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FIRM SIZE AND IN-HOUSE R & D: THE INDIAN EXPERIENCE REVISITED

PRADOSH NATH

I. INTRODUCTION

THIS paper is a follow-up of the study done by Siddharthan [27] on the relationship between innovation activity and firm size in Indian industries. Siddharthan's study was based on 1985 data from the Department of Scientific and Industrial Research (DSIR), Government of India. The DSIR data base is the compilation of information furnished by industrial enterprises seeking registration of their respective in-house R & D centers. The first volume was published in 1985, and since then it has become a yearly publication of the DSIR as a public document [11, 1985–89 editions]. Subsequent volumes include many new industrial enterprises, thereby creating the opportunity for an exercise with a wider data base.

Siddharthan visualized a U-shaped relationship between firm size and innovation activity. The implication of such a relationship was not detailed in Siddharthan's paper. We attempt to do this in Section II.[1] Section III examines the implication of a U-shaped curve in the particular context of India which can be taken as a representative less-developed country (LDC). In Section IV, we elaborate similarities and dissimilarities between exercises done by us and Siddharthan. Section V presents the results of our exercise and compares them with those of Siddharthan's. Summary and conclusions are presented in Section VI along with policy implications of the findings.

II. THE CASE OF A U-SHAPED RELATION

The relationship between firm size and innovative activity is a direct off-shoot of the Schumpeterian description of capitalism and its dynamics.

Schumpeter argued that with a rise in degree of market concentration, price competition would be replaced by non-price competition (technological innovation). The sufficient condition for any innovation to take place within the Schumpeterian scheme is market power and economic rent accruing from the

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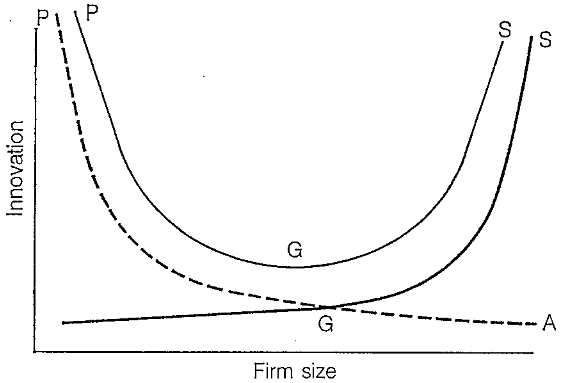
Fig. 1



market power.[2] Firms large enough to attain at least temporary market power will innovate as a means of attaining higher profits, meaning the larger their market power the more innovative firms are.[3] The distinction between major and minor innovations is not very clear in this statement. But if we assume that major innovations require very large market power, then an implication of the Schumpeterian hypothesis is that the larger the firm (in terms of market power) the larger would be its innovative activities. In fact, Galbraith's interpretation [8] brings out this dimension of the Schumpeterian hypothesis.[4] Galbraith suggested that present-day innovation requires large resources that can be afforded only by very large firms. Let us call it the Galbraithian necessary condition for major innovations and let us assume that we can define a lower limit of the firm size for undertaking major innovation activities. In Figure 1 the darker portion (GS) of the curve depicts the Galbraithian necessary condition and a stylized version of the basic Schumpeterian hypothesis (the sufficient condition for firms undertaking major innovations). Point "G" in the curve is the Galbraith point for minimum firm size capable of undertaking major innovations.

Although both Schumpeter and Galbraith were concerned about firm size and market power of the firm, they were not specific about market structures. A market structure dominated by a few firms is implicit in their hypotheses. But

[2] For a detailed discussion of the Schumpeterian condition of innovation, see Kamien and Schuwartz [12] and also Cohen and Lebin [6].

[3] Nelson [22] argued that although this proposition was widely being accepted for empirical verification of the Schumpeterian hypothesis, Schumpeter had never suggested a continuous relationship between firm size and innovation (also see Cohen and Lebin [6]). We, however, propose a continuous relationship as a stylized version of the Schumpeterian hypothesis for analytical convenience.

[4] The Galbraithian condition had been seen as a corollary to the original Schumpeterian hypothesis by Kamien and Schwartz [12]. We would like to suggest taking the Galbraithian hypothesis as the necessary condition for understanding the relation between firm size and innovation.

incentive to innovate and, therefore, innovative behavior of firms is likely to be different in different types of market structures.

