LIBERALISATION, FIRM SIZE AND R&D PERFORMANCE: A FIRM LEVEL STUDY OF INDIAN PHARMACEUTICAL INDUSTRY

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In the present paper, an attempt is made to empirically verify the impact of economic liberalisation on the R&D behaviour of Indian pharmaceutical firms, controlling for the effects of several firm specific characteristics including firm size. The results from the Tobit analysis for a sample of firms over the period 1989-90 to 2000-01 indicate that competitive pressure generated by liberalisation has worked effectively in pushing Indian pharmaceutical firms into R&D activity. A host of firm characteristics like age, size, profitability, intangible assets, export orientation and outward foreign direct investment of the firm are also found to be important determinants of innovative activity in the industry. The study suggests several policy measures to further indigenous technological efforts of pharmaceutical firms, which include removing obstacles that inhibit outward orientation of firms, providing special scheme for small size firms in the overall technology policy for the industry, intensifying collaborative research efforts between private sectors and government research institution, and utilising flexibilities in the TRIMs agreements to persuade foreign firms to relocate their R&D units into the country.

I. Introduction

India's pharmaceutical industry today stands among the technologically most vibrant segments of Indian manufacturing. It is well understood in the literature that the level of growth and technological development exhibited by the industry is a success of strategic policy interventions consciously undertaken since late 1960s with the specific objects of self-sufficiency in drugs production, self-reliance in drugs technology and accessibility of quality drugs at reasonable prices.[1] These interventions included encouraging indigenous production and technological developments through local content and linkage requirements, incentives to local R&D, encouraging generics over branded products, subsidising small-scale sectors, Drug Prices Control Order (DPCO) and containing the activities of foreign multinational enterprises (MNEs) through Foreign Exchange Regulation Act (FERA) and discriminatory licensing system. The soft Intellectual Property Protection (IPR) regime as envisaged in the Patent Act 1970 was a turning point in the growth of indigenous pharmaceutical industry. The provisions of process patents with a maximum duration of patenting reduced to seven years and the compulsory licensing after three years from the time of grant of the patent had boosted local innovation, mainly in process and formulation development.[2] The availability of life saving and other drugs in India at a fraction of the prices prevailing internationally and significantly at a lower time gap between its introduction in the domestic market and introduction in the world market underscore the success of favorable policy interventions.[3] At the dawn of Independence, the industry hardly had any technological base to start local production and was only processing imported bulk drugs into formulations. By the eighties the industry had accumulated technological capability to produce bulk drugs from as basic a stage as possible and achieved a high degree of self-sufficiency concerning requirements of basic raw materials and intermediates. This rising domestic technological

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capability in the industry is also reflected in the favorable trade balance that the country is enjoying in pharmaceutical products since the late eighties as compared to the huge deficits of sixties and seventies.

However, as a part of the ongoing economic reforms, many of the favorable policies that had nurtured this industry through the decades after Independence are radically changing. TRIPs agreements seek to completely undermine the existing process patent regime - the heart of growth impetus of the industry. The country has a 10-year transition period to implement a 20-year patent protection for an innovation, irrespective of the fact that the product is locally manufactured or imported. With the amendments of Indian Patent Act, 1970 in December 1999 in Parliament, the mechanism of exclusive marketing rights (EMRs) and a mailbox system of accepting product patent are already in place as transitory measures to shift to the product patent regime. As per rule, Indian companies will not be able to reverse engineer any patented product in the post 2005 scenario. Even though they have the freedom to do so in the case of all molecules registered until December 1994, their scope for adaptations and process developments will progressively reduce in the long run. Therefore, this emerging policy regime has significant implications for the future technological development in the industry.

The pharmaceutical industry is a research and development intensive industry. Therefore, a continuous flow of R&D efforts is essential for the development of pharmaceutical industry. Against the backdrop of the recent policy reforms, the most important question is, how has the indigenous technological activity of the industry been affected by the new policy regime. The primary objective of the present study is to empirically examine the impact of liberalisation on the innovative activity in Indian pharmaceutical industry. It will also analyse the role of several firm-specific characteristics like firm size, age, knowledge acquisition from abroad, export orientation, outward investment, multinational affiliations, etc., which literature on R&D had identified as important determinants of R&D behaviour at the firm level. The main purpose of such a quantitative analysis is to derive some strategic policy options that can help to strengthen the technological life-blood of the industry to maintain its competitiveness in a liberalising regime coupled with product patent system.

The paper is structured as follows: Section II presents recent trends and patterns of R&D in Indian pharmaceutical industry. Section III formulates the empirical framework and the hypotheses on the determinants of R&D activity. It also discusses methodological issues. The empirical results and discussion are presented in Section IV. Section V provides concluding remarks with some underlying policy implications.

II. R&D Activity in Indian Pharmaceutical Industry: Recent Trends and Patterns

R&D activity in Indian pharmaceutical industry has increased substantially in the latter half of the nineties, both in absolute amount in rupees spent and as a proportion of the total turnover. The estimated R&D expenditure by the sample firms has risen from mere Rs 8 crores in 1990 to an impressive figure of Rs 515 crore in 2001 (Table-1). The trend in R&D intensity indicate that the sample firms have spent around 2.2 per cent of their sales in 2001 as compared to 0.2 per cent in 1990. In terms of R&D intensity, the performance of foreign firms is, however, observed to be contrary to the expectation, compared to domestic firms. The observed R&D intensity of domestic firms, 2.6 per cent, is three and half times higher than that of foreign firms, which is low at 0.74 per cent. The R&D intensity curve of the domestic firms is lying continuously above the sample average since 1994 and has been

more or less rising (Figure-1), while that of foreign firms is continually lying below the sample average after 1994 and appear to be declining since 1997.

