The Determinants of R&D in the Indian Pharmaceutical Sector: A Firm Level Study of Outward Investors

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Abstract

This study is an attempt to identify the determinants of R&D in the Indian Pharmaceutical sector and specifically examine the role of outward investment in the determination. We use firm level data from 1990 to 2005 to analyse the determinants of R&D. The data set consist of an unbalanced panel of 173 firms. Probit and Tobit models are employed to analyse the determinants of probability of undertaking R&D and R&D intensity. A host of firm specific characteristics like firm size, age, rate of profit, export intensity, technology imports, advertisement intensity, foreign ownership and outward investment are taken up for empirical analysis. Firm size turned out statistically significant in both Probit and Tobit models. Study identified an inverted U shaped relationship between firm size and the decision of the firm to spend on R&D and R&D intensity. Older firms appear to invest more on R&D. Exports, import of capital goods and advertisement intensity also turned out significant on the decision of the firm to invest in R&D and R&D intensity. We found that the out ward investment by a firm reduces the probability of investing in R&D. Further, a sub-sample with 390 observations is formed separately to examine the determinants of R&D for outward investing firms. In the case of sub-sample, firm size, export intensity, import of capital goods, advertisement intensity, advertisement intensity are found to have positive and significant influence on the decision to invest in R&D. The findings of the study implies that the R&D intensity of the sector could be increased only through supportive measures from the government by fostering exports, encouraging small firms to undertake R&D and by maintaining the competitive pressure in the industry.

Keywords: Outward Investment, Pharmaceutical Industry, R&D
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1. Introduction

Technological change and innovation have been identified as important elements which contribute to growth and development of countries in the economic literature (Romer, 1990). Many empirical studies on different industries reveal that technological progress and innovation is rooted in the research and development spending in these sectors (Dhalman et al, 1987; Pavitt, 1984). Unlike the developed countries, R&D efforts in developing countries are more towards minor and incremental innovations rather than major innovations (Dosi 1988). Technological learning (learning through R&D and learning through experience), integration with other firms also contribute substantially in this regard. Moreover, towards this end the R&D capability of the developing economies like India depend on the capacity to select, absorb, assimilate, adopt, imitate and perhaps improve given technologies (Cohen and Levinthal, 1989). Existing sectoral studies on determinants of R&D activities in developing countries are confined to the manufacturing sector and does not take into account the recent internationalization strategies adopted by different sectors .

Outward investment as a distinguishable internationalization strategy started visible in the Indian manufacturing sector after 1990's. There was a rapid outflow of capital in the form of foreign direct investment and a spurt in foreign acquisitions by Indian firms. However, the nature of variables capturing industrial structure, technical knowledge and policy environment are different in various industrial sectors (Malerba and Orsenigo, 1992). Therefore, in order to understand the dynamics of innovative efforts and the internationalization effect on the same, a detailed firm level investigation pertaining to a specific sector need to be undertaken.

In this scenario, pharmaceutical sector in India is an interesting case due to the high- tech nature of its product and manufacturing techniques. The pharmaceutical sector has achieved a pivotal position in the Indian manufacturing sector through its innovative capability. Therefore, innovative efforts of the Indian pharmaceutical industry demands special attention due to: (i) high R&D intensity compared to other industries (ii) the contribution of R&D in building the technological capability in this sector is well accepted through the productivity growth, net value added and through rapid rise of export surplus[1]; (iii) Indian pharmaceutical

[1] see Pradhan (2006); Dhar and Gopakumar (2006)

industry enjoys two major home-grown advantages in terms of R&D, cheaper manufacturing facilities and world-grown chemistry skills honed by years of reverse engineering (Mani, 2006). Besides, the R&D in this sector is assumed to introduce incremental innovations[2] .

Even though the contribution of variables like market structure, firm size, technology imports in determining the R&D in various Indian manufacturing industries has been analysed, pharmaceutical sector stands without a comprehensive analysis which can provide answers to various R&D related questions with the emergence of new international firm. In this context, our paper try to address the following, *first*, whether outward investment is an important determinant of pharmaceutical R&D in India?. *Second*, what determines R&D in the case of outward investing firms?.

The paper is organized as follows: Section 2 identifies the theoretical foundation of industrial R&D and Outward investment. Section 3 highlights R&D in pharmaceutical industry in India and the nature of outward investment in the sector. Section 4 develops an analytical framework to identify the determinants of R&D. Section 5 provides data description, methodology and presents the results. Section 6 synthesises the results and provide the conclusion.

2. Theoretical support

Industrial R&D is viewed as a production process where research inputs such as R&D spending (equipment, manpower, etc) are transformed into research outputs such as invention, innovation and diffusion. Supporting this definition, firms efforts to undertake R&D depends on two aspects first, it is assumed that firms do not typically sell their innovation to other firms due to the imperfections in the market for information (Arrow,1962) and secondly, expected returns to R&D could be scaled by a firms ex ante output (Mansfield,1968).

Different from the above dimension of R&D, it has been stated that, R&D develops the firms's ability to identify, assimilate and exploit knowledge from the external environment. In other words, R&D expenditure increases the absorptive capacity of the spending unit

[2] defined as adaptation of known technologies to local conditions as they may be new to the Indian firms although not new to the universe in which these firms are located.

(Cohen and Levintal, 1989). Further it has been recognized that many innovations are most valued by the innovators themselves because they are idiosyncratic to the particular need of the innovator (Nelson and Winter, 1982) or require idiosyncratic expertise for their exploitation that is only generated in the course of innovation process itself (Dosi, 1998; Cohen and Klepper, 1992). Moreover, pointing out the 'Applied' nature of research undertaken in the industrial units it has been further interpreted that the absorptive capacity encompasses the firm's ability to imitate new process or product innovations. Empirical studies on the determinants of R&D widely supported and acclaimed this view on R&D especially in the case of capital less developing countries.

The theory regarding the operation and outwards orientation of firm was systematically formalized from the approach adopted by Kindlberger(1969), Caves (1971), Lall(1983), Wells(1977) and Dunning(2000). FDI firm are monopolistic rent seeker with a possession of intangible assets such as technology, product differentiation, management know how, marketing and selling skills. These advantages must provide cost advantages to the firm. Further, this dimension of firm growth has been extended to the developing country context by wells (1977) and Lall (1983). The MNE's would benefit from the localization and indigenous technology efforts in the developing countries. The ability to create adequate innovate capability through adaptation and imitation will confer certain ownership advantage to the developing country firms for outward orientation. Again, Dunning (1986) identified ownership, location and internalization advantage(OLI) to reflect on the outward orientation of firm. Globalizsation and the liberalization process and the related expansion of multilateral tie-ups further this argument.

3. R&D and the nature of OI in Indian pharmaceutical industry

The Key to success in pharmaceutical industry is Research & Development. R&D is the starting of the industry value chain and is also the most important value creator. Companies that involve in R&D do so in specific areas. They chose specific therapeutic areas to target based on their strengths in the market, and the commercial potential. In the drug development process in any pharmaceutical company a typical product takes 7-10 years, and $350-500 million internationally but the statistic varies greatly with the disease type KPMG (2006). The overall structure of pharmaceutical industry highlight that the R&D undertaken in

pharmaceutical companies differ form other manufacturing in terms of organisation and linkages.

