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IN-HOUSE R&D, IMPORTED TECHNOLOGY, AND FIRM SIZE: LESSONS FROM INDIAN EXPERIENCE

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I. INTRODUCTION

THIS paper analyzes the relationship between in-house R&D expenditure, lump-sum payments made to foreigners for import of technology, and the size of the firms, for a sample of Indian manufacturing firms during the 1980s. Initially during the 1960s, work in the field of industrial organization concentrated mainly on the relationship between industrial structure and industrial performance [2]. Later on, during the 1970s, the emphasis shifted to the role of conduct variables as seen from the expenditures on technology, product diversification, and differentiation in influencing the market performance as well as market structure. Many of these works highlighted the mutual interrelationships between the structure, conduct, and the performance variables. In recent years, however, the emphasis is shifting in favor of analyzing the relationship among the conduct variables. In this context with regard to expenditure on technology, a distinction is made between in-house R&D expenditure and expenditure incurred to purchase technology from outside [7] [6] [5]. One of the objectives of this paper is to examine the relationship between these two technology expenditures.

For the purpose of examining the relationship between these variables the following sample will be used in this paper. The sample will consist of all the 166 manufacturing firms whose research and development units are registered with the Ministry of Science and Technology and who reported their activities to the ministry as given in the publication "Compendium on In-house R&D Centres, 1985." The paper is organized as follows. Sections II and III survey the recent literature in this area and specify the model to be tested. Section IV discusses the statistical results and brings out the main conclusions.

This work differs from the earlier works in aspects relating to functional specification of the model, coverage, and variables. It is based on firm-level data for a cross section of industries and firms, rather than on industry-level data. This distinction is important as further light on many of the issues arising out of the earlier recent works [5] can be had only with firm-level data for a number of

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industries. This work also covers the current period (1982–85) which exhibited a record increase in technology imports. Further it takes into account the possible differences in the behavior of the public- and private-sector firms with regard to in-house R&D and technology imports. While the earlier works postulated a linear relationship between size and R&D expenditure, this work takes into account the possibilities of nonlinearities in the relationships as the sample contains small partnership firms as well as large multinational corporations. Given these variations in size as discussed in Section III, the nature and scope of R&D done by the small and very large firms could be different, and under these conditions a linear specification might not be the most appropriate one.

II. IN-HOUSE R&D AND PURCHASE OF TECHNOLOGY

Analysis of the relationship between in-house R&D expenditure and purchase of technology from other firms by making lump-sum/royalty payments, assumes importance as there are very few firms in the industrialized and industrializing countries that are self-sufficient in technology, or capable of generating all their requirements through their in-house R&D efforts. In practice most firms buy technology from other firms. In a newly industrializing country like India purchase of technology is usually made from a firm belonging to a developed country. However, the nature of the relationship between in-house R&D and imported technology is not clear from the existing literature. Some of the empirical works do indicate a weak complementary relationship. On the other hand arguments could also be advanced in favor of a competitive one.

Odagiri [7] hypothesized a substitution relationship between royalty payments and R&D expenditure, as firms could make a choice between undertaking research themselves and acquiring licenses for outside payments. Hence, he felt that it was more logical to include royalty payments as an alternative to R&D expenditures. However, his statistical results for a sample of 370 Japanese manufacturing firms showed a positive relationship between R&D and expenditure on royalty payments (both taken as percentage of sales). But this positive relationship was statistically significant only among the non-innovators. His conclusion was that the R&D and royalty payments for patents were complements rather than substitutes, and a firm with a larger expenditure on internal R&D tended to make more expenditure on royalty. Since the relationship was significant only among the non-innovative firms, it is possible that purchase of technology is complementary only to adaptive R&D and not to innovative research. Lall [6], for a sample of 100 Indian engineering firms for the year 1978, found the royalty payments to be positively related to R&D expenditure (both variables being taken as a percentage of sales) in his equations explaining R&D expenditures. Lall considered this to be a confirmation of the complementary relationship between these two variables. However, the value of the coefficient was low, indicating a weak complementarity.

Katrak [5] assumed that the Indian R&D was mainly of an adaptive nature, and developed a model to analyze the relationship between the adaptive R&D and imported technology. The hypotheses derived from this model were tested for a cross section of Indian industries for the year 1978–79. His dependent variable was the expenditures on research and development in the industry divided by the number of enterprises in that industry. Import of technology was captured by two variables used alternatively in two different versions of the model. In the first version it was captured by the import of capital and non-capital equipment per enterprise, and in the second by the expenditure on royalty and technical fees per enterprise. His results indicated that the import of technology did stimulate R & D but the stimulative effect was rather limited, and what is more, it was weaker for more complex technologies.