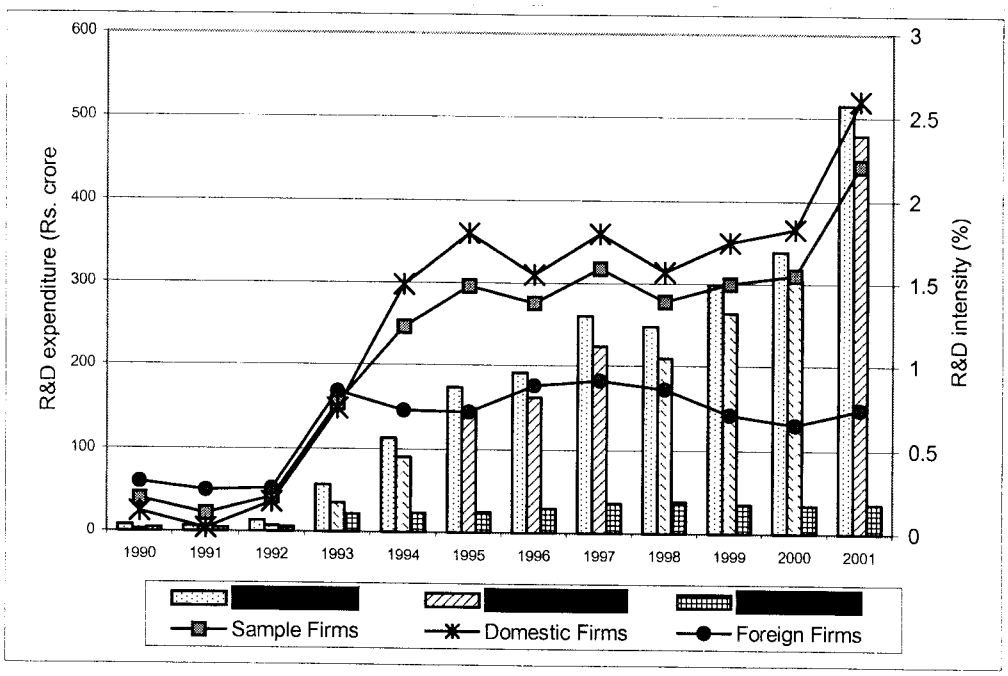
The advocates of strict patent regime generally argued that product patent would lead to an increase in the international technology transfer to India by encouraging foreign firms to introduce their new products and relocating their R&D units into the country because of its cheap personnel costs. The trends in R&D intensity, however, appear to be not supportive of this view. Foreign firms, given their captive access to the laboratories of their parents, are incurring minimal R&D expenditure in the nature of local adaptation of their product in the country. This is in accordance with the trend in R&D activity of MNEs to be concentrated in the home country because of the economies of scale in innovative activities, agglomeration economies, and a need to protect firm-specific technology. The country had bitter experience with the Patent and Designs Act, 1911 where a strong patent regime led foreign firms to merely engage in trading activities by processing imported bulk drugs into formulations and virtually holding back indigenous efforts towards technological self sufficiency.[4] Empirical studies on the relationship between patent protection and location of R&D activity by MNCs fails to detect any significant correlation in the case of developing countries.[5] Therefore, the low R&D intensity of foreign firms as compared to domestic firms should not surprise us. Nor should we expect that their R&D intensity is going to be changed substantially after the product patent regime comes into force. Given their monopoly status enjoyed under TRIPs and also the provision that imports of the product is akin to local production, the hope on foreign firms as a source of R&D activity may be unrealistic.

Table 1. R&D Intensity in Indian Pharmaceutical Industry, 1990-2001

Year	Sample Firms					Domestic Firms					Foreign Firms				
	Number of firms	Number of firms incurring R&D	% Share of R&D firms	R&D (in Rs crore)	R&D Intensity (%)	Number of firms	Number of firms incurring R&D	% Share of R&D firms	R&D (in Rs crore)	R&D Intensity (%)	Number of firms	Number of firms incurring R&D	% Share of R&D firms	R&D (in Rs crore)	R&D Intensity (%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1990	61	4	6.6	8	0.20	45	2	4.4	3	0.12	16	2	12.5	5	0.30
1991	82	6	7.3	5	0.11	65	4	6.2	1	0.02	17	2	11.8	5	0.25
1992	101	21	20.8	13	0.21	84	16	19.0	7	0.18	17	5	29.4	6	0.26
1993	124	47	37.9	57	0.77	106	33	31.1	35	0.74	18	14	77.8	22	0.84
1994	175	62	35.4	113	1.23	157	50	31.8	90	1.49	18	12	66.7	23	0.73
1995	215	79	36.7	174	1.48	197	64	32.5	149	1.80	18	15	83.3	25	0.72
1996	234	90	38.5	192	1.38	215	74	34.4	162	1.55	19	16	84.2	30	0.88
1997	221	94	42.5	260	1.59	202	78	38.6	224	1.80	19	16	84.2	36	0.91
1998	220	85	38.6	248	1.39	201	69	34.3	210	1.57	19	16	84.2	38	0.86
1999	221	82	37.1	298	1.50	200	67	33.5	264	1.75	21	15	71.4	35	0.71
2000	229	84	36.7	340	1.55	208	71	34.1	305	1.83	21	13	61.9	34	0.65
2001	188	77	41.0	515	2.21	171	64	37.4	479	2.60	17	13	76.5	36	0.74

Note: Data are for fiscal year ending March 31 of the year shown Source: Authors' computation based on RIS-DSIR database (2002).

Figure 1. R&D in Indian Pharmaceutical Industry, 1990-2001



Note: Bars represent R&D expenditure; lines represent R&D intensity.

It is encouraging to find that R&D intensity of the industry has risen substantially in the latter part of the nineties. However, it is very low compared to the existing international level of 10-15 per cent of sales. The fact that only one-thirds of sample firms were incurring R&D expenses in the industry needs attention. Further, most of the research efforts are confined to process improvements and, to a limited extent, to research on drug delivery system. Barring a few firms, the industry has not yet made progress in channeling research activity into basic research wherein the goal is to invent new drugs. The resource constraints appear to explain this inability of private sector firms to meet the huge cost entailed in developing a new drug. This is clear from the fact that from Independence to 2001, only 14 new drugs have been developed in the country out of which 11 have come from CSIR, a public funded research institution.[6]

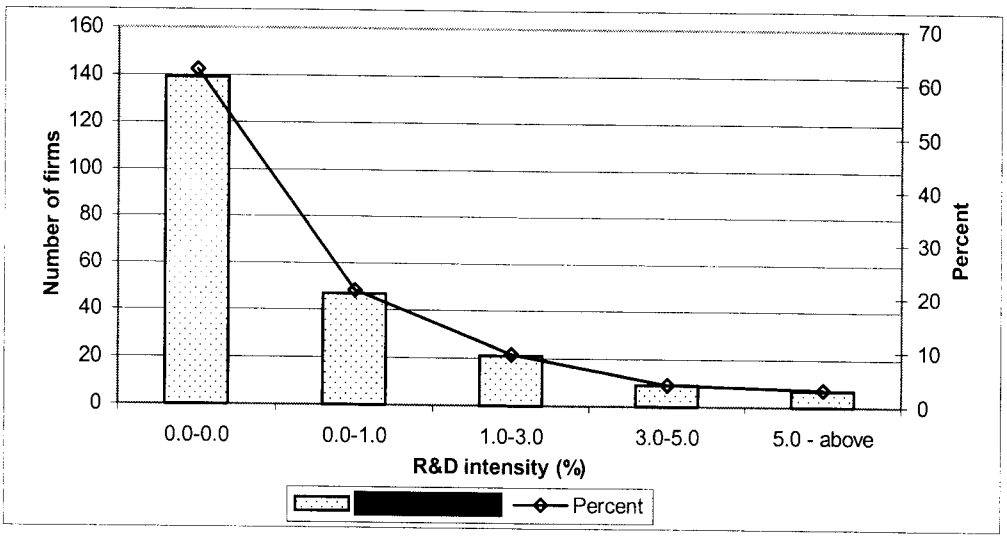
Table 2 gives the distribution of firms over different size classes of R&D intensity in 1999-2000 (also see Figure 2). The number of firms is unevenly distributed across different classes with a strong concentration in the lower end. There are 139 firms in the industry who did not undertake any R&D activity (0.0-0.0 size) and another 47 firms who engaged in R&D but it amounted to less than 1 per cent of their total sales (0.0-1.0 size). Only in case of 16 firms the observed R&D intensity was found to be respectable at 3 per cent and above. Therefore, the pattern of R&D activity in Indian pharmaceutical industry reveals that majority of firms do not engage in innovative activities and the majority of those engaged spent very small proportion of their sales.

Table 2. Distribution of Firms According to R&D Intensity, 1999-2000

R&D Intensity (%) (1)	Number of Firms (2)	Per cent (3)	Cumulative Per cent (4)
0.0-0.0	139	62.3	62.3
0.0-1.0	47	21.1	83.4
1.0-3.0	21	9.4	92.8
3.0-5.0	9	4.0	96.9
5.0-above	7	3.1	100.0

Source: Authors' computation based on RIS-DSIR database (2002).