During the past decade R&D profile of Indian Pharamaceutical industry has undergone changes in terms of structure, organization and trends. In 2004, R&D spending of the organized pharmaceutical sector as a whole was nearly US $ 4340 million, which was an increase of more than 300 percent from the level existing in 2000 Dhar and Rao(2002). When we look at the growth rate of R&D, the overall R&D spending (comprising of public, private and small scale) in the sector has grown by around 21 percent, Mani (2006).In this private sector accounts for about 85 percent of the R&D expenditure. The share of small scale sector stood at percent. Eventhough, R&D expenditure of Indian companies has grown over years, it is only a small percentage of the global figure. Indian pharmaceutical industry on an average spends 2percentage of its sales turnover in R&D which compared with the global average of 18.5 is quite low.

The overall structure of pharmaceutical industry R&D has undergone changes over years. In the early 1950's MNC had a considerable market share hence the R&D spending were undertaken for the production of formulation with the imported bulk drug. With the patent act of 1970 this composition underwent changes, and initiated the growth of a strong indigenous domestic sector with R&D spending for the development of generics. It has been identified that the R&D spending undertaken in Indian pharmaceutical sector is mainly for the development of generics, development of novel drug delivery system, development of new processes and the development of new chemical entities (new drugs).One of the important indicator of R&D efforts is the increasing patent filings Indian companies made in Indian as well as US patent office. In addition to this, the aggressive R&D spending adopted by the selected Indian firms like Ranbaxy, Dr. Reddys , Nicholas piramal, Wockdhardt Ltd etc made them highly competitive and helped in developing the technology base.

Technology regime, especially the 1970 patent act had a favorable impact on the development of R&D in Indian pharmaceutical industry. Patent act recognized only process patent allowing Indian firms to reverse engineer and make incremental innovations surrounding the original version of the drug. Further, the specific regulatory policies adopted by the government of India related with quality and recognition of in -house R&D units motivated the interest in the companies to spend on R&D. Fiscal incentives like depreciation

allowances, customs duty exemptions, 150 percent weighted tax exemptions are made to boost the R&D spending in the sector. Hence in this scenario it is highly of importance to academicians and policy makers the impact of various firm level factors on the R&D spending of the pharmaceutical sector.

The Outward Investment (OI) in Indian pharmaceutical industry has grown substantially in recent years. This is in continuity with the trends followed by other sectors of the economy[3]. As per the recent studies the Out ward investment from India took two forms one in the form of direct investment oversees and second in the form of merger and acquisitions abroad[4]. The composition of investment highlight that the firms undertake investment abroad not only for manufacturing tie ups but also for trading and marketing. The OI firms differ each other in terms of grographical/ locational setup and ownership. Till 1990's the outward investment from the sector was mostly confined to developing countries. This locational advantage could have provided initial production advantages in the form cheap availability of labour. The trend followed a dramatic change after reform when the sectoral composition of outward investment increased. Indian pharmaceutical companies started investing in developed and the transition economies[5].

4. Description of Variables and Hypothesis

For the construction of variables data has been collected on a host of firm specific characteristics like expenditure on research and development, sales turnover, expenditure on Import of capital goods, expenditure on royalty and other technical fees, profits, year of incorporation, advertisement expenditure, foreign equity participation and value addition. Data on Net Value Added has been included in the initial stage of estimation as a non technology variable to measure the impact of vertical integration on R&D intensity .In the later stages this variable has been dropped due to high correlation between Profit (PBDIT) variable and value addition

[3] The flow of Foreign direct investment from India increased $121 million in 1990 to $45274 million in 2005.The same figures as percentage of GDP indicate an increase from .0.4 percentage to 1.2 . Outward FDI stock increased from $124 million to 7080 in 2004 though it showed a decline in 2005. The cross boarder acquisitions and mergers by Indian firms also increased in the same years. For detailed figures on outward FDI see UNCTAD, *World Investment Report 2006*

[4] See Pradhan (2007)

[5] For a detailed discussion see Sauvant (2004)

Table 4.1 Description of variables

	Dependent variable	**Notation**	**Description**
	R&D Intensity	RDCINT	(R&D expenditure/Sales) * 100
	Independent Variable		
1	Firm Size	SIZE	Total sales of the i^{th} firm to the total sales of the industry**.
2	Export Intensity	EXPINT	Total exports as a percentage of sales turnover
3	Capital goods import intensity	IMPCINT	Expenditure on import of capital goods as a proportion of sales turnover
4	Disembodied technology Imports intensity	IMPRPINT	Royalties and technical fees paid as a percentage of sales turnover
5	Rate of Profit	PBDIT	Profit as a percentage of sales
6	Age	AGE	Number of year since the incorporation of the firm
7	Advertisement Intensity	ADVINT	Expenditure on advertisement as a percentage of sales
9	Ownership	FP	=1 if foreign equity participation exist* =0 otherwise

RDINT in probit model,RDCINT in tobit and RDS in Fe and RE specification.
if atleast 10% of the equity capital of the firm is held abroad. ** Sales are deflated on 1993 base year prices

4.1.1 Firm size

Literature discussed section 2 provides the primary motive of including firm size as a variable in determining R&D activity of firms. Schumpeterian argument on innovation gives superior importance to firm size as an important factor which influence the behavior of firms (Cohen and Klepper, 1992).A positive relationship between firm size and R&D activity is explicated under this hypothesis. That is, larger the firm larger its market power and larger its capacity to appropriate economics rents. Greater size confers two important advantages one in terms of economics of scale and other through the increased capability to mobilize resources. Since R&D cost is fixed big firms can spread it over a large amount of out put than large firms. In case of financing of R&D large firms are usually have more internal funds at their disposal and can mobilize huge amount of funds required to spend on R&D form the market.

Empirical evidence from numerous studies carried out on the relationship between R&D activity and firm size remains inconclusive. Lall (1983) identified a positive relationship between firm size and R&D activity of a sample of 100 Indian firms. Katrak (1985) for a period of 1978-79 identified a positive but non-proportional relationship between R&D expenditure and firm size for a cross section study of Indian industries. Siddharthan (1998) following Acs and Audretsch (1988) reported a U shaped relationship between firm size and

R&D for a sample of 166 manufacturing firms over a period 1982-1985. That is, R&D intensity decreases to a limit where the firm size reaches a threshold limit and then, starts increasing. Further, contrary to the above results Kumar and Saquib(1996) for a sample of Indian manufacturing industries from 1977-78 to 1980-81 explicated an inverted U shaped relationship between firm size and probability to undertake R&D activity and, positive and linear relationship between firm size and intensity to undertake R&D (using Probit and Tobit model). In a recent study, Kumar and Agarwal (2005) for a sample of 291 Indian manufacturing firms reported a horizontal 'S' shaped relation (cubic relation) between firm size and R&D activity.

Studies proxied firm size with indicators like employment, market share, sales etc. Following previous studies on Indian industry, the firm size is proxied as sales (SIZE) for the present. We expect a non-liner relationship between firm size and R&D intensity. Quadratic term is included to check for non-linearity.

