitate, and adapt, international inventions can have a positive effect on Indian inventive activity. The net effect of international inventive activity on Indian innovation will depend on the relative magnitudes of the blocking and disclosure effects.

The impact of international inventive activity on the purchase of foreign technology is closely related to its impact on local inventive activity. If international inventions result in increased local innovations, and if local innovation and foreign technology purchase are substitutes for each other, the relationship between international inventive activity and foreign technology purchase will be negative. On the other hand, if international inventions depress local innovation, the relationship will be positive.

The effect of foreign ownership on local inventive activity is hypothesized to be negative, since a foreign company in India is more likely to use innovations developed by its parent company in the home country than to do its own R&D locally. In a survey of U.S.-based multinational corporations, Mansfield et.al. (1979) found that, on average, 29 to 34 per cent of the profit returns from R&D projects came from overseas exploitation. The multinationals estimated that their R&D budgets would be reduced from 12 to 15 per cent if they were unable to pass innovations on to their foreign subsidiaries. This observation suggests that, holding other things constant, foreign companies in India will tend to import more technology from abroad (especially from their parent companies) than locally-owned companies. (Since the foreign technology input in this paper is defined in terms of expenditure, it is not possible to separate the (hypothesized) positive effect of foreign ownership on foreign technology use from its effect on overinvoicing of technology imports, which is likely in a situation where there are government curbs on profit repatriation. A positive relationship between foreign ownership and foreign technology imports may, therefore, imply that foreign companies in India are using more foreign technology than locally-owned companies or that they are paying a higher price per unit of foreign technology.)

The size of the public sector in an industry is also likely to be an important variable in explaining local inventive activity and reliance on foreign technology. One of the important motives for establishing public-sector companies in India was to promote self-reliance and independence in national technological needs (Industry Policy Resolution of 1948). Public-sector companies thus have a mandate to engage in substantial research and development. It is, therefore, not surprising that some of the largest in-house R&D laboratories in India often belong to state-owned enterprises. Many Indian public-sector companies are engaged today in technology exports to other less-developed countries! We, therefore, expect the size of the public sector in an industry to be positively related to inventive activity in that industry and -- assuming local inventive activity and foreign technology to be substitutes for each other -- negatively related to foreign technology use.

Finally, the relationship between inventive activity and firm size is of interest, since it has produced a large literature in the context developed countries. The general evidence from developed countries is that, with the possible exception of the chemical industry, the intensity of research effort (i.e., research effort deflated by a measure of firm size) does not increase with firm size. This implies that the elasticity of research effort with respect to firm size is positive but less than unity (Worley, 1961; Hamberg, 1966; Mueller, 1967; Mansfield, 1968). In some cases, research intensity has been found to initially increase but then decrease with firm size (again with the exception of the chemical industry) (Scherer, 1965a; Grabowski, 1968). Most of the above studies have used R&D expenditure as percentage of sales or R&D employees as percentage of total employees as their dependent variables.

Studies that have used patents as a measure of inventive activity have generally found the relationship between the absolute number of patents granted and firm size to have an inverted U-shape (Scherer, 1965b; Johannisson and Lindstrom, 1971). This suggests that "... beyond some magnitude, size does not appear especially conducive to either innovational effort or output in either this country or in European countries where studies have been conducted... It seems noteworthy that the chemical industry is cited as an exception both for the U.S. and abroad" (Kamien and Schwartz, 1975, p. 19).

In this paper, the fixed capital stock and output variables will provide a measure of firm size effects. On the basis of the results obtained in other countries, we expect domestic patenting to increase at a diminishing rate with firm size.

6. RESULTS

The regression results for the light, chemical, and engineering industry groups are presented in Tables 4, 5, and 6, respectively. The results are generally good in that they are largely consistent with the predictions of production theory. For instance, out of a total of nine own-price effects that have been estimated (three for each industry group), only one has the wrong sign (and this is not significant). Six of the nine own-price effects have the right signs and are significantly different from zero. Furthermore, with the exception of domestic patenting, all inputs have positive output effects, as would be expected of non-inferior inputs. Finally, the symmetry restrictions across equations can be rejected only for the engineering industries.

