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Foreign Direct Investment and R&D: Substitutes or Complements - A Case of Indian Manufacturing After 1991 Reforms

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Abstract

One of the objectives of the economic reforms undertaken in India since 1991 was to open the doors for foreign firms to invest in the country. As a result, the last 15 years has witnessed large scale FDI inflows to various industries in the Indian economy. Apart from the direct effect of bringing capital and technology, FDI is also an important channel which influences the R&D activities in an economy. The presence of foreign firms as well as the entry of foreign firms leads to an increase in the competition in the domestic market. Therefore, in order to compete with the MNCs the domestic firms have to undertake R&D activities or obtain technology from other sources. Under this backdrop, this study is an attempt to examine the relationship between FDI and R&D of the domestic firms in the post-liberalization regime. To realise the objective, we have used an unbalanced panel data of 1843 Indian manufacturing firms operating during the period 1994-2005. In order to see the influence of FDI on R&D behaviour, we controlled for the firm specific variables like size, exports, technology imports, vertical integration and age in determining the R&D activities. An important contribution of the present paper is to correct for the self-selection problem by using a Heckman-two step procedure.

In the first stage, the analysis involving full sample firms produced no clear picture about the impact of FDI on the innovation strategies of domestic firms. In the second stage, when analysis was carried out according to different sub-samples, we find some interesting results. FDI inflow induces foreign-owned firms irrespective of the extent of ownership to invest in R&D. In all other specification, FDI inflow does not have any impact on the selection equation. For outcome equation, there is no impact of the inflow. Among other firm specific variables size (large firms) and age (older firms) consistently influence the probability to invest in R&D. All other variables like technology import or outward orientation or market concentration, only selectively affect the probability and R&D intensity. An important finding of the present study is that the technological efforts in the form of R&D have declined marginally for both categories of firms during the study period. This is a cause of concern for the policy makers. We also find that firms are increasingly depending on technology imports. The removal of restriction on the imports during the reform period might have played a catalytic role for this phenomenon.

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1. Introduction

Technological advancement is considered as one of the vital factors in achieving a high level of economic growth. The endogenous growth models consider generation of new knowledge through investment in research and development (R&D) as the major source of technical progress and hence growth (Romer 1990). In the case of Newly Industrialised Countries (NICs), technology was found to be an important catalyst in fostering their spectacular growth (Nelson and Pack 1999). Developing countries like India have been striving hard to promote technological advancement through indigenous R&D efforts as well as through technology imports (Basant 1997).[1] Of late, many countries have acknowledged foreign direct investment (FDI) as a main channel of technology transfer. It is based on the realization that FDI brings superior technology that is previously unavailable in the host country. The presence of foreign firms can also create positive externalities in the form of spillover effects to the domestic firms (Kathuria 2000).[2]

The role FDI in the host country cannot be looked at solely from the angle of technology beyond transferring technology, provider. Foreign firms can significantly contribute directly or indirectly innovative activities in the host country. For instance, foreign firms may undertake R&D activity in order to adapt to the host economy conditions or to meet the competition from the domestic firms. Similarly, in the case of domestic firms, the presence of foreign firms may force them to invest in innovative activities so as enhance their technological capability. Investment in R&D also enables the domestic firms to assimilate the technological spillover effects from the foreign firms (Kathuria 2001, 2002). However, there is some amount of skepticism about the technological efforts of foreign firms in the host country (Hu *et al*. 2005). Since the foreign firms have access to the parent firms technology, there is little incentive for them to undertake new technological efforts. Studies have found that foreign firms undertake little or no research activities in the host country (see for example, Beers 2004). Moreover R&D being an uncertain activity with gestational lag, in order to compete with foreign firms, the local firms may procure technology from outside rather than investing in R&D. Therefore, the pertinent question is whether the entry of the foreign firm enhances or diminishes the innovativeness of the domestic firms?

The empirical studies have found complementary as well as substitution effect between the technology imports, FDI and R&D (see for example, Pack and Saggi 1998 and the literature cited below). A large number of studies carried for India, Japan, Brazil, Germany and China etc. have found a complementary relationship i.e., positive sign for the coefficient between technology imports and R&D. See for instance, Katrak (1985), Siddharthan (1992), Deolalikar and Evenson (1993),

[1] A clear manifestation of this is increased R&D intensity (as defined as ration of R&D to GNP) in India. At the all India level, R&D to GNP increased from 0.78 in 1991-92 to 0.86 in 2000-01 (DST 2006).

[2] According to Moran (1998: 126) “greater the activities of wholly-owned subsidiaries in a given economy the more likely the prospects of spillover effects and externalities to domestic firms”.

Kumar and Aggarwal (2005) for India, Odagiri (1983) for Japan, Braga and Wilmore (1992) for Brazil, Bertschek (1995) for Germany, Zhao (1995) and Hu *et al*. (2005) for China among others. The substitution effect of technology imports on the domestic R&D was obtained by Kumar (1987), Basant and Fikkert (1996), Kathuria and Das (2005) for India, Veuglers and van den Houte (1990) for Belgium, Lee (1996) for Korea, Chuang and Lin (1999) for Taiwan, and Fan and Hu (2006) for China among others. However, some studies like, Kumar and Saqib (1996) and Katrak (1997) find neither substitution nor complementary effects in technology imports-R&D relationship.

An important contribution of the present paper is the correction of self selection bias arising from R&D activities. We have a reason to believe that results of most of the earlier studies using firm level data are biased – known as self-selection bias. Previous studies suffer from this problem of self-selection, as they have carried out analysis for only R&D performing firms. The R&D activities of the firms depend on the prevailing market structure. Therefore, firms can decide to do R&D depending on the market structure or in other words, self-select in doing R&D. Analysing only those firms that invest in R&D would imply we are selecting a category of firms. In India or Japan or elsewhere, the way R&D data is reported can also result in self-selection bias. According to the Indian Company Act, firms need to report R&D expenses in their balance sheet provided the expenses are at least one per cent of their sales turnover. For adaptive R&D or shop floor modifications many a times, R&D expenditure of firms is often less than one per cent, hence these firms do not report it.[3] This implies that the results of the previous studies (Kumar and Aggarwal 2005; Kathuria and Das 2005) based on only those firms which report R&D are biased - self-selection bias. Therefore, use of OLS will yield estimates that would be biased and inconsistent. Therefore, in the present study, we correct for the problem of self-selection bias by applying Heckman's two-step procedure.[4]

Until 1991, India followed a restrictive policy on foreign capital (Rao *et al*., 1999). The reforms undertaken during the early nineties have led to large inflows of FDI into the Indian economy.[5] FDI is now allowed in almost all the sectors except for those reserved for small scale industries or for strategic reasons. As a result, the competition in the domestic market has considerably increased. In order to thwart the competition from the foreign firms the domestic firms need to either invest in indigenous R&D or obtain new technology through imports. Since liberalization has also made import of technology cheaper and easier, firms can prefer technology imports instead of spending on R&D.

[3] There are few firms in our sample also which have R&D units recognized by the Department of Science and Technology (DST) but incidentally do not report any R&D expenses. Since we do not have any information about the R&D activities, we assume that they undertake little or negligible investment in R&D and we treat them as non-R&D units.

[4] The bias caused by not reporting R&D data is partly taken care in the study by looking into other sources of information, apart from using data from the list of firms having recognized R&D units.

[5] The magnitude of FDI inflows to India has increased from US$ 155 million in 1991 to US$ 2514 million in 2006.

The investment in R&D is however essential to compete with the global players as well as to adapt the imported technology. Under this backdrop, the purpose of the present study is to explore the nature of the relationship between FDI and R&D in the post-liberalization era.

The remaining paper is as follows. Section 2 provides a brief literature review. Section 3 discusses the FDI inflows into India. The section also compares the inflow with BRICS (Brazil, Russia, China and South Africa) countries. Section 4 gives the hypothesis and the model used to see the impact of FDI on R&D behaviour. In Section 5, data sources and summary statistics of the key variables are discussed. Section 6 discusses the empirical results. Paper concludes in Section 7.