4.1.2 Technology imports

Developing countries are characterized with limited research capability (both in terms of skill and technology)so import of technology(in the form of direct purchase) is identified as a major source to boost up the technology as well as R&D capability of domestic industries. Further, import of technology requires local R&D activity(local learning) to absorb ,adapt and assimilate the imported technology to suit local technology needs.

Literature identifies two modes of technology imports embodied and disembodied. The relationship between technology imports can be of substituting type if the imported technology curbs the R&D activity in the country. As against this, imported technology could support the local firms effort to adopt, absorb and assimilate by increasing its R&D activity then, the relationship is complementary. Studies carried out in India showed mixed results in terms of the relationship between R&D and import of technology. Lall (1983), Katrak (1985) reported a complementary relationship between R&D intensity and import of technology. This results has been supported further by Kumar and Agarwal (2005), Basant (1997) Dolenkar and Evenson (1989). Kathuria and Das (2005) using CAPITALINE data (1996-2001) reported substitution relationship between import of technology and probability to undertake R&D activity and R&D intensity. Further, Kumar and Saquib (1996) using RBI firm level data during the pre-reform period based on a sample of 291 Indian manufacturing

firms found neither complementary nor substitution effect between R&D intensity and imported of technology in both forms.

For our purpose, both the variables are included in the study to test the impact of import of technology on the R&D activity. IMPCINT indicating embodied technology import and IMPRPINT for disembodied technology imports.

4.1.3 Export orientation

R&D performance depends on the mode and degree of outward orientation. One argument regarding this is that exports are likely to increase the returns to investment in R&D through the increase in the size of the market. Braga and Willmore (1991) identified for Brazilian firms a statistically significant positive relationship between export orientation and R&D intensity. Kumar and Saquib (1996), Kumar and Agarwal (2005) for India found a significant positive relationship between R&D investments and exports. It has been argued in these studies that diversification through exports increases the probability and intensity to undertake R&D activity. Hughes (1986) argues that elasticity of foreign demand with respect to R&D is likely to be greater than that for the domestic market. One argument in favour of this is that exports could target segmented markets and could pool the profit from this for further R&D activity another is that of increased benefits through product differentiation.
Kumar and Siddharthan (1997) firm level observation of 13 manufacturing industries found export orientation influence R&D activity for medium and low industries and not for the high technology industries. Pharmaceutical industry has the advantage of using firm specific knowledge like innovative design, New formulations and compounds to enhance its exports which in turn further the R&D growth and firm level capability.

Study expects a positive relationship between R&D and exports .Export intensity is identified as a ratio of exports to sales in the study (EXPINT). Study however ignores possible Simultaneity problem between exports and R&D expenditure and carries all limitation of static panel data models.

4.1.4 Foreign ownership

Evidences shows that foreign firms with high foreign equity participation does not usually invest in R&D as they have continued access to the research labs of their parent firms. This hypothesis has been tested in case of India by several studies Kumar and Saquib (1996);

Kumar and Agarwal (2005) and the evidences suggest that foreign firms in Indian manufacturing have done significantly less R&D compared to their local counterparts. Access to capital generated by the parent firm-is one of the important factor which limits the spending by the foreign firms. On the other hand, foreign equity participation can have favorable effect on the R&D intensity of a firm if foreign firms technology is adapted to suit local needs. Such adaptations take place in joint ventures than in purely local firms. Compared to the local firms there are evidences the R&D activity of the foreign firms are more determined by the profit rates rather than the firm size.

Collaborative ventures could support and reduce technology search cost which in turn could pool more resources for R&D. There is probability to undertake R&D activity if the foreign partnership firm wants to take advantage of the low cost R&D personal in the country. Following other studies the Dummy variable is introduced in the analysis to take care of the foreign ownership (FP). A negative sign is for FP is expected in the study.

4.1.5 Rate of profit

One of the important source to finance the R&D expenditure of the firm is profits. Moreover it has been noted that firms may be unwilling to fund R&D activity with the borrowed funds knowing the uncertain nature of R&D.

Kamian and Schwartz (1982) pointed that profitability is a threshold factor necessary in some degree for R&D activity but no direct functional relationship with innovative activity. Kumar and Saquib (1996) identified negative relationship for a sample of Indian manufacturing industries. Profit before depreciation, interest and tax (PBDIT) is taken as rate of profit variable in the study. Following recent Indian studies a positive relationship is expected between R&D and probability to undertake R&D and R&D intensity.

4.1.6 Age of firm

It has been identified that by way of learning by doing and through accommodating more experience, the firm could posses a greater advantage in undertaking research(Bell and Pavitt,1997). Moreover, experienced firms have the advantage due to accumulation of learning to cater the need for further technology up gradation. Age of the firm is expected to affect the probability and intensity to undertake R&D activity. Age of the firm (AGE) is

Proxied by the year of incorporation. A positive impact of age on probability to undertake R&D activity is expected.

4.1.7 Advertisement intensity

Advertisement intensity helps the firm to increase the market share which in turn increases the R&D intensity. Advertisement enhances R&D only if it increases market share and thereby increases the rate of return on R&D intensity. Advertisement intensity is taken as ratio of advertisement expenditure to sales (ADVINT). A positive sign is expected in the estimation.

4.2 Methodology

Study employs the framework of Probit and Tobit models to empirically verify the relationship of various explanatory variable (determinants of R&D), on the probability and intensity of investment in R&D. Data on both R&D incurring and non R&D incurring firms are used for the model. Since the estimated coefficients of Tobit and Probit model are not the marginal effects of the explanatory variables marginal effects are also calculated and reported. In case of Tobit model, marginal effects are decomposed following (Moffit and Mc Donald, 1980). Since the data is in the panel form fixed and random effects model is employed to estimate the degree of relationship between R&D intensity and other variables for those firms which undertake R&D activity (R&D intensive firms). One of the drawback of the present methodology is that it does not takes into account the causality issue (between the explanatory and explained variables). It has been argued that the econometric estimates of the impact of various explanatory variables on companies R&D investments are subjected to simultaneity bias (Kumar and Agarwal, 2005). Hence while interpreting the results it should be noted that the results hold all the limitations of using a static panel data model.

4.2.1 Probit Model

Probit model explains the probability of undertaking R&D activity taking into account the host of firm specific factors. The dependent variable in the case of Probit model is binary type, i.e.,0,1 type depending upon whether the firm spends on R&D or not.

$$RDINT^{*}_{it} = \alpha + \beta_1 SIZE_{it} + \beta_2 SIZE^2_{it} + \beta_3 EXPINT_{it} + \beta_4 IMPCINT_{it} + \beta_5 IMPRPINT_{it} + \beta_6 PBDIT_{it} + \beta_7 AGE_{it} + \beta_8 ADVINT_{it} + \beta_9 FP_{it} + \mu_{it}$$

$$RDINT = 1 \quad \text{if} \quad RDINT^* > 0, \text{ and}$$
$$= 0 \quad \text{otherwise} \qquad \ldots\ldots\ldots(1)$$

Where the subscript i stands for particular observation, RDINT* is the latent variable and RDINT is a binary variable that takes the value 1 whenever RDINT* is greater than zero else RDINT* is zero.