Arrow [2] examined the issue of incentive to invent by specifying monopoly and competitive market conditions. If monopoly is defined as "barrier to entry," Arrow argued, "the incentive to invent is less under monopolistic than under competitive conditions but even in the latter case it will be less than is socially desirable" [2, p. 176]. He further argued, "the preinvention monopoly power acts as a strong disincentive to further innovation.... The only ground for arguing that monopoly may create superior incentives to invent is that appropriability may be greater under monopoly than under competition. Whatever differences may exist in this direction must, of course, still be offset against the monopolist's disincentive created by his preinvention monopoly profits" [2, p. 177–78]. Arrow also suggested that if incentive to invent in competitive circumstances is compared with social benefits, it is seen that "the inventor obtains the entire realized social benefit of moderately cost reducing inventions but not of more radical inventions. Tentatively, this suggests a bias against major inventions,..." [2, p. 179].

Philips' argument [24] adds another dimension to Arrow's. Instead of comparing monopoly and competitive market conditions, Philips examines an industry dominated by a few large firms coexisting with number of small firms. Under such circumstances, Philips argued, higher market concentration might inhibit the Schumpeterian non-price competition as well through a tacit market-sharing agreement among large firms. In such a situation, it is likely that smaller firms, in competitive conditions, would become more innovative in order to create their own market niche. Baldwin and Childs [5] argued that with the advantages of size and resources the big firms might instead take the position of "first second" by quickly imitating the innovations by other firms. If we add the Galbraithian necessary condition (only large firms being capable of major innovations) and Arrow's argument (under competition a bias against major inventions) then it follows that Philips' small firms will be essentially engaged in minor innovations.[5] Hence we can get a stylized version of the Philips-Arrow curve "PGA" as depicted in Figure 1 which will intersect the "GS" curve at the Galbraith point "G." The envelope of the two curves ("GS" and "PGA") gives a U-shaped curve describing the relationship between firm size and innovation, accommodating all the hypotheses discussed above.[6]

Empirical verification of the relationship between firm size and innovation as shown in Figure 1 is riddled with many problems. Apart from numerous problems encountered in measurement of both firm size and innovation, the exact relation

[5] It is to be made clear that large firms doing major innovations do not mean that they do not do any minor innovations. In fact any major innovation requires a series of minor innovations before the major innovation reaches the final stage of commercial use.

[6] What is not captured by the two dimensional presentation of Figure 1 is the distinction between minor and major innovations at the left and right side of the curve, respectively. It is to be noted that curve PGS is the juxtaposition of two different curves in the same plane, where the left side of "G" measures minor innovations and the right side of "G" measures major innovations.

will depend on type of industry, market structure, and also on industrial characteristics of particular countries.

The study done by Pavit et al. [23] which is the latest major study in this field on the basis of 4,378 innovations in the United Kingdom since 1945, supports a U-shaped relationship between firm size and innovation activity. This result is quite different compared to the earlier studies showing; (a) R&D intensity increasing up to a certain firm size and then remaining constant or gradually declining [26]; (b) no relationship between R&D intensity and firm size [19] [28]; and (c) R&D intensity increasing with size at the global level [28].

Studies which included market concentration as one of the explanatory variables, however, did not bring out any clear indication towards a positive relationship between market concentration and innovation activity [6] [25]. In fact a negative relationship has been reported by many studies [1] [16] [9]. Acs and Audretsch argued that the actual question to be asked within a Schumpeterian hypothesis is: "Under which circumstances do large firms have the relative innovative advantage...?" [1, p. 573] instead of probing into whether large firms are innovative or not.

Most of these studies are based on data of the developed countries where industries and market structures of the industries have characteristic differences with those of the less-developed countries (LDCs). It would be interesting to examine how the innovative characteristics of industries in less-developed countries are accommodated within the scheme suggested above.

III. U-SHAPED RELATION FOR LDCs

The basic difference between industries in developed countries (DCs) and LDCs is the latter's technological dependence on the former. Large corporations of the size and dynamism which Schumpeter found to be the forerunners of technological progress are nonexistent in most of the LDCs. Firms and large corporations in LDCs mostly operate in a narrow domestic market whereas their counterparts in the DCs are globalized. Hymer [10] has presented an excellent description of the process of imitation and development of industries in LDCs, where consumption and later production activities both follow the patterns of the developed countries. As a result, Bagchi [3] [4] argues, industries in LDCs get an elite bias and technological dependence perpetuates in a narrow market.