A large number of the coefficients on the squared fixed factor variables are significant, indicating the presence of non-linearities in input demand with respect to the fixed factors. Because the fixed factors enter the demand equations both in linear and quadratic form, the partial derivatives of the inputs with respect to the fixed factors vary with the levels of the fixed factors. The partial derivatives have been evaluated at the sample means of each industry group and reported in Table 7.

Finally, the elasticities of demand with respect to prices and with respect to the fixed factors (including output) have been computed and

Table 4

Estimated System of Factor Demand Equations -
Light Industries, India, 1960-70

(Normalized Quadratic Cost Function)

(asymptotic t-statistic in parentheses)

Independent Variables	Production Labor	Non-Production Labor	Fuel	Technology Imports	Domestic Patenting
W_P/P_F	-409,347,106*	-5,576.22*	-128,956	-6,329,136	16,708.2
	(-9.8)	(-6.3)	(-1.5)	(-1.2)	(0.5)
W_N/P_F	-5,576.22*	-0.39*	1.27	474.99	4.73*
	(-6.3)	(-5.4)	(0.1)	(0.9)	(1.6)
USPATNTS	-2,099.06*	-0.04*	2.35*	409.68*	4.26*
	(-4.9)	(-4.2)	(2.8)	(8.2)	(14.2)
USPATNTS Squared ($X10^4$)	12,865.61*	0.28*	-15.26*	-2,524.13*	-17.05*
	(3.0)	(3.2)	(-1.8)	(-5.11)	(-5.7)
FORSHARE	4,168,019*	-65.66	14,235.4*	-213,083.2	-347.76
	(1.9)	(-1.4)	(3.3)	(-0.8)	(-0.2)
FORSHARE Squared	-87,365.52*	1.35	-295.42*	4,335.47	7.76
	(-1.9)	(1.4)	(-3.3)	(0.8)	(0.2)
PUBSHARE	1,476,072*	-12.36	3,945.81*	-79,567.92	-73.39
	(2.4)	(-0.9)	(3.2)	(-1.1)	(-0.2)
PUBSHARE Squared	-168,779.6*	1.71	-484.30*	9,582.17	10.58
	(-2.2)	(1.0)	(-3.2)	(1.7)	(0.2)
FIXEDCAP ($X10^4$)	1,818.81	0.16*	11.21*	-68.57	-0.31
	(1.5)	(6.2)	(4.5)	(-0.5)	(-0.4)
FIXEDCAP Squared ($X10^{12}$)	132,064*	1.75*	-89.32*	-678.67	12.87
	(5.7)	(3.5)	(-1.9)	(-0.2)	(0.8)
OUTPUT ($X10^4$)	396.99*	0.02*	1.00*	7.43	-0.09*
	(6.1)	(11.2)	(7.8)	(1.0)	(-2.0)
YEAR	-62,937.33*	-0.48*	-63.95*	6,060.67*	43.40*
	(-4.8)	(-1.7)	(-2.4)	(3.9)	(4.6)

Notes: 1) Equations have been estimated jointly by Generalized Least Squares Zellner, 1963). Symmetry restrictions across equations (1) and (2), as well as zero homogeneity in prices for each equation, have been imposed.

2) A full set of three-digit industry dummies as well as an intercept were included in each equation. The coefficients on these terms have not been reported in the table due to space limitations.

3) For a description of the variables, see Table 3.

4) *Significant at the 0.10 level of significance.