Probit analysis, does not provide explanation for the intensity to undertake R&D activity hence, Tobit model is employed.

4.2.2 Tobit model

Tobit model explains the intensity of R&D activity where large number of firms report no R&D activity. Moreover, in such cases where the information on the regressand is not available for some observation, the coefficients obtained using the OLS technique are biased towards the censoring point.(zero in the current study). Tobit estimation is employed in numerous studies dealing with censored data (Kumar and Siddharthan, 1994; Kumar and Saquib, 1996). In addition it has been argued that the MLE maximum likelihood estimation based Tobit model could take care of the problems associated with the censored data (Green, 2000 ;Wooldridge,2002). Statistically, the functional form of Tobit model could be expressed as

In the study the Tobit model for the R&D intensity of the firms can be specified as:

$$RDCINT^*_{it} = \alpha + \beta_1 SIZE_{it} + \beta_2 SIZE2_{it} + \beta_3 EXPINT_{it} + \beta_4 IMPCINT_{it} + \beta_5 IMPRPINT_{it} + \beta_6 PBDIT_{it} + \beta_7 AGE_{it} + \beta_8 ADVINT_{it} + \beta_9 FP_{it} + \mu_{it}$$

$$RDCINT = 0 \quad \text{if} \quad RDCINT^* \leq 0$$
$$= RDCINT^* \quad \text{if} \quad RDCINT^* > 0 \qquad \ldots\ldots\ldots (2)$$

One of the important aspects regarding the censored regression models are the coefficient is a weighted average of two marginal effects 1. The effect of an increase in the independent variable on the cumulative probability that the depenbdent variable exceeds the limit. 2. The change in the expected value of being above the limit. Magnitude of marginal effects depends on the values of the independent variable if it grows large the second effect converges to the values of the Tobit coefficient and the first effect tends to be zero(MC Donald and Moffitt,1980).

4. 3 Data Source and Descriptive Statistics

As discussed in the introduction the study uses firm level data, PROWESS, provided by the centre for monitoring Indian economy(CMIE) for a period of 16 years from 1990 to 2005, PROWESS provides Annual Report Data for nearly 5000 manufacturing firms listed in the Bombay Stock Exchange. Out of this, 338 firms belong to Pharmaceutical sector. PROWESS database is based on NIC 1998 classification. A number of truncation rules are followed to clean and find the final data set for empirical analysis. First, those firms which report zero sales or negative net value added is deleted from the initial data set. Second, study includes only those firms which reported continuous data for at least four years. Unbalanced panel is formed for the present analysis with an average of 173 firms in each year including firms from both domestic and foreign categories (Sample details are given in Table 4.2. According to the NIC classification the present sample belongs to 'Drugs and Pharmaceutical' category under three- digit industry classifications. On the basis of the end product classification the sample include those firms which produce Bulk drug, Formulation or both.

Table 4.2 Sample characteristics

Year	Sample firms	Number of R&D Incurring firms	Domestic firms	Foreign firms	R&D Incuring Foreign firms	Domestic firms Incuring R&D	OI firms[6]	No of OI firms incuring R&D
1990	77	5	63	14	2	3	15	0
1991	82	10	68	14	2	8	17	3
1992	86	19	72	14	3	16	17	3
1993	107	42	92	15	10	32	17	8
1994	146	56	129	17	8	48	23	13
1995	191	69	173	18	9	60	25	15
1996	209	77	189	20	12	65	26	16
1997	191	83	171	20	12	71	27	19
1998	200	80	181	19	13	67	28	18
1999	209	84	189	20	13	71	31	20
2000	215	86	194	21	11	75	30	18
2001	215	86	193	22	14	72	30	20
2002	208	98	185	23	15	83	29	24
2003	226	97	205	21	14	83	29	21
2004	223	109	201	22	15	94	30	25
2005*	183	99	165	18	14	85	28	25

* figures are for march 2005

[6] The data on outward investment has been obtained from http://www.geocities.com/pradhanjayaprakash/jp.html

4.3.1 Descriptive statistics

Table 4.3 given below shows the Minimum, Maximum, Mean and Standard Deviation of the variables included. Separate summary statistics highlighting the same for OI firms and other domestic firms with significance test for mean differences are included in view of comparison. Since the structure and behavior of R&D incurring and Non R&D incurring OFDI firms are different the summary statistics of those firms (the study expects difference in the behavior) are included in table 4.6

Table 4.3 Summary Statistics (Sub Sample)

VARIABLE	**Mean**	**Std. Dev.**	**Min**	**Max**
SIZE	2.9762	3.5869	0.0003	24.9566
RDCINT	1.2948	1.9347	0.0000	14.4811
EXPINT	24.4006	21.4702	0.0000	90.9064
IMPCINT	1.6359	7.0209	0.0000	100.0000
IMPRPINT	0.0419	0.2248	0.0000	3.2468
PBDIT	19.4824	14.3432	-20.5500	150.0000
AGE	29.7308	24.0578	1.0000	104.0000
ADVINT	0.8805	1.6405	0.0000	12.9808

Total number of observations = 390

Table 4.3 shows that the observations in the sample are fairly experienced with the mean age of the firm being approximately 30 years. The mean expenditure for advertisements is around .8 percent with a maximum advertising expenditure at nearly more than 12 percentage of sales. The sample includes nearly hundred percentage export oriented firms as well as those cater to the domestic market only. It is evident that import of technology in the form of machinery and equipment is the favorite means of obtaining technology compared to disembodied technology imports. There are firms which resort to 100 percentage import of capital goods. The mean R&D intensity is nearly 1.2 with a maximum spending of around 14 percentage of sales.

From Table 4.4 it is clear that on an average foreign firms are larger than the domestic firms. Further, domestic firms are better in terms of profitability(here one should consider that the number of foreign observations is comparatively less than that of the domestic one and those foreign firms which entered the market during the liberalization period faced a small gestation period to reap returns). The significance test for difference in mean highlights that

the average age of foreign firms is higher than that of domestic firms, indicating more level of experience and accumulated knowledge.

