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TECHNOLOGICAL IMPORTS AND TECHNOLOGICAL EFFORT: AN ANALYSIS OF THEIR DETERMINANTS IN BRAZILIAN FIRMS*

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Logit analysis is employed to measure the effect of selected variables on the probability that a firm (1) purchases imported technology, (2) engages in research and development and (3) controls the quality of its production. Analysis of 4342 industrial establishments show these technological activities to share common determinants: all increase significantly with foreign ownership, exports and firm size. Other variables, including state ownership, profits and effective protection, affect only some activities. Imports of technology have a positive effect on technological effort and quality control.

I. INTRODUCTION

FIRMS in the industrial countries invest vast sums in research and development (R&D) in order to create new products and new production processes. Their incentive for creative innovation is great, for they can capture the rents from inventions in their large home market in addition to returns from exports, foreign investment and licenses. Firms in developing countries like Brazil, or even the smaller industrial countries like Canada, find it difficult to appropriate the rents from new technology, hence devote few resources to basic, innovative research. Instead, they typically direct their R&D activity toward the assimilation of foreign technology and its adaptation to local conditions.[1]

Conventional wisdom used to hold that the relationship between technological imports and technological effort is necessarily one of substitution: increased imports of technology imply a decrease in local R&D. We now know that the relationship may be one of complementarity, and complementarity may well dominate. The example of Japan illustrates this very well, for initial efforts to adapt and assimilate foreign technology gave rise to more innovative research. One student goes so far as to conclude that 'technology imports have been the most significant stimulant to the development of Japan's own R&D industry' (Ozawa [1985, p. 241]).

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[1] See Caves *et al.* [1980, pp. 168–175] and Dahlman *et al.* [1987].

In this paper we attempt to determine the effect of selected variables on technological activity in Brazilian industry. Despite the obvious usefulness that an understanding of the determinants of technological activity can have in the formation of industrial policies, this is the first study of this type to be done in Brazil.

The data utilized in the study are from a survey carried out in 1981 by the Institute of Administration of the Faculty of Economics and Administration, University of Sao Paulo, under contract from the Industrial Development Council (Ministry of Industry and Commerce) of the Government of Brazil. The survey covered 4342 establishments, of which 3903 are owned by national private firms, 48 by state enterprises and 391 by foreign enterprises. Given the qualitative nature of most of the information collected on technological activities (the dependent variables), a logit model is employed to measure the effect of explanatory variables on the probability of the existence of a particular activity.

II. SPECIFICATION OF THE MODEL

The dependent variables in this analysis are binary, taking the values of unity or zero, and the model employed to 'explain' the existence or non-existence of a technological activity is a cumulative logistic function of the form

$$(1) \qquad E(Y_i) = P_i = 1 \Big/ \left[1 + \exp\left(-\sum_{j=1}^{J} b_j X_{ij} \right) \right]$$

where

Y_i = a discrete, random variable equal to one if the i^{th} establishment carries out a given activity and zero if it does not;
P_i = probability that the i^{th} establishment engages in the activity;
X_{ij} = value of the j^{th} explanatory variable for the i^{th} establishment.

This logit regression was applied to data for five distinct activities. The establishments surveyed were asked whether or not they used a foreign source for product design or for production engineering; 9% and 5%, respectively, answered in the affirmative.[2] The responses to these questions provide the data for two dependent variables: *TECHM1* and *TECHM2*.

Technological effort is measured by two binary variables. One comes from a question asked of each establishment: 'Do you have a programme for the systematic development of new products (*PRODEV*)?' The other variable

[2] Each establishment was also asked whether it had imported the technology for tool and fixture design, project engineering or plant layout. Affirmative responses amounted to 7%, 6% and 4% of the sample, respectively.

comes from the balance sheet of the firm: the presence of recorded expenditures on research and development (R&D) in fiscal years 1978, 1979 or 1980. More than a quarter of the establishments reported the systematic development of new products, and more than two-thirds reported at least some activity in this area, yet fewer than ten percent of the firms registered R&D expenses on their balance sheets. Obviously there is considerable technological effort that never enters formal accounts, probably because most of the smaller firms have neither a research department, nor full-time employees dedicated to research and development (Kleinknecht [1987]).

