The impact of FDI inflows on R&D investment by medium- and high-tech firms in India in the post-reform period *

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As a result of the 1991 liberalization, many transnational corporations have set up affiliates in India, which in turn have prompted domestic firms to seek new technology to compete with them. The reforms have also made technology imports cheaper and easier. Domestic firms, instead of undertaking their own R&D, can purchase technologies or license them from abroad. The present study analyses the effects of FDI inflows on the innovation strategies of firms in the medium- and high-tech industries. The paper differs from the existing literature in two ways. First, it takes into account those firms that reported zero R&D expenditures in their annual report but had in-house R&D units. Second, it uses actual FDI inflows instead of approvals. The probit and tobit models show that in the initial period after 1991, increased FDI inflows had a negative impact on domestic R&D, whereas in the later period, the impact was not significant.

Key words: foreign direct investment, R&D, liberalization, India.

1. Introduction

The role of technology in fostering economic growth is well acknowledged. Evidence suggests that only those countries that aggressively promote technological efforts of their domestic firms can sustain growth in the long run. An important factor influencing R&D activity in an economy is

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the inflows of foreign direct investment (FDI), which is an important conduit of cross-border technology diffusion.[1]

For developing and transition economies, FDI is particularly important as it induces faster economic restructuring and promotes better corporate governance in addition to facilitating the acquisition of new technology. The 1991 reform in India with respect to FDI was intended to achieve such transformations. Since the introduction of the reform, the inflows of FDI into the country have steadily increased, resulting in many transnational corporations (TNCs) setting up affiliates in India. In order to compete with these foreign affiliates, domestic firms have had to innovate or adopt new technologies.[2]

As the reforms have also made the import of technology cheaper and easier, domestic firms now have more options in formulating their technology strategies. Instead of expending resources on R&D, they can buy or license new technologies from abroad. The declining or near stagnant R&D to GNP ratio in the 1990s on the one hand, and rising technology import intensity and FDI inflows on the other, as illustrated in figure 1, suggest a trend of increasing reliance on technologies from abroad. A recent study by Basant (2000) found that R&D expenditure in real terms fell in 12 out of 28 industries in the 1990s. Even in those industries where R&D expenditures rose, the R&D to sales ratios either remained static or declined.

Given that a competitive domestic manufacturing sector is indispensable for the growth of the economy, such reliance on foreign technology may not be viable in the long run. Relying on imported technology is unlikely to foster the competitiveness of the domestic manufacturing sector. Moreover, with the world moving towards a stronger intellectual property rights regime, it is important that Indian firms are able to develop their own technologies. In-house R&D efforts are even more important in medium- and high-tech industries, such as automobiles, biotechnology, chemicals and electronics.

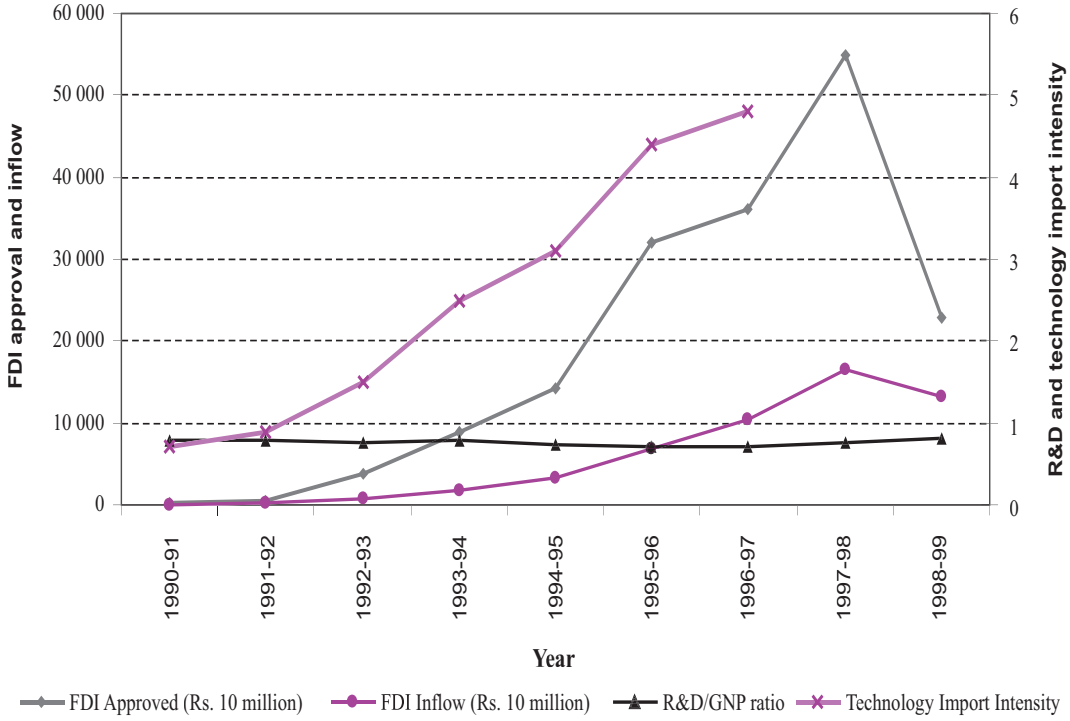
Against this backdrop, this study investigates the effect of FDI inflows on the R&D activities of domestic firms in the medium- and high-tech industries in the post-reform period. The study analyses the

[1] According to Damijan *et al.* (2003), technology transfers via FDI can take four different routes: demonstration-imitation effects, competition effects, foreign linkage effects and training effects.