It is felt that to form firmer conclusions, it is necessary to work with firm-level data, rather than with industry-level data. Further, in order to gain the results comparable to those of Katrak [5] and Odagiri [7], it is necessary to consider a cross section of firms from a number of industries, rather than from one industry. However, to take into account industry characteristics, one could estimate the equations for each industry separately and see how the estimates differ compared to the one based on the pooling of all industries and firms.

Secondly, with regard to the variable used to capture expenditure on import of technology, at least in the Indian case, contracts relating to lump-sum payments to be paid to foreigners for the import of technology is a better indicator of technology imports than a general variable like the import of capital and other equipment, or royalty payments. During the 1980s lump-sum payments constituted more than 80 per cent of the payments made for import of technology. Lump-sum payments are also more directly related to in-house R & D efforts, as the technology policy resolution of the government of India directly links these two variables. On the other hand there are no direct links between in-house R & D and import of machinery and equipment. Further, all technology imports do not involve royalty payments. Normally no royalty payments are allowed in the case of import of design and drawings. On the other hand there are reasons to believe that design and drawings are more directly linked to domestic R & D efforts. They are covered by lump-sum payments. Moreover, where technology payments are involved, in India only a small part was made in royalties while lump-sum payment accounted for the major portion till recently. Currently there has been an attempt to increase the share of royalties, to make it on a par with lump-sum payments. Thus agreements relating to lump-sum payments would represent both royalty and non-royalty payments for the import of technology and are also more directly related to R & D effort.

Thirdly, the weak relationship observed by the earlier authors between R & D and import of technology could also be due to the complex relationship between these two variables. Both Odagiri [7] and Katrak [5] agree that only adaptive R & D will be positively related to import of technology and not innovative R & D. In fact there is a general agreement that the relationship between innovative R & D and import of technology could even be competitive. But Katrak [5] and Lall [6] assume all Indian R & D to be of an adaptive nature and postulate a complementary relationship. If some of the firms in an industry did innovative R & D while others did adaptive research, then the relationship between their research and import of technology would be negative for the former group of firms and positive for the latter. In a sample consisting of both groups of firms, the regression coefficient could turn out to be statistically insignificant. But that does not mean that there is no relationship. The insignificant coefficient is the result of mutual cancellation of opposite forces.

The earlier authors found a weak positive relationship. That could indicate the dominance of adaptive R&D firms in Indian industries compared to innovative R&D firms. But since the innovative R&D firms were not absent from the sample, it did affect the coefficient of technology imports and hence the weak relationship. The problem is one of identifying the firms that do innovative R&D and taking them out of this sample as was attempted by Odagiri [7]. However, the Indian R&D data does not classify activities in terms of adaptive and innovative research. While most of the firms in the private sector could be expected to do mainly adaptive R&D, since innovative R&D under Indian conditions might be less profitabe in relation to the import of technology, this may not be the case for many of the large public-sector units. The public-sector units have been encouraged to do innovative R&D and they are also allotted a larger R&D budget by the government. Therefore, in what follows, the relationship will be tested for the private-sector firms separately, apart from estimating the equation for a pooled sample of both public- and private-sector firms, to examine the differential behavior. It is hoped that this procedure will improve the results. Following this argument Katrak [5] used dummies for the public sector in one set of equations but they were not significant.

The introduction of these changes, namely, firm-level data for a cross section of industries instead of industry-level data or data for a particular industry, alternative definitions for the technology-import variable that take into account Indian government regulations and actual practices involved in payments for technology import, and introduction of the possible differential behavior of the public-sector units that spend large sums on both innovative and adaptive R&D, would, it is hoped, help in arriving at firmer conclusions.