Figure 2. Distribution of Firms based on R&D intensity in Indian Pharmaceutical Industry, 1999-2000



A list of twenty firms, with largest R&D expenses incurred during the period 1999-2000 is given in Table 3. Ranbaxy Laboratories Ltd., spent around Rs 55 crore in R&D activity and ranks at the top. It is one of the few research based domestic pharmaceutical companies driving the competitiveness of the industry in international market with subsidiaries in more than 20 countries across the globe. The company has a strong presence in the anti-infective segment with 12 brands in the top 250 in the domestic market. The Indian company that has ranked second in terms of R&D expenses is Wockhardt Ltd.; it has very strong presence in antibiotics and analgesics. Even though the company stood second in absolute amount of R&D, it is at the top considering R&D expenses in relation to sales. There are only two foreign firms, namely Novartis India Ltd. and Glaxosmithkline Pharmaceuticals Ltd, which make into the list by virtue of their absolute amount of R&D expenditure. It is important to note that these two foreign firms spent substantial amount on R&D in absolute terms; but it is in fact very nominal in terms of R&D intensity. These two firms stood last in the rank based on R&D intensity.

Table 3. List of Twenty Firms with Highest R&D Expenses, 1999-2000

Name of company	Ownership	R&D (in Rs Crores)	Rank	R&D intensity	Rank
(1)	(2)	(3)	(4)	(5)	(6)
Ranbaxy Laboratories Ltd.	Domestic	55.39	1	2.93	9
Wockhardt Ltd.	Domestic	40.25	2	7.21	1
Cipla Ltd.	Domestic	30.02	3	3.89	7
Cadila Healthcare Ltd.	Domestic	21.27	4	4.45	4
Sun Pharmaceutical Inds. Ltd.	Domestic	18.8	5	3.92	6
Aurobindo Pharma Ltd.	Domestic	14.34	6	1.92	11
U S V Ltd.	Domestic	14.23	7	5.93	3
Pfizer Ltd.	Domestic	13.47	8	4.08	5
Dr. Reddy's Laboratories Ltd.	Domestic	13.27	9	2.69	10
Panacea Biotec Ltd.	Domestic	12.59	10	6.48	2
Lupin Laboratories Ltd. [Merged]	Domestic	9.32	11	1.71	15
Nicholas Piramal India Ltd.	Domestic	9.26	12	1.89	12
Novartis India Ltd.	Foreign	6.72	13	0.81	19
Ipca Laboratories Ltd.	Domestic	6.44	14	1.75	13.5
Glenmark Pharmaceuticals Ltd.	Domestic	5.2	15	3.58	8
Orchid Chemicals & Pharmaceuticals Ltd.	Domestic	4.54	16	1.26	18
Glaxosmithkline Pharmaceuticals Ltd.	Foreign	4.14	17	0.43	20
Unichem Laboratories Ltd.	Domestic	3.62	18	1.75	13.5
Cheminor Drugs Ltd. [Merged]	Domestic	3.51	19	1.53	16
R P G Life Sciences Ltd.	Domestic	3.1	20	1.47	17

Source: Author's computation based on RIS-DSIR database (2002).

III. Determinants of R&D behaviour: The Framework and Hypotheses

The R&D behaviour of a firm is generally conceptualised into two important decisions that it has to make: (1) whether it will engage in R&D activity or not, and, if yes, (2) how much resource it will devote to this. The first question boils down to estimating the probability to do R&D and the second one to estimating R&D intensity regression. In this case the obvious choice is to estimate a Tobit model for Indian pharmaceutical firms of the following form:

$$R\&D_{it} = X_{it}\beta + u_{it} \quad \text{if} X_{it}\beta + u_{it} > 0$$
$$= 0 \quad \text{if} X_{it}\beta + u_{it} \leq 0 \qquad (1.1)$$

Where X_{it} is a vector of k (k=1...k) factors that explain the R&D intensity ($R\&D_{it}$) of ith (i=1...227) firm in tth time (t=1989-90...2000-01). β is the vector of Tobit coefficients and u_{it} is a normally distributed error term.

The important reason for estimating a Tobit model is the fact that the dependent variable R&D intensity takes on the value of zero for a large proportion of cases and hence simple OLS estimation will produce biased estimate. As there are two types of effects associated with each independent variable in the Tobit model - (1) the effects on the value of R&D intensity for cases at the limit value (i.e., zero) and (2) another for cases above the limit, the single ordinary Tobit coefficient is not directly interpretable. Researchers often make mistake by interpreting Tobit coefficients as the effects of independent variables on the dependent variable for cases above the limit. McDonald and Moffitt's [1980, p. 318] decomposition is therefore highly useful due to the fact that it disaggregates Tobit effects into these two types of effects:

$$\frac{\partial E(R\&D)}{\partial X_k} = F(z)\left(\frac{\partial E(R\&D^*)}{\partial X_k}\right) + E(R\&D^*)\left(\frac{\partial F(z)}{\partial X_k}\right) \quad \ldots(1.2)$$

Where F(z) is the cumulative normal distribution function for the proportion of cases above the limit. E(R&D) is the expected value of R&D intensity for all cases (firms with and without R&D). $E(R\&D^*)$ is the expected value of R&D for cases above the limit (firms with R&D). $\partial E(R\&D^*)/\partial X_k$ is the change in the expected value of R&D intensity for cases above the limit (with R&D). $\partial F(z)/\partial X_k$ is the change in the cumulative probability of being above the limit (having R&D) associated with an independent variable.

Thus, equation (1.2) states that the total change in R&D consists of two interesting effects: (1) the change in R&D intensity of firms incurring R&D, weighted by the probability of doing R&D; and (2) the change in the probability of doing R&D, weighted by the expected value of R&D of firms incurring R&D. The study will estimate this decomposition for deriving more information than what ordinary Tobit coefficient commonly provides.

Following the earlier theoretical and empirical literature on the determinants of R&D activity at firm-level for India and other countries, the study envisage that R&D activity of pharmaceutical firms may depend upon a number of factors (X_{it}) as discussed below.

Firm Size

Most of the empirical literature on the determinants of R&D following the Schumpeterian perspective of innovation stresses firm size as an important factor influencing R&D behaviour of firms [for recent surveys, see Cohen, 1995; Kumar and Siddharthan, 1997]. The basic Schumpeterian hypothesis visualises a direct positive relationship between firm size and innovation. Larger the firm size the larger its market power and larger its capacity to appropriate economic rent from innovative activity. By nature R&D activities involve huge financial resources, contain considerable risks and the outcome is unpredictable [Lall, 1992]. Firm size, which is considered to proxy for the resource base of the firm, risk perception and scale economies, is thus predicted to be favorably affecting the R&D behaviour of firms. The empirical findings on the role of firm size, however, is observed to be mixed in the case of Indian manufacturing. Lall [1983], for a sample of 100 Indian engineering firms for the year 1978, found that R&D intensity of the sample firms depend positively on their size. For a cross-section of industries for the year 1978-79, Katrak [1985] reported a less than proportionate increase in R&D expenditure with an increase in firm size. There is another group of studies, which detected a non-linear relationship between firm size and R&D behaviour. Siddharthan [1988], for a sample of 166 manufacturing firms over the period 1982-85, found that the relationship between R&D intensity and firm size is U-shaped. The R&D intensity of firms decreases until firm size, as measured by sales, reached a threshold limit of Rs 600 million and thereafter it increases with sales volume. Kumar and Saqib [1996] have estimated both Probit and Tobit models for a sample of 291 Indian manufacturing firms for the period 1977-78 to 1980-81 to examine the determinants of probability and intensity of R&D expenditure respectively. They found an inverted-'U' shaped relationship between firm size and probability to undertake R&D activity whereas the R&D intensity of firms is positively and linearly related to firm size. In a recent study, Kumar and Agarwal [2000] for a much larger sample of Indian manufacturing firms over the period 1992-93 to 1998-99 have reported a horizontal S-shaped relationship between firm size and R&D intensity. In the pooled OLS estimation, firm size and its cubic term have a significant negative

coefficient whereas quadratic term has a significant positive coefficient. In view of the inconclusive findings on the role of firm size in innovative activity in Indian manufacturing the present study will also examine for possible non-linear relationship. Specifically firm size (SIZE) as well as its quadratic term ($SIZE^2$) will be included in the estimation of model (1.1).