These factors together create an industrial and market structure which is typical of LDCs and definitely influence the innovation activities of their industries. Here, we restrict ourselves to the Indian case as a representative LDC and try to develop a hypothesis for firm size and innovation activities for the LDCs by further elaborating the market structure of Indian industries.

Desai [7] characterized Indian industries in broad groups of long-tailed and short-tailed industries. Long-tailed industries are those where the market is dominated by a few large firms coexisting with a large number of small firms. These are the industries where technology is not scale dependent and products are not highly standardized and markets are segmented.

Desai argues, "The most important form of segmentation is in the labor market. Wages in large-scale industry which increase with its size and productivity, are quite out of proportion with unskilled wages outside, whilst small-scale industry can get workers at a wage little above the going unskilled wage. The resulting wage differential is roughly of the order of 1:4 in the textile weaving industry, and even higher in other industries. This is the outstanding cause of the viability of small-scale enterprises." [7, pp. 115–16] Market segmentation also might be the result of product differentiation based on differences in consumption patterns between income groups or location groups (e.g., rural and urban). Desai argued, "but it would be wrong to assume that product differentiation by itself protects small-scale or labor-intensive industrial techniques; there must in addition be substantial costs attached to the integration of differentiated markets" [7, p. 116].

In addition, the Government of India has definite policies of encouraging a long-tailed industry through excise duty discrimination against large firms, the industrial licensing mechanisms, anti-monopoly legislation and product reservation for small firms. Desai concludes, "the long tailed market structures common in India are not necessarily conducive to technological progress" [7, p. 119].

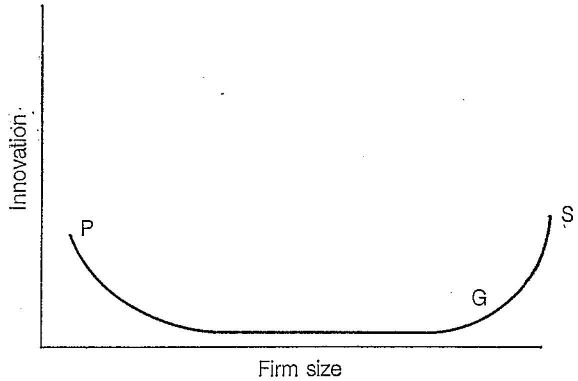
There is a close resemblance between Desai's description of long-tailed market structures, common in Indian industries, and market structures described in Philips' hypothesis. In such a market, in addition to the tacit market sharing among a few large firms, there are disincentives to becoming larger through more and more technological innovations. On the other hand, small firms at the tail, because of competition among themselves and also taking advantage of the disincentives to the large firms, are likely to become more innovative to create their own market niche.

A short-tailed industry is that which has an "entry barrier in terms of pronounced economies of scale" and high capital cost. The automobile industry in the consumer-goods sector and the metal industry (steel and aluminum) in the basic industry sector are examples. In such cases if the market is protected (by high tariffs and/or import restrictions) and firms are inward looking (without any presence in the international market), the Philips condition of tacit agreement among firms for market sharing is likely to hold. No major innovative activities are expected in such a market.[7] In other cases where firms in the short-tailed industry have international presence, or face international competition in the domestic market, they have to be more innovative. But R&D for any major innovations is so expensive (the Galbraithian condition) that these large firms from LDCs would be nowhere near the international giants in terms of resource availability for R&D to fulfill the Galbraith condition. Innovations in such cases are, therefore, likely to be dependent on imported technology and also likely to be only adaptive R&D in nature, as suggested by Lall [18].

There are still cases of giant enterprises in India, mostly in the public sector (Steel Authority of India Ltd., Bharat Heavy Electrical Ltd., Oil and Natural Gas Commission, India Oil Corporation, etc.) but also a few in the private sector

[7] The experience of the Indian automobile industry supports this view [20]. Katrak [13] also observed similar features for large enterprises in India.

Fig. 2



(Tata Iron and Steel Company and Tata Electrical and Locomotive Company). In the public sector, the giants and a few large firms have to invest in R&D as a part of governmental policy of promoting technology development. Similar giants in the private sector who have international presence and prestige have to invest at a higher proportion for new innovations.

These are the firms which have the resources to satisfy the Galbraith condition of undertaking major innovative activities.