Table 5

Estimated System of Factor Demand Equations -
Chemical Industries, India, 1960-70

(Normalized Quadratic Cost Function)

(asymptotic t-statistic in parentheses)

Independent Variables	Production Labor	Non-Productive Labor	Fuel	Technology Imports	Domestic Patenting
W_P/P_F	-116,490,552* (-5.1)	1,492.27 (0.8)	-513,440 (-1.0)	1,202,555 (0.1)	1,386.30 (0.1)
W_N/P_F	1,492.27 (0.8)	-0.58* (-2.1)	93.18* (2.3)	-1,105.35 (-1.3)	-0.92 (-0.8)
USPATNTS	201.75 (0.6)	0.04 (0.8)	-2.62 (-0.4)	231.92* (1.6)	1.35* (6.7)
USPATNTS Squared ($X10^4$)	-638.71 (-0.6)	-0.13 (-0.9)	0.43 (0.0)	-570.89 (-1.4)	-2.76* (-5.0)
FORSHARE	-37,879.53 (-1.5)	-3.87 (-1.1)	-1.38 (-0.0)	-3,414.09 (-0.3)	-57.90* (-4.0)
FORSHARE Squared	813.20 (1.3)	0.09 (1.0)	2.77 (0.2)	101.14 (0.4)	1.33* (3.7)
PUBSHARE	23,905.20 (1.5)	1.48 (0.7)	409.00 (1.3)	4,327.99 (0.7)	22.53* (2.5)
PUBSHARE Squared	-524.16 (-1.5)	-0.02 (-0.5)	-7.56 (-1.1)	-89.81 (-0.7)	-0.52* (-2.7)
FIXEDCAP ($X10^4$)	681.95* (9.1)	0.08* (7.3)	5.54* (3.8)	3.72 (0.1)	0.05 (1.3)
FIXEDCAP Squared ($X10^{12}$)	-390.19* (-4.4)	-0.03* (-2.8)	-2.91* (-1.7)	-21.39 (-0.6)	-0.03 (-0.6)
OUTPUT ($X10^4$)	112.55* (2.9)	0.00 (0.2)	3.19* (4.1)	0.57 (0.0)	-0.06* (-2.6)
YEAR	-115,240.10* (-7.0)	-8.24* (-3.6)	-879.78* (-2.7)	9,595.8 (1.5)	20.06* (2.2)

Notes: 1) Equations have been estimated jointly by Generalized Least Squares (Zellner, 1963). Symmetry restrictions across equations (1) and (2), as well as zero homogeneity in prices for each equation, have been imposed.

2) A full set of three-digit industry dummies as well as an intercept were included in each equation. The coefficients on these terms have not been reported in the table due to space limitations.

3) For a description of the variables, see Table 3.

4) *Significant at the 0.10 level of significance.

Table 6

Estimated System of Factor Demand Equations – Engineering Industries, India, 1960-70

(Normalized Quadratic Cost Function)

(asympotic t-statistic in parentheses)

Independent Variables	Production Labor	Non-Production Labor	Fuel	Technology Imports	Domestic Patenting
W_P/P_F	-23,671,437 (-1.1)	-4,913.27* (-2.4)	-442,899* (-2.4)	68,330,770 (1.3)	17,727.50 (0.9)
$W_N/F/_F$	-4,913.27* (-2.4)	-21.79* (-10.0)	4.83 (0.3)	-13,359.15* (-2.6)	-2.29 (-1.3)
USPATNTS	-35.36 (-0.7)	0.01 (0.2)	0.15 (0.4)	396.00* (3.2)	0.01 (0.02)
USPATNTS Squared ($X10^4$)	-5.42 (-0.1)	-0.01 (-0.2)	-0.11 (-0.3)	-57.19 (-0.6)	0.07* (2.1)
FORSHARE	1,688,754* (3.8)	142.08 (0.3)	6,290.64* (1.6)	778,779 (0.7)	146.90 (0.4)
FORSHARE Squared	-34,416.85* (-3.9)	-2.46 (-0.3)	-128.21* (-1.7)	-14,822.63 (-0.6)	-3.04 (-0.4)
PUBSHARE	-48,569.65* (-6.9)	-14.82* (-1.8)	-100.32* (-1.6)	2,243.76 (0.1)	9.65 (1.5)
PUBSHARE Squared	618.63 (8.3)	0.14* (1.6)	0.88 (1.4)	-24.32 (-0.1)	-0.08 (-1.3)
FIXEDCAP ($X10^4$)	1,853.49* (7.7)	0.06 (0.2)	3.21 (1.5)	-938.98 (-1.5)	-0.39* (-1.8)
FIXEDCAP Squared ($X10^{12}$)	-2,876.94* (-6.0)	0.12 (0.2)	-4.27 (-1.0)	1,683.30 (1.4)	0.52 (1.2)
OUTPUT	235.18* (1.8)	0.22 (1.5)	4.44* (3.9)	595.22* (1.8)	0.18 (1.5)
YEAR	-34,721.31* (-2.1)	-85.39* (-4.4)	-153.71 (-1.1)	-36,048.52 (-0.8)	-25.10* (-1.7)