Imports of Foreign Technology

As firms of developing countries tend to have limited research capabilities to develop their indigenous technological capabilities, they resort to imports of technologies from abroad. A domestic firm can import technological inputs like plant and machinery and further it can acquire knowledge through technology and know-how agreements. How are these embodied and disembodied channels of technology imports related to own in-house R&D activity of the firm? To the extent that imports of foreign technology require further R&D on the part of importing entity to absorb, adapt and assimilate the imported knowledge to local conditions, it may stimulate local knowledge-creating activities. It is also possible that the relationship will be dominated by substitution when availability and use of foreign technology discourage and hence substitute R&D activity of receiving firms. The nature of R&D determines whether the relationship will be complementary or a substituting type. If R&D activity is mainly of an adaptive type as assumed by Lall [1983] and Katrak [1985] for R&D activity in Indian manufacturing then a complementary relationship can be postulated. Previous studies on Indian manufacturing predominantly indicate a complementary relationship between imports of foreign technology and R&D activity of domestic firms [Lall, 1983; Katrak, 1985, 1990; Kumar, 1987; Siddharthan, 1988; Deolalikar and Evenson, 1989; Basant, 1997; Kumar and Agarwal, 2000]. To test the impact of foreign technology on local R&D activity of Indian pharmaceutical firms, the study has included two variables- *DISTECH* (royalties and technical fee paid abroad by the firm as a percentage of sales) and *EMTECH* (imports of capital goods as a percentage of sales) as two measures of technology imports.

Outward Orientation

R&D performance of firms may also depend upon whether the firm is outward oriented or not and if yes the degree and mode of outward orientation. An outward oriented firm is one which sees not only domestic market but also external market as an important avenue for its growth and expansion. It can serve the external market through export or outward direct investment. In a knowledge-intensive segment of global market like pharmaceutical, the export competitiveness increasingly lies in consciously created firm-specific knowledge like better quality, innovative design and marketing by incurring greater R&D expenses. Therefore, the export intensity (*EXPOINT*) of a firm is expected to affect favorably its R&D activity. Braga and Willmore [1991] for Brazil and Kumar and Saqib [1996] and Kumar and Agarwal [2000] for India have found that diversification of firms into international markets significantly increases both their probability to do R&D and ability to do R&D more out of total sales. When the outward oriented firm chooses to serve the external market through the mode of foreign direct investment, the industrial organisation theory suggests that such international operation of firms can be possible only when it possessed some monopolistic advantages conferring on it some superiority over local rivals in that market.[7] The R&D is an important channel of accumulating monopolistic advantages and therefore firms aspiring to go for international production are likely to undertake R&D activity. Lall [1983] documented that the proprietary advantages of Indian firms operating overseas activity mainly depend upon their ability to reproduce a given technology, assimilating and adapting to local raw materials or operating

conditions rather than pushing back the frontiers of knowledge. Several other studies on the third-world MNEs (*TWMNEs*) such as on Korean MNEs [Kumar and Kim, 1984; Euh and Min, 1986], on Hong Kong MNEs [Chen, 1983], on Argentine MNEs [Katz and Kosacoff, 1983] and on Brazilian MNEs [Villela, 1983] suggest that the technological strength of developing countries' MNEs lies in their ability in local adaptations and modifications and sometimes little improvements of imported technologies. Therefore, literature on TWMNEs indicate that firms undertaking direct investment abroad from developing countries have strengthened their technological capabilities by undertaking R&D mainly in the nature of adaptation, assimilation and improvements of foreign technologies. The study thus postulated a positive relationship between the variable of outward investment (*OINV*) and R&D performance.

Ownership

In the case of ownership of the firm the working hypothesis is that the foreign firms spend relatively lower than what domestic firms spend on R&D. It is argued that foreign affiliates tend to do little R&D because they have captive access to the laboratories of their parents situated in home country. This hypothesis has been tested by several studies in India [Kumar, 1987; Kumar and Saqib, 1996; Kumar and Agarwal, 2000] and overwhelming evidence suggests that foreign firms in Indian manufacturing have done significantly less R&D than their domestic counterparts. Many studies on the internationalisation of innovative activities also suggest that MNEs tend to conduct little R&D outside their home base [Patel and Pavitt, 1995; Patel and Vega, 1999]. Amsden [2001] in a study on major developing countries of East Asia and Latin America found that the more the foreign ownership the less is the depth and breadth of R&D. Among developing countries Singapore stands out to be an outlier in the sense that MNE affiliates had undertaken large proportion of R&D, accounting for more than one-third of Singapore's total R&D spending. However, even in the case of Singapore it was found that the R&D activities conducted by foreign companies are rarely of basic research or even applied research and are generally less advanced than at corporate headquarters [Amsden et al., 2001]. Therefore, a negative coefficient for the foreign dummy (*FDUM*) has been postulated in the model.

Intangible Assets of Firms

R&D activity of a firm can be argued to depend positively on the intangible assets (*INASSET*) of the firm. Firms with superior intangible assets in the form of trade marks, brands, copy-rights and consumer goodwill are likely to invest more in R&D as their brand superiority enable them to better appropriate returns from their innovative activity. Brand loyalty gives the firm required monopoly power to undertake R&D and meet the preferences of a more informed consumer today.

Firm Age

Technological capacity building by a firm is an incremental and cumulative process, which requires that the firm must accumulate knowledge, skills, learning, operating know-how and experience that support continuous changes and improvements in production process, products and procedures [Bell and Pavitt, 1992; Aw and Batra, 1998]. A firm learns from past production experiences and uses these accumulated learning for further technological improvement. Therefore, firm age (*AGE*) as a proxy for accumulated experience and technological learning is hypothesised to affect R&D performance positively.

Profit Margins

Given the fact that R&D activity involves huge resource capability on the part of innovating firm,

a higher profit margin indicating internal resource generation is likely to have favorable impact on R&D decision of the firm [Kumar and Saqib, 1996; Kumar and Agarwal, 2000]. This variable also captures the impact of fiscal measures like tax exemption offered by the government for firms with recognised R&D units. Other things being constant it is expected that a higher profit margin (*PMRG*) is likely to induce firm to undertake R&D and spent more as a proportion of sales.