III. IN-HOUSE R&D AND THE SIZE OF THE FIRM

The relationship between firm size and its R&D expenditure was originally postulated by Schumpeter [9]. Schumpeter hypothesized a positive relationship between market concentration and R&D expenditure, and expected larger firms to spend more on R&D. Empirical workers interpreted the Schumpeterian theory to mean that as the firm size increases R&D would increase in greater proportion [11, Chap. 8]. The evidence in favor of this hypothesis [4] is not conclusive. However, from the writings of Schumpeter it is not clear whether he actually predicted a linear (or log-linear) relationship between these two variables wherein R&D would increase in greater proportion to size. On the other hand, if there are substantial scale economies as well as minimum economies of size in R&D units, then the increase in R&D expenditures needs to be proportionately less than the increase in firm size. In other words, R&D intensity, or R&D as a ratio of firm size will in fact fall with increase in size. Since Schumpeter also emphasized the role of economies of scale in R & D, the latter interpretation is also not inconsistent with the Schumpeterian position. Katrak [5] postulated an increase in R & D expenditure with regard to an increase in firm size but not as fast as the increase in firm size. That is, larger firms will undertake proportionately less R & D than smaller ones. His results confirmed this, as the coefficient of size in his R & D equation was less than one. If he had taken R & D intensity, that is R & D deflated for size (in his case sales), then the coefficient would have had a negative sign. On the other hand Lall [6] found the relation between size and R & D intensity to be positive. Lall attributed this to the fact that the largest firms tended to be more diversified, more technologically complex, more aware of technological complexities, and could afford more investment in R & D activities.

However, it could be argued that the relationship between the size of the firm and its conduct and performance is seldom linear as postulated and tested in these works. In the case of the relationship between the growth of the firms and their size, most of the available evidences [8] [1] [10] indicate a nonlinear U-shaped relationship. In the case of the relationship between size and a conduct variable like R & D also there are strong reasons to believe that it would be nonlinear. To start with, small firms tend to spend a larger proportion of their sales on R & D due to the presence of the minimum economies of size. However, with an increase in size, R & D needs to increase only in a small proportion due to the presence of significant scale economies. But for very large firms with large R & D establishments, the nature, scope, and quality of R & D could be very different from those of the smaller firms. In the current sample some of the expenditure on R & D establishments of the larger firms are larger than the sales turnover of the smaller firms. In fact some of the very small firms had R & D units manned by less than two or three technical personnel. Under these conditions the nature of their R & D activities is bound to be different from the very large ones. All these point to the strong possibility of a nonlinear relationship and in this work it is proposed to test explicitly for it. Since the sample size is large, it will not be difficult to capture nonlinearities if they exist.

In addition to these factors the age of the R & D unit could also be a determinant of the R & D intensity. It is therefore proposed to include this variable among the determinants.

The arguments developed so far will be tested using the following regression equation for a sample of 166 firms for the year 1983–84.

$$RD/S = A + b_1 MT/S + b_2 AGE + b_3 \log S + b_4 \log^2 S,$$

where S is the size of the firm measured by sales turnover; RD, expenditure on research and development; AGE, age of the R & D establishment measured from the date of recognition given by the Ministry of Science and Technology. The equation will be estimated for the combined pool of government and private-sector companies as well as for the private-sector companies separately. Separate regressions will also be run for firms belonging to chemical, electronic, machinery, automobiles, and other firms respectively to test for any industry differences that could be present.

IV. DATA AND STATISTICAL RESULTS

For the purpose of this section the sample will consist of all the manufacturing firms registered with the Ministry of Science and Technology reporting their activities to the ministry as given in their publication "Compendium on In-house R & D Centres," published for the first time in March 1985. The list also contained the names of certain non-manufacturing units. These units were excluded from the sample. The sample consists of 166 firms, of which 17 belonged to the public sector. Of these, 49 firms belonged to the chemical industry, 53 to electronics and electricals, 32 to industrial machinery, 14 to automobiles, and 18 firms to low-technology industries like textiles and others. Separate regressions were also run for each of these industries. Variables relating to R & D expenditures, firm size as measured by sales turnover, and the age of the R & D units were taken from the same publication. The data was for 1983–84. However, for some of the firms the 1985 publication gave data for 1982–83, and in the absence of other alternatives those figures were taken.

Technology imports *MT* are measured in terms of lump-sum payments agreed to in the approved foreign collaboration contracts during the last four years, namely 1982 to 1985, listed in the national register of foreign collaborations (1982, 1983, 1984, and 1985) published by the Department of Scientific and Industrial Research, Ministry of Science and Technology. For this variable a four-year period was chosen instead of one year as firms need not enter into foreign collaborations every year. Thus if a firm has entered into any collaboration in the last four years, then it would be taken into account. Lump-sum payments have been considered instead of royalties as in the last five years lump-sum payments account for more than 80 per cent of technology payments. During this period this is the most important mode of payment, and not royalties.