Notes: 1) Equations have been estimated jointly by Generalized Least Squares (Zellner, 1963). Symmetry restrictions across equations (1) and (2), as well as zero homogeneity in prices for each equation, have been imposed.

2) A full set of three-digit industry dummies as well as an intercept were included in each equation. The coefficients on these terms have not been reported in the table due to space limitations.

3) For a description of the variables, see Table 3.

4) *Significant at the 0.10 level of significance.

Table 7

Partial Derivatives of Factor Demand with Respect to the Fixed Factors: Indian Industries, 1960-70

Industry Group	With Respect to:	Partial Derivative of: Production Labor	Non-Production Labor	Fuel	Technology Imports	Domestic Patenting
Light	USPATNTS	-1,772.78*	-0.03*	1.96*	345.67*	3.83*
	FORSHARE	-516,520*	6.71	-1,605.02*	19,385	68.48
	PUBSHARE	227,103*	0.32	362.03*	-8,659.86	4.89
	FIXEDCAP ($X10^4$)	4,483.01*	0.20*	9.40*	-82.30	-0.05
Chemicals	USPATNTS	-41.74	0.03	-2.59	194.62*	1.17*
	FORSHARE	-15,711.62*	-1.50	74.21	-657.04	-21.52*
	PUBSHARE	7,394.22	0.74	646.99	1,498.98	38.90*
	FIXEDCAP ($X10^4$)	530.00*	0.06*	4.40*	-4.63	0.04
Engineering	USPATNTS	-36.86	0.01	0.122	380.10*	0.03
	FORSHARE	90,435*	28.05	336.75	90,416	5.88
	PUBSHARE	-26,089*	-9.88*	-68.07*	1,359.93	6.62
	FIXEDCAP ($X10^4$)	1,610 .00*	0.07	2.85	-800.00*	-0.34*

Notes: 1) All derivatives have been calculated at the sample means of the independent variables, using the coefficients reported in Tables 4, 5, and 6.

*Significant at the 0.10 level of significance.

shown in Tables 8 and 9, respectively, for each of the three industry groups. The tests of statistical significance reported for the partial derivatives and the elasticities are approximate, since they only take account of the variance of the estimated coefficients and not of the predicted values of the random variables.

Some of the salient findings from the empirical analysis are:

1) Production and non-production labor are observed to be complements, except in the case of chemical industries where there is no significant relationship between them. Non-production labor and fuel appear to be substitutes for each other, although the relationship between production labor and fuel demand is ambiguous.

2) Patenting by nationals in India does not appear to be significantly responsive to prices, except in the case of the light industries. Even in these industries, the price elasticities, although statistically significant, are small in absolute magnitude. They suggest that local inventive activity is complementary to both production and non-production labor but substitutable for fuel. Foreign technology, on the other hand, appears to be a good substitute for non-production labor and fuel both in the light and engineering industries, but is not significantly related to non-production labor in any of the three industry groups.