Liberalisation

There has been a radical shift in the country's policy framework governing production and trade in 1991. Along with several regulatory changes in the Indian economy including abolition of mandatory licensing system and liberalising FDI policy, the hold of price control on pharmaceutical industry has been significantly reduced. The domestic firms no longer can count on domestic markets for their growth and survival. In the face of stiffer competition from free imports as well as entry of new foreign firms they are forced to utilise their resources and constantly upgrade and improve their technological capabilities. To the extent liberalisation forces firms to undertake R&D on account of foreign competition for their survival, a positive relationship between Liberalisation and R&D can be expected. The effect of liberalisation has been captured by including a dummy variable (*LIBDUM*) taking value of 1 for reform period (1993-94 to 2000-01) and 0 for pre-reform period (1989-90 to 1992-93).

After discussing the probable determinants of R&D, we shall include them in our model explicitly to obtain the following form:

$$R\&D_{it} = \beta 0 + \beta 1 AGE_{it} + \beta 2 SIZE_{it} + \beta 3 SIZE_{it}^2 + \beta 4 DISTECH_{it} + \beta 5 EMTECH_{it} + \beta 6 INASSET_{it} + \beta 7 OINV_{it} + \beta 8 EXPOINT_{it} + \beta 9 PMRG_{it} + \beta 10 FDUM + \beta 11 tLIBDUM + u_{it} \quad if X_{it}\beta + u_{it} > 0$$
$$= 0 \quad if X_{it}\beta + u_{it} \leq 0 \qquad (1.3)$$

Fitting a regression equation like equation (1.3) for the search of the determinants of firms' R&D behaviour has been the standard practice in the literature. However, regressing R&D expenditure on its supposed determinants in a contemporaneous setting, as pursued by the majority of existing studies and the present study, suffers from the problem of simultaneity. The R&D behaviour of firms is a complex phenomenon and the lines of causation often run from supposed determinants to R&D and from R&D to its supposed determinants. For example, foreign technology purchase by firms may depend on their initial indigenous technological capabilities [Katrak, 1997] or high profit margins of the firm may itself have resulted from its successful R&D activities [Kumar and Saqib, 1996]. A few of the previous studies have used lagged independent variables in the estimation but precedence in time does not necessarily distinguish causes from effects. Although the simultaneous equations approach has not been pursued, the single equation Tobit estimation adopted in the study serves as a useful exploratory estimation. As a result of ignoring the problem of simultaneous relationship, the estimates of all the parameters presented in the study are likely to be biased to an unknown extent.

IV. Results and discussions

The model (1.3) has been estimated for a sample of 277 Indian pharmaceutical firms over the period 1989-90 to 2000-01. The study draws upon an exclusive *RIS-DSIR* database to conduct the quantitative analysis. Details about the database used and measurements of variable have been provided in Appendix A. Table 4 reports the maximum likelihood estimation of pooled Tobit model as well as panel data random-effects of

Tobit estimation. The pooled estimation results given under the heading column-A have been provided with robust standard errors. STATA - the statistical package used for the estimation purpose - produces robust standard errors using the Huber-White sandwich estimators which can effectively deal with a collection of minor problems of not meeting the classical regression assumptions, namely about normality, heteroscedasticity or some observations that exhibit large residuals, leverage or influence. In column-B we have provided fully standardised coefficients of independent variables which are by construction scale free and hence are useful in comparing the relative strength of the independent variables in terms of effect on the dependent variable. As discussed before, the ordinary output as presented under column - A provides only one unstandardised Tobit coefficient for each independent variable, notwithstanding the presence of two types of cases - those with zero value of R&D intensity (firms not incurring R&D) and those with non-zero value of R&D (firms doing R&D). Therefore, these single Tobit coefficients are not useful for effective interpretations. We have provided two types of marginal effects in McDonald-Moffitt Decomposition framework, which are directly and effectively interpretable (Column - C & D). In view of the panel structure of our dataset, we also have estimated random-effects Tobit model and the results obtained thereof have been presented in column-E. As theoretical development on the conditional fixed-effects Tobit model is still in infancy and there does not exist a sufficient statistic allowing the fixed effects to be conditioned out of the likelihood, we are not able to provide results from fixed effects. However, it is possible to estimate unconditional fixed effects model by including firm-specific dummies in the estimation, but the results obtained will be biased and hence inferences drawn from those result will be misleading.

The reported Wald Chi-square statistics for pooled and random-effects Tobit model indicates that the estimated models are statistically significant. That means taken together all our independent variables explain a significant proportion of variation in the dependent variable. It is remarkable that the overall conclusions derived from pooled Tobit model is same as those provided by the random-effects Tobit model. This similarity thus suggests that obtained result on the determinants of R&D activity is robust to alternative estimation procedures, at least between the pooled and random-effects model. The performance of individual independent variables are as discussed below.

Age: The role of firm age in the R&D performance of firms in Indian pharmaceutical industry is found to be favorable. Both the pooled and random-effects model indicates that the variable has a positive coefficient, which is statistically significant at 1 per cent level. Keeping all else constants, a one-year increase in age, on an average, produces about 0.012 increase in R&D intensity of sample firms and about 0.002 increase in their probability to undertake R&D activity. This strongly supports our hypothesis that older firms in the industry have the competitive advantages of technological learning and experience in doing R&D as compared to start-ups. The vector of standardised coefficients, however, indicate that the relative contribution of firm age in the explanation of R&D behaviour of pharmaceutical firms is less dominant than other factors like PMRG, SIZE, INASSET, etc. In particular, for a standard deviation increase in age, R&D intensity is expected to increase by 0.117 standard deviations, holding all other variables constant.

Table 4. Tobit Estimation of R&D Intensity

Dependent variable: R&D intensity (%)

Independent Variable	Pooled Tobit Estimation				Random-effects Tobit Estimation
	Coefficients (Robust Z-value)	Fully Standardised coefficients	McDonald-Moffitt Decomposition Marginal Effects at Means		Coefficients (Z-value)
			$\partial Ey^*/\partial k_i$	$\partial F(z)/\partial k_i$	
(1)	(Column- A) (2)	(Column- B) (3)	(Column- C) (4)	(Column- D) (5)	(Column- E) (6)
Firm Age	0.0486098***	0.1171	.01161679	.00200513	0.0461297***
	(3.22)				(3.67)
SIZE	0.0225460***	0.4320	.00538806	.00093001	0.0210577***
	(5.49)				(8.09)
$SIZE^2$	-0.0000159***	-0.3260	-3.791e-06	-6.543e-07	-0.0000142***
	(4.30)				(5.72)
DISTECH	-0.0089174	-0.0118	-.00213108	-.00036784	-0.0173747
	(0.70)				(0.49)
EMTECH	-0.0021737	-0.0226	-.00051948	-.00008967	-0.0014154
	(1.31)				(0.27)
INASSET	0.0037849*	0.1912	.00090453	.00015613	0.0036426**
	(1.75)				(2.55)
OINV	0.0032283***	0.0772	.00077149	.00013316	0.0027093**
	(3.14)				(2.04)
EXPOINT	0.0636728***	0.1769	.01521654	.00262646	0.0602249***
	(3.09)				(6.25)
PMRG	0.0127921**	1.2505	.00305707	.00052767	0.0120648***
	(2.30)				(3.87)
FDUM	0.5857572	0.0231	.14256104	.02465797	0.5873535
	(1.21)				(0.82)
LIBDUM	3.3509366***	0.1624	.73797654	.12371236	3.1924808***
	(3.77)				(5.33)
Constant	-10.9466250***		-2.6160279	-.45154167	-10.4132003***
	(4.15)				(14.44)
Sigma	7.607516				
Sigma_e					7.049186
Sigma_u					1.201745
Log likelihood	-3001.5141				-2969.8501
Wald chi2(11)	60.18				214.37
Prob > chi2	0.0000				0.0000
Observations	1998				1998
Number of group	277				277

Absolute value of z-statistics in parentheses.