Since most of Indian R & D is of an adaptive nature, one expects a positive relationship between expenditures on import of technology and domestic in-house R & D. With regard to this argument, one should expect b_1 to be positive. If the public-sector units do a lot of innovative R & D then the relationship could be negative for the public-sector units. Thus for the pooled sample consisting of both the public- and private-sector firms the statistical significance of the relationship could be reduced. One could therefore expect the statistical significance to improve when the public-sector units are dropped from the sample.

Katrak [5] and Lall [6] tried a linear/log-linear relationship between size (sales) and R & D. Kartak found a less than proportionate increase in R & D expenditure with an increase in firm size (which in terms of the regression equation given above would indicate a negative value for b_3). Lall however found a positive value for b_3 but it was less than one. The specification in this paper is different from theirs as it contains $\log S$ and $\log^2 S$. Based on the arguments presented in the previous sections one expects a negative value for b_3 and a positive value for b_4.

The regression results are presented in Table I. Equations (1) and (2) deal with the cross section of industries. Equation (1) considers all firms while equation

TABLE I

DETERMINANTS OF RD/S

Equation No.		Constant	MT/S	AGE	$\log S$	$\log^2 S$	$\bar{R}^2$	R^2	F	Nos.
(1)	All firms	19.519 (9.646)	−0.00136 (−0.073)	−0.0236 (−0.643)	−9.687 (−6.558)	1.238 (4.949)	0.3930	0.4077	27.707	166
(2)	Without public sector	20.585 (10.374)	0.184 (2.093)	−0.0258 (−0.727)	−10.669 (−7.250)	1.441 (5.510)	0.4628	0.4773	32.877	149
(3)	Chemical firms	3.840 (4.743)	0.0287 (0.585)	0.0546 (0.844)	−0.882 (−2.960)		0.1226	0.1774	3.236	49
(4)	Without public sector	3.903 (4.643)	0.0299 (0.595)	0.0583 (0.874)	−0.914 (−2.886)		0.1203	0.1777	3.098	47
(5)	Electronic firms	22.586 (4.835)	−0.00945 (−0.323)	−0.063 (−1.150)	−10.959 (−2.824)	1.440 (1.971)	0.3759	0.4239	8.829	53
(6)	Without public sector	27.423 (6.410)	0.5506 (2.452)	−0.0745 (1.535)	−15.548 (−4.301)	2.242 (3.279)	0.5235	0.5659	13.360	46
(7)	Machinery firms	15.770 (5.258)	0.00529 (0.146)	0.0709 (0.404)	−8.120 (−3.796)	1.077 (3.050)	0.3893	0.4681	5.940	32
(8)	Without public sector	16.156 (5.025)	0.212 (1.021)	0.231 (1.010)	−8.610 (−3.611)	1.021 (2.495)	0.4637	0.5495	6.403	26
(9)	Textiles and other firms	23.603 (2.358)	0.927 (3.183)	0.094 (0.695)	−14.251 (−2.051)	2.124 (1.854)	0.5383	0.6470	5.956	18
(10)	Without public sector	25.353 (2.341)	0.9007 (2.968)	0.071 (0.482)	−15.498 (−2.056)	2.357 (1.871)	0.5262	0.6447	5.443	17

Notes: 1. t-values are given in the brackets.

2. RD/S=Expenditure on R&D divided by sales for the year 1983–84.

MT/S=Lump-sum payments as mentioned in the apprɔved contracts for the years 1982–85 as a proportion of firm's size measured in terms of sales.

AGE=Age of the R&D establishment from the date of recognition granted by the Ministry of Science and Technology.

S=Sales turnover of the firm for the year 1983–84.

(2) considers only the private-sector firms. In both the equations *AGE* did not turn out to be an important determinant of the R&D intensity. In both the equations the relationship between R&D intensity and firm size as measured by sales was U-shaped. R&D intensity decreased with the increase in firm size, till the sales volume increased to Rs.600 million, but for sizes beyond that level, R&D intensity increased. This was true for the combined sample of both public- and private-sector units, as well as for the sample consisting of only private units. The firms included in the sample ranged from very small ones that had an annual turnover of around one million rupees to giant steel corporations like SAIL and TISCO which had annual turnovers of several thousand millions. Given this wide range in the sample size the emergence of a statistically significant U-shaped relationship between size and R&D intensity is not surprising. The nature and quality of R&D done by the smaller firms with a turnover of a few millions is bound to be different from those of giant corporations having turnovers of several thousand millions per annum. There were fourteen firms in the sample that had turnovers of more than Rs.1,000 million per annum. Thus the minimum economic size argument for R&D units and economies of scale arguments for R&D expenditure that were used to explain a negative relationship between R&D intensity and *S* in the case of the small firms in the sample might not be valid for the very large ones. The results confirm this.