A fifth variable measures not technological effort, but rather the application of technology to the production process: the control of the quality of the plant's output with modern methods (*QUALITY*). Nearly a third of the establishments claimed to employ modern methods of quality control, while the other two-thirds admitted that quality control was either non-existent, or was implemented without the benefit of modern technology.

It should be emphasized that four of the five dependent variables are based on responses by establishments to specific questions, thus reflecting the subjective judgement and memory of the manager. Information regarding the importation of technology may underestimate actual dependence on foreign supply if management has changed or does not recall the source of technology in use. Responses to questions regarding new product development and quality control may well overstate activity in these areas if respondents exaggerate the extent to which their plants are modern and innovating. As a control for such bias, one of the dependent variables, R&D, is 'objective' in that it is based on the balance sheet of the firm and not on the memory or judgement of its management.

Ten explanatory variables and thirteen industry dummies are included in the model. These are listed in Table I along with a brief description of each. In the text which follows we summarize hypotheses as to the probable effect of each explanatory variable on the dependent variables. Although the hypotheses are nearly always expressed in terms of effects on research and development (the focus of most of the literature on technological activity), they can be extended, with only minor modifications, to the rest of the dependent variables.

Foreign control (*FOR*) captures differences in the technological activity of transnational firms *vis à vis* national firms. Transnational firms tend to concentrate research and development in their home countries; this implies a negative coefficient for *FOR* in the technological effort equations, and a positive coefficient in the two technoloical import equations. Nonetheless, the negative coefficient could become positive, depending upon the necessity of adapting technology to local conditions. *FOR* is expected to have a positive effect on quality control.

A number of authors argue that the presence of transnational firms can have 'spillover' or external effects on the efficiency and technological activity

TABLE I
LIST OF EXPLANATORY VARIABLES

Variable Name	*Definition*
FOR	Foreign control, a dummy variable equal to unity if non-residents own more than 10% of the voting shares (and state ownership is less than 50%) and zero otherwise (mean = 0.09).
FORSHARE	Proportion of the output of a four-digit industry accounted for by *FOR* firms (mean = 0.182).
FORTECH	Foreign technology, a dummy variable equal to unity if an establishment imports any type of technology, equal to zero otherwise (mean = 0.14).
STATE	State control, a dummy variable equal to unity if government ownership of voting shares is 50% or more, and zero otherwise (mean = 0.01).
SIZE	Size of the firm, measured as the natural logarithm of average value-added of the firm, in December 1980 cruzeiros, of fiscal years 1978, 1979 and 1980 (mean = 13.97).
DIVERS	Diversification of output, measured as $1-\sum S_i^2$, where S_i = the proportion of sales by the firm of the i^{th} product (mean = 0.32).
PROFIT	Operating profit of the firm, measured as the natural logarithm of average profits, in December 1980 cruzeiros, in fiscal years 1978, 1979 and 1980 (mean = 10.95).
EXPORT	Dummy variable equal to unity if the firm exports and zero otherwise (mean = 0.30).
PROTECT	Effective protection in 1985 of the four-digit industry as a proportion of the international price (mean = 1.12, range = −0.4 to 52.5).
HERF	Herfindahl index of concentration in the four-digit industry (mean = 0.04).
IND1...IND13	Technological opportunities, controlled for by dummy variables equal to unity if an establishment belongs to one of 13 two-digit industries, and zero otherwise.

Note: The data base covers 4342 establishments owned by 3754 firms. Since most of the dependent variables refer to establishments, the means reported here are for establishments rather than firms. Detailed descriptive statistics for the sample are available from the authors on request.
Source: FORSHARE and *HERF* are from Willmore [1987] and *PROTECT* is from Braga *et al.* [1988]; all other variables were constructed from the sample data.

of other firms in an industry.[3] Domestic firms may become more aware of technological options available to them. All firms may benefit from the increased availability of trained labour and management, react positively to increased competition, and find that supply of imported technology improves with the increased presence of transnational enterprises. The hypothesis to be tested is thus the larger the foreign share of industry output (*FORSHARE*), the greater the probability of technological activity.