Summarizing the above discussion of market structure, the following few points emerge as salient features:

(a) A Philips' kind of long-tailed structure is common in Indian industries, where smaller firms are likely to be more innovative (minor innovations) and closely imitated by large firms. In terms of R&D intensity this would show a gradual continuous decline in R&D intensity as firm size increases. So the Galbraith point in Figure 1 is not likely to be reached by firms in these industries.

(b) If the industry consists of giants in the public sector or private sector it is likely that these firms would undertake some innovative R&D at least due to policy compulsion. In that case the relationship between firm size and innovation might show an upward trend (the Galbraith point) for very large firm size.

(b) Even in short-tailed industries firms are likely to be dependent on imported technology for any major innovations, and R&D is likely to be adaptive in nature only. Hence, these firms also cannot attain the Galbraith point.

On the basis of the above understanding a stylized representation of the relationship between firm size and innovative activity for LDCs like India would be a much elongated U-shaped curve as shown in Figure 2.

Since in the typical Indian context most of the firms in any industry belong to firm sizes to the left of "G," it is quite unlikely to get any considerable support for a U-shaped curve. Some weak support, however, is possible if the industry has the presence of a few giants in the public and/or private sectors.

The earliest study on R&D and firm size with Indian data was on the chemical industry in 1971 by Subramanian [29].[8] He did not find any support for the hypothesis that innovative activities (measured by R&D intensity) increase with market power and also found that the R&D intensity of small firms was at least as high as that of large firms. The finding indicates a U-shaped relationship having the same R&D intensity at two different levels of firm size. He, however, estimated a linear relationship.

In a follow-up study Subramanian [30] found sales, depreciation, and past R&D as factors strongly influencing current R&D and concluded that "in a given industry the financial variable (internal funds) influences strongly the scale of R and D by business firms" [30, p. M-171].

Most of the works after Subramanian essentially focused on that section of Indian industries where, as Desai described, importation of technology was possible. The original hypothesis was suggested by Lall [17] that innovative activities are likely to depend on imported technology and, therefore, are likely to be adaptive R&D in nature. Lall [18] studied 100 enterprises in Indian engineering industry and found royalty payments (a measure of technology imports) positively related to R&D expenditure and suggested a complementary relationship between the two variables. Katrak [14] worked on a similar hypothesis and found support for import induced adaptive R&D for Indian industries.[9]

In a follow-up study Katrak [15] disaggregated firms in terms of technology importers and non-importers and found that the importation of technology positively influences R&D and that the higher the imports the higher is R&D expenditure.

For both Lall and Katrak the question was the influence of technology importation on R&D behavior of firms and not size of the firm per se. Siddharthan [27] brought the question of firm size back into the analysis of the technological behavior of Indian firms and the present paper is also set in the same tune. In the following section similarities and dissimilarities of our exercise with that of Siddharthan's are elaborated.

IV. APPROACH

With a limited data base Siddharthan tried to estimate a U-shaped relationship between firm size, measured by annual sales turnover (ATO) of the firm, and innovative activity (input measure), by defining R&D intensity as a ratio between R&D expenditure and ATO. He also considered two more variables: firms' experience in innovation activity captured by the age of its in-house R&D center as measured by the date of initial registration of the in-house R&D center with the DSIR, and the influence of foreign technical collaboration as measured by data on lump-sum payments made by a company to its foreign collaborator as a ratio of ATO. Regression analysis was carried out separately

[8] Subramanian's paper does not cite any similar earlier studies on Indian industries.

[9] Katrak had used industry-level data and used expenditure on capital imports and non-capital equipment as indicators of dependence on imported technology.

for each industry segments and all segment together. He stretched the exercise further by separating out public-sector units in each industry segment.

A reasonable degree of support for a U-shaped relationship was found in the exercise. The size of the firm, however, was seen as having the strongest influence on R&D intensity compared to very weak influence shown by the two other variables.

The source of information used by us is the DSIR data base from 1985 to 1989. The latest volume of 1990 had not been published at the time of the present study. The five DSIR volumes covered by us also include the 1985 volume used by Siddharthan. We have made a review of the data base elsewhere [21] and found that except for information on firm size and R&D expenditure the rest of the data base is not usable with a reasonable degree of reliability for any analytical purpose.