2. Literature Review

Numerous studies examining the relationship between FDI and technology imports on R&D exists. These studies are based on the theoretical arguments regarding the potential effects of FDI on the host country. The most prominent among them are the works of authors like Buckley and Casson (1976) and Dunning (1993). Buckly and Casson (1976) applied the transaction cost framework to understand the international production activities. They identified market imperfections as the main reason for the internalization activities by MNCs. The most noteworthy aspect of the authors' analysis is the perception of the MNC as an "*international intelligence system for the acquisition and collation of basic knowledge relevant to R&D, and for the exploitation of the commercially applicable knowledge generated by R&D*" (p. 35). Dunning (1993) formulated a framework called as the "eclectic paradigm" to explain the motive for international production. According to the eclectic paradigm, the internationalization decision of the firms is based on its ownership, location and internalization advantages. In this section, we provide an overview of the previous studies on technology imports and FDI on R&D. For the purpose of the present study, it is interesting to broadly classify the studies based on the Indian context and other countries experiences. The India specific studies can be further divided into pre-reform and reform period studies. The pre-reform and reform period studies mainly attempted to study the role of technology imports and the domestic R&D efforts.

2.1 Indian Context

One of the earlier studies examining the role of technology imports and R&D activity was by Katrak (1985). The study was based on an industry level data for a period of three years (1975-77). The results of the study find a complementary relationship between technology imports and R&D.

Kumar (1987) used a cross sectional data for 43 industries during the period 1978-81 to study the effect of technology imports on the domestic R&D. The study also considered FDI as means of technology transfer in addition to the technology imports through licensing. The empirical analysis reveals substitution effect in the case FDI and complementary effect operating in the case of licensing firms. On similar lines Siddharthan (1988) analysed the role of technology imports through licensing & lump sum payments on the local R&D activities. The study was based on a cross sectional data of 166 firms belonging to six manufacturing industries. Similar to the findings of Kumar, Siddharthan's study also found a complementary relationship between technology imports and domestic R&D expenditures. The effect was more pronounced in the case of private sector firms as compared to public sector units (which showed a negative coefficient value).

Deolalikar and Evenson (1993) analysed the determinants of inventive activity in Indian industries. In contrast to the pre-reform studies using the R&D expenditure as a proxy for innovative activity, they have used patents as an indicator of technology imports. The empirical analysis was based on a demand system framework (generalised quadratic cost function) for 50 manufacturing industries during the period 1960-70. The study found a complementary relationship between foreign technology purchase and inventive activity.

Siddharthan (1992) analysed the role of technology transfer and R&D efforts in Indian industries using a transaction cost framework. The empirical analysis was based on a sample of 69 private sector firms during the period 1985-87. The study considered the role of foreign equity participation as a means of technology transfer along with technology imports. The results of the study show a positive and significant value for both foreign equity and technology import variable. Thus, the study found a complementary relationship between foreign equity, technology imports and domestic R&D activities.

Kumar and Saqib (1996) studied the role of technology imports and R&D efforts using firm level data during the pre-reform period. The study used information about 291 firms belonging to nine industries. A Probit and Tobit model was employed to analyse the determinants and intensity of R&D. The study however could find neither substitution nor complementary effects in technology imports-R&D relationship.

Katrak (1997) used a sample of electrical and electronics industries (82 firms) to examine the role of technology imports on domestic technological efforts. The data for the study was obtained from the Compendium of Electrical and Electronic Industries (1991) provided by the Department of Scientific and Industrial Research. The in-house technological efforts were measured by R&D expenditures and R&D manpower. The technology imports had a positive effect for the R&D expenditure equation while it was negative for the R&D manpower equation. He argued that the differential impact may be due to the presence of physical inputs included in the R&D expenditures.

Basant and Fikkert (1996) analysed the role of technology purchase on in-house R&D activities. The study used a firm level panel data for the period 1974-82. The technology purchase was measured in terms of licensing fees in the form of lump-sum payments, royalties and technical fees. The analysis yielded a substitution effect between foreign technology purchase and domestic R&D activities.

Kumar and Aggarwal (2005) study is one of the first attempts to understand the technology behaviour of MNCs and Indian firms during the reform period. They make use of a firm level data during the period 1992-1998. The panel data analysis revealed that there exists a complementary relationship between technology imports and R&D during the liberalisation period. .

Kathuria and Das (2005) explicitly took into consideration the role of FDI as a means of technology transfer to analyse the R&D efforts of the domestic firms. They used a firm level data for two time periods 1996 and 2001. An additional analysis was carried out to understand the determinants of the R&D efforts of the domestic firms. The study found a substitution effect between FDI and R&D in the later period.

2.2 Experience of other countries

Odagiri's (1983) study based on a sample of 370 Japanese manufacturing firms analysed the effect of technology imports on domestic R&D efforts. Technology imports were measured as payments made on royalties. Even though he found a complementary relationship between technology imports and R&D, the results was statistically insignificant for certain industries.

Veuglers and van den Houte (1990) developed a game theoretic approach to analyse the R&D activities of domestic firms in the presence of foreign firms. They empirically verify the hypothesis of positive/negative effect on a sample of 47 Belgian manufacturing firms over a period of three years. The econometric estimations reveal a negative effect on the domestic firms.

Braga and Wilmore (1992) study based on a cross-sectional data for 4,342 Brazilian enterprises found a strong complementarity between foreign technology imports and domestic R&D. The main objective was to analyse the determinants of R&D efforts and technology imports. They found that foreign equity participation is a significant variable in determining R&D efforts and technology imports along with size and exports.

Zhao (1995) using an industry level data analysed the indigenous technological efforts and technology imports in China. The study used a time series data for the period 1960-1991. The empirical evidence provides support for complementarity between technology imports and indigenous technological efforts. The findings of the study point out the enhancement of technology generation and utilization due to the technology imports.

Bertschek (1995) used Chamberlain's random effects probit model to investigate the effects of multinational corporations and technology imports on product and process innovations of domestically-owned German manufacturing firms. The study is based on a balanced panel data of 1270 firms for the period 1984-1988. Unlike Veuglers and van den Houte (1990) study, the results of the study revealed a positive effect due to the presence of MNCs and imports on the innovative activities of domestic firms.

In almost all the earlier studies, there was no attempt to correct for the selection bias. However, a couple of studies have tried to rectify the sample selection problem by using appropriate method. Lee (1996) analysed the relationship between technology imports and R&D efforts for Korean firms using a two stage selectivity bias correction method. In the first stage, the study estimated a probit model for all the firms. The second stage analysis was confined only to those firms with recognised R&D units. The results of the study point to a substitution effect operating between technology imports and R&D efforts.

Chuang and Lin (1999) using a sample of 8,846 manufacturing enterprises in Taiwan found a substitution effect between FDI and domestic R&D efforts. The study used a Heckman two stage estimation to correct for the selection bias. They argue that the substitution effect may be due to the absence of any R&D undertaken by the MNCs in the host country or acquisition of technology from the parent affiliate.

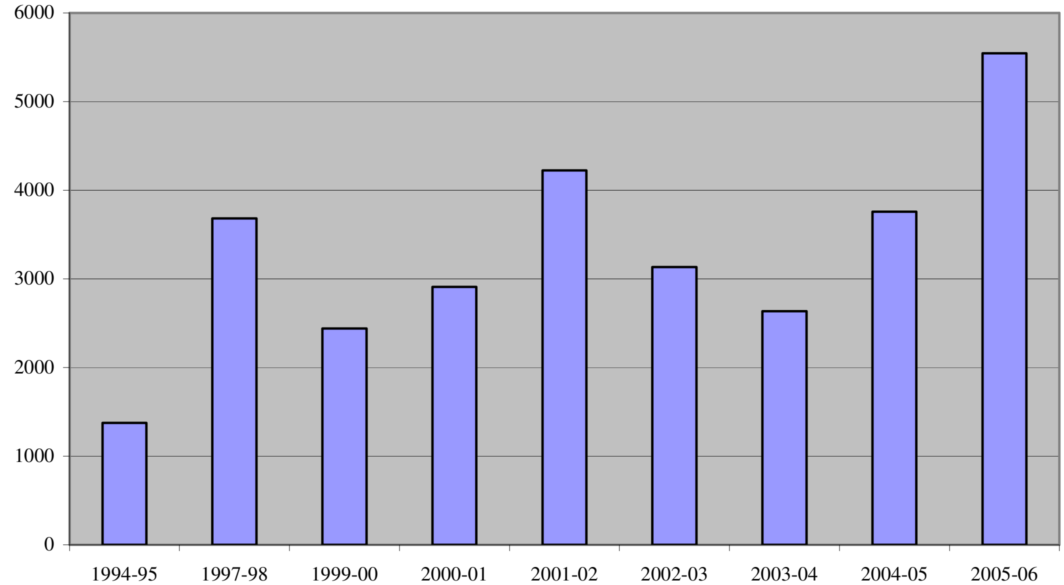
Hu, Gefferson and Jinchang (2005) examined the relationship between foreign firms and the R&D efforts of the domestic Chinese manufacturing firms. The sample consisted of large and medium sized firms belonging to 29 two-digit manufacturing industries for the period 1995-99. The econometric estimations showed that in-house R&D efforts complemented foreign technology transfer. However, they found that there were significant returns to R&D and technology transfer.