[2] These options are under the assumption that the two groups of firms differ only with regard to technology. Any productivity difference across the two groups is also attributed to these technological differences.

relationship between FDI and the decision of the firms to invest in R&D in the post-1991 period.

Figure 1. FDI Approvals, inflow, R&D and Technology Import Intensity in the 1990s in India



Source: Banga (2005); Research and Development Statistics, DST (2003); SIA (2002); and Rao, Murthy and Ranganathan (1999).

Notes: $1 = 40 rupees (approx.). Technology import intensity (Import of technology to total sales) is for the manufacturing sector and not for the whole economy.

The paper contributes to the existing literature in two ways. First, a number of studies on the issue (e.g. Kumar and Saqib, 1996; Pradhan, 2003; Kumar and Aggarwal, 2005) used R&D expenditures as the indicator of firms' R&D efforts. However, reported R&D expenditures may not accurately represent the firms' R&D efforts since firms in India are not obliged to report R&D expenditures if the amount is below 1% of their total sales (Kumar and Aggarwal, 2005). The present study addresses this problem by considering not only R&D expenditures, but also whether a firm has a Department of Science and Technology (DST) recognized in-house R&D unit. The DST, by granting several fiscal incentives and other support measures, has encouraged firms to establish their own in-house R&D units. The extent of the problem is evident from the fact that among the 65 firms with a DST recognized in-house R&D unit in our sample of 190 firms, only 20 reported expenditures on R&D in 1996.

The second contribution of the paper is the use of actual FDI inflows. Some studies, due to the lack of data, used FDI approvals instead of actual FDI inflows. Evidence suggests that only one-fifth to one-fourth of approvals are actually implemented in India (Rao et al., 1999; SIA, 2002). This discrepancy is not a problem if all industries receive actual investment in the same proportion in relation to approved FDI, but this is not the case. The data show that during the period from August 1991 to December 2002, the metallurgy industry received only 6.5% of approved FDI, whereas the chemicals industry received nearly 37% of approved FDI (SIA, 2002). Thus, FDI approvals are not a reflection of the true extent and distribution of FDI inflows.

The analysis carried out with more appropriate data shows that the relationship between FDI and domestic R&D has undergone a change, with a negative impact clearly evident in the initial period after the reform, in contrast to previous studies.

The remaining paper is organized as follows. Section 2 gives a synoptic view of the debate on the relationship between FDI and R&D investment. Section 3 reviews the literature on the issue. This is followed by the description of the methodology in section 4. Section 5 discusses the variables in the model. Section 6 gives the results and section 7 concludes.

2. FDI and R&D investment – a debate

The effect of FDI/technology import on in-house R&D efforts has been the subject of an intense debate. One view given by Blumenthal (1976), Lall (1989) and Mowery and Oxley (1995), among others, suggests that technology import complements in-house R&D efforts. An opposite view, enunciated by authors such as Pillai (1979) and Mytelka (1987) argues that technology import reduces the likelihood of firms in developing countries to undertake their own technological efforts.

A number of arguments have been put forward in the literature suggesting that inflows of FDI increase R&D undertaken in the host economy. Since factor intensities and raw materials available in a developing host country are not the same as those in the developed countries where much of FDI originates,[3] the technologies of investing TNCs may not suit local conditions (Katrak, 1985; Cassiman and Veugelers, 2003; Tomiura, 2003). Hence, some adaptive R&D needs be

[3] The data indicate that nearly two-third of FDI originates from the six developed countries (Kathuria, 2000).

undertaken to modify such technologies to suit local conditions (Nelson, 2004). As for domestic firms, the entry of foreign firms is likely to intensify competition of the domestic market (Caves, 1974). To remain competitive, local firms need to invest in R&D to improve the quality of their products and reduce costs. Moreover, some local firms may undertake R&D activities so as to enhance their absorptive capacity in order to benefit fully from the spillover effects of FDI (Kathuria, 2001, 2002).