The total number of firms covered by our study is 805 (as opposed to 166 in Siddharthan's). This excludes firms that are listed in the volumes but cannot be categorized either as industrial unit (no manufacturing activity) or as in-house R&D.

We also have defined R&D intensity and firm size the way it has been defined by Siddharthan. Siddharthan's data on lump-sum payments for foreign collaboration was collected from non-DSIR sources. What was possible for a small number of firms in his study has not been so for the larger data base of our study. Also it has not been made clear exactly how R&D intensity is functionally related to lump-sum payments for foreign technology. In a developing economy like India it is quite reasonable to assume that foreign collaboration would greatly influence the indigenous technological activity. But the same is also dependent on the global technological strategy of the foreign collaborator. How far lump-sum payments for foreign technology can approximate the influence of foreign collaboration on technological behavior of Indian firms needs clarification.

We, however, have restricted ourselves to the question of whether foreign technical collaboration (TC) has any influence at all on the technological behavior of the firm by treating it as a dummy variable taking the value "1" if the firm has foreign collaboration and "0" if the firm does not have any foreign collaboration.

The age of the R&D centers used by Siddharthan as a proxy for R&D experience of the firm has some problem. The age is calculated from the date a firm got initial recognition for its R&D center from the DSIR. Obviously this does not mean that the firm did not have any R&D experience before. In fact there are firms (both very old and new) who are known for their R&D orientation but are not registered with the DSIR. The registration is actually associated with the incentives scheme introduced by the government for promoting in-house R&D in Indian industries and, therefore, registration would mean firms coming forward to take advantage of the scheme and is not necessarily an indicator of the R&D experience of a firm.

Instead, we are introducing a new variable, age of the firm, available from the same DSIR source. A firm which has survived in the market and retained its market share for a very long time is expected to be technologically more dynamic and likely to show higher R & D intensity. At the same time if a firm is a new entrant in a market it is expected to be more R & D oriented to create its own market niche. We are, therefore, postulating again a U-shaped relationship between age of the firm and R & D, expecting that old and established firms and new entrants will be more R & D oriented. No support to this relationship will, in a way, mean that the general industrial environment is not conducive to technological innovation. This will imply that there are non-technological means[10] of market control in the typical industrial environment of India.

Siddharthan argued that, in the Indian case, private industries mostly do adaptive R & D, and because of governmental policy pressure public sectors are expected to do more innovative R & D. To avoid possible bias in the analysis he tested both sectors together as well as separating out the public sector. His results improve for the latter case.

Since he used the input measure of innovation activity (not the output measure) the difference in the nature of innovation activity cannot be captured by his method. Only at the innovation end of R & D it might become possible to distinguish between adaptive R & D and innovative R & D. Although his results improve considerably, there is no prima facie reason for that being so. Hence, in our exercise we did not make any such attempt.

In his statistical exercise Siddharthan followed broad sector classification available from DSIR compendium [1, 1985–89 editions]. We also have maintained the same classification as seen in Table I. This kind of classification, as it appears, poses some limitations to the study because it may not throw enough light on industries understood as consisting of firms with manufacturing activities in a particular product line or at least in a broad group of products line. The DSIR data base follows a broad technology-based classification of firms by putting together those firms which can be broadly categorized as using a particular group of technology, e.g., chemical, electronics, mechanical, etc. It is evident that DSIR groupings are more in line with the academic disciplines in universities. Product-based classification of industries definitely refers to a particular technology or a particular group of technologies, whereas technology-based classification refers to generic technologies irrespective of the nature of the products. It is expected that a few groups of firms under the former classification will be subsets of a group of firms classified by generic technology and, therefore, it is possible that some of the analytical details will be missed if the latter classification is chosen instead of the former.[11]

It is the unavailability of relevant information which makes it almost impossible to undertake any aggregate study on the basis of product-based classification of firms. For example, Hindusthan Lever is one of the largest firms in the chemical sector having interests in a wide range of fields from agro-business to industrial chemicals to home toiletries. Many smaller firms have different ranges of inter-

10 By non-technological means we mean market control or a market niche which is created or acuired by tacit market sharing agreement among firms, and/or by taking advantage of various government policies such as licensing, taxation, excise duties, etc.