Fan and Hu (2006) analysed whether the indigenous technological efforts increase or decrease as a result of FDI for a sample of 998 Chinese manufacturing firms for the period 1998-2000. The empirical results provided evidence of substitution effect between technology transfer through FDI and indigenous technological efforts.

Based on the brief survey of the literature, we observe both a complementary and substitution effect between FDI, technology imports and R&D. Except for the studies by Lee (1996) and Chuang and Lin (1999), none of the studies have corrected for the possible selection bias.

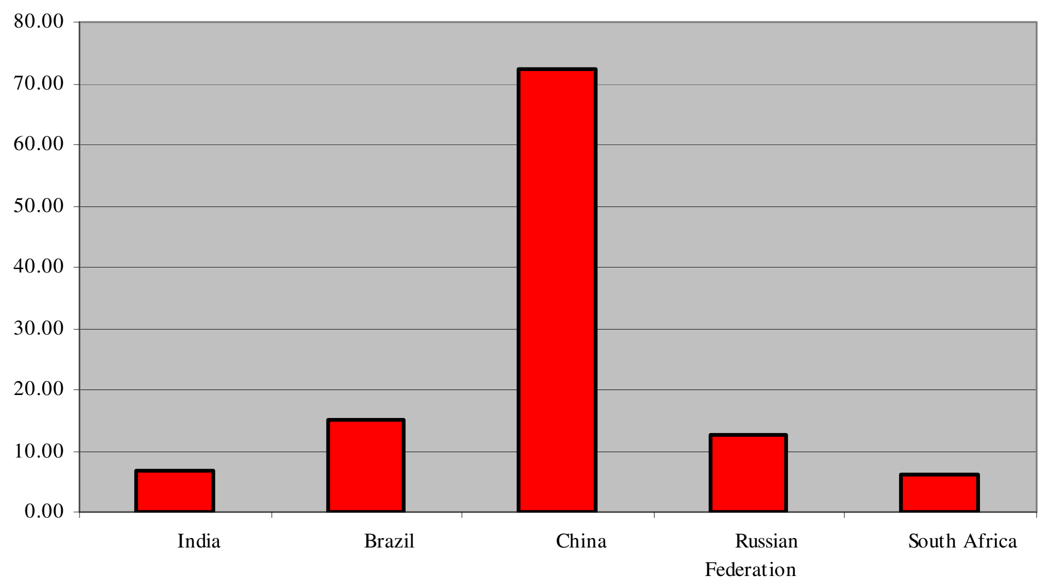
3. Foreign Direct Investment in India

Until the late eighties Indian policy makers followed a restrictive attitude towards the foreign firms. However, the adoption of a liberal regime in the early nineties marked a transition towards market economy. Since then, the government opened up the economy for the foreign investors. The net effect was a significant inflow of FDI in Indian economy. From the Figure 1, it is clear that the inflows peaked in 2005. Even though, the inflows have picked up momentum in the recent years, India receives less FDI inflows when compared to the other countries especially the BRICS (Brazil, Russia, China and South Africa) nations (see Figure 2).



Source: http://dipp.nic.in accessed in July 2008.

Figure 1: FDI Flows into India 1994-2005 (US $ Million)



Source: UNCTAD World Investment Report 2007 database

Figure 2: FDI Inflows to BRICS Countries in 2005 (US $ Billions)

The composition of FDI has drastically changed during the reform period. During the pre-reform period plantation and mining accounted for nearly 80 per cent of total FDI. It can be observed that in the post reform period the bulk of FDI has been shifted to manufacturing sectors. The share of plantation and mining which was 85 per cent of the total FDI stock by the end of 1990, fell sharply to 48 per cent by the end of the year 1997 (Kumar 2005). It is noteworthy to examine the share of the sectors which has attracted largest inflow of FDI for the period 1991-2005. From the Table 1, it can observed that around 17 per cent of the total FDI inflows has been towards the electrical equipment industry (mainly software) followed by the transportation industry. From the state wise distribution of FDI, it can be observed that the three Southern states (Andhra Pradesh, Karnataka, Tamil Nadu) and two Western states (Maharashtra and Gujarat) accounted for almost 71 per cent of the total FDI approvals during the period 1991-2005.

Table 1: Sectors Attracting Highest FDI Flows

(Amount in Rupees crores)

Sector	Cumulative Inflows (1991-Nov 2005)	Share of Inflows (in per cent)
1.ElectricalEquipments (including computer software and electronics)	20,898	16.62
2.Transporatation Industry	13,073	10.39
3.Telecommunications	12,076	9.60
4. Services Sector	11,918	9.53
5. Fuels	10,678	8.49
6.Chemicals (other than fertilizer)	7,444	5.92
7.Food Processing Industries	4,677	3.72
8.Drugs and Pharmaceuticals	4,047	3.21
9.Cement and Gypsum Products	3,229	2.57
10.Metallurgical Industries	2,679	2.13

Source: SIA Newsletter (Various Issues)

Given the fact that FDI in manufacturing has increased multifold in the reform period, it would be an interesting and relevant exercise to see how this inflow has affected the R&D behaviour of firms.

4. Model Specification

4.1 Hypothesis

Based on the results of the existing studies, there is lack of consensus whether FDI complements or substitutes for R&D. Theoretical arguments also suggest either of the possibilities. Domestic firms will have to invest in R&D if they want to absorb the technology spillover effects from foreign firms. Similarly, as a result of the entry of foreign firms, the domestic firms may loose the market share and may be forced to move up along the average cost curve. The easier way to recapture market share is to invest on technology import which has sure and faster returns against own R&D. Therefore, FDI may act as a disincentive for domestic firms to invest in R&D. In our study, we refrain from hypothesizing the nature of relationship *a priori*.

With respect to the foreign ownership, we expect that the firm with foreign equity to undertake more R&D activities so as to adapt the parent firms technology to local conditions. Moreover, foreign affiliates in the host country do not face any constraint in obtaining funds to invest in R&D activities since they have access to vast pool of financial resources from the parent company (Kumar and Aggarwal 2005). The data shows that due to the availability of vast pool of scientific manpower and low cost of R&D personnel, several MNCs have set up R&D centres[6] in India in the recent period (Kumar 2001). Therefore, we hypothesize that higher percentage of foreign equity has a positive effect on R&D intensity.

2.2 Model

In any industry, not all the firms undertake R&D. The firms can self-select into R&D either due to the prevailing market structure or expected net gains from R&D. Therefore, using an OLS method to estimate the R&D intensity of only those firms undertaking R&D can lead to selection bias. Moreover, due to uncertainty involved in R&D outcome and existence of sunk costs in the establishment of R&D labs and equipments, only few firms decide to spend on R&D. Therefore, we can visualize the whole process in two stages. The decision to undertake R&D as stage 1 (i.e., selection stage) and how much resources need to be spend on undertaking R&D as stage 2 (i.e., outcome stage). By using Heckman's procedure we can carry out the analysis of the R&D phenomenon visualized above. The procedure which is described below involves estimation of a selection equation (decision to invest in R&D) and an outcome equation (involving only those firms undertaking R&D).

Following Greene (2003) and Hill *et al.* (2003), we estimate a model consisting of two equations. The first equation is the selection equation. In our case it refers to the decision to invest in R&D.

$$z^*_{it} = w'_{it}\gamma + u_{it} \qquad (1)$$

$$z^*_{it} = 1 \qquad \text{if} \quad z^*_{it} > 0$$

$$z^*_{it} = 0 \qquad \text{if} \quad z^*_{it} \leq 0$$

where z^*_{it} is a latent variable, γ is a K x 1 vector of parameters, w'_{it} is a 1 x K row vector of observations on K exogenous variables, and u_{it} represent the random error term. In reality z^*_{it} (the process influencing R&D investment decision) is unobservable, we only observe when firm has decided to invest in R&D.

The second equation (i.e., the outcome equation) is the linear model and can be represented by:

$$y^*_{it} = x'_{it}\beta + v_{it} \qquad (2)$$

[6] The important among these are Motorola, IBM, Pfizer, Cummins, Colgate Palmolive, Intel, Monsanto, Dupont, GE etc.