The coefficient of the technology-import variable was not significant in equation (1) consisting of both private- and public-sector firms. However, it was significant in equation (2) which consisted only of private-sector firms. The evidence indicates a mild complementary relationship between import of technology and in-house R&D effort for the private-sector firms. It is possible that the relationship is the other way round for the public-sector firms. In order to find out whether the public-sector firms were outlayers and analyze their behavior in particular with regard to the import of technology, the coefficients of equation (2) were used to predict the values of the dependent variable for the seventeen public units. The actual values of five out of these seventeen units exhibited large percentage deviations from the predicted values [predicted using equation (2) which did not include the public units]. For all these five units the actual R&D intensities were much lower than the predicted ones. All of them also happened to be heavy importers of technology. For the sample of private sector firms the average technology imports was 0.86 per cent of their sales, while the corresponding figures for these five public-sector firms ranged between 12.09 and 152.10. The average R&D intensity of the firms included in equation (2) was 3.04 per cent, while all these five firms had substantially lower intensities. On the other hand the public sector firms that had very high R&D intensities in the sample did not spend much on lump-sum payments. Thus for the public-sector firms included in the sample there appears to be a negative relationship between import of technology and their in-house R&D efforts. In other words the data points to a substitution relationship. With regard to other variables, however, the behavior of public-sector firms was not much different from those of the other firms in the sample.

In the case of the firms belonging to the chemical industry, as seen from equations (3) and (4), there does not appear to be any difference in the behavior of the two samples. In both equations technology imports were not important in explaining R & D intensity. One of the reasons could be that the average expenditure on import of technology by chemical firms is much lower compared to firms operating in other industries. In both the equations $\log^2 S$ was not statistically significant and the coefficient of $\log S$ was negative indicating a less than proportionate increase in R & D with respect to increase in size.

The behavior of the firms belonging to the electronics industry [equations (5) & (6)] are by and large similar to that of the inter-industry cross-section sample [equations (1) & (2)], namely, a U-shaped relationship between firm size and R & D intensity, and a complementary relationship between the expenditures on the import of technology and in-house R & D for the private firms. In fact for this industry, the complementarity seems to be stronger as seen from the higher value of the coefficient of MT and its t-value. In the case of the machinery firms also [equations (7) & (8)] the relationship between size and R & D intensity was U-shaped where both the terms were statistically significant. The coefficient of MT was positive but not significant. There were only fourteen automobile firms in the sample ranging from big automobile corporations producing passenger cars and heavy vehicles to small ancillary units. The equation is not reported here as none of the variables turned out to be import; this could be due to the small number of observations and large variations in the size of the firms. The sample size was not large enough to capture nonlinearity.

Equations (9) and (10) dealing with firms operating in low-technology industries like textiles are interesting for the following two reasons. Firstly, unlike in the previous cases, there does not appear to be any appreciable difference between the two equations [(9) and (10)]. This could be partly because there was only one government firm in the sample. Secondly, the relationship between the two expenditures is much more significant and stronger in this case compared to other industries. The values of the coefficients are substantially higher and their respective t-values are also larger. Thus the complementary relationship appears to be much stronger for these low-technology industries than for the relatively high technology ones. A similar finding was also made by Katrak [4] and he concluded that the relationship was weaker for the more complex technologies. It is possible that Indian firms do not perform much adaptive R & D on relatively high and more recent technologies, and merely import and use them as they are. However, when it comes to more standardized technologies they do perform adaptive R & D on them. A similar observation was also made by Ito [3] based on a sample survey of Japanese firms that transferred technology to the Indian firms in recent years. Even though this result might not be conclusive, it is in line with the findings of other studies. The relationship between size and R & D intensity in these two equations is similar to those of other industries, namely, U-shaped.

The study points to the following conclusions. The relationship between import of technology and domestic R & D expenditures is mainly complementary for the private-sector firms, but is a more complex one for the public-sector firms. The complementary relationship is stronger in the case of more standardized and low-technology imports than in the case of sophisticated ones. There are strong nonlinearities in the relationship between size and R&D intensity. For the smaller firms R&D expenditure increases more slowly than the increase in firm size, but for the very large ones it increases faster than the increase in size. This is mainly because the nature and type of R&D activity between the large and small firms is different, and therefore are not strictly comparable.

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