* Significant at 10%; ** significant at 5%; *** significant at 1%.

Note: 1. $\partial Ey^*/\partial x_i$ is the change in the expected value of dependent variable for cases above the limit (i.e., R&D intensity > 0) and $\partial F(z)/\partial x_i$ is the change in cumulative probability of being above the limit associated with an independent variable. 2. Marginal effects is for discrete change of dummy variable from 0 to 1.

Firm Size: According to the vector of standardised coefficients the effect of firm size on R&D behaviour of Indian pharmaceutical firms stood as the second dominant factor after the effects of profit margin (PMRG). Not only it is the second most important factor influencing R&D but it is also observed to possess non-linear effects. The firm size and its squared terms turn out with statistically significant positive and negative coefficients respectively. Apparently, firm size has a positive effect on R&D performance of firms but after some threshold the effect decreases with increasing levels of firm size (see Figure-3). This finding of inverted U-shaped relationship between R&D and firm size lend support to the earlier finding of Kumar and Saqib (1996) for a sample of Indian manufacturing firms.

It should be noted that majority of earlier studies suggesting that firm size and R&D behaviour is characterised by non-linearity indicate only the shape of the relationship, falling short of providing any exact figure of threshold effect. In our opinion researchers should calculate and present the value of threshold, as such a quantity may be of direct substantive interest for useful policy purposes and academic interest alike. For Indian pharmaceutical industry this information has been furnished in Table 5. The numerically precise estimate of the turning point after which extra size affects R&D negatively is estimated to be Rs 710.7 crore. Following the delta method[8] the standard error of the turning point is computed to be 69.9. The 95 per cent confidence interval formed on the assumption that the turning point is normally distributed clearly overlaps with the relevant range of firm size.

Figure 3. Fitted quadratic effect of firm size on R&D intensity[9]

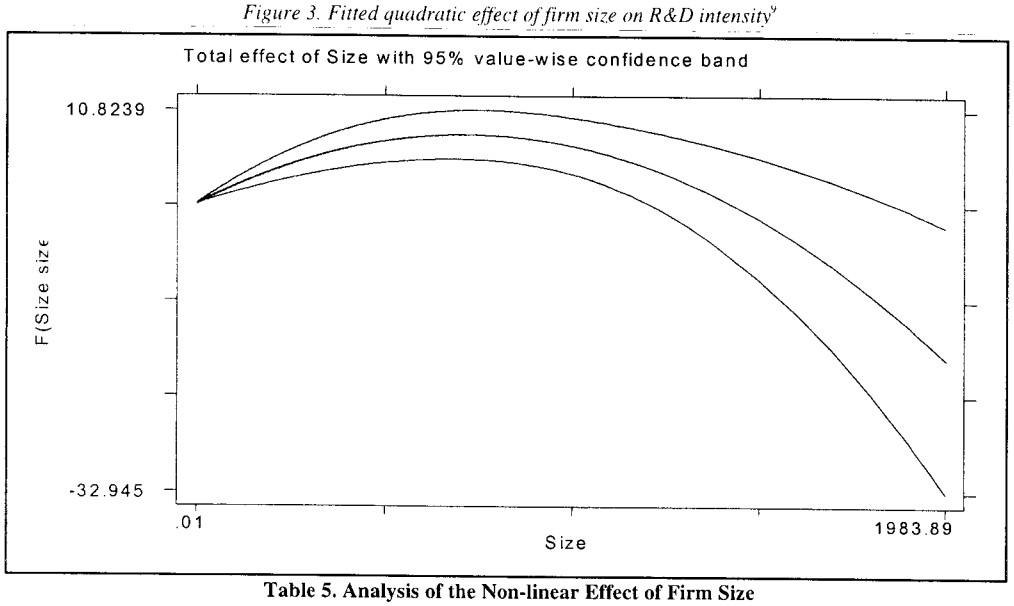


Table 5. Analysis of the Non-linear Effect of Firm Size

Statistics (1)	Value (2)
Range of Size (Rs Crore)	[.01, 1983.89]
Size+size^2 has maximum in the turning point	710.6994
Std Error of turning point (delta method)	69.9656
95% confidence interval for the turning point	(573.5693, 847.8295)

As we know now that firms sizes only up to Rs 710.7 crore have a positive impact on the R&D performance, it will be useful to look at the size wise distribution of the total sample observations.[10] From Table 6 it can be seen that nearly half of the observations fall in the lowest size class of Rs 0-20 crore. By the time size reach Rs 200 crore, 90 per cent of the sample has been exhausted. There are only 25 observations that fall in the size class 700-above range. This finding only verifies the often emphasized feature of Indian pharmaceutical industry as highly fragmented with more than 20,000 firms competing for around Rs 19,737 crore market.[11] The bulk of these 20,000 firms are small-scale firms that are active in the industry now. Therefore, majority of Indian pharmaceutical firms are far below the turning point and suggests that small firm size has been a foremost factor responsible for keeping the R&D performance of the industry at a low level.

Table 6. Distribution of Sample Observation According to Sales Range

Sales Size (Rs Crores) (1)	Number of observations (2)	Per cent (3)	Cumulative Per cent (4)
0-20	1,015	49.0	49.0
20-50	359	17.3	66.3
50-100	246	11.9	78.2
100-200	238	11.5	89.7
200-400	143	6.9	96.6
400-700	45	2.2	98.8
700-above	25	1.2	100.0

Source: Author's computation based on RIS-DSIR database (2002).

The government policy in the past had actively encouraged small-scale sector in the pharmaceutical industry as a part of the overall industrial development strategy of protecting and promoting small-scale sector to achieve a multiple of socio-economic objectives such as employment generation and equity, decentralised industrial development, tapping new sources of entrepreneurial capabilities and so on. However, the two most important objects that marked the government policy in the case of pharmaceutical industry were the objects of self-reliance in the production of basic drugs and ensuring supply of cheap drugs to the poor. A number of drugs like Paracetamol, Parabenes, Calcium Gluconate, Benzyl Benzoate, Pyrazolones, Lanolin Anhydrous, Citrates, Halogenated Hydroxy Quinolines, etc., have been reserved for exclusive development in the small scale enterprises. The small-scale firms were kept outside the purview of DPCO and were exempted from the drug policy parameters. They were provided with substantial share of the market in the Government Health Care Programme.

This policy of encouraging small-scale enterprises has significantly influenced the structure and development of Indian pharmaceutical industry. It led to the emergence of a strong small-scale sector in Indian pharmaceutical industry engaged in the manufacture of drugs and pharmaceuticals. Perhaps more important effects are felt on the production of bulk drugs and consequently on the accessibility of people to health security.[12] The government protection of small-scale sector coupled with low level of patent protection finally has resulted in the larger role that small firms are playing in the growth performance of the industry. Another upshot of this policy is the generation and strengthening of inter-firms linkages between small and large enterprises in the industry. Many large firms who formerly used to undertake all stages of drug production with their integrated production process started subcontracting work on several intermediate stage of production to various small firms to take advantage of government subsidies to the small-scale sector.