$y_{it} = y^*_{it}$ if $z^*_{it} = 1$

$y_{it} = 0$ if $z^*_{it} = 0$

where y_{it} is an observed variable, β is a M x 1 vector of parameters, x'_{it} is a 1 x M row vector of observations on M exogenous variables, and v_{it} represent the random error term. We assume that the random error terms in equations 1 and 2 are normally distributed jointly.

$$\begin{bmatrix} u_i \\ v_i \end{bmatrix} \approx N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & \sigma_v^2 \end{pmatrix}\right]$$

The second equation is the R&D intensity equation. The R&D intensity is zero when the firm decides not to carry out R&D and assumes a positive value when the firm decides to invest in R&D. The problem of selection bias occurs when model is estimated for those firms having observed y_{it} only i.e., when $z_{it} = 1$, and if $\rho \neq 0$. Therefore, applying OLS will lead to biased estimates. In order to obtain unbiased estimates, we need to use the two-step estimation of Heckman popularly known as "HECKIT". The first step of the Heckman two-step or Heckit estimation involves estimation of the selection equation parameters (γ) using Probit model (with R&D dummy as dependent variable) by the method of maximum likelihood. The estimation gives "inverse Mill's" ratio (λ) from the selection equation.

$$\lambda = \frac{\phi(w_i'\gamma)}{\Phi(w_i'\gamma)}$$

where, $\phi(.)$ and $\Phi(.)$ are the probability density function and the cumulative distribution function for a standard normal random variable.

The second step involves adding the inverse mills ratio to the response equation (i.e., R&D intensity equation) to obtain consistent estimates using OLS method.

4.3 Description of the Variables

The literature has identified a number of both - firm- and industry-specific factors influencing a firm's decision to invest in R&D and the extent of investment. These factors and how do they influence R&D behaviour of the firms are described below.

Firm specific factors

Size: One of the most important determinants of the innovative activities is the size of the firm. The Schumpeterian notion of large firms being more innovative is due to the existence of scale economies (Cohen and Levinthal 1989). The large firms are able to spread the fixed capital over a large sales volume due to the availability of greater financial resources. Likewise, they can hedge the uncertainty and risk of failure by undertaking variety of R&D. However, empirical studies investigating the effect of firm size on innovation have brought out a variety of pattern between the two. Even though studies postulate a linear relationship between the two variables; some studies have found a U-shaped relation or a cubic relationship (see for example, Acs and Audrestch 1988; Siddharthan 1988; Kumar and Saquib 1996; Pradhan 2003; Kumar and Aggarwal 2005). In our data set, due to the large scale differences in the size of the firms, we also include a quadratic term for the firm size to capture the possible non-linear relationship. Since size is relative, it is defined as the share of firm's sales to the median sales in the industry.

Export Intensity: The export oriented firms in general face immense competition in the international markets. As a result, they need to produce technologically superior and quality products, which is feasible if they are more R&D intensive. Theoretically, it has been well established that trade is the best possible channel for a firm to obtain technology and hence invest in R&D to assimilate it (Cohen and Levinthal 1989). Empirically, Braga and Wilmore (1991) in a study of Brazilian firms found a positive relationship between export orientation and R&D intensity. Similarly, in a study of Indian manufacturing, Kumar and Siddharthan (1994) found a positive relationship between R&D intensity and export behaviour in the case of low and medium technology industries. In this study, we also postulate a positive relationship between the two.[7]

Vertical Integration: A firm with large scale activities organized within will have a greater possibility of appropriating it, hence an incentive to invest in R&D. Therefore, we assume that a firm with higher value added to sales will have greater inclination to do R&D and have higher R&D intensity. Kumar and Saqib (1996) found a positive relationship between value added to sales ratio and R&D intensity. Similarly, Kathuria and Das (2005) also found a positive and significant effect of value added on the decision of the firm to invest in R&D.

Technology Imports: In developing countries, the major source of technology transfer is through import of technology from industrialized countries. The technology imports can either be in the form of embodied or disembodied means. *Embodied technology* consists of import of capital goods. *Disembodied technology* refers to the royalties, licensing and technical fees paid by the domestic firms for using the technology of the foreign firms. Similar to the investment in R&D, the impact of technology imports can be either complementary or substitution in nature. In the case of Indian enterprises, it has been found that disembodied technology imports are mainly complementary in nature (Katrak 1989; Siddharthan 1992; Aggarwal 2000). Domestic firms obtaining technology through licensing are induced to invest in R&D in order to adapt the technology. In the case of embodied technology import, Basant (1997) found a positive impact on R&D. Therefore, based on the results of the previous studies, we postulate a positive relationship between technology imports and R&D.

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[7] In the case of R&D intensity and export behaviour, there is a problem of simultaneity bias, as more R&D intensive firm may tend to export more (Kumar and Aggarwal 2005). Therefore, the results of the relationship between the two need to be interpreted with caution.

Raw Material Imports: It is well acknowledged that firms operate on severe budget constraints (Kathuria and Das 2005; Mytelka, 1987). Any rise in raw material import would result in limited resources to invest in R&D. The relevance of this variable has enhanced in the post-1991 period as firms are freer to import the raw-material. The sample data also shows that a large number of firms have imported raw materials in the past 4-5 years and domestic firms have high raw-material import intensity. Hence, raw material import to sales, in percentage terms - is expected to have a negative coefficient on in-house R&D decision.

Foreign affiliation: Studies about the innovative activities of multinational corporations (MNCs) reveal that most of their innovative activities are carried out in their home country (Cantwell 1992 cited in Gustavsson and Poldhal 2003). A recent study however has found that many MNCs prefer R&D activities in the host country (Kumar 2001), if host country supplies quality R&D personnel. At the same time, foreign firms may carry out R&D activities in the host country to adapt the products to the local conditions. An earlier study by the same author (Kumar, 1987) however, finds that the foreign firms investing in Indian industries do not invest in R&D since they have access to parent firm's technology. Hence, both arguments exist - in support and against carrying out R&D in the host country. The post 1991 reforms situation is much different as demonstrated by setting up of R&D labs. Thus, we expect foreign firms to spend on R&D. We use foreign promoters share[8] to capture the effect of foreign equity participation on R&D activity and assume that foreign-equity participation induces firms to spend on R&D.

Age: Age variable often proxies for learning. Older firms due to the accumulated experience are assumed to have edge over new entrants. Therefore, it is posited that older firms with their experience are able to make decisions which enable them to get more return on their R&D per unit of investment. However, new firms are able to obtain the latest vintage of technology through intra-firm technology transfer (Katrak 1997). Therefore, any R&D investment is to assimilate the technology and not to further their technological advancements. Thus the extent of R&D investment by newer firms would be less. We expect a positive relationship between age of the firm and R&D.

Location: The new economic geography literature provides evidence of positive relationship between innovativeness and clustering (Feldman 2000). Clustering forces firms to invest in innovative activity through collaboration and knowledge spillovers (Krugman 1991). We use a dummy variable to capture the location effect that takes the value one for those firms located in an industrial estate and zero otherwise.

[8] We define foreign firms as those having foreign promoters share greater than or equal to 10 per cent. This is consistent with the definition of the foreign firm as given by the Reserve Bank of India.

Industry-specific factors

Competition Effect: The empirical literature has attempted to examine the relationship between the market concentration and R&D based on the Schumpeterian school of thought that oligopolisitc market structure, where few firms dominate, is conducive for innovative activities Most of the studies in this tradition have found a positive relationship between the two (see for example, Vossen 1999). Firms with large market shares (i.e. concentrated industries) tend to spend more on R&D activities. In a study of Indian industries Kumar (1987) found that market concentration had an adverse effect on the R&D activities. The study attributes this phenomenon to the lack of competition and entry barriers. The situation may be altogether different in post-1991 period, where opening up and delicensing has resulted in increased competition from imports, entry of foreign and domestic firms. Thus, the effect could be positive. In the present exercise, we use Hirschman-Herfindhal Index (HHI) as a measure of concentration to evaluate the effect of competition.[9]

Foreign Direct Investment: FDI - the main variable of interest, represents the inflow of foreign investment to the respective industry. For the present analysis, we have used FDI approvals as a variable to see its effect on R&D investment behaviour. As hypothesized earlier, FDI influence on R&D investement behaviour will be exploratory in nature.

In addition to these variables, we include industry specific dummies (25 three-digit dummies) to capture the inter-industry differences. We also include time dummies to capture the year to year variations.