However, arguments have also been put forward to suggest that inflows of FDI reduce R&D efforts in the host economy. Foreign affiliates would have access to the technology of their parent firms, and perhaps the only way domestic firms in a developing country can compete is by acquiring similar technologies. This can be achieved either by investing in their own R&D or buying technologies from foreign firms. Given financial and capacity constraints, R&D is likely to become the less favoured option as it involves uncertainty, risk and a gestation lag (Lall, 1992; Katrak, 1985, 1990). Thus, firms may opt for the purchase of technologies from abroad. Moreover, in the context of India, economic reforms also made the import of technology easier and cheaper. Not only have the laws governing such import and commercial licensing been relaxed and the duty structure rationalized, but also efforts have been made to simplify the procedures involved in acquiring technologies from abroad.

The post-liberalization period has witnessed the establishment of a number of foreign affiliates in R&D intensive industries, such as the electrical, electronics and pharmaceuticals industries. Having access to the centralized research labs of their parent firms, these affiliates may not have the need to carry out much R&D, apart from adapting products to the local market, which is likely to involve relatively small expenditures.

3. Brief review of the literature

A number of studies for India and other countries have examined the relationship between R&D and the two primary means of acquiring foreign technology, namely FDI and technology import.[4] Studies on this issue can be grouped into three categories: those that have found a complementary relationship; those that have found substitutable relationship; and those in which researchers could not establish any relationship.

[4] Cohen (1995) has an exhaustive review of these studies.

A large number of studies carried out on India, Brazil and China have found a complementary relationship between technology import and R&D. For India, these include industry-level analyses by Katrak (1985) and Deolalikar and Evenson (1993), and firm-level analyses by Katrak (1989), Siddharthan (1988, 1992), Kumar and Saqib (1996), Aggarwal (2000) and Kumar and Aggarwal (2005). In addition, there are sector-specific studies that have also found a complementary relationship, including Katrak (1990) for the electrical and industrial machinery industries and Pradhan (2003) for the pharmaceutical industry, among others. In the context of other economies, Braga and Wilmore (1992) for Brazil, Bertschek (1995) for Germany, and Zhao (1995) and Hu et al. (2005) for China also found a weak but positive relationship between technology import and R&D.

On the other hand, studies by Kumar (1987), Fikkert (1993), Basant and Fikkert (1996) for India, Veuglers and van den Houte (1990) for Belgium, Lee (1996) for the Republic of Korea, Chuang and Lin (1999) for Taiwan Province of China and Fan and Hu (2006) for China, among others, found a substitution effect of technology import on domestic R&D.

However, some studies, including Kumar and Saqib (1996), Katrak (1997), have found neither a substitutable nor complementary relationship between technology import and R&D.

A major limitation of the earlier studies, such as Katrak (1985) and Deolalikar and Evenson (1989), is the use of industry level data. Since R&D decision is taken at the firm level and is affected by various firm specific attributes, firm-level data are more appropriate. Although Kumar and Saqib (1996) used firm-level data and partly overcame the limitations of previous studies, the data covered only the pre-liberalization period and also suffered from the problem of R&D data discussed earlier. The study by Basant and Fikkert (1996) and Kumar and Aggarwal (2005) used firm level data in a panel framework. However, these studies did not address the problem concerning R&D data either.[5]

To date, apart from two, all the studies for India have used data from the pre-liberalization period.[6] As the policy focus in the pre-reform period was on import substitution and the FDI policy was also selective

[5] Also, the decisions to purchase technology or conduct R&D are undertaken simultaneously. Thus, estimates of these studies are subject to the problem of simultaneity making conclusions invalid (Basant, 1993).

[6] Even the studies, which have used post-liberalization data, have defined liberalization very loosely – by dummy or considering only later years as liberalized.

in nature, post-liberalization data may give different results, especially since the focus has now shifted from adaptive to assimilating R&D. Also, the FDI policy has changed from being selective to generally promoting inflows of FDI. Hence, an analysis using post-liberalization data and accounting for those firms spending an amount below the threshold level but having a DST-recognized in-house R&D unit may perhaps shed more light on the relationship.

4. Model Formulation

4.1 Hypothesis

The liberalization process has affected domestic firms' investment decision in two ways: by making technology import cheaper and easier and by forcing Indian firms to continuously upgrade their technology to compete with foreign firms and with each other. Since firms have now easier access to technologies from abroad than in the past and given the uncertainty involved in R&D, firms are more likely to opt for the former route. The present study examines the following hypothesis: increased FDI has led to a reduction in R&D investment in the Indian manufacturing sector.

4.2 Model

The decision for the firms can be considered as binary: either to invest in R&D or not to invest in R&D. In this case, a model which allows the use of a discrete dependent variable is required. The probit model is a non-linear statistical model that achieves the objective of relating the choice probability to explanatory factors.