3) International inventive activity, as proxied by the total number of patents granted in the United States over the previous 5-year

Table 8

Own-and Cross-Price Elasticities of Demand: Indian Industries, 1960-1970[a,b]

(t-statistics in parentheses)

Industry Group	With Respect to:	Elasticity of: Production Labor	Non-Production Labor	Fuel	Technology Imports	Domestic Patenting
Light	W_P	-2.652* (-10.3)	-0.277* (-6.7)	1.536* (2.3)	1.396* (2.0)	-0.003* (-5.1)
	W_N	-0.727* (-6.7)	-0.390* (-5.7)	1.562* (5.5)	-0.443 (-1.5)	-0.001* (-4.4)
	P_F	-0.512* (-1.6)	0.039 (0.2)	-2.449* (-3.1)	2.919* (3.5)	0.002* (2.9)
Chemicals	W_P	-0.893* (-5.7)	0.093 (0.9)	0.803* (3.8)	-0.004* (-1.6)	0.001 (0.6)
	W_N	0.110 (0.9)	-0.344* (-2.3)	0.237 (1.0)	-0.004 (-1.2)	0.001 (0.9)
	P_F	-0.330 (-1.1)	0.486* (2.5)	-0.155 (-0.4)	-0.000 (-0.0)	-0.001 (-0.4)
Engineering	W_P	-0.196 (-1.2)	-0.250* (-2.6)	0.057 (0.4)	0.389* (4.1)	-0.001 (-0.8)
	W_N	-0.143* (-2.6)	-3.887* (-10.6)	3.914* (7.4)	0.115 (0.3)	0.001 (0.2)
	P_F	-0.948* (-2.5)	0.064 (0.3)	0.509 (1.4)	0.375* (1.7)	0.001 (0.4)

Notes:

[a]Elasticities have been evaluated at the sample means of each industry group. The coefficients used in calculating the elasticities have been taken from Tables 4, 5, and 6.

[b]Since all prices have been normalized by the fuel price in the estimated equation, no symmetry has been imposed between the fuel price effects on labor demand and the wage effects on fuel demand. As such, the signs of these effects may not be the same.

*Significant at the 0.10 level of significance.

Table 9

Output and Fixed Factor Elasticities of Demand: Indian Industries, 1960-1970[a]

Industry Group	With Respect to:	Elasticity of: Production Labor	Non-Production Labor	Fuel	Technology Imports	Domestic Patenting
Light	USPATNTS	-0.327*	-0.119*	0.218*	1.308*	1.128*
	FORSHARE[b]	-0.751*	0.205	-1.404*	0.578	0.159
	PUBSHARE[b]	0.330*	0.010	0.317*	-0.258	0.011
	FIXEDCAP	0.658*	0.617*	0.830*	-0.248	-0.013
	OUTPUT	0.297*	0.242*	0.453*	0.114	-0.108*
	YEAR[b]	-0.092*	-0.015*	-0.056*	0.181*	0.101*
Chemicals	USPATNTS	-0.012	0.099	-0.065	1.107*	2.120*
	FORSHARE[b]	-0.014*	-0.013	0.006	-0.011	-0.120*
	PUBSHARE[b]	0.007	0.007	0.050	0.026	0.216*
	FIXEDCAP	0.947*	1.075*	0.664*	-0.157	0.464
	OUTPUT	0.260*	0.021	0.622*	0.025	-0.809*
	YEAR[b]	-0.105*	-0.073*	-0.068*	0.167	0.111*
Engineering	USPATNTS	-0.059	0.055	0.051	0.557*	0.196
	FORSHARE[b]	0.105*	0.111	0.101	0.095	0.027
	PUBSHARE[b]	-0.030*	-0.039*	-0.020*	0.001	0.030
	FIXEDCAP	0.785*	0.123	0.360	-0.356	-0.655*
	OUTPUT	0.169*	0.553	0.827*	0.391*	0.499
	YEAR[b]	-0.040*	-0.338*	-0.046	-0.038	-0.114*

Notes:

[a]Elasticities have been evaluated at the sample means of each industry group using the coefficients reported in Tables 4-6. Elasticities have been computed only for those coefficients significantly different from zero at the 0.10 level of significance.