Thus, the selection model with R&D dummy (DRD) as dependent variable is:

$$DRD_{it} = \alpha_0\, SIZE_{it} + \alpha_1\, FE_{it} + \alpha_2\, EXPINT_{it} + \alpha_3\, IMPCG_{it} + \alpha_4\, DISTECH_{it} + \alpha_5\, IMPRM_{it} + \alpha_6\, FDI_{jt} + \alpha_7\, VI_{it} + \alpha_8\, HHI_{jt} + \alpha_9\, LOC_{it} + \text{Industry Dummies} + \text{Time Dummies} + u_{it}$$

Outcome equation with R&D intensity (RDINT) as the dependent variable is:

$$RDINT_{it} = \beta_0\, SIZE_{it} + \beta_1\, FE_{it} + \beta_2\, EXPINT_{it} + \beta_3\, IMPCG_{it} + \beta_4\, DISTECH_{it} + \beta_5\, IMPRM_{it} + \beta_6\, FDI_{jt} + \beta_7\, VI_{it} + \beta_8\, HHI_{jt} + \text{Industry Dummies} + \text{Time Dummies} + e_{it}$$

It can be seen from the selection and outcome equations that the former has one variable different than the outcome equation. The next subsection while discussing the econometric issues highlights the need for choosing extra variable. Table 2 gives the definition of different variables and the expected sign.

[9] The R&D-profitability (an inverse of HHI) relationship may be subject to simultaneity bias if successful R&D leads to higher profit margins (and hence more concentrated market structure). The bias may be minimal if the firms do not consider indigenous R&D as a main source of technology input (Kumar and Saquib 1996). In the recent period, situation may have changed due to emergence of some of the technology-oriented industries like biotechnology, nano-technology or IT. Incidentally, our data set does not contain these industries, hence the simultaneity bias may not exist.

Table 2: Variable Description

Dependent Variables		
R&D Intensity, RDINT	Expenditure on R&D as a proportion of firm's sales	
R&D dummy, DRD	= 1 for R&D firms = 0 for non-R&D firms	
Independent Variables		
Variable	**Description**	**Expected Sign**
Size	Share of *i*'th firm's sales to the median sales in an industry	+
Foreign equity, FE	Share of foreign promoters in the total equity (%)	+
FDI	FDI inflows into the industry	+/-
Export Intensity, EXPINT	Total exports as a proportion of sales turnover	+
Capital Goods Imports Intensity, IMPCG	Imports of machinery and equipment as a proportion of sales turnover	+
Disembodied Technology Imports Intensity, DISTECH	Royalties and technical fees paid as a proportion of total firm's sales	+
Raw material Imports Intensity, IMPRM	Raw materials imports and components as a proportion of sales turnover	-
Location Dummy, LOC	= 1 if located in a industrial estate = 0 if an independent firm	+
Vertical Integration, VI	Value added as a proportion of sales turnover	+
HHI	Hirschman-Herfindhal index obtained from the CMIE publications	+
Age	Number of year since the incorporation of the firm	+
CMIE	Center for Monitoring Indian Economy	

Econometric Issues

Estimation of Heckman two-step procedure requires addressing following issues. As explained above, in the first stage we estimate a probit model and obtain the inverse Mill's ratio. The identification of the first step estimates is through the non-linearity of the "inverse Mill's ratio". However, it is linear for certain ranges of index. Therefore, we require additional variable(s) to be included in the selection equation (probit model) to take care of the identification problem in the second step estimates. In reality, such variables are hard to find if process involved in selection and response are identical (Vella 1998; Puhani 2000). In our model specification we include an additional variable - location (LOC), which guides the decision to invest in R&D but not the R&D intensity. The variable is defined as a dummy that takes the value 1 if the firm is located in an industrial estate and 0 otherwise. An industrial estate comprises of large number of firms located in a small geographical area and whose employees meet more often then when units are disperses. This implies that the information flow between them would be faster (Stewart and Ghani, 1991). By virtue of being located in the industrial estate may force a firm to undertake R&D so as to benefit from knowledge spillovers, or as other firms in the estate may be spending on R&D. However, it may not affect the amount spent on R&D, as the amount is primarily a function of the market structure.

Since the data consists of firms of different sizes, the error term obtained from the second step may be heteroskedastic, which does not satisfy the property of efficient estimator. Therefore, it is necessary to correct for the heterosckedasticity. One way to obtain a consistent covariance matrix is to use a White's heterosckedasticity consistent estimator (HCE) (Amemiya 1984). Carter *et al.* (2003) using a Monte Carlo simulation method have shown that in large sample, bootstrapping is a superior technique to obtain consistent variance-covariance matrix for the Heckit estimators. The study thus uses bootstrapping method suggested by Carter *et al*. (2003) to obtain consistent covariance matrix estimators.

5. Data Source and Descriptive Statistics

For the present study, we have used the firm level data, PROWESS from the Center for Monitoring Indian Economy (CMIE). PROWESS provides annual report data for nearly 10,000 firms listed in the Bombay Stock Exchange (BSE), of which around 5,000 firms belong to the manufacturing sector. For our purpose, we cleaned the data following three truncation rules. First, we dropped those firms reporting zero sales or negative value added. Second, given the objective of finding the role of FDI in influencing R&D behaviour, we dropped those industries without any foreign presence. Third, firm should not belong to any industry which is reserved for small scale industry such as leather. After the cleaning process, our final data set consist of an unbalanced panel of 1850 firms belonging to 26 three-digit manufacturing industries spanning 12 years from 1994 to 2005. The number of foreign firms in our data varies from 234 to 293 (i.e., 12-15 per cent of the total) during the study period. The PROWESS data base is based on the NIC 1998 classification. For FDI in the industry, we have used data given by the Secretariat of Industrial Approvals (SIA). The SIA classification is different from NIC classification. Since it is the only source for obtaining the FDI approvals data at the sectoral level, we have matched NIC classification with the SIA classification so as to obtain the total FDI approved in each of these 26 three-digit manufacturing sectors. It is to be noted that use of approvals may create bias as approval is different than actual investment, and there are studies indicating that only one-fourth to one-fifth of approvals turn out to be real investment (Rao *et al*., 1999; SIA, 2002). FDI approvals data refer to the intention of the foreign firms to invest in India. In reality, the approvals in the current year may not materialize in the same year or sometimes the projects may never occur. Therefore, the approvals data do not necessarily reflect the actual FDI inflows. Hence, we have tried to investigate how approvals differ from actual investment in our sample industries too. We find the ratio fairly consistent, thereby indicating that the bias may be non-existent or minimal in our analysis.[10]

Table 3 gives the distribution of total and foreign firms in different industries. The distribution of foreign firms reveals that, in terms of numbers, they are mostly in industries like prime-movers, transport equipment, electrical equipments, and drugs and pharmaceuticals. Whereas, in industries

[10] In this context, it is important to note that even if actual entry does not take place, the threat of potential entry is enough to change firms' behaviour (Schmpeter 1942; Dunning 1993).

like vegetable oils & Vanaspati, Textiles, and Cement & Gypsum products, they are at the fringe with a presence of less than 5%.