Two series of data on R&D can be used as the dependent variable in a probit model. In the first Probit regression, the dependent variable takes value 1 if the firm had a DST recognized in-house R&D unit or reports any R&D expenditure and 0 otherwise. In the second probit regresssion, the dependent variable takes the value 1 if the firm reported any R&D expenditures and 0 otherwise. The explanatory variables are continuous variables that may affect the decision of the firm. Thus, the general model is represented as follows:

$$RD=\alpha + \beta_i x_{ik} + u,$$

where α and β_i are unknown parameters and u is the residual. RD is an unobserved latent variable as discussed above.

The probit model explains only the probability of a firm reporting R&D. Therefore, the hypothesis is also tested using R&D intensitiy as the dependent variable. Since many firms had zero R&D expenditure, the intensity of R&D among R&D reporting firms has to be analysed using a censored regression model. For this purpose, a tobit model can be used.[7] R&D intensity, defined as the ratio of R&D expenditures to total sales, is taken as the dependent variable. The tobit model can be written as:

$$RDI = \alpha + \beta_i x_{ik} + u,$$

where RDI is the R&D intensity. In the case of the ptobit and tobit models, the coefficients do not give the marginal effects. The marginal effects are obtained by multiplying the coefficients the probability density function for probit model and with the probability that the observation is uncensored for tobit model (Greene, 2003).

The analysis is carried out for two different time periods, one immediately after the 1991 reforms (when the reforms had just begun and hence would not have had much impact) and one in the late 1990s (when the effects of liberalization had presumably become pervasive). A cohort of firms that were in operation in both of these time periods are used for the analysis so that the precise effect of liberalization on these firms can be investigated.

5. Variables and data

5.1 Explanatory variables

The firm's decision on R&D efforts are influenced by resource availability, alternative sources of acquiring technology, growth strategy of the firm and the prevailing market conditions, among others. The present section discusses these factors and their influence on the R&D investment decision of the firms.

Size

Since R&D activities are costly, risky and unpredictable (Lall, 1992; Katrak, 1990), firms with larger financial and other resources

[7] The important reason for estimating a Tobit model is the fact that for a large number of firms the dependent variable R&D intensity takes on the value of zero and hence simple OLS estimation will yield biased estimate.

would have an advantage. Firm size is thus presumed to be positively related to firms' R&D activity. A counter-argument is that larger firms may be less affected by market competition and, accordingly, will have less incentive or need for technological improvements (Katrak, 1990). Empirical studies have found mixed results on the nature of this relationship. Studies by Braga and Willmore (1991) and Tomiura (2003) found firm size had a positive impact on R&D activity of the firm, whereas Katrak (1985) found a less than proportionate increase in R&D expenditures in relation to firm size.

A group of studies have found a non-linear relationship between firm size and R&D effort. Siddharthan (1988) found a U-shape relationship. Kumar and Saqib (1996) found an inverted U-shape relationship between firm size and the probability of undertaking R&D activity, although the relationship is linear when R&D intensity of the firm is accounted for. Kumar and Aggarwal (2005) and Pradhan (2003) found a horizontal S-shaped and an inverted U-shaped relationship respectively. Given that the reforms introduced in the 1990s increased the overall competition, the present study expects firm size, measured as the natural logarithm of the gross assets of the firm, to have a positive effect on the probability of undertaking R&D.[8]

Export orientation

Competing in the international market is likely to require technologically advanced quality products, which forces export-oriented firms to invest in R&D. The theory of industrial organization also suggests that outward orientation of a firm is possible only when it possesses some advantages, and R&D is an important channel of accumulating such advantages. Thus, firms serving international markets – through export or having production bases abroad – are likely to undertake R&D activity. Export also allows firms to exploit economies of scale, thus increasing the return on R&D investment (Zimmerman, 1987; Katrak, 1990).

A number of empirical studies confirm this link between forays into the international market and the firm's propensity and ability to undertake R&D (Braga and Willmore, 1991; Kumar and Saqib, 1996; Pradhan, 2003; Kumar and Aggarwal, 2005). In the present case, this variable is measured as the ratio of exports to total sales in percentage terms, and it is expected to have a positive effect on R&D investment

[8] Using log also takes care of non-linearity in the relationship.

Extent of vertical integration

A more vertically integrated firm, which undertakes a greater part of value-adding activities in the value chain, is thought to have more opportunities to introduce innovation. Hence, the variable is expected to have a positive effect. Kumar and Saqib (1996) found a positive relationship between the extent of value addition and the R&D investment decision of a firm. The present study measures variable by the ratio of total value added by the firm to the sales turnover in percentage terms.

Import of technology

With respect to the import of technology, two opposing factors interact. It is well recognized that imported technologies typically need to be remodelled and reconfigured to suit the local conditions. Hence some adaptive R&D is usually undertaken for the purpose (Lall, 1983; Nelson, 2004). The need for adaptive R&D increases if the technology is from a country which is higher on the technological ladder. Given that OECD countries account for a substantial portion of India's technology import, it is likely that firms need to undertake adaptive R&D. On the other hand, as discussed in section 2, increases in expenditures on imported technology may result in reduced outlays for R&D. Furthermore, more technology import may create a "dependence culture", thereby dampening the in-house efforts (Katrak, 1990). Empirical evidence suggests a positive impact of technology import on R&D (Lall, 1983; Katrak, 1985; Sidharthan, 1988; Deolalikar and Evenson, 1989; Kumar and Aggarwal, 2005). The royalty payments as a proportion of sales is used to construct the variable.