As the small size firms do not have huge resources necessary for developing any new chemical compounds, their survival in the product patent regime without government support is unthinkable. Even their small size do not permit them to undertake adaptive innovation as reflected in the large number of firms not doing any R&D at all and in the very small share of R&D in the total size of the majority of those who do some R&D. The fact that competition in pharmaceutical industry is based on technology and that small size firms lack resources to strengthen their technological capabilities warrant appropriate policy response specifically focusing on the technological needs of small scale sector. Just because small size firms do not have the required technological strength to survive in a market driven regime, the country can ill-afford to see the withering of its small-scale sector that is so

instrumental in keeping the prices of many life saving drugs affordable to the poor people. What the government at least could do is to strengthen the technology support and training for small-scale sectors.

Technology Imports: None of the two measures of technology imports, viz., *DISTECH* measuring disembodied technology imports and *EMTECH* measuring embodied technology imports have come up with significant effect. The sign of both these variables are observed to be negative but statistically not different from zero. This suggests the relationship between technology imports and R&D efforts of firms is neither marked by complementarity nor substitution. The impact of technology imports tends to vary across firms and on the average does not possess any systematic effect on the technological efforts of importing firms. This findings is consistent with the earlier findings of Kumar and Saqib [1996] that the R&D activity of Indian manufacturing firms is neither complemented by technology import measured as technology licensing payments nor is substituted by it.

Intangible Assets: INASSET representing the intangible assets of the firm turns up with a positive sign and is statistically significant at 10 per cent level. In terms of the strength of relative contribution as indicated by standardised coefficients vector, intangible assets of the firm stood as the third dominating factor. A 1 percentage increase in the intangible assets of the firm, on an average, brings about 0.0009 increase in R&D intensity of firms engaging in R&D activity, keeping other variables constant. The marginal impact of 1 per cent increase in the intangible assets on the probability of firms engaging in R&D activity is, on an average, estimated to be about 0.00016. The finding weakly lends support to our contention that firms with high brand valuation are inclined to do R&D as they are better placed to appropriate returns from their R&D activity.

Outward Orientation: Both the measures of outward orientation, viz., *OINV* signifying serving of the foreign market through outward foreign direct investment and *EXPOINT* indicating serving of the foreign market via exports turns out with positive coefficients and are significant at 1 per cent level. Obviously Indian pharmaceutical firms that are branching out into foreign markets whether via FDI or via exports exhibit higher probability to undertake R&D and invest more in R&D as a proportion of total sales. In a knowledge-based industry like pharmaceuticals, the global competitiveness of a firm is driven by high technology, high skill, quality and reliability. Therefore, entry into global market requires a strong technological backup on the part of entrant, and intense competitive pressure, based on technological dynamism, ensures that the firm is continuously innovative in order to be able to stay in the market.

Profit Margins: The link between profit margins, *PMRG,* and R&D activity has been found to be positive. *PMRG* has come up with a positive sign and significant at 5 per cent level. In particular a 1 per cent increase in the profit margins of firms on an average increases about 0.00053 in the probability of firms to undertake R&D and about 0.0031 in the R&D intensity of firms keeping other variables constant. The effect of this variable is the most significant on R&D performance as shown by the vector of standardised coefficients. Therefore, the result suggests that internal resource generation of the firm significantly increases the R&D activity of Indian pharmaceutical companies.

Ownership: The *FDUM* capturing the effect of foreign ownership on the performance of R&D emerges with a positive coefficient that is statistically not different from zero. Therefore, there is no evidence to suggest that R&D behaviour of firms differs on having majority foreign ownership as opposed to having domestic ownership. This finding is particularly significant and at

variant with the view that liberal FDI policy and strengthening of patent system will lead to a spurt in innovative activities of foreign firms and hence will lead to an increase in the international technology transfer to India. It is argued that foreign firms will introduce their new products in the country and may relocate their R&D units in India because of its cheap personnel costs. However, the view that MNEs may act as an engine of R&D performance does not inspire much confidence in the face of many MNEs like Ciba Geigy, Boots, Hoechst and Rhone Poulence closing down their R&D units at a time when the country is moving towards a product patent regime. If experiences are any indication, the monopoly status of MNCs may even lead to contraction of innovative activities, as happened in the case of Patents and Designs Act, 1911. Given the provision of TRIPs that imports is akin to local production it may even result in shifting of existing R&D units in the country to the home country of foreign firm concerns. TRIMs, which prohibit the imposition of performance requirements like, export obligations, local content requirements, local manufacturing requirements, etc., by host countries further undermine the capability of developing courtiers to induce foreign firms to do R&D locally.[13]

Liberalisation: The variable, *LIBDUM*, which capture the possible effects of liberalisation on the R&D performance of Indian pharmaceutical firms has come out with a positive coefficient statistically different from zero at 1 per cent significance level. This suggests that R&D performance of pharmaceutical firms has increased substantially in the reform period (1993-94 to 2000-01) as compared to pre-reform period (1989-90 to 1992-93). The standardised coefficient indicate that in the post reform period R&D intensity of Indian pharmaceutical firms is expected to increase by 0.1624 standard deviations, holding all other variables constant. The marginal effects of *LIMDUM* on R&D intensity and probability to do R&D are also quite considerable. This suggests that liberalisation of industrial, trade policies with impending product patent regime have made Indian pharmaceutical firms more conscious of the need to undertake R&D activity, and indeed they had devoted substantial resources in that direction. Remembering the structure of industry where majority of firms are essentially small size imply that the improved R&D performance in the reform period may well have come from the performance of a small group of large size firms. Small-scale sector, due to scale and resource constraint, are not in the position of venturing into R&D-led growth as a few large Indian pharmaceutical firms are doing. The government incentive package often was of little help to small sector as compared to large enterprises because latter are better placed to obtain import permits for capital goods, intermediate inputs and raw materials and have preferential access in the domestic credit market. In many cases, small firms were ignorant of available concessions or were unable to handle the procedural and administrative complexity involved in the relevant office work. The fact that small-scale sector is instrumental in ensuring the access of the poor to quality drugs calls for greater role of government to directly strengthening its technological capabilities so that it can survive in a liberalised business environment.

V. Conclusions and Implications

Along with the implementation of macroeconomic liberalisation in the country the nineties had witnessed significant changes in the policy regime governing Indian pharmaceutical industry. The progressive dilutions of DPCO, liberal FDI policy, and transitory measures of TRIPs have induced intense competition in the market. The above empirical exercise finds that this competitive pressure has worked effectively in pushing Indian pharmaceutical firms into R&D activity. However, it is inferred that this impact of liberalisation is likely to be limited to a few

large and medium size firms, as large segment of small size firms lack the huge resources that are required for product development. The impact of firm size is also observed to have strong non-linear impact on the R&D performance. Recently government has taken some initiatives like establishment of a Drug Development Promotion Foundation (DDPF) and a Pharmaceutical Research and Development Support Fund (PRDSF) in order to promote R&D activity in the industry. These government measures are steps in the right directions but also need to be target orientated towards small size firms as these firms are instrumental in keeping drugs prices accessible to the poor. Also, at the same time we should promote some national champions as is done by developed countries under their strategic trade policies.