Table 3: Distribution of Firms according to Industry Classification

Industry	Foreign Firms			Total Number of Firms		
	1994	2000	2005	1994	2000	2005
Food Processing Industries	6 (17.1)	6 (16.7)	6 (16.7)	35	36	36
Vegetable Oil and Vanaspati	2 (4.4)	2 (4.3)	2 (4.3)	45	46	47
Sugar	2 (5.4)	2 (5.1)	2 (5.1)	37	39	39
Fermentation Industries	10 (8.2)	10 (8.2)	10 (8.2)	122	122	122
Textiles	5 (2.5)	5 (2.4)	5 (2.4)	201	206	206
Paper and Pulp	4 (7.1)	3 (5.2)	4 (6.9)	56	58	58
Chemicals	33 (14.9)	33 (14.4)	32 (14.0)	222	229	229
Dye Stuffs	5 (21.7)	5 (20.0)	4 (16.0)	23	25	25
Fertilisers	2 (9.1)	1 (4.5)	2 (9.1)	22	22	22
Drugs & Pharmaceuticals	19 (13.5)	19 (13.4)	19 (13.2)	141	142	144
Soaps, Cosmetic and Toilet preparations	6 (21.4)	6 (21.4)	6 (21.4)	28	28	28
Rubber Goods	3 (9.7)	2 (6.5)	2 (6.5)	31	31	31
Miscellaneous Mechanical & Engineering	11 (11.8)	11 (11.7)	11 (11.5)	93	94	96
Glass	2 (20.0)	2 (16.7)	2 (16.7)	10	12	12
Ceramics	6 (21.4)	6 (21.4)	6 (21.4)	28	28	28
Cement & Gypsum Products	1 (2.4)	1 (2.4)	1 (2.4)	41	42	42
Metallurgical Industry	18 (8.6)	18 (8.4)	17 (7.9)	210	215	216
Prime Movers other than electrical +Boilers	21 (45.7)	21 (45.7)	21 (45.7)	46	46	46
Industrial Machinery	3 (16.7)	3 (16.7)	3 (16.7)	18	18	18
Machine tools	10 (38.5)	10 (38.5)	10 (40.0)	26	26	25
Earth Moving Machinery	10 (31.3)	10 (30.3)	10 (30.3)	32	33	33
Commercial, Office and Household Equipment	11 (27.5)	11 (26.8)	11 (26.8)	40	41	41
Electrical Equipments like lamps	26 (21.8)	26 (21.8)	23 (19.2)	119	119	120
Medical & Surgical Appliances	5 (22.7)	5 (22.7)	5 (22.7)	22	22	22
Scientific Instruments	2 (66.7)	2 (50.0)	2 (50.0)	3	4	4
Other Transportation Industry like Automobile ancillaries	44 (29.5)	44 (29.5)	44 (29.3)	149	149	150
Total	**267 (14.8)**	**264 (14.4)**	**260 (14.1)**	**1800**	**1833**	**1840**

Note: Figures in parenthesis indicates percentage to the total

Table 4 provides the summary statistics of the key variables included in our empirical analysis. Regarding the size variable (row 1), we observe considerable inter-firm differences. We find that in our sample there are both categories of firms - hundred per cent export oriented units as well as those which cater only to the domestic market (row 2). Pertaining to the sources of technology, we can infer that CG import (row 3) is the most preferred means for obtaining technology followed by R&D (row 6). Disembodied technology import (row 4) constitutes only a miniscule part. From the mean age (row 8), we can deduce that firms operating during the study period are fairly experienced. Lastly, the firms in our sample are not highly vertically integrated (row 7). This is in tune with the global trend towards lean and flexible manufacturing, but is a dampener for R&D investment. Only three firms were found to have vertical integration greater than 25 per cent.

Table 4: Summary Statistics for different Controlling variables

	Variable	All firms			
		Mean	Std. Dev.	Min	Max
1	Size (SIZE)	3.27	9.14	0.00013	186.47
2	Export Intensity (EXPINT)	8.87	18.73	0.00	100.00
3	Capital Goods Imports Intensity (IMPCGI)	1.02	4.52	0.00	76.32
4	Disembodied Technology Imports Intensity(DISTECH)	0.15	1.07	0.00	34.35
5	Raw material Imports Intensity (IMPRM)	3.40	8.86	0.00	79.07
6	R&D Intensity (RDINT)	0.96	2.64	0.00	51.00
7	Vertical Integration (VI)	0.25	0.54	0.001	37.91
8	Age (AGE)	24.95	21.27	1	136.00

Comparison between Foreign and Domestic Firms

Given the objective, we also carried out a test for the differences in mean between foreign and domestic firms. Table 5 reports the results. On an average we find that foreign firms are larger (row 1). The share of disembodied technology imports (row 4) is higher for those firms which have foreign equity participation while domestic firms exhibit higher capital goods imports intensity (row 3). Similarly, we find that greater dependence on embodied technology import has resulted in large imports of raw materials by the domestic firms (row 5). Interestingly, the innovative efforts (R&D intensity) of the foreign-owned firms (row 6) are lower compared to the domestic firms. However, we find no systematic difference between foreign and domestic firms in terms of their vertical integration (row 7).

Table 5: Significance Tests for difference in Means for Domestic and Foreign Firms

S. No	Variable	Domestic	Foreign
		Mean (Std. Dev.)	
1	Size (SIZE)	2.72* (7.68)	8.59* (15.76)
2	Export Intensity (EXPINT)	7.95* (18.31)	1.19* (4.57)
3	Capital Goods Imports Intensity (IMPCG)	0.75* (3.37)	0.37* (0.83)
4	Disembodied Technology Imports Intensity (DISTECH)	0.11* (1.09)	5.96* (10.38)
5	Raw material Imports Intensity (IMPRM)	3.47* (8.89)	0.68* (0.90)
6	R&D Intensity (RDINT)	1.09* (2.67)	0.50* (0.50)
7	Vertical Integration (VI)	0.25 (0.74)	0.24 (0.13)
8	Age (AGE)	24.83* (20.83)	27.91* (20.95)

Notes: * indicates significant differences in the mean values based on the t-test with unequal variances.

Since our main concern is evaluating R&D behaviour of firms, we provide details of the R&D intensity of foreign and domestic firms for the period 1994-2005 (Table 6). We find that for both the groups there does not exist any trend in R&D intensity, though the R&D intensity has declined marginally for both the groups. Interestingly, we observe that the R&D intensity of foreign firms is lower than that of domestic firms, however the differences are statistically significant only for the year1994-2005.

Table 6: R&D intensity of FDI and Non-FDI firms

Year	Domestic (1)	Foreign (2)
1994	1.18*	0.69*
1995	0.94	0.70
1996	0.99	0.63
1997	1.07	0.85
1998	1.29	1.00
1999	1.08	0.73
2000	0.97	0.70
2001	1.09	0.70
2002	1.03	0.67
2003	0.98	0.71
2004	1.10	0.70
2005	1.15*	0.65*

Note: * indicates significant differences in the mean values based on the t-test with unequal variances

6. Results and Discussion

In order to understand the role of FDI in influencing the R&D behaviour, we have carried out analysis involving all the firms belonging to 26 three-digit manufacturing industries. In this section we provide results of different estimations (equations 1 and 2) based on Heckman's two step self-selection model. All the estimations have been carried out using the statistical software - STATA *version 8.0*. In all the models, we have estimated standard errors using used bootstrapping method following Hill *et al* (2003) to correct for heteroskedasticity.

6.1 Full Sample

In Table 7, we present the results for the entire manufacturing sector. The Wald-chi square statistics are significant at 1% for all the specifications, thereby indicating that independent variables explain for the variations in R&D intensity. We find that the lambda value (inverse mill's ratio) is negative and significant. This implies that sample selection bias indeed exists and without correcting for it, the OLS estimates of the coefficients will tend to be overestimated. We summarize the findings of the estimations for the full sample below.

Export orientation (row 15) of a firm though does not influence its decision to invest in R&D but more export oriented firms (row 4) tend to invest more in R&D. This implies that probability of spending on R&D is not different between export-oriented firms and firms which cater to domestic market. However, once an export-oriented firm decides to invest on R&D, given the fact that it is competing on outside front, it needs to devote considerable amount in R&D. Similarly, a firm which imports technology (row 16) is less likely to go for R&D, however once the decision is taken, the extent of R&D is more for technology importing firm (row 5). This is true to our conjecture that technology importing firms tend to complement the R&D efforts. The size variable in our selection model (row 13) is positive and significant, but is negative and significant in outcome model (row 2).

We can deduce from the results that larger size propels firms to invest in R&D. However, the intensity of investment in R&D is found to be greater for small firms.

Table 7: Heckit Estimation Results with All firms

Sl No.	Variable	Coef. (1)	Std. Err. (2)	Coef. (3)	Std. Err. (4)
Outcome Equation with RDINT					
1	FE	-0.006*	0.002	-0.006*	0.002
2	SIZE	-0.007*	0.003	-0.005	0.007
3	SIZESQ			0.001	0.003
4	EXPINT	0.005*	0.044	0.005*	0.044
5	IMPCGI	0.063*	0.041	0.061*	0.040
6	DISTECH	0.012	0.005	0.015	0.005
7	IMPRM	-0.004	0.413	-0.003	0.389
8	HHI	-0.294	0.486	-0.148	0.472
9	VI	0.916*	0.000	0.983*	0.411
10	FDI	-0.0000062	0.0000065	0.00001	0.000006
11	AGE	-0.015*	0.002	-0.013*	0.002
Selection Equation with RDDUM					
12	FE	0.003*	0.001	0.003*	0.001
13	SIZE	0.033*	0.004	0.051*	0.006
14	SIZESQ			0.001*	0.0005
15	EXPINT	0.001	0.002	0.001	0.002
16	IMPCGI	-0.015*	0.005	-0.016*	0.005
17	DISTECH	0.014	0.031	0.011	0.031
18	IMPRM	0.006*	0.003	0.006*	0.003
19	HHI	0.893*	0.250	0.880*	0.250
20	LOC	0.011	0.059	-0.006	0.059
21	VI	0.475*	0.287	0.565*	0.289
22	FDI	-0.00000593	0.00000589	-0.00001	0.0000059
23	AGE	0.016*	0.002	0.016*	0.002
24	Lambda	-1.013*	0.508	-1.82*	0.411
25	Rho	-0.793		-0.633	
26	Industry Dummy	Yes		Yes	
27	Time Dummy	Yes		Yes	
28	No. of Observations	2655		2655	

Notes: * 10 % level of significance; Standard errors are generated using Bootstrap with 1500 replications.