[b]The figures in these rows are partial elasticities. That is, they show the percentage change in the dependent variable due to a 1 unit increase in the independent variable.

*Significant at the 0.10 level of significance.

period, does adversely affect the demand for production and non-production labor, as we had hypothesized, but only in the light industry group. (In the other industry groups, it has no significant effect on labor demand.) It also has a positive effect on fuel demand in light industries.

4) The relationship between local and international inventive activity is observed to be positive and strong. For every one per cent increase in U.S. patenting, there is a two per cent increase in Indian patenting in the chemical industries and a slightly more than one per cent increase in the light industries. This indicates that the disclosure effect of U.S. patenting on Indian patenting is greater in magnitude than its blocking effect. However, the increased level of Indian patenting is not accompanied by a decline in the use of foreign technology by Indian firms, as we had hypothesized. Instead, U.S. patenting is observed to stimulate foreign technology purchase by Indian firms. This suggests that local innovation and foreign technology use are complements to, not substitutes for, each other. In other words, before being applied successfully to production activities, foreign technology needs to be extensively worked on and adapted to local conditions. This requires that firms which import more foreign technology also perform more R&D and inventive work than firms not importing technology from abroad.

A comparison of the elasticities of local patenting and of foreign technology purchase with respect to U.S. patenting reveals that the latter is greater than the former in light and engineering industries, but that the reverse is true in the chemical industries. Thus, while international inventive activity does stimulate local innovation by Indian firms via a strong disclosure effect, it also encourages more use and import of foreign technology by these firms. The net effect of international inventive activity on Indian self-reliance in technological needs may thus well be negative, especially in the case of the light and engineering industries.

5) Foreign and public sector ownership are not associated significantly with local innovation or foreign technology purchase, except in the chemical industries where local patenting is observed to vary negatively with the level of foreign control and positively with the size of the public sector (as we had hypothesized).

6) Firm size, as proxied by the fixed capital stock and output, does not appear to have a significant positive association with patenting in any of the industry groups. In the light and chemical industries, capital and capital squared do not have significant effects on patenting, although output does have a significant negative effect. On the other hand, in the engineering industries, the output coefficient is not significant, while the fixed capital stock coefficient is significantly negative. On the whole, then, it appears that inventive activity and firm size are not positively related. The results suggest that the relationship, if anything, is negative.

7) Holding all other factors constant, a steady rate of growth of domestic patenting (of approximately 10 per cent per annum) is observed in the light and chemical industry groups. In the engineering industry group, however, patenting appears to have a significant negative trend over time (-11.4 per cent per annum).

8) Several other interesting findings -- which are not the primary focus of this paper -- emerge from the empirical analysis. For instance, the demand for production labor is observed to depend negatively on foreign ownership and positively on public sector ownership in the light and chemical industries. Interestingly, the relationship is exactly reversed in the engineering industries, where public-sector firms appear ceteris paribus to use fewer production workers than other firms and foreign companies appear to use more. The estimated elasticities of production labor demand with respect to capital stock are positive but less than unity in all industries, suggesting that the incremental labor:capital ratio falls with firm size in Indian manufacturing. Additionally, we find that the demand for both production and non-production labor has been steadily falling over time, holding wages and other factors constant, across all industries.

7. POLICY IMPLICATIONS

Assuming that the goals of Indian policy makers are to encourage local inventive activity by Indian firms and discourage reliance on foreign technology, several policy prescriptions are suggested by the empirical results. First, the wages of production workers in the manufacturing sector, which are already at artifically high levels relative to the supply of labor in urban and rural markets, could be reduced. This would have the twin effects of increasing the demand for production and non-production labor (since the two are complements) and generally reducing the demand for foreign technology by Indian firms. In the light industry group, such a policy would also have a small positive effect on local inventive activity.