Table 4.4 Significance test for difference in mean for domestic and foreign firms (Standard deviation in parentesis)

Variable	Foreign	Domestic
	Mean	
SIZE	2.20* (2.56)	.87* (1.83)
RDCINT	.67 (2.56)	.59 (4.43)
EXPINT	10.67* (19.2)	15.31* (22.32)
IMPCINT	0.81 (6.48)	.53 (3.44)
IMPRPINT	0.33 (2.09)	0.04 (.48)
PBDIT	2.13* (32.03)	8.16* (42.55)
AGE	36.65* (21.72)	20.92* (18.26)
ADVINT	2.23* (3.31)	1.95* (6.62)

*indicates difference in the mean values based on the t-test significance level with unequal variances which is better than or equal to 5 percent. Total number of observations belong to foreign category= 298, Domestic =2468

Table 4.5 indicates that there is a significant difference in the mean of firm size for R&D incurring and non R&D incurring firms. In addition, the export performance of R&D incurring firms is better than that of the non R&D firm. This implies that R&D incurring firm depend more on outward orientation. Again, R&D firms are better in terms of experience and profitability. However there is no systematic difference between R&D and non R&D firms in terms of import of technology (both embodied and disembodied technology)

Table 4.5 Mean and standard deviation of variables for R&D incurring and Non – R&D incurring firms

Variables	R&D Incurring firms	Non R&D Incurring firms
	Mean	
SIZE	1.92* (2.67)	.43* (1.89)
RDCINT	4.16 (17.26)	-
EXPINT	19.64* (23.4)	11.61* (20.51)
IMPCINT	.92 (4.59)	.33 (3.32)
IMPRPINT	.08 (.32)	.07 (1.03)
PBDIT	13.46* (16.21)	-2.12* (43.03)
AGE	30.08* (21.07)	17.69* (16.24)
ADVINT	2.03* (8.14)	1.76* (4.48)

*indicates difference in the mean values based on the t-test significance level with unequal variances which is better than or equal to 5 percent. Total number of observations with R&D=1100

Table 4.6 shows the significance test for mean difference between outward investing and other domestic firms. The significance test for mean scores highlight that OI firms differ from the domestic counterparts on firm size, R&D intensity, export intensity, import of capital good intensity, profit and age.

Table: 4.6 Mean difference (OI firms and other Domestic firms)

VARIABLE	OI Firm	Other Domestic firm
	Mean	
SIZE	2.98* (3.59)	0.49* (0.77)
RDCINT	1.29* (1.93)	0.46* (2.49)
EXPINT	24.40* (21.47)	13.64* (22.12)
IMPCINT	1.64* (7.02)	0.33* (2.15)
IMPRPINT	0.04 (0.22)	0.04 (0.52)
PBDIT	19.48* (14.34)	6.04* (103.81)
AGE	29.73* (24.06)	19.27* (16.44)
ADVINT	0.88 (1.64)	0.93 (2.73)

*indicates difference in the mean values based on the t-test significance level with unequal variances which is better than or equal to 5 percent.
Note: Total number of OI observations 390. Total number of observation belongs to other Domestic firm category 2078.

Significance test for difference in mean for R&D incurring and non- R&D incurring OI firms highlight in table 4.7. R&D intensive firms exhibit a significant difference in mean score on size of the firm, export intensity, and age of the firm. Mean scores in exports highlight that the R&D incurring OI firms are more outward oriented. R&D incurring firms also has a comparative advantage in terms of size. Contrary to this two figures mean difference in age R&D intensive firms are less experienced than

Table 4.7 Significance test for Mean difference (R&D incurring and non – R&D incurring OI firms

VARIABLE	R&D Incuring	Non R&D Incuring
	Mean	
SIZE	3.82* (4.09)	1.57* (1.82)
RDCINT	2.07 (2.09)	-
EXPINT	29.42* (22.32)	16.10* (17.06)
IMPCINT	1.58 (5.26)	1.71 (9.24)
IMPRPINT	0.05 (0.27)	0.01 (0.09)
PBDIT	19.19 (6.90)	19.95 (21.65)
AGE	28.55* (20.34)	31.66* (29.15)
ADVINT	0.93 (1.73)	0.79 (1.46)

*indicates difference in the mean values based on the t-test significance level with unequal variances which is better than or equal to 5 percent.Total number of observations with R&D 243

Significance test for difference in mean for R&D incurring and non- R&D incurring OI firms highlight in table. R&D intensive firms exhibit a significant difference in mean score on size of the firm, export intensity, and age of the firm. Mean scores in exports highlight that the R&D incurring OI firms are more outward oriented. R&D incurring firms also has a comparative advantage in terms of size. Contrary to this two figures mean difference in age R&D intensive firms are less experienced than

4.3.2 Correlation matrix

The correlation matrix provided in table shows that the correlation coefficients are low for most of the cases. The correlation matrix reveals low levels of pair-wise correlation values but there are chances of higher order colleniarity among variables where one variable is a liner combination of more than one other explanatory variable. In comparison with other

variables correlation coefficient values of export intensity and firm size with the R&D intensity is greater.

Table 4.8 Correlation Matrix (Sub Sample)

Variables	SIZE	RDCINT	EXPINT	IMPCINT	IMPRPINT	PBDIT	AGE	ADVINT
SIZE	1							
RDCINT	0.4122	1						
EXPINT	0.1822	0.2354	1					
IMPCINT	-0.0303	-0.0239	0.0196	1				
IMPRPINT	-0.0487	0.094	0.1829	0.0672	1			
PBDIT	-0.0234	0.0318	0.0162	0.098	-0.0419	1		
AGE	0.12	-0.0807	-0.2547	-0.1209	-0.0946	0.0551	1	
ADVINT	0.1301	0.0894	-0.1192	-0.034	-0.0405	-0.099	0.127	1

4.4 Results and Discussion

Table and Table provides estimation results based on Probit and Tobit models respectively for unbalanced panel of 2766 observations (full sample).One should infer that Tobit results are not robust with respect to Heteroscedasticity in the data (since STATA 8 package does not have the option to correct for Heteroscedasticity in Tobit).

Table 4.9 Probit Results (Full Sample)

Variables	Coef.	Std. Err.	Marginal effects
SIZE	0.5617***	0.0477	0.2157
$SIZE^2$	-0.0239***	0.0026	-0.0092
EXPINT	0.0116***	0.0012	0.0044
IMPCINT	0.0178***	0.0073	0.0068
IMPRPINT	0.0124	0.0228	0.0048
PBDIT	0.0012**	0.0006	0.0004
AGE	0.0142***	0.0016	0.0054
ADVINT	0.0329***	0.0104	0.0126
FP	-0.1829**	0.1010	-0.0686
OI	-0.2725***	0.0960	-0.1011
_cons	-1.2108***	0.0495	
Wald chi2(10)	428.44		
Prob > chi2	0		
Pseudo R2	0.2171		
Log pseudolikelihood	-1455.37		
Number of obs	2766		

*Indicates significance at 10% level;** significance at 5%, ***significance at 1%
[a]marginal effects are for the discrete change of the dummy variable from 0 to 1

4.4.1Probability of undertaking R&D activity (Full sample)

As expected the (SIZE) variable indicating the size of the firm and its quadratic term ($SIZE^2$) turns out significant with positive and negative coefficient. This indicates an inverted

'U' shaped relationship between the size of the firm and the probability to undertake R&D activity of the firm. This is in line with the findings of many other studies and reinstates the fact that investment in R&D is a uncertain and risky activity and could be undertaken by firms only with enough resources. In case of probability of undertaking R&D same results has been explicated in case of pharmaceutical industry by Pradhan (2006) & Ray and Badhuri (2001) for electrical and pharmaceutical industry.

As was postulated, a positive relation between export performance of a firm and R&D activity is directly explicated from the given results. Export intensity turns out to be statistically significant at 1 percentage level. This indicates that during the liberalization phase and it's after math the Export performance of the firms has had a favorable effect on the firm decision to invest in R&D.