For selection equation, we find positive influence of FE participation (row 12) in its decision to invest in R&D, but the extent of R&D investment is less for foreign-owned firms (row 1) as the variable is negative and significant in outcome equation. This implies that firms with foreign ownership tend to invest less in R&D (also refer row 6 of Table 4). This can be attributed to the fact that foreign firms obtain more technology through imports (refer row 4 of Table 4), which needs to be adapted to local conditions. Since climate, factor conditions, of the host country may be different than that of the countries producing technology, this implies that the technology need to be modified so as to make it suitable for the host country market. Since adaptation requires less R&D investment vis-à-vis R&D spending for development of a new product or process, the impact on R&D intensity is accordingly less. Similarly, foreign firms investing in India might perceive that investment in R&D is more risky due to the possibility of leakage of information, a result of weak Intellectual Property protection[11] and long gestation of investment. Similarly we find that firms which are vertically integrated (rows 21 and 9) has a positive and significant effect on the R&D activities. Vertical integration not only motivates them to invest in R&D but also influences the extent of investment.

With respect to the two technology imports variables IMPCGI and DISTECH (rows 16 and 17), we find that the former affects negatively the decision to do R&D, whereas the latter has no impact. But once the firm has decided to spend on R&D, the firms which go for capital goods imports tend to have larger R&D intensity (rows 5 and 6). Thus, for the capital goods imports and R&D intensity we find a complementary relationship. Contrary to our expectation, we find that raw material imports (rows 7 and 18) favour the decision to invest in R&D but not the R&D intensity of the Indian manufacturing firms. Lastly, older firms are more likely to invest in R&D (row 23) while young firms are more R&D intensive (row 11) than old firms. As mentioned, the R&D spending of the new firms is mainly to adapt the imported technology. This is verified when we compare the technology imports intensity of old and new firms.[12] We find that the average capital goods imports intensity of new firms is significantly higher than that of old firms. The new firms have an import intensity of 1.14 as against 0.94 for the older firms.

With regard to our main variable of interest FDI (rows 22 and 10), we find that though the coefficient value is positive, it is not significant in both the selection and outcome equation. Therefore, we are unable to reach any conclusion regarding the role of FDI in influencing R&D activities.

Previous studies related to Indian manufacturing have found either U or inverted U-shaped or horizontal S-shaped relationship between size and R&D (Acs and Audretsch 1988; Pradhan 2003; Kumar and Aggarwal 2005). Therefore, to see the non-linearity of size, we also included a quadratic term for the variable in our specification. Columns 3 and 4 of Table 6 report the results. Though, SIZE and SIZESQ variables (rows 13 and 14, column 3) are found to have a positive and significant effect on the probability of investment in R&D, they have no impact on the outcome equation (rows 2 and 3, column 3). All other variables including FDI inflow retain same sign and significance level.

Based on the results, we do not find any evidence of complementary or substation effect of FDI inflow on the decision to invest in R&D as well as on the intensity of investment in R&D. One possible reason for not finding any effect could be the fact that the sample consists of all the firms irrespective of the industry to which they belong and their ownership profile.

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[11] The argument has lost some teeth in the recent past, especially after 2005, as India is in the process of reforming her Intellectual Property laws. Since the present study is until 2005, the argument will be valid for the analysis.

[12] We define new firms as those, which are incorporated after 1985. The cut-off 1985 is not entirely arbitrary, as the partial liberalization programme was undertaken since then.

The sectoral characteristics may also influence R&D behaviour. For firms belonging to the high-tech sector (e.g., drugs and pharmaceuticals or chemicals), the competitive advantage is partly governed by the investment in R&D leading to product / process innovation. Therefore, those firms belonging to high-tech sector will be devoting more resources for R&D activities. This is well supported by the data as against an average of 1.22% R&D intensity for firms belonging to high-tech sectors, firms in the low and medium-tech sectors spend only 0.33% and 0.51% of their sales turnover on R&D. Similarly, the extent of foreign ownership may also play an important role in determining the R&D intensity. The main motive for the FDI itself is to exploit the firm specific knowledge. In the case of majority owned foreign firms, it can fully internalize the gains from the R&D activities. Thus, to see whether technological opportunities within the industry and the extent of foreign ownership have any role to play, the analysis is repeated for the sample firms divided according to their technology intensity and the degree of foreign ownership. By doing so, we are able to capture the considerable heterogeneity of the sample firms.

6.2 Classification according to Industry Groups

Technological opportunities vary by industry and in order to appropriate those opportunities, R&D intensity of firm may differ accordingly. Therefore, it is important to investigate the R&D behaviour of firms belonging to technologically homogenous groupings. For this purpose we divide the entire sample into high-tech, medium-tech and low-tech industries. The classification is as per the OECD classification – which divides the industries on the basis of their R&D intensities. Table 8 presents the results.

Similar to the results of the full sample, we find that older (row 21) and large sized firms (row 12) irrespective of the industry in which they are falling, are more inclined to do R&D. However, size and vintage (rows 2 and 10, column 1) are a deterrent for R&D investment if firms belong to high-tech sector. For medium-tech sector, size discourages them to invest highly in R&D (column 3) whereas Age (row 10) having no impact. For firms belonging to low-tech sector neither size nor age (column 5) has any influence on the R&D intensity.

Foreign equity participation (rows 11 and 1), export orientation (rows 13 and 3) and extent of vertical integration (rows 19 and 8) behave differently for the three groups in selection as well in outcome equation. FE participation though encourages firms in the high tech sector to do R&D, it negatively impacts investment. For medium tech industries, foreign equity participation discourages to invest in R&D, whereas for low-tech firms equity participation does not influence decision to invest but is a significant predictor of extent of investment. The results raise few questions: Is it a weak patent regime that may be preventing foreign-owned firms from undertaking R&D in high-tech sectors? Is it ready availability of technology that militates against R&D investment by the firms in medium-tech sectors?

Results show that for medium-tech firms, export orientation is also motivating firms to invest in R&D, the extent of investment is influenced only in the case of high-tech firms. This is entirely different than what Kumar and Siddharthan (1994) found. Vertical integration (row 8, column 3) is found to have a positive and significant influence in the case of medium-tech industries.

Table 8: Heckit Estimation Results - Firms classified based on Technology Opportunity of Industry

Sl. No	Variable	High-Tech		Medium-Tech		Low-Tech	
		Coef. (1)	Std. Err. (2)	Coef. (3)	Std. Err. (4)	Coef. (5)	Std. Err. (6)
Outcome Equation with RDINT							
1	FE	-0.011*	0.004	-0.004	0.006	0.006*	0.003
2	SIZE	-0.012*	0.004	-0.016*	0.009	-0.003	0.008
3	EXPINT	0.008*	0.005	0.000	0.005	0.004	0.003
4	IMPCGI	0.077*	0.058	0.014	0.017	-0.010	0.049
5	DISTECH	-0.004	0.054	-0.192*	0.127	0.146	0.103
6	IMPRM	-0.009	0.007	-0.003	0.008	0.012	0.014
7	HHI	-0.806*	0.543	2.318*	0.797	0.464	0.680
8	VI	0.461	0.791	1.348*	0.838	-1.428	0.621
9	FDI	-8.91E-06	8.74E-06	0.0000159	1.88E-05	-1.07E-06	5.36E-05
10	AGE	-0.019*	0.006	-0.009	0.014	0.017	0.010
Selection Equation with RDDUM							
11	FE	0.006*	0.002	-0.017*	0.004	0.011	0.011
12	SIZE	0.044*	0.006	0.020*	0.008	0.072*	0.030
13	EXPINT	-0.003	0.002	0.012*	0.005	-0.001	0.006
14	IMPCGI	-0.016*	0.006	-0.017	0.012	-0.048	0.075
15	DISTECH	0.024	0.034	-0.041	0.144	-0.258	0.225
16	IMPRM	0.009*	0.004	-0.005	0.009	-0.002	0.015
17	HHI	0.847*	0.270	0.745	1.033	2.942*	1.774
18	LOC	0.048	0.066	0.101	0.179	0.082	0.463
19	VI	1.124*	0.370	0.355	0.763	-1.631*	0.847
20	FDI	-2.39E-06	6.11E-06	-1.73E-05	5.62E-05	0.0000439	0.000133
21	AGE	0.012*	0.002	0.043*	0.006	0.044*	0.011
22	Lambda	-1.780*	0.719	0.013	0.535	0.537	0.199
23	Rho	-1.000		0.034		1.000	
24	Wald chi2	596.19*		823.4*		70.27*	
25	Industry Dummy	Yes		Yes			
26	Time Dummy	Yes		Yes			
27	No. of Observations	1992		424		249	

Notes: * Same as Table 6.