11 The author is grateful to anonymous referees for drawing attention to this problem.

TABLE I

RESULT OF THE REGRESSION ANALYSIS

Industry Sector (No. of Firms)	Equation No.	Constant (t-value)	log ATO (t-value)	$\log^2 ATO$ (t-value)	Age (t-value)	Age^2 (t-value)	R^2	$\bar{R}^2$ (F-value)
All sectors (805)	(1)	0.02	−2.92	2.58			0.231	0.228
		(12.16)	(10.94)	(9.68)				(104.107)
	(2)	0.02	−2.94	2.58	0.07	0.016	0.237	0.233
		(12.11)	(10.63)	(9.37)	(0.82)	(0.18)		(50.54)
Chemical sector (278)	(1)	0.02	−2.48	2.22			0.161	0.155
		(6.16)	(5.54)	(4.97)				(23.39)
	(2)	0.02	−2.50	2.22	0.11	0.058	0.187	0.172
		(5.90)	(5.33)	(4.78)	(0.67)	(0.37)		(12.82)
Electrical & Electronic sector (203)	(1)	0.03	−4.97	4.58			0.46	0.45
		(11.10)	(10.14)	(9.33)				(72.35)
	(2)	0.03	−4.98	4.62	−0.19	0.187	0.47	0.45
		(10.71)	(9.75)	(9.02)	(1.29)	(1.18)		(33.75)
Mechanical sector (157)	(1)	0.003	−0.66*	0.48*			0.04	0.02
		(1.29)	(0.91)	(0.66)				(2.81)*
	(2)	0.004	−0.76*	0.56*	−0.14*	−0.13*	0.04	0.01
		(1.30)	(0.98)	(0.74)	(0.58)	(0.53)		(1.40)*
Processing sector (108)	(1)	0.04	−3.74	3.30			0.38	0.36
		(5.96)	(5.24)	(4.62)				(25.34)
	(2)	0.03	−3.57	3.05	0.81	−0.68	0.43	0.40
		(5.50)	(4.99)	(4.24)	(2.65)	(2.25)		(14.75)
Miscellaneous sector (59)	(1)	0.009	−0.62*	0.11*			0.26	0.22
		(1.58)	(0.67)	(0.12)				(7.39)*
	(2)	0.009	−0.63*	0.16*	−0.16*	0.12*	0.26	0.18
		(1.44)	(0.57)	(0.14)	(0.26)	(0.85)		(3.38)*

* t- and F-values are not significant at the 10 per cent level. In other cases t-values are significant at the 5 per cent level and F-values at the 10 per cent level.

sections of business interests with Hindusthan Lever. In a product-based classification, therefore, Hindusthan Lever will figure in many groups, and the analysis would require product-wise information on firm size and R&D which is not available for Indian industries.

V. RESULTS OF THE STATISTICAL ANALYSIS

In keeping with the above discussion, we try to examine the R&D activities of 805 Indian industrial enterprises having in-house R&D centers according to the models expressed in equations (1), (2), and (3) below.

$$RDI = A + B_1 \log ATO + B_2 \log^2 ATO \qquad (1)$$

$$RDI = A + B_1 \log ATO + B_2 \log^2 ATO + B_3 Age + B_4 Age^2 \qquad (2)$$

$$RDI = A + B_1 \log ATO + B_2 \log^2 ATO + B_3 Age + B_4 Age^2 + B_5 + B_5 TC \qquad (3)$$

It is evident that new variables are added in each subsequent equation. This was done to see whether R^2 changes with the introduction of new variables. It has been found that although R^2 increases with the introduction of *Age* with *ATO*, the same decreases if *TC* (foreign technical collaboration) is introduced as a new variable. t and F values are also found to be insignificant. Finally, therefore, equation (3) has been dropped.

The results of the regression analysis for equations (1) and (2) are presented in Table I. As shown in the table, t and F values are significant for all sectors except for mechanical and miscellaneous sectors.

Although R^2s are not directly comparable with those derived by Siddharthan because of differences in the nature of variables, coefficient of *ATO*s are much smaller in our case compared to the same derived by Siddharthan. In both exercises, firm size emerges as having the strongest influence. It is interesting to note that in Siddharthan's case the coefficients of $\log^2 ATO$ are much smaller in magnitude than the coefficients of $\log ATO$. This suggests that the rising portion of the "U" is much flatter than the declining portion. In our case both are almost similar in magnitude with a difference in sign.

R^2 values are highest for the electrical and electronics sector and the processing sector. They are considerably lower in the chemical sector and almost negligible in the mechanical sector.