The technology variable capturing embodied imports IMPCINT turns out with coefficient having positive signs which is statistically significant. This in fact adds to the debate raised by recent studies regarding the nature of relation between capital imports and R&D intensity of the firm. Since the coefficient values are statistically significant it could be concluded that a complementary relationship exist between disembodied imports and the decision of the firm to spent on R&D.

On the contrary, the technology variable indicating disembodied imports in the form of royalty payments, technical fees and patents holds a statistically insignificant with positive coefficient. Since the coefficient values are not significant neither a substitution nor a complementary relationship can be inferred.

As postulated, rate of variable rate of profit of a firm directly determines whether a firms spends on R&D or not in the industry. The variable indicating rate of profit PBDIT has come up with a positive sign and is significant at 5%level. Being more specific, the marginal effects provided at column of the same table highlights that, a one percent increase in the profit margins of the firm on an average increases about .0004 in the probability of the firm to undertake R&D activity keeping other variables constant.

As expected the coefficient of the age variable (AGE) turns out with a positive sign with a statistical significance at 1% level. This shows accumulated experience and learning has a

positive effect on R&D Intensity. More over the average age of the firms in the sample is 23 which in tandem with the estimation results suggest that experience and learning has direct effect on the firm's decision to spend on R&D in pharmaceutical sector. ADVINT variable showing advertisement intensity has a significant positive effect on the probability of a firm to spend on R&D activity. Advertisement expenses, as hypothesized increases the market share of the firm and could in turn influence the firms decision to invest in research and development activity.

Coefficient of dummy variable capturing the ownership of the firm has a negative sign which is statistically not different from zero. This provides reason to suggest that the R&D activity of firms with high foreign equity participation would differ from those of the domestic firms. Again, OFDI dummy capturing outward investment turned out significant with negative coefficient suggesting that outward orientation in the form of investment abroad aversely affect the R&D spending of the firm. One reason for this is that firm could undertake R&D investment in their plants abroad.

Table 4.10 Tobit Estimation of R&D Intensity(Full Sample)

Variables	Coef.	Std. Err.	ME 1	ME 2
SIZE	0.9245***	0.1010	0.2406	0.0763
$SIZE^2$	-0.0382***	0.0064	-0.0099	-0.0031
EXPINT	0.0421***	0.0044	0.0110	0.0035
IMPCINT	0.1799***	0.0214	0.0468	0.0148
IMPRPINT	0.0540	0.1358	0.0141	0.0045
PBDIT	0.0033	0.0029	0.0008	0.0003
AGE	0.0348***	0.0055	0.0091	0.0029
ADVINT	0.0858**	0.0384	0.0223	0.0071
FP	-0.3664	0.3360	-0.0934	-0.0296
OI	0.0207	0.3025	0.0054	0.0017
_cons	-4.6155	0.2224	-1.2011	-0.3809
LR chi2(10)	472.07			
Prob > chi2	0			
Pseudo R2	0.0582			
Log likelihood	-3817.98			
Number of obs	2766			

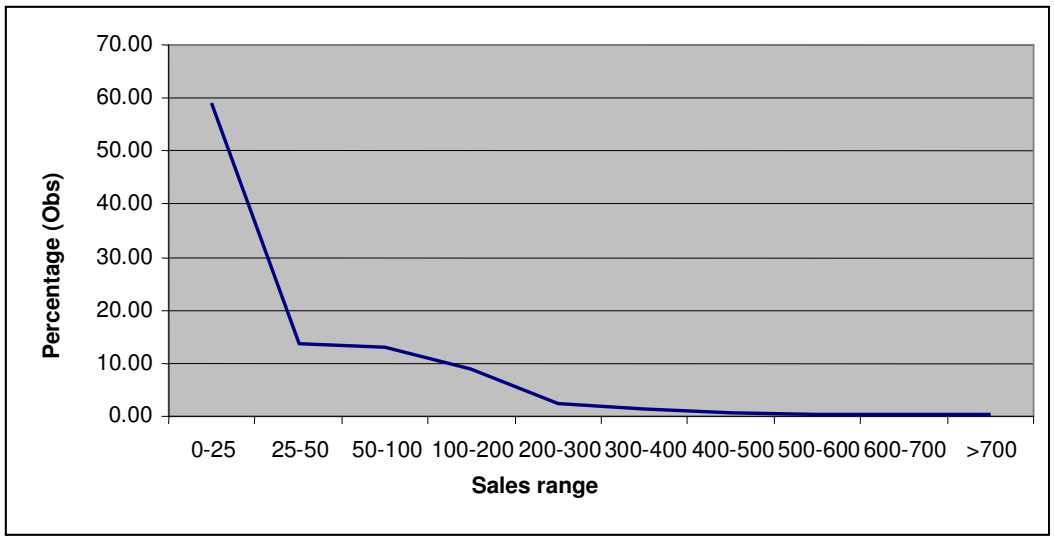
*Indicates significance at 10% level;** significance at 5%,significance at 1%
Marginal effect are decomposed following Mc Donald and moffitt(1980)
[a]Marginal effects are for the discrete change of the dummy variable from 0 to 1

4.4.2 Explanation for R&D intensity (Full sample)

Firm size and its squared term turns out to be statistically significant with positive and negative sign (Table 4.10). Coefficient of the firm size variable using market share is

comparatively higher than that of absolute sales amount. Direct inference could be made from the sign of the coefficient values that a non linear relation exist between the firm size the firms R&D intensity. The nature of the non liner relationship is explicit from the positive and negative sign of the coefficients. Which indicate an inverted 'U' shaped relationship. Firm size has a positive influence on R&D intensity of the firm to a threshold limit but after the limit R&D intensity decreases with an increase in the firm size.

Figure 1. Distribution of sample observations on the basis of sales range



Above chart highlight that the large number of observations falls in the sales range of less than 50. This indicates that the size variable as indicated by sales is unevenly distributed. Further it could be inferred that industry is composed of a large number of small sized firms and a small number of large sized firms. Pradhan (2006) calculated the threshold (the turning point on which the R&D intensity is maximum) level for the R&D intensity. It has been further identified in the study that large number of firms belongs to small size category and are far below the threshold level R&D. Hence, following same argument Pradhan (2006) It could be explicated that the R&D spending of the small or medium sized firms has to be increased to reach the threshold level.

Export intensity has a positive impact on the R&D intensity of the firms. This is same as the Probit model. Outward orientation and diversification of the firm through exports not only have a positive influence on the R&D intensity but also it increases the technological inputs

of the pharmaceutical enterprise there by influences both R&D intensity and probability to undertake R&D activity.

Unlike the Probit model, IMPCINT, the variable indicating embodied technology imports turns out with a positive sign which is statistically significant. Hence it not explicit that a complementary relation exist between R&D intensity and capital imports. Like the Probit model embodied imports variable IMPRPINT turns out with a positive sign but here it is not statistically significant. Hence we could not infer whether a substitution or complementary relationship exists between disembodied technology imports and the R&D intensity. Like the Probit model PBDIT indicating rate of profit turns out with a positive coefficient which is statistically not significant.