A priori, we expect the relationship between technological imports and technological effort to consist of both substitution and complementarity. Since firms can choose between purchasing technology and developing it themselves, it is logical to expect some substitution: the greater the dependence of a firm on imports of technology, the lower its technological effort. On the other hand, a complementary relationship is also likely, both

[3] See Blomström [1986] and the references cited therein.

because foreign technology can be a catalyst for domestic effort and because imported technology must often be adapted to local conditions. Evidence from Europe (Blumenthal [1978]), Japan (Odagiri [1983]) and India (Lall [1983], Katrak [1985], Siddharthan [1988]) suggests that the relationship of complementarity dominates that of substitution. The relationship is tested for the first time in Brazil by including the variable *FORTECH* in each of the technological effort equations. In the equation 'explaining' the use of modern methods of quality control, the expected sign of the coefficient of *FORTECH* is unambiguously positive.

Katrak [1985] suggests that the competitive pressures on public enterprises may be weak since they have access to public subsidies. For this reason we can expect a negative coefficient for *STATE* in the technological import and quality control equations. For technological effort, however, the sign of *STATE* is ambiguous: lack of concern with efficiency dictates a negative coefficient whereas social objectives, e.g. increased labour-intensity or skill-intensity, might yield a positive coefficient. Katrak [1985, p. 225] himself found, 'no apparent difference between public and private enterprises' in the case of research and development expenditures.

The natural logarithm of the value-added of the firm is intended to serve as a proxy for firm size. Since the pioneering work of Schumpeter, a vast literature has emerged concerning the effect of firm size on research and development. Theory suggests a positive effect, and the available evidence, which refers to firms with established R&D programmes rather than research participation rates, supports the hypothesis that the effect is positive, but not linear (Kamien and Schwartz [1975, pp. 16–18]). Non-linearities have been allowed for first by using the logarithm of value-added instead of the raw value, secondly by using a logit model, and third by introducing a quadratic term into the regression equations. A positive effect is also expected for *SIZE* on imports of technology and quality control.

Diversification (*DIVERS*) is another variable that can be expected to have a positive impact on technological effort. Nelson [1959] argued that a firm producing a wide range of products is more apt to engage in research because the outcome of research can never be known with certainty, and a diversified firm is more likely to find use for unanticipated research results. This hypothesis has been confirmed in a number of studies. Imports of technology involve less risk than in-house research, so a negative coefficient is expected for *DIVERS* in those equations. No particular sign is predicted, a priori, for the effect of diversification on quality control.

Profits are expected to affect technological activity, but there is no consensus as to the direction of this effect. On the one hand, firms may be unable or unwilling to borrow funds for the acquisition or development of technology, with the result that substantial liquidity, in the form of high profits, is necessary for investment in technology. (See, for example, Link [1982].) Alternatively, Horowitz [1961] argued that low or declining profits put pressure on a firm to innovate in order to become more competitive. Since the empirical evidence on this issue is inconclusive (Kamien and Schwartz [1975, pp. 24–26]), the sign of the coefficient of *PROFIT* will depend on the Brazilian data.

Analysing the case of American industry, Pugel [1978] argued that exports, by increasing the size of the market, increase the return to innovative activity.[4] Brazil, however, is a less developed country, so it is more likely that greater technological activity on the part of exporters would be due to the supposedly more rigorous requirements of external compared to domestic markets. A positive coefficient is thus expected for *EXPORT* in each logit regression.

There exists a well-known argument that firms operating in industries protected from foreign competition are apt to enjoy a 'quiet life', paying little attention to technical efficiency or product quality. Teitel [1984, p. 45] has argued, however, that while protection may inhibit technological effort it may also induce it through 'wasteful efforts to substitute raw materials, scale down plant size, or stretch the capacity of existing equipment.' In Brazil, exchange controls block the entry of nearly all competing imports. The variable *PROTECT*, the ratio of value-added at border prices to value-added at internal prices less unity, measures the result of this indiscriminant protection. Holding the rate of profit constant, a high value for *PROTECT* implies high costs and inefficiencies. It is an empirical question as to whether these inefficiencies are associated with greater or lesser technological activity, so the coefficient of *PROTECT* can take any sign.