Table I is to be interpreted in the light of Table II which presents structures of firm size in different sectors. Table II shows size class of firms in three categories: (a) the smallest firms which have annual turnover (ATO) less than Rs.200 million; (b) middle-level firms which have a broad range of ATO from Rs.200 million to Rs.999 million; and (c) large firms which have ATO of Rs.1000 million and above. It is to be noted that in every sector most of the firms belong to the smaller and medium-size categories and, therefore, resemble the long-tailed structure of Indian industries observed by Desai [7].

It is to be mentioned that the number of giant firms in each sector in the broad

TABLE II
PERCENTAGE OF FIRMS BELONGING TO DIFFERENT SIZE CLASSES IN DIFFERENT SECTORS

(%)

Sectors	Firm Size (Annual Turnover in Rs. Million)		
	Less Than 200	200–999	1,000 and Above
All Sectors	50.43	34.16	15.41
Chemical	38.85	50.36	10.79
Electrical/Electronics	70.44	15.77	13.79
Mechanical	48.41	27.39	24.20
Processing	39.81	36.12	24.07
Miscellaneous	61.02	35.59	3.39

category of large firms is not more than six. It is also to be mentioned that the turnover totals of even the top ten firms in Indian industry (1991–92) do not figure anywhere near the giants of the developed countries. This implies that the above mentioned Galbraith point for major innovation is farfetched in Indian industries. It is, therefore, expected that Indian industries will be largely dependent on imported technology for any major innovation and also, as suggested by Lall [18] and Katrak [14] [15], R&D in Indian industries will be related to the extent of technology importation.

It is only in the chemical sector that medium-size firms outnumber small firms. In high-technology areas in this sector where economies of scale are clearly pronounced, even the largest firms are fully dependent on imported technology with very little scope for any further innovations. In low-technology areas firms in small and medium categories, mainly engaged in the production of either common drugs and pharmaceutical products or cosmetics products, compete with each other and also with large firms. The nature of innovations in this field, irrespective of the size category of firms, is essentially of very minor types of new formulations for product differentiation. The small R^2 derived for this sector is, therefore, quite in line with expectations.

Like the chemical sector, the mechanical sector is also heavily dependent on imports, particularly the heavy machinery sector which is dominated by very large firms. The same argument regarding major innovations applies in this case also. The additional feature of this sector is that it has witnessed very sluggish growth over the last decade or so and of course more so in R&D activities. A U-shaped relationship is, therefore, nowhere near to the reality.

On the contrary the electrical and electronics sector, in particular the electronics industry, has observed phenomenal growth during the last decade. Numerical strength wise this sub-sector is dominated by small firms (ATO being less than Rs.200 million for 70 per cent of the firms). The main growth of industry has been in the field of home electrical goods and electronics. This particular field has wide scope for minor process and product innovations for product differentiation.

Larger firms in this field would differ from the small ones in terms of product diversification whereas smaller firms would be restricted to one or two specialized products. Although the nature of R&D activities (mainly for minor innovations) remains the same for both small and very large firms, in the case of the latter R&D activities would be much more diversified because of their diversified production activities (e.g., video, audio, medical instruments, etc.). This appears to be the reason behind the better R^2 received for this sector. Heavy electrical industry in this sector, like the chemical and mechanical sectors, is heavily dependent on imported technology with very little scope for minor innovations and major innovations being definitely beyond the reach of even the very large firms in this industry segment.

The processing sector includes industries like paper, textiles, jute, etc. which have very long production experience and very little room for minor or major innovations. Comparatively better R^2 for this sector could be because the food-processing and packaging industry segments are included in this sector. These two industry segments have seen quite considerable growth during the last decade and have all the features of the electronics industry.

The miscellaneous sector includes consultancy firms, the service industry, and cooperative industrial R&D centers. The apparent reason behind separating out these firms as miscellaneous industry is that they are not engaged in manufacturing activities. This sector shows better R^2 compared to the chemical and mechanical sectors. The reason appears to be the presence of consultancy firms which are likely to be more R&D oriented because typically in this sector better business depends on better technological capability.

We postulated a U-shaped relationship also for *Age* as an explanatory variable. The expectation was that a firm which has survived in the market for a very long time must be having stronger R&D orientation. On the other hand a very young firm, because of higher technology consciousness is also likely to be more innovative.