Foreign ownership

Evidence suggests that firms with foreign equity participation are less likely to invest in R&D as they have access to the research labs of their parent firms. Hence foreign affiliates are expected to have less investment in R&D than firms without foreign equity participation (see Kumar and Saqib, 1996; Kumar and Aggarwal, 2005 for evidence). Many studies on the internationalization of innovative activities also suggest that TNCs tend to conduct little R&D outside their home country, especially in countries with a significant technology-gap (see for example, Patel and Pavitt, 1995; Patel and Vega, 1999; Tomiura, 2003 among others). However, it is also noted that foreign collaboration brings more technology from abroad that needs to be adapted to suit local conditions. Hence, these firms have to engage in adaptive R&D. This would imply a positive relationship between foreign equity share

and R&D investment. A study by Amsden (2001) on East Asian and Latin American countries found that the greater the foreign ownership is, the smaller the depth and breadth of R&D activities are (except in the case of Singapore).

Concentration in the industry

Given the nature of R&D investment, a degree of monopoly power is needed to recoup the cost. However, in a concentrated market, the incentive to invest in R&D declines while a competitive industry exerts pressure on the firm to invest more in R&D (Katrak, 1990). In this study, it is assumed that market power has a negative influence on the probability of a firm undertaking R&D. The variable in the present analysis is measured by the Herfindahl index (H-index).

FDI

The variable FDI measures the actual inflows of FDI into the industry to which the firm belongs. It is noted that there is always a lag between actual inflows and the start of the production. Therefore, the present study uses cumulative FDI upto the previous year of the periods under analysis.

Table 1 summarizes the explanatory variables with their probable impact on the probability of investing in R&D. The expected signs are the same for the regression using R&D intensity as the dependent variable. Thus the econometric model to be estimated is:

$$\textbf{RD (or RDI)} = \beta_1 + \beta_2\textbf{*FDI}_{t-1} + \beta_3\textbf{*ln(Size)} + \beta_4\textbf{*Export Intensity} + \beta_5\textbf{*H-index} + \beta_6\textbf{*Foreign Share} + \beta_7\textbf{*Vertical Integration} + \beta_8\textbf{*Royalty} + \textbf{u},$$

where RD = 1 if the firm has a DST recognized in-house R&D unit or reports R&D expenditures, and RD=0 otherwise in the probit estimation. In the tobit estimation, RDI = R&D intensity.

Table 1. Summary of explanatory variables

Variable (1)	Description (2)	Expected Sign (3)
FDI	FDI Inflows into the industry	−
Industry Concentration	H-index	−
Import of technology	Royalty payments as a proportion of sales	?
Size	Logarithm of gross assets of firm	+
Foreign Share	Extent of foreign equity participation in the firm	?
Export orientation	Exports as a proportion of sales	+
Vertical Integration	Total value added by firm as a proportion of sales	+

Source: Author.

5.2 Data

The firm-level data used in the analysis are collected from the Capitaline database of Capital Market. The Capitaline database is compiled from the audited annual reports of nearly 10,000 firms listed on the Bombay Stock Exchange. Since the analysis is concerned with the liberalization period, all those firms which were incorporated after 1991 are omitted. Services sector firms such as banking and trading firms are taken out from the data set as the analysis is concerned with only the manufacturing sector. Firms belonging to industries which were heavily regulated to protect small-scale producers (e.g. the leather industry and the tobacco industry) are also excluded from the analysis.

Data are collected for two time periods: the period 1994–1996, which is the period immediately after the 1991 liberalization[9]; and the period 1999–2001, which is the period when the effects of liberalization are expected to have been absorbed.[10] However, data are not available uniformly for all the firms for all the years, thereby restricting the analysis to only two years, 1996 and 2001, which are used to carry out a comparative cross sectional analysis. Those industries having less than five firms are also excluded.[11] Firms belonging to the public sector are also excluded as the motive of undertaking R&D and the general behaviour of such firms are presumably different from private manufacturing firms.

On examination of R&D figures, it is found that in many industries such as fertilizer, cement and steel, only a few firms have invested in R&D and even those had a negligible R&D intensity i.e., below 0.1%. Incidentally, these industries are also classified as non-R&D intensive by

[9] Ideally we should have taken the financial year 1992/1993 as the first year of our study, but the data are not available prior to 1994/1995.