Age of the firm has a positive coefficient with a significance level of 1 percentage indicating the experience and learning internalized by the firm increases the R&D intensity of the firm. This highlights that, the more the firm accumulate experience and learning, compared to the average age of the firm the higher the chance of increase in both the probability to undertake R&D and R&D intensity.

Dummy variable indicating the ownership pattern of the firm has a negative sign which is statistically not different from zero. Hence it could reflect the notion that majority foreign ownership does not raise the R&D intensity of the firms compared to the domestic ownership. OI dummy capturing outward investment of the firm turns out with a positive coefficient which is statistically insignificant. Hence it could be inferred that the outward investment of the firms does not have a systematic influence on the R&D intensity.

Table 4.11 Probit estimation results (sub sample - OI firms)

Variable	Coef.	Std. Err.	Marginal effects
SIZE	0.3386***	0.0550	0.1244
$SIZE^2$	-0.0127***	0.0024	-0.0047
EXPINT	0.0188***	0.0035	0.0069
IMPCINT	-0.0031	0.0076	-0.0011
IMPRPINT	0.6648*	0.4745	0.2444
PBDIT	0.0010	0.0038	0.0004
AGE	-0.0023	0.0028	-0.0009
ADVINT	0.0584*	0.0419	0.0215
_cons	-0.8100*	0.1984	
Wald chi2(8)	76.73		
Prob > chi2	0		
Log pseudolikelihood	-210.046		
Pseudo R2	0.1871		
Number of obs	390		

4.4.3 Probability of undertaking R&D activity (Sub Sample)

Results provided in Table 4.11 highlight the probability of undertaking R&D activity for the outward oriented firms. The results highlight that size variable exibit an inverted 'u' shaped relationship with R&D intensity. This is similar to the results obtained with the full sample using OFDI dummy. Coefficient of export variable turns out significant with positive sign. This explains that exports of those domestic firms invested abroad have a positive impact on the decision to undertake R&D in the domestic market. In otrher words, this result adds that the alternative path of internationalization of the firm through exports, increases its probability to spend on R&D activity. Variable indicating technology imports in the form of know-how turns out to be significant with positive coefficient. This indicate that the probability of undertaking R&D by outward oriented firms depends on the. Further, this could be supported by the fact that the outward oriented firms have greater opportunity to adopt foreign technology know to the local condition. Again, probability of investing in R&D activity (advent)

Unlike the full sample PBDIT, AGE, IMPCINT indicating profit, age and import of capital goods out shows no systematic relationship between the probability of undertaking R&D by outward oriented firms.

Table 4.12 Tobit estimation results (sub sample -OFDI firms)

RDCINT	Coef.	Std. Err.	Marginal effects 1	Marginal effects 2
SIZE	0.6340***	0.0865	0.2630	0.1062
$SIZE^2$	-0.0211***	0.0048	-0.0087	-0.0035
EXPINT	0.0296***	0.0066	0.0123	0.0050
IMPCINT	-0.0173	0.0221	-0.0072	-0.0029
IMPRPINT	1.0268**	0.5442	0.4259	0.1720
PBDIT	0.0091	0.0108	0.0038	0.0015
AGE	-0.0139**	0.0062	-0.0058	-0.0023
ADVINT	0.2000**	0.0797	0.0829	0.0335
_cons	-1.5905***	0.4217	-0.6597	-0.2664
LR chi2(8)	121.88			
Prob > chi2	0			
Pseudo R2	0.0866			
Log likelihood	-643.075			
Number of obs	390			

4.4.4 Explanation for R&D intensity (Sub sample)

Results in the tobit model highlight that the firms size variable has an inverted u shaped relationship with the R&D intensity. This is similar with the earlier model with the full sample. EXPINT, ADVINT variables indicating the exports and advertisement intensity of the outward investing firms turns out with statistically significant positive coefficient highlighting positive relationship with R&D intensity. Unlike the probit results the Tobit results the AGE variable highlighting the age of the outward oriented firms provides a statistically significant negative coefficient. This highlights that the less experienced firm has higher R&D intensity. That is, relatively new OFDI firms in the industry are more R&D intensive.

5. Summary and Conclusion

The present study has strived to explain the determinants of R&D in Indian pharmaceutical industry in the context of outward orientation of firms. The determinants of R&D have been estimated using Probit and Tobit model. Study employed Probit model to estimate probability of undertaking R&D and Tobit model for R&D intensity. An unbalanced panel was constructed with an average of 173 firms, which include R&D intensive and non R&D intensive, OI and non – OI firms. A sub-sample of 390 observations is used to analyse the R&D behavior of outward investing firms.

Empirical analysis of the factors that influence a firm's decision to invest in R&D has been carried out using Probit model. The reported wald chi square statistic for the probit model

indicate high statistical significance for the estimated model. All the independent variables together explained large portion of variation in the dependent variable. Full sample results indicate that the firms decision to invest in R&D depends on firms size, export intensity, import of technology in the form of disembodied imports, rate of profit, age of firm and advertisement intensity, foreign ownership, Outward investment. Size variable and its squared term turned out with positive and negative sign indicating the non linearity. The degree of outward orientation indicated by export intensity has a favorable effect on the decision of the firm to spend on R&D. Like the previous studies, rate of profit, import of capital goods and advertisement intensity has positive coefficients implying that the decision of the firm to invest in R&D increase with rate of profit and advertisement spending and import of capital. Further, coefficient of age of the firm indicate that greater the firm's experience and accumulated learning greater the probability to undertake R&D. Coefficient of foreign ownership dummy in the Probit model has a statistically significant negative sign implying low R&D efforts by foreign firms compared to their domestic counterparts. The payments made in the form of royalty payments, technical fees etc for acquiring technology know- how helped firms to forego its expenditure on R&D. Estimated results denote that the outward investment has a negative impact on the decision of the firm to spend on R&D. This could be due to resource mobilization by the outward investing firms abroad. Probit results in case of the sub- sample (OI firm) highlight that the decision of the firm to invest in R&D depends on size, export intensity, advertisement intensity. Imports in the form of technological know-how influences firms decision to invest in R&D. Unlike the full sample, age indicating the experience of firm has less impact on the R&D decision of the firm.

Empirical analysis on the determinants of R&D intensity has been carried out using Tobit model (Full sample). LR statistic of Tobit model indicate high statistical significance for the estimated model. Results for the full sample highlight that the R&D intensity of Indian firms is not systematically affected by profit, ownership and outward investment. However, Outward orientation of the firms measured by export intensity and firm size are significant determinants of R&D intensity. Advertisement intensity and age turned out important determinants of R&D intensity of the sample firms. Unlike the full sample, import of technology (in the form of know-how) turns out to be significant in determining R&D in the sub sample.

The empirical analysis on the determinants of R&D suggests several policy implications. Since firm size of a R&D incurring and non R&D incurring firms are different, government should come up with measures to mobilize the resources of the small and medium sized firms towards R&D with adequate incentives. Further, government policies should also encourage the outward orientation of firms by promoting joint ventures abroad through liberalizing the rules governing them. Since R&D efforts of the firms are systematically affected by the rate of profit, the government must ensure competitive pressure in the industry through the institutional mechanism.