Our results, however, do not show any considerable support for our expectation. Neither the magnitude nor the sign of the coefficient show any pattern of further interest. This lends preliminary support to an overall impression that in the Indian industrial environment technological innovation is not a prerequisite for a firm to have either temporary or long-term control over the market. The matter, however, deserves more rigorous study for a more definite conclusion.

VI. CONCLUSION

Although there is empirical evidence supporting the existence of a U-shaped relationship between R&D intensity and firm size, the theoretical implications of such a relationship are not much discussed in the relevant literature in this field. We have argued that this relationship is actually an envelope of stylized versions of the Schumpeter-Galbraith and Arrow-Philips hypotheses. We have also argued that there is a difference in the nature of innovation on both sides of the curve. While the right side of the curve shows major innovation, the left side shows minor innovations undertaken by smaller firms. Both the hypotheses can be accommodated in one scheme if they are seen in the context of the nature of innovations (major and minor) as implied in Galbraith's view on major innovations.

Further, on the basis of the above understanding we have postulated a much elongated U-shaped relationship between firm size and innovation for less-developed countries with particular reference to the long-tailed structure of Indian industry. We have argued that since under typical Indian conditions most of the firms would not satisfy the Galbraithian condition of major innovation, it was quite unlikely to get any reasonable support for a U-shaped relationship.

In an earlier study on Indian industry Siddharthan ignored these points and generally accepted the hypothesis that in Indian industries very small and very large firms are more R&D oriented. He neither asked the question why it should be so, nor tried to explain the considerable variations in the value of R^2 over the sectors under consideration.

With a larger data base the R^2s derived by us are much smaller than that those derived by Siddharthan. We have tried to examine the result with broad information on scope of technological innovations in different industrial sectors, nature of dependence on imported technology and long-tailed structure in different sectors. The general finding is that major innovations being beyond the financial and technological means of even very large firms, wherever there is scope for minor innovations a U-shaped relation appears to be more acceptable. Sectors which are heavily dependent on modern imported technology (particularly in high-technology areas) have little scope for minor innovations and presumably depress the result. This could be the reason behind *TC* as an explanatory variable giving a poorer fit to the U-shaped relation and probably lends support to our hesitation in using lump-sum royalty payments as a proxy for the influence of foreign collaboration on the R&D behavior of Indian firms.

The policy implications of the above findings are twofold. The first is related to protection of small firms in an industry; and the second is related to the question of protection of infant domestic industries. Both these questions are to be addressed in the light of the general economic and technological policies of a country. If a country aspires to catch up with the developed countries it has to develop technological capabilities in high-technology areas (major innovations), and, therefore, has to provide its industries opportunities for creating market leadership through technological dynamism. This will definitely mean (a) a less cozy cushion for firms at the tail end of an industry; and (b) making domestic industries more exposed to global challenges.

While there is no denying the importance of providing resource-poor small firms and infant domestic industries, particularly in less-developed countries, with breathing space to equip themselves to face the challenges of the marketplace, the nagging question remains of when do infant firms and industries really reach maturity.

Industrial protection is generally provided in the form of tax and duty concessions of different varieties, import restrictions on competitive products and processes, etc., which give a price advantage to the small firms over their larger counterparts, and to the infant industries over their potential foreign competitors. In an overall environment of rising unemployment and lack of industrial growth, firms and industries take the political opportunity of lingering under the benefits of protection without ever attaining maturity. As a result infancy perpetuates, so does low industrial growth, and catching up remains an unfulfilled aspiration for most of the less-developed countries.

Alongside, as a part of technology policy, incentives in the form of tax benefits, more liberal import licenses, etc. are given to firms undertaking industrial R&D (some of these incentives have been withdrawn from 1990 onwards). There is no apparent link between the policy of R&D incentives and the policy of protection to firms and industries. One way of establishing some kind of link between the two sets of industrial and technology policies appears to be by shifting incentives from the R&D end of technological initiative of firms to the innovation end of technological dynamics. This will mean providing incentives to the firm only on the basis of evidence of actual innovation. A policy of general protection of small firms and infant industries can, therefore, be withdrawn, because a policy of providing incentives only to technologically dynamic firms (small or large) will ensure the exit of incompetent firms from any industry. Such a policy, it is expected, will help development of technology orientation among both small and large firms in any industry and a new entrant, small or large, or an old established firm will not be able to hold control over the market through nontechnological means.

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