[10] A two year period is selected because some of the variables like sales, exports (even R&D investment) show wide variations year to year. For the peirod 1994–1996, the averages of the two consecutive finacial years 1994/1995 and 1995/1996 are taken, and similarly for the peirod 1999–2001, the averages of 1999/2000 and 2000/2001 are taken.

[11] The cut-off was to facilitate computation of a variable accounting for the competitiveness effect. There were a few industries in the data set which had fewer than five firms and for which data for both 1996 and 2001 were available. Since the data set is for those firms listed in the Bombay Stock Exchange, the small number of firms is not necessarily because these industries are highly oligopolistic; rather, a large number of firms are either not listed in the stock exchange or are not included in the Capitaline database.

the DST (2003).[12] Thus, FDI is not expected to have a major impact on the R&D decision in these industries. Firms belonging to these industries are thus removed from the analysis. The final dataset which is used for the analysis has 190 firms belonging to seven medium- and high-tech industries,[13] the distribution of which are given in table 2. Of these 190 firms, nearly one-third are foreign affiliates (i.e. firms in which a foreign firm controls more than 10% of its equity). Columns 3 and 4 of the table give the distribution of foreign-owned firms for the two periods.

As can be seen from the table, there has been an increase in the number of firms having foreign ownership over the years., which is not surprising given increased foreign investment in the country.

Table 2. Distribution of firms across industries

	Industry (1)	No. of Firms (2)	Foreign affiliates, 1996 (3)	Foreign affiliates, 2001 (4)
1	Auto Ancillaries	34	13 (38.2%)	21 (61.8%)
2	Chemicals	47	11 (23.4%)	10 (21.3%)
3	Electric equipment	15	8 (53.3%)	6 (40.0%)
4	Electronic components	19	5 (26.3%)	8 (42.1%)
5	Engineering	40	14 (35.0%)	17 (42.5%)
6	Petrochemical	9	2 (22.2%)	1 (11.1%)
7	Pharmaceuticals	26	7 (26.9%)	6 (23.1%)
	Total	**190**	**60 (31.6%)**	**69 (36.3%)**

Source: Author's compilation

Note: Figures in parentheses are their percentage in the total in each industry.

5.3 Sample characteristics

Table 3 gives R&D intensity by these two categories of firms in the two time periods. From the table, an interesting pattern emerges with respect to R&D investment. Though a larger number of firms – both foreign affiliates and domestic firms – invested in R&D in the later period, the R&D intensities of these two categories of firms evolved

[12] The DST uses two indices – R&D expenditure as percentage of sales turnover; and the number of personnel employed in R&D per thousand employees to classify the industries into three categories – high-, medium- and low-tech industries. For 1996–1997, the value of two indices for the three categories are 1.68 and 54, 0.67 and 25; and 0.31 and 8 respectively (DST, 1999).

[13] The classification of the industries follows the one as used by capitaline. However, this classification does not match the ones used by CMIE (Centre for Monitoring Indian Economy) and SIA (Secretariat for Industrial Assistance) from where H-index and FDI data have been collected respectively. Hence, suitable assumptions have been made to match the three industry classifications.

differently over time. The R&D intensity of foreign firms increased whereas that of domestic firms fell. This is contrary to the widely held perception that foreign firms do not undertake much R&D as they have access to their parent firms' R&D labs. The data show that, of the total 190 firms, 65 had DST recognized in-house R&D units. But not all of them reported R&D expenditures in 1996; in fact, of these 65 firms, only 20 did. In 2001, there is a dramatic increase in reported R&D activity; of the 65 firms, 61 reported expenditures on R&D. Perhaps, increased competition may have induced them to spend more on R&D.

Table 3. R&D intensity of foreign affiliates and domestic firms

Year	Foreign affiliates undertaking R&D (No.) (1)	Domestic firms undertaking R&D (No.) (2)	R&D intensity of foreign affiliates (3)	R&D intensity of domestic firms (4)
1996	11 (18.3%)	23 (17.7%)	0.115	0.714
2001	28 (40.6%)	39 (32.23%)	0.543	0.38

Source: Author.

Note: Figures in parentheses give percentage of R&D intensive firms to total firms in the category, where R&D intensive firms are those which have incurred expenditure on R&D in 1996 or 2001.

Table 4 gives the average size and export behaviour of firms that undertook R&D and those that did not. The comparison indicates that the average size of firms undertaking R&D is nearly twice as big as those that did not undertake any R&D (columns 3 and 4). Moreover, the size of the former has increased proportionately more over the period. The table also indicates that the export intensity of both groups increased with R&D intensive firms showing a larger increase.

Table 4. Size differences and export intensity of two categories of firms

Year	Firms with R&D expenditures (No.) (1)	Firms without R&D expenditures (No.) (2)	Gross assets of firms with R&D expenditures (10 million rupees) (3)	Gross assets of firms without R&D expenditures (10 million rupees) (4)	Export intensity of firms with R&D expenditures (%) (5)	Export intensity of firms without R&D expenditures (%) (6)
1996	34	156	94.44 (146.72)	50.46 (88.55)	6.63 (7.48)	10.55 (17.95)
2001	67	123	157.01 (205.48)	79.3 (146.48)	11.64 (15.34)	11.84 (19.65)

Source: Author.