Second, what little evidence there is suggests that local inventive activity is positively associated with the presence of state-owned enterprises in an industry and negatively related to the presence of foreign-based companies. This has important implications for government policy toward multinational corporations.

Finally, the absence of a strong positive relationship between local innovation and average firm size should influence government policy toward large industrial units and business houses. The argument that government restrictions on firm size (prompted primarily by equity considerations) reduce innovation in India does not find support in the results presented in this paper.

It should, of course, be realized that government policy is based on several other objectives with which the above policy actions may not be consistent. For instance, nothing is said about productive efficiency in this paper. It may be that public-sector firms, although better at local innovation than other firms, may not be the leaders in profitability or factor productivity. Similarly, a policy to encourage small businesses and firms may not always be consistent with high investment and rapid growth in the economy. As with all policy prescriptions, these caveats have to be borne in mind when using the empirical results of this paper for policy purposes.

8. SUMMARY

We have reported evidence in this paper that Indian industrial firms do engage in inventive activity and in the purchase of foreign technology. The legal and institutional setting in India appears to be generally conducive to enabling both domestic inventive activity and technology purchase to benefit from international invention. This finding is strongest in the light and chemical industries. It does not follow, however, that the legal and institutional setting cannot be improved.

The finding that foreign technology purchase is increased because of increases in international invention is open to the interpretation that payments per unit of technology might have increased. Further study is required to determine whether the real quantity of technology purchase does increase with greater international inventive activity. Further study is also required to determine the effects of general industrial policies such as tariffs and licensing on domestic innovation and foreign technology purchase.

FOOTNOTES

1) Expenditures are in current terms. Inflation rates in India over this period were low -- less than 4 per cent per year.

2) Comparable firm-level data can be obtained from a number of secondary sources. The authors are currently engaged in assembling these data for over 1,000 Indian firms in all industries.

3) As part of an N.S.F. research project on technology choice and innovation in less-developed countries, the authors -- along with Kent Mikkelsen -- are engaged in a primary survey of selected firms in the agricultural machinery industries of India and the Philippines It is hoped that the survey will shed more light on informal innovation effort by firms in less-developed countries.

4) A random effects model was not estimated since it requires an identical number of time-series observations for each cross-sectional unit. In our case, data for several industries were not available for each of the years between 1960 and 1970. Forcing the data into a rectangular block would have reduced the sample size considerably.

APPENDIX

Data Sources

1) Data on technology imports and on foreign equity share were obtained from the Reserve Bank of India, Foreign Collaboration in Indian Industry: Survey Report, Bombay: Reserve Bank of India, 1968, for the period 1960-61 to 1963-64, and from the Reserve Bank of India, Foreign Collaboration in Indian Industry: Second Survey Report 1974, Bombay: Reserve Bank of India, 1974, for the period 1964-65 to 1969-70.

2) Data on the fuel price index was obtained from India, Planning Commission, Statistics and Surveys Division, Basic Statistics Relating to the Indian Economy 1950-51 to 1970-71, New Delhi, 1972.

3) Data on the public sector in production was obtained from the Commerce Yearbook of the Public Sector, Bombay: Commerce Publications, 1974.

4) Data on number of patents granted in the U.S. were obtained, tabulated by industry, directly from the U.S. Patent Office.

5) Data on patenting by nationals in India were hand tabulated directly from actual patent applications on file at the New Delhi office of the Indian Patent Office. Data on approximately 42,000 patents granted through 1979 were collected. A relatively complete concordance of the Indian patent classification with the Indian industrial classification was also possible. Only 5,845 of the 41,588 patents in the basic file were in classes where assignments to industries proved unreasonable.

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