References

Acs, Z. J and Audretsch, D. B. (1987), "Innovation, market Structure, and firm size", T*he Review of Economics and Statistics*, Vol. 69, No. 4, pp. 567-574.

Amemiya,T.(1984), " Tobit models: a survey", *Journal of econometrics*,Vol.24, pp3-61

Arrow, K. J. (1962), "Economic Welfare and the allocation of resources for technological innovation", in R. R. Nelson, (ed.) *The rate and direction of inventive activity: Economic and social factors*, NBER, Princeton University Press: UK.

Bell, M. and K. Pavitt(1997), "Technological accumulation and industrial growth: contrast between developed and developing countries", In :D. Archibugi and J. Michie(ed) Technology, *Globalisation and economic performance*, Cambridge university press, Cambridge

Braga, L and Willmore, L. (1991), "Technological imports and technological effort: an analysis of their determinants in Brazilian firms", *Journal of Industrial Economics*. Vol. 39, No. 4, pp. 421-432.

Basant, R. (1997), "Technology strategies of large enterprises in Indian industry: some explorations", *World Development*, Vol. 25, pp. 1683-1700.

Baltagi, B.(1995), "Editor's Introduction: Panel Data," *Journal of econometrics*, Vol. 68 , pp. 1-4.

Caves, R.E. (1971) International comparisons; the industrial economics of foreign investment, *Economica*,No. 38, pp. 1-27

Chaudhuri, S. (2005), *The WTO and India's pharmaceuticals industry patent protection TRIPS, and developing countries,* New Delhi: Oxford University Press.

Cohen,W.M and S. Klepper (1992),"The Anatomy of Industry R&D Intensity Distributions" *The American Economic Review*, Vol. 82, No. 4,pp. 773-799.

Cohen, W. M and Levinthal, D. (1989), "Innovation and learning: two faces of R&D", *Economic Journal* ,Vol 99, PP 569–596.

Dhalman, C .J, B. R. Larsson and L. E. Westphal (1987), Managing technological development : lessons fro newly industrialising countries", *World development*, Vol.15,pp.759- 775.

Dasgupta, P. and Stiglitz, J.(1980), "Industrial structure and the nature of innovative activity", *Economic Journal*, Vol. 90, No.358, pp. 266-293.

Deolalikar, A. B. and Evenson, R. E. (1989), "Technology production and technology purchase in Indian industry: an econometric analysis", *The review of economics and statistics*, Vol. 71, No. 4, pp. 687-697.

Dhar, B and Rao, C. R. (2002), "Transfer of technology for successful integration into the global economy: a case study of the pharmaceutical industry in India",

UNCTAD/UNDP Programme on Globalization, Liberalization and Sustainable Development, United Nations, Geneva

Dosi,G.,(1988) “Sources, procedures and microeconomic effects of innovation”, *Journal of economic literature*,Vol.26,pp1120-1171

Dunning, J.H. (1986) The investment development cycle revisited, Weltwirtshaftliches Archiv,No.122, pp. 667-677.

Greene,W.H.(2000) Econometric Analysis -fourth edition, Prentice Hall International, New jersey

Griliches,Z.(1986)"Productivity, R&D, and Basic Research at the Firm Level in the 1970s,"*American Economic Review* ,vol. 76,No 1,pp l4l-l54.

Kamien, M. K., N. L. Schwartz (1982), Market Structure and innovation, Cambridge University Press, Cambridge.UK

Katrak, H.,(1985) “Imported technology, enterprise size and R&D in a newly industrializing country: The Indian experience" *Oxford Bulletin of Economics and Statistics,* Vol 47.pp 213-30.

Kindleberger, C.P. (1969), American Business Abroad, Yale University Press, New Haven.

KPMG (2006), The Indian Pharmaceutical Industry, Collaboration for Growth, Mumbai: KPMG Consulting Private Ltd.

Kumar. N and Aggarwal, A. (2005), “Liberalization, outward orientation and in-house R&D activity of multinational and local firms; a quantitative exploration for Indian manufacturing”, *Research Policy*, Vol. 34, pp. 312-443.

Kumar, N and Saqib, M. (1996), “Firm size, opportunities for adaptation and in-house R&D activity in developing countries: the case of Indian manufacturing”, *Research Policy*, Vol. 25, No. 5, pp. 712-722.

Kumar, N. and Siddharthan, N. S. (1997), *Technology, Market Structure and Internationalization: Issues and Policies for Developing Countries*, Routledge and UNU Press: London and New York.

Kathuria,V and Das,S.(2005) “Impact of FDI on R&D strategies of firms in the post-1991 era. *IIMB management review,* Vol.53 ,No.1 ,pp17-28.

Lall, S. (1983), “Multinationals from India”, in Lall (ed.) *The New Multinationals: The Spread of Third World Enterprises*, John Wiley & Sons: New York. pp. 21-87.

McDonald, J. F. and R. A. Moffitt (1980) ‘The uses of Tobit analysis’, *The Review of Economics and Statistics*, Vol. 62, pp. 318-321.

Mani, S. (2006), “Sectoral system of innovation of Indian pharmaceutical industry”, Working Paper: No 382, Centre For Development Studies, Trivandrum, Kerala.

Malerba, F. and Orsenigo, L. (1992) Technology regimes and firm behaviour. Mimeo. Bocconi University, Milan. Italy, July.

Mansfield. E (1968), *Industrial research and technological innovation*, Norton Publishers, New York, US

Pavitt, K(1984), "Sectoral pattern of technological change: towards a taxonomy and a theory".*Research Policy*, Vol 13, pp 343-373

Pradhan, J. P. (2006), "Liberalization, firm size and R&D performance: a firm level study of Indian pharmaceutical industry", RIS Working Paper. No RIS-DP 40/2003, New Delhi

Pradhan, J. P. and Abhinav, A (2006),"Overseas acquisition versus greenfield foreign investment Which Internationalization Strategy is better for Indian Pharmaceutical Enterprises?", ISID Working Paper, No. WP2006/07, New delhi

Pradhan, J. P. (2007), Growth of Indian multinationals in the world economy implications for development, ISID Working Paper, No. 2007/04, Institute for Studies in Industrial Development, New Delhi

Ray, A. S and Badhuri, S. (2001), "R&D and technological learning in Indian industry: econometric estimation of research production function", *Oxford Development Studies*, Vol 29, No.2, pp.155-171

Romer,P.(1990)"Endogenous Technological Change," *Journal of Political Economy*, Vol. 98, No. 5,pp. S71-102

Sauvant, K. P. (2005) 'New Sources of FDI: The BRICs', Journal of world investment & trade, No.6, pp. 639–70

Scherer, F. M. (1965), "The size distribution of innovative firms in U. K.:1945-83", *Journal of Industrial Economics*, pp. 297-316

Siddharthan, N. S. (1988), "In house R&D, imported technology and firm size: lessons from Indian experience", *The Developing Economies,* Vol. 26, pp. 212–221.

Wells, Louis T. Jr., (1983), Third World Multinationals: The Rise of Foreign Direct Investment from Developing Countries, MIT Press, Cambridge, Massachusetts.

Woolridge, J.,(2002) Econometric analysis of cross section and panel data, The MIT Press, Cambridge