Note: Non-R&D intensive firms are those which have not incurred any expenditure on R&D in 1996 or 2001. Figures in parentheses give the standard deviation for the indicator.

Table 5 gives the descriptive statistics of the various firm specific variables used in the analysis. From the table, it can be seen that in the five year period, R&D intensity, raw material imports, royalty paid, extent

of vertical integration, export intensity and size of the firms increased. It is interesting to note that the average industrial concentration in the sample industries has declined over the period (row 7). With respect to R&D (row 1), not only the average intensity increased but also the spread diminished.

Table 5. Descriptive statistics of the explanatory variables
(No. of obs. = 190)

SNo.	Variable	1996	2001
1	R&D intensity	0.525 (3.77)	0.676 (1.437)
2	Export intensity	9.85 (16.62)	11.79 (18.20)
3	Foreign share	11.08 (17.98)	15.17 (21.53)
4	Raw material import (Millions of rupees) rrup)	73.7 (391.5)	657.3 (1289.9)
5	Royalty (Millions of rupees)	2.34 (11.5)	3.86 (15.56)
6	Value added (i%)	28.79 (13.1)	37.69 (16.36)
7	H-index	0.222 (0.155)	0.108 (0.058)
8	Size (Millions of rupees)	583.3 (1023.5)	1067.0 (1731.5)

Source: Author.

Note: Figures in parentheses are the standard deviations.

6. Results and findings

Before proceeding to report the results, it needs to be mentioned that the present study could not run a tobit regression for the initial period, as many firms did not report spending on R&D despite having in-house R&D units. The data show that there were 40 such firms in 1996, which had a DST recognized in-house R&D unit, yet did not report any R&D expenditure. In contrast, in 2001 this number fell to only four.

Table 6 gives the results of the probit regression for the year 1996. The FDI data used for the analysis of this period are cumulative FDI inflows from July 1991 to March 1995. The marginal effects are given in column 3. The results indicate that the size of the firm (row 2) has a positive and significant impact on the probability of investment in R&D. This implies larger firms have a greater probability of conducting R&D. The negative impact of market concentration (row 3) on the probability implies that the absence of competitive pressure in the market acts as a disincentive for investing in R&D. Though the vertical integration (row 7) has come up with the right sign, it is not statistically significant. Royalty paid (row 6) has a positive sign, but it is not statistically significant. Interestingly, foreign ownership does not appear to have an impact on

the R&D decision of the firm (row 4). The export intensity variable (row 5) also has a negative sign but is not statistically significant.

The variable in focus, FDI, has a negative sign as expected and it is statistically significant (row 1). This implies that the increased inflow of FDI after 1991 liberalization negatively affected the propensity to invest in R&D in the earlier years after 1991.

Since one contribution of this paper is to investigate the potential problem associated with the use of R&D expenditure data, the above analysis is repeated by using the dependent variable which takes the value of one if the firm reported R&D expenditures and zero otherwise. Column 4 reports the results. The sign and significance of most of the controlling variables remain same. However, with respect to FDI inflows (row 1), the results change completely. The variable becomes not only insignificant but also positive. Thus, the use of different measures of R&D has an important implication for econometric analysis.

Table 6. Probit estimation for 1996

	Variable (1)	Dependent variable = presence of a DST recognized R&D unit or reported R&D expenditure (2)	Marginal effect (3)	Dependent variable = reported R&D expenditures (4)
1	**FDI Inflow$_{1995}$**	- 0.42* (0.156)	-0.165* (0.061)	0.026 (0.177)
2	**Size**	0.86* (0.19)	0.33* (0.074)	0.61* (0.224)
3	**H-index**	-1.28* (0.66)	-0.50* (1.94)	-0.152 (0.75)
4	**Foreign share**	-0.0003 (0.006)	-0.0001 (0.002)	-0.003 (0.007)
5	**Export intensity**	-0.002 (0.006)	-0.0007 (0.0024)	-0.017 (0.011)
6	**Royalty payments**	0.097 (0.13)	0.038 (0.05)	0.062 (0.093)
7	**Value added**	0.002 (0.008)	0.001 (0.003)	0.015* (0.009)
8	**Constant**	2.65* (1.40)		-2.33 (1.65)
	N	190		190
	Prob > χ^2	0.00		0.033
	Pseudo R^2	0.15		0.086
	LR(χ^2)	38.12		15.28

Source: Author.

Notes: * Indicates significance at the 10% level. Figures in parenthesis give standard errors.