Technological activity is a form of nonprice competition, and the economic literature on nonprice competition predicts a concave relationship between investment in technology and seller concentration.[5] Nonprice competition is expected to increase with concentration up to a point, then decrease once a threshold is reached. Firms in atomistic industries compete by cutting price rather than varying quality, while firms in oligopolistic rivalry tend to use advertising, technological innovation and other forms of nonprice competition. With very high concentration, however, nonprice competition declines as a result of collusive behaviour. We thus predict a positive sign for the coefficient of our index of concentration (*HERF*) and a negative sign for the square of this variable ($HERF^2$).

The relationship between technological activity and concentration is, as noted by Scherer [1967, p. 530] 'a complex one, since high concentration and rich technological opportunity tend to coincide'. Certain industries, e.g.

[4] See also Zimmerman [1987].

[5] There exists a large literature on the concave relationship between advertising and concentration, and little for such a relationship between technological effort and concentration, but see Scherer [1967] and Scott [1984]. Caves *et al.* [1980, p. 180] failed to find a concave relationship between R&D spending and concentration in Canada, attributing this to 'the different character of R&D in a small, open economy'.

chemicals or machinery, would conceivably register high levels of technological activity regardless of seller concentration, firm size, or foreign ownership. To control for interindustry differences in technological opportunities, we include thirteen dummy variables, one for each two-digit industry covered by the survey.

The single-equation model takes explanatory variables as given and hypothesizes a casual connection that runs from these variables to technological activity. This approach is widely used in the literature and seems reasonable for modelling the behaviour of individual plants and firms in the short run. In the long run, however, technological activity may be jointly determined with other variables, or technological activity may affect other variables, i.e. there may be reverse causation. Foreign control and technological activity, for example, may both depend on technological opportunity. And firms that engage in technological activities may eventually increase their market share, profits and exports. Since these effects are long-term, and our data cover only three years, we have made no attempt to endogenize any of the explanatory variables.[6]

III. EMPIRICAL FINDINGS

Table II reports the maximum likelihood estimates of the parameters of the logit model for each of five regressions. A nonlinear regression package was used to iteratively weight the least squares results of each regression by the reciprocal of the estimated variance of each observation. It can be shown that this method produces asymptotically efficient, unbiased estimates of the parameters of the model.[7]

In general, the regression coefficients have the expected sign and tend to be statistically significant, often at the one percent level. In each of the five equations, a likelihood ratio test allows us to reject the hypothesis that all the regression coefficients are jointly equal to zero. The same test applied to the thirteen coefficients of the industry dummies allows us to reject the hypothesis that probabilities do not vary from industry to industry. In other words, technological opportunities, hence technological imports, technological effort, and methods of quality control, all vary significantly from industry to industry.[8]

The coefficient of the foreign ownership dummy (*FOR*) is positive in all five equations, and highly significant in all save the R&D equation. The coefficient

[6] For efforts to endogenize research intensity, concentration, price–cost margins and other variables, see Levin and Reiss [1984] and the references cited therein.

[7] See Kmenta [1971], pp. 425–427 and 461–462.

[8] Industry dummies were significant, in a joint test, at the 1% level in all five equations. It is possible that coefficients of variables other than the intercept vary by industry, but a key equation (R&D) was estimated for each of the thirteen industries, with no evidence of significant inter-industry variation for any coefficient other than the intercept.