The R&D behaviour of Indian firms appears to be not systematically affected by the availability of foreign technology through licensing and imports of capital goods. However, the outward orientation of an enterprise is a significant determinant of in-house R&D. Therefore government policies that encourages Indian firms to export and to undertake outward direct investment are very crucial in inducing firms to focus more on the development of indigenous technologies. For a long time the government policy with respect to outward foreign direct investment has been restrictive due to the insufficient foreign exchange reserves and precarious BOP position. Only joint ventures were promoted with minority Indian ownership and even that minor equity participation was required to be in the form of exports of Indian made capital goods, equipments and know-how. It is encouraging to note that recently these restrictions on outward direct investment have been liberalised. In October 1992 government had issued the modified Guidelines for Indian Joint Ventures (JVs) and Wholly Owned Subsidiaries Abroad (WOSs) which provided for automatic approval for cases with equity value up to $2 millions of which up to $ 500,000 could be in cash and rest by capitalisation of Indian exports of machinery, equipment, know-how or other services. These procedures have been further liberalised in 1999 and 2002 Guidelines. These outward oriented policies are likely to improve the competitiveness of Indian pharmaceutical firms and hence there need to undertake large-scale R&D activities.

Another significant observation of the study is that the R&D behaviour of Indian pharmaceutical firms crucially depends on their intangible assets mainly brand valuation. Firms that are promoting and creating brands are found to be doing more R&D activity as these intangibles strengthen their power to appropriate rents from their innovative activity. In addition, profit margins and firm age are other two important determinants of R&D behaviour of Indian pharmaceutical firms. The R&D behaviour of foreign firms is found to be not different from domestic enterprises.

The policy implications from the above analysis are obvious. In order to enhance R&D performance of Indian pharmaceutical firms the government should focus on removing obstacles that inhibit Indian firm's participation in international markets via exports or via outward foreign direct investment. Recognising the important role of firm size in R&D performance policy must contain special scheme for small size firms in the overall technology policy for the industry. Given the huge cost involved in the basic research, the path of collaborative research efforts between private sectors and government research institution appears to be an important strategic option that needs to be promoted seriously. Technology transfer requirements for foreign firms or other performance requirements that are permitted under TRIMs agreements can be utilised to the fullest extent to persuade foreign firms to relocate their R&D units into the country.

NOTES

1. See Kumar and Pradhan [2002] for details of policy changes and its impact on the growth of Indian pharmaceutical industry.

2. Fikkert [1993], Haksar [1995] and Kumar and Saqib [1996] have argued in their quantitative explorations into the R&D activity of Indian firms that the innovative activity of these enterprises was stimulated by the soft patent regime under the 1970 Patent Act.

3. For example the prices of Ranitidine, Famotidine, Astemizole, Ondansetron in the US market are at about 50 times the Indian prices and most of these drugs had been introduced in the domestic market within 4-5 years of their introduction in the world market (see Table 2 in Kumar and Pradhan, 2002).

4. Desai [1980] documented two cases where foreign patent owner neither had used their patents for domestic manufacturing nor allowed them to be used by local firms. These are: (1) Hoeshst preventing Unichem Laboratories from producing tolbutamide, and (2) thereupon Excel Industries being prevented from producing the fumigant by another foreign firm.

5. Kumar [1996] found that R&D intensity of US affiliates is positively and significantly dependent upon the strength of patent protection (Rapp and Rozek index) in the case of developed countries but not statistically different from zero for developing countries. Kumar [2001] in a more recent study confirmed that the strength of patent protection (Ginarte and Park index) is not a significant factor in explaining R&D intensity of US and Japanese affiliates.

6. GOI, 2001, Pp. 140.

7. The industrial organisation theory of FDI as proposed by Hymer [1960] and later extended by Kindleberger [1969] and Caves [1971] has been the most dominant explanation for foreign operation of national firms. This approach traces the existence and growth of the international operation of firms in the phenomenon of market imperfections. According to Hymer, firms undertaking investment abroad must possess some monopolistic advantages like product differentiation, management skill, patents and superior technology, control of the supply of key raw materials, economies of scale, etc., which they can profitably exploit abroad by internalising production rather than exporting from home country or licensing those advantages to a third party abroad.

8. Linear approximation of the nonlinear function of the turning point in the regression coefficients.

9. The graph has plotted SIZE against $0.02255*SIZE-0.000016*SIZE^2$.

10. The number of sample observations in the present case may not be equal to what was reported in the estimation as STATA had dropped some observations owing to missing values of independent variables.

11. The production figure is for the year 1999-2000 taken from Organisation of Pharmaceutical Producers of India (OPPI).

12. The share of small-scale sector in the production of bulk drugs has increased from 7.7 per cent in 1975-76 to 20.9 per cent in 1985-86. The corresponding share of *MNE* affiliates has decreased from 40 per cent in 1975-76 to 18 per cent in 1985-86 [see, Table 1 in Kumar and Pradhan, 2002].

13. See UNCTAD [2001] for an illustrative list of 39 host country operational measures, Pp. 8-9. Historically both developed and developing host countries alike have used these measures as a developmental tool to ensure maximum benefits from foreign capital while keeping at minimum its negative impact. However, the use of these measures is increasingly under attack from developed countries led by the United States. The agreement on TRIMs in the 1994 Uruguay round GATT negotiation covered (i) local content requirements, (ii) export performance requirements, (iii) local manufacturing requirements, (iv) trade balancing requirements, and (v) foreign exchange restrictions.

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Appendix A: Dataset and Measurements of Variables

The dataset used in the present study is a sub-sample of a larger dataset, RIS-DSIR database, constructed from different sources at the Research and Information System for the Non-aligned and Other Developing Countries, as a part of the Department of Scientific and Industrial Research (DSIR) research project 'A Strategic Approach to Strengthening the International Competitiveness in Knowledge-based Industries: Some Explorations into the Role of FDI Inflows, Outward Investments, and Enterprise Level Technological Effort in Promotion of India's Knowledge Intensive Exports'. The dataset, which covers firm-level data on various financial variables like exports, imports, sales, R&D, outward investments, etc. of more than 500 Indian manufacturing companies, has been compiled from the PROWESS database (2002), the Ministry of Commerce, the Ministry of Finance, and the India Investment Centre.

Measurements

A1. Dependent Variable.
$R\&D_{it}$: Total R&D expenditure as a percentage of total sales of ith firm in tth year.
A2. Independent Variables.
AGE_{it}: The age of *i*th firm in number of years.
SIZE*it*: Total sales of *i*th firm in *t*th year.
$SIZE^2_{it}$: The squared term of the sales of *i*th firm in *t*th year.
$DISTECH_{it}$: Royalties, technical and other professional fees remitted abroad by ith firm as a percentage of sales in the year t.
$EMTECH_{it}$: Imports of capital goods by *i*th firm as a percentage of sales in *t*th year.
$INASSET_{it}$: Intangible asset of the ith firm as a percentage of sales in the year t. This is the brand valuation as given in the balance sheet of the company.
$OINV_{it}$: Defined as the stock of outward direct investment of the ith firm as a percentage of sales multiplied by the age of multinationality.
$EXPOINT_{it}$: Exports of ith firm as a percentage of sales in the year t.
$PMRG_{it}$: Profit before tax (PBT) as a percentage of sales.
FDUM: Dummy variable for foreign owned firm taking value 1 for firms with 25 per cent or more foreign equity participation and 0 otherwise.
LIBDUM: Liberalisation dummy taking 1 for reform period 1993-94 to 2000-01 and 0 for the pre-reform period 1989-90 to 1992-93.