Columns 2 to 4 of table 7 present the results of the probit estimation for the year 2001. The FDI data used for these regressions are cumulative FDI inflows during the period 1996–2000. Column 4 of the table reports results of the probit estimation using reported R&D expenditures as the dependent variable. Since, of the 65 firms with a DST recognized R&D

unit, 61 firms reported R&D investment in 2001, the bias should be minimal. The results confirms this; the coefficient of the variable, FDI Inflow (row 1), has the same sign in both of the probit estimations. The variable is still negative, but it has lost its significance.

Table 7. Probit and tobit estimations for 2001

	Variable (1)	Dependent variable = presence of a DST recognized R&D unit (2)	Marginal effect (3)	Dependent variable = presence of reported R&D expenditures (4)	Tobit estimation (5)
1	**FDI Inflow$_{2000}$**	- 0.158 (0.167)	- 0.063 (0.067)	-0.038 (0.167)	-0.44 (0.34)
2	**Size**	0.81* (0.18)	0.32* (0.07)	0.71* (0.178)	0.87* (0.35)
3	**H-index**	-2.43 (2.16)	-0.97 (0.86)	-0.14 (2.12)	-4.62 (4.48)
4	**Foreign share**	0.0015 (0.005)	0.0006 (0.002)	-0.0001 (0.005)	-0.0007 (0.0105)
5	**Export intensity**	0.007 (0.006)	0.0028 (0.002)	-0.003 (0.0057)	0.0138 (0.011)
6	**Royalty payments**	0.123 (0.23)	0.05 (0.092)	0.014 (0.22)	0.37 (0.437)
7	**Value added**	0.007 (0.006)	0.003 (0.0025)	0.007 (0.006)	0.019 (0.012)
8	**Constant**	0.21 (1.74)		-1.33 (1.74)	2.32 (3.48)
	N	190		190	190
	Prob > χ^2	0.00		0.000	0.0015
	Pseudo R^2	0.15		0.133	0.0437
	LR(χ^2)	38.82		34.74	23.28

Source: Author.

Notes: * Indicates significance at the 10% level. Figures in parenthesis give standard errors.

With respect to other variables, only size (row 2) significantly impacts the probability of undertaking R&D (column 3). A larger firm is more likely to invest in R&D. The negative impact of market concentration on the probability implies that the absence of competitive pressure in the market acts as a disincentive for investing in R&D. Export intensity and vertical integration have come up with the expected sign but are not statistically significant.

In order to examine which factors affected the R&D intensity of the firms, a tobit model is estimated (column 5). The significance and the sign of the coefficients are the same as the results of the probit estimations.

Based on these results, it can be concluded that immediately after 1991 liberalization, increased FDI inflows negatively affected the R&D propensity of firms, but subsequently the negative impact of FDI inflows diminished.

7. Interpretation and conclusions

This study analysed the impact of increased FDI flows on the R&D investment of manufacturing firms in medium- and high tech-industries in India. FDI and the intrinsic competition with foreign firms can conceivably induce more R&D by Indian companies in their effort to maintain parity, or it could undermine R&D if these firms succumb to the competition. Alternatively, easier access to imported technology than in the past could result in Indian firms resorting to importing technologies rather than investing in R&D, especially given the costs and uncertainties involved. The present study hypothesized that increased FDI in India has resulted in a reduction in R&D by manufacturing firms. This was tested for two time periods, 1994–1996 (just after foreign entry regulations were relaxed) and 1999–2001 (after a second period of reforms in 1997). The analysis covered seven industries, including pharmaceuticals, automotive components and electrical equipment.

The analysis shows that in the first period, 1994--1996, the inflow of FDI had a negative impact on R&D investment by Indian manufacturing firms, but no significant effect in 1999--2001. One possible explanation for the divergent results in the two time periods could be the expectation of firms with respect to the reforms. At the beginning, the reforms could have caught the firms off-guard, thereby affecting their R&D investment. The second round of reforms, which started around 1997, increased the pace and scope of inward investment. The reforms comprising of opening-up of many sectors reserved for the government and increasing the upper limit for foreign equity could have given clearer signals to domestic firms that the liberalization measures and the accompanying enhanced competition were now irreversible. This irreversibility and nature of reforms could have forced firms to adjust their behaviour accordingly.

With regard to firm characteristics, size was an important determinant of R&D activities of domestic firms in both time periods and the probability of a firm undertaking R&D increased with its size. Industry concentration as measured by the H-index was significant only in the first time period and had a negative impact on the probability of undertaking R&D. This implies that firms belonging to a less competitive industry had less incentive to invest in R&D.

The results and conclusions in this paper are statistically robust, but need to be qualified. In particular, the study only covers firms listed on the stock exchange and those in R&D intensive industries. There is

thus scope to extend the analysis to take non-stock market and non-R&D intensive firms into account, as well as to examine other issues which arose, such as differences in R&D intensity and behaviour between foreign and domestic firms.

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