TABLE II
LOGIT REGRESSIONS

	TECHM1	*TECHM2*	*PRODEV*	R&D	*QUALITY*
FOR	2.329‡	2.085‡	0.677‡	0.309	1.032‡
	(0.151)	(0.185)	(0.133)	(0.190)	(0.136)
FORSHARE	1.056†	0.197	−0.437	0.152	0.284
	(0.632)	(0.638)	(0.374)	(0.552)	(0.327)
FORTECH			0.238†	0.357†	0.704‡
			(0.110)	(0.157)	(0.106)
STATE	−0.182	0.159	0.221	−0.437	−0.577†
	(0.755)	(0.649)	(0.384)	(0.753)	(0.345)
SIZE	0.118‡	0.163‡	0.085‡	0.082‡	0.114‡
	(0.026)	(0.030)	(0.016)	(0.023)	(0.015)
DIVERS	−0.306	−0.350	1.033‡	0.710‡	0.436‡
	(0.303)	(0.370)	(0.168)	(0.266)	(0.166)
PROFIT	−0.038‡	−0.059‡	0.013	−0.016	−0.018†
	(0.013)	(0.013)	(0.009)	(0.012)	(0.008)
EXPORT	0.824‡	0.603‡	0.565‡	0.422‡	0.444‡
	(0.136)	(0.168)	(0.080)	(0.124)	(0.081)
PROTECT	−0.151*	0.014	−0.057	−0.032	−0.060*
	(0.083)	(0.042)	(0.035)	(0.057)	(0.034)
HERF	13.303‡	8.549†	9.286‡	−0.640	2.400‡
	(5.357)	(4.592)	(3.016)	(1.524)	(0.908)
HERF^2	−45.736†	−24.354*	−39.098‡		
	(24.996)	(17.547)	(14.226)		
Likelihood ratio test	628.8‡	367.5‡	411.2‡	124.7‡	729.4‡
McFadden's R^2	0.266	0.224	0.083	0.052	0.136
Affirmative responses	9.1%	5.2%	25.9%	9.7%	31.3%
No. of obs.	3881	4023	4324	3754	4352

Significance levels: *10%, †5%, ‡1% or higher. Most tests are one-tailed; see text for expected signs.
Asymptotic standard errors in parentheses. Coefficients of the thirteen industry dummies are available from authors on request. The number of observations vary due to varying non-response and because R&D refers to firms, the other questions to plants.
Dependent variables:
TECHM1 = Unity if foreign source for product design, otherwise = 0.
TECHM2 = Unity if foreign source for production engineering, otherwise = 0.
PRODEV = Unity if there exists a systematic programme of new product development, otherwise = 0.
R&D = Unity if R&D expenses on balance sheet, otherwise = 0.
QUALITY = Unity if the plant controls the quality of its output with modern methods, otherwise = 0.

of *FOR* is particularly high in the first two equations; the point estimates of 2.085 and 2.329 imply that foreign ownership increases by eight to ten times the odds that a firm is an importer of technology.[9] Concerning technological effort, there is no evidence of a negative effect from foreign ownership, and considerable evidence of a positive effect. Apparently the demonstration or 'spillover' effects of the presence of foreign firms is of minor importance, for the coefficient of *FORSHARE* is statistically significant in only one equation (*TECHM1*).

The coefficient of foreign technology (*FORTECH*) is positive and

[9] The antilog of 2.085 is 8.0 and that of 2.329 is 10.3.

statistically significant in the two equations relating to technological effort. This shows that complementarity dominates any effects of substitution between these two activities; in other words, technological imports, far from diminishing or inhibiting the technological effort of Brazilian firms, actually increases this effort. *FORTECH*'s coefficient is also significantly positive, as expected, in the quality control equation.

The coefficient of firm size is positive and highly significant in each equation, but the estimated coefficients are rather low. A doubling of firm size increases the odds of engaging in technological activity by only six to nine percent, a small (though statistically significant) effect compared to that of foreign ownership. The coefficient of the square of *SIZE* was not significantly different from zero in any equation, so this variable was deleted from the regression.

STATE performs quite poorly as an explanatory variable, but its coefficient is significantly negative, as predicted, in the quality control regression.

The highly significant, positive coefficients for *DIVERS* in the R&D and *PRODEV* equations confirm Nelson's [1959] hypothesis that diversification of output stimulates technological effort. Diversified firms are also more likely to utilise modern systems of quality control.

The coefficient of *PROFIT* is significantly *negative* in the *TECHM1*, *TECHM2* and *QUALITY* regressions. Competition, reflected in low profits, encourages both the importation and the utilisation of new technology by Brazilian firms. On the other hand, profits have no significant effect on technological effort.

The coefficient of the *EXPORT* dummy is highly significant and quite large in each equation, evidence that the competitive pressure of producing for foreign markets demands greater access to imported technology, encourages technological effort and increases the utilisation of modern methods of quality control. In contrast, *PROTECT* attains statistical significance, at the 10 percent level, in only two equations, providing weak evidence that firms in protected industries are *less* likely to engage in technological activity.

In three of the five logit regressions, the coefficients of the concentration index (*HERF*) and its square have the expected signs and are statistically significant. In one equation (*QUALITY*), the coefficient of the square of *HERF* was not significant, and in another (R&D), neither coefficient was significant.

An increase in firm size appears to have only a modest effect on technological activity. But the coefficient of *SIZE* does not reflect the full impact of this variable for, as Culbertson [1985, p. 102] has reminded us, 'firm size cannot change *ceteris paribus*'. If industry size is held constant, an increase in size for some firms implies a decrease in size for others, and an increase in concentration.

It is difficult to summarize the implications of our findings for the relationship between concentration and technological activity of an industry, for the precise effect depends upon the initial size distribution of firms as well as the resulting changes in this distribution. Nevertheless, it is possible to conclude that, under plausible circumstances, the effect of an increase in concentration on technological activity is minimal.

To illustrate this point, consider the *QUALITY* equation of Table II. Since the coefficient of *HERF* is significant, some assumption must be made as to the initial number and size distribution of firms in the industry. If we assume the existence of twenty-five firms of equal size, this implies a Herfindahl index of 0.04, which is average for firms in our sample. Suppose that all firms initially have a probability of 0.5 of utilising modern methods of quality control, and that the output of one firm is doubled at the expense of another. The result is an increase in *HERF* to 0.0408, an increase in the probability that the largest firm will engage in this activity to 0.512, a decrease in probability for the smallest firm to 0.481, and an increase for the other 23 firms from 0.5000 to 0.5005. In contrast, a change from non-exporter to exporter for any of the firms implies an increase in calculated probability from 0.5 to 0.609.

IV. CONCLUSIONS

If Brazil is to return to the high rates of growth it enjoyed in the past, the country must modernize and improve the technological capabilities of its manufacturing industries. The State has an important role to perform in this process by creating a favourable environment for technical change and by granting high priority to the acquisition of new technology. Formulation of sound policies on technology requires knowledge of both the type of technology currently in use and the factors that affect technological activity at the level of the firm.

The present study is intended as a contribution to the second type of knowledge, i.e. the determinants of technological activity in individual plants and firms. Using an appropriate data base, we have measured the effect of selected variables on the decision of the firm to engage in five technological activities, including imports of technology, new product development, research and development, and quality control.

Three variables—firm size, exports and foreign ownership—have a positive and highly significant effect on virtually all five activities.[10] Nonetheless, it must be emphasized that the coefficient of firm size, though significant in a statistical sense, is very small in each of the logit regressions, as is the coefficient of a related variable, the Herfindahl index of concentration. Other variables affect only some types of technological activity. The more diversified the output of a firm, for example, the greater the probability of observing

[10] The coefficient of foreign ownership, though positive, failed to attain statistical significance in one equation (R&D).

quality control and technological effort. And state ownership affects (negatively) only quality control.

From a policy point of view, the most important finding of this study is that complementarity dominates any effect of substitution between technolgical imports and technological effort. The importation of technology requires local effort to assimilate it and to adapt it to differences between Brazil and the source country in terms of climate, geography, consumer preferences, market size, cost and skills of labour, the availability and quality of raw materials and intermediate goods, etc. It is inevitable that in small economies, especially underdeveloped economies, most technological knowledge will come from abroad. To allow Brazilian industrialists greater access to this knowledge is a certain way to increase their own technological effort.

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