With respect to technology import variables – IMCGI and DISTECH - in the case of high-tech firms we find that the import of capital goods though discourages R&D (row 14) but plays a positive role in influencing R&D investment (row 4). For medium tech firms, disembodied technology import (row 5, column 3) has a detrimental effect on R&D investment. The concentration in an industry, HHI has a differential impact depending upon the technology opportunity of the industry. As predicted, a concentrated industry induces firms to spend on R&D in low and high tech sectors (row 17). The extent of investment however falls in the case of high-tech sectors if the industry has high HHI (row 7). This suggests that if the market is concentrated in few hands, especially in high-tech industries, firms have little incentive to invest in R&D. In the case of medium-tech industries the competitive pressure has a positive impact on R&D intensity. Lastly, the FDI inflow (rows 20 and 9) is found to have no impact in either of the three categories for both selection and outcome equations though the coefficient value is positive.

6.3 Effect of Degree of Foreign Ownership

In this sub-section, we examine the differences between the association of select variables with R&D activities with respect to (i) majority owned foreign firms, and (ii) minority owned foreign firms. . The sample is divided into two categories - Category A consist of firms with more than 50% promoters share, called as majority-owned firms and category B are the firms with less than 50% promoters share, termed as minority-owned firms. Foreign promoters are defined as ownership (10% or more equity) controlled by a single foreign holder or organized group of foreign holders in a host country firm. There are many reasons why R&D orientation of majority-owned foreign firms should be different than that of minority-owned foreign firms. In the case of minority ownership, firms bear the risk of monitoring and coordinating the activities with the local firms (Caves 1996). The parent firm may be reluctant to transfer the state of the art technology in a joint venture where domestic firm holds higher equity due to the risk of leakage. This may force minority-owned foreign firms to spend more on R&D or technology-import. Since the majority-owned firms may have an access to parents' technology, they are likely to generate more spillover effects (Javorcik and Spatareanu 2005). The univariate comparison also yields that the minority-owned foreign firms are more R&D intensive and CG import oriented than the majority-owned firms. In the case of minority ownership firms, we find that the average R&D intensity is 0.86 and CG imports intensity is 1.71, whereas in the case of majority foreign ownership firms, it is 0.060 and 1.16 respectively. In Table 9, we provide the results of the estimations for both categories of firms depending on the extent of foreign ownership.

Older (row 21) and big firms (row 12) irrespective of the extent of foreign ownership are more inclined to spend on R&D, though the size (row 2) and the age (row 10) does not influence the R&D intensity. We find that the extent of ownership (row 11) has a differential impact on the probability of undertaking R&D investments. In support of our conjecture, FE in the minority-owned firms motivates the firms to undertake R&D, whereas the parent firm's high ownership acts as a detriment for the majority-owned firms from undertaking R&D investments in the host country. The differential impact vanishes when we compare the effect on R&D investments, as ownership (row 1) has no statistical significance effect for either category. Export intensity (row 13) has a negative and significant influence on the probability of doing R&D in the case of minority-owned foreign ownership while it is positive and significant for majority-owned firms. We observe a reversal of the phenomenon in the case of spending on R&D (row 3). Though we do not have any explanation for this peculiar behaviour, but we are aware that the export orientation of the majority foreign owned firms is formulated according to the parent firms' strategy. The direction of exports can shed more light on such R&D behaviour. If firms are exporting to countries less developed than India, export may have limited or no influence on the R&D behaviour. However, we need data to substantiate this.

Table 9: Heckit Estimation Results with firms classified based on Ownership

Sl .No	Variable	Majority Ownership (> 50)		Minority Ownership(<50)	
		Coefficient (1)	Std. Err. (2)	Coefficient (3)	Std. Err. (4)
Outcome Equation with RDINT					
1	FE	0.003	0.003	0.001	0.007
2	SIZE	-0.001	0.001	-0.012	0.011
3	EXPINT	-0.010*	0.002	0.017*	0.007
4	IMPCGI	0.011	0.016	0.077	0.073
5	DISTECH	0.015	0.040	0.003	0.098
6	IMPRM	0.004	0.003	-0.007	0.007
7	HHI	-0.544*	0.184	-0.146	0.464
8	VI	0.530	0.314	1.507*	0.803
9	FDI	0.0000026	0.000003	4.59E-06	9.51E-06
10	AGE	-0.003	0.003	-0.013	0.011
Selection Equation with RDDUM					
11	FE	-0.005*	0.003	0.010*	0.003
12	SIZE	0.015*	0.005	0.049*	0.011
13	EXPINT	0.010*	0.003	-0.007*	0.002
14	IMPCGI	-0.042*	0.013	-0.005	0.007
15	DISTECH	0.029	0.050	0.111*	0.047
16	IMPRM	0.002	0.004	0.002	0.004
17	HHI	0.746*	0.370	0.124	0.268
18	LOC	0.416*	0.086	-0.130*	0.076
19	VI	-0.397	0.347	0.176	0.350
20	FDI	0.000013*	0.000006	0.0000147*	5.92E-06
21	AGE	0.021*	0.003	0.014*	0.002
22	Lambda	0.033	0.326	-0.998*	0.148
23	Rho	0.044		-0.693	
24	Lambda	0.033	0.218	-1.057	0.604
25	Wald chi2	29.92*		30.79*	
26	Number of Observations	1247			1329

Notes: Same as Table 6.

The concentration in an industry has effect only on majority owned firms. As hypothesized, a concentrated industry induces firms to spend on R&D (row 17). But the extent of investment falls if the industry has high market concentration (row 7). Similarly, we find that vertical integration though does not influence the probability to invest in R&D for either category, it has a positive effect on the R&D expenditure of minority-owned firms (row 8). Investments in disembodied technology imports (row 15) are found to have a complementary effect for the minority owned foreign firms in undertaking R&D. Regarding our main variable of interest, we find that sectoral FDI inflow induces both - the majority and the minority-owned foreign firms to invest in R&D (row 19) (the motive could be different), but has no impact on the extent of investment (row 9). In other words, there is a complementary relationship between R&D decision and FDI inflow.

Based on the overall and category-wise results, we conclude that FDI inflow induces only foreign-owned firms to invest in R&D. In all other specification, FDI inflow does not have any impact. FDI inflow does not have any impact in any specification on the outcome equation. Among other firm specific variables size (large firms) and age (older firms) consistently influence the probability to invest in R&D. All other variables like technology import or outward orientation or market concentration, only selectively affect the probability and R&D intensity.

7. Conclusion

One of the objectives of the economic reforms undertaken in India since 1991 is to open the doors for foreign firms for investment in the country. As a result, the last 15 years has witnessed large scale FDI inflows to various industries in the Indian economy. Apart from the direct effect of bringing capital and technology, FDI is also an important channel which influences the R&D activities in an economy. The entry of foreign firms leads to an increase in the competition in the domestic market and in order to compete with them the domestic firms have to undertake R&D activities or obtain technology from other sources. Under this backdrop, this study is an attempt to examine the relationship between FDI inflow and R&D behaviour of Indian firms in the post-liberalization regime. Most previous studies addressing the issue are based on only those firms which report R&D, thereby creating the self-selection bias. The present paper corrects for the self-selection problem by using Heckman-two step procedure. To realise the objective, we have used an unbalanced panel data of 1843 Indian manufacturing firms operating during the period 1994-2005. The FDI approvals were used as a proxy for FDI inflow. In order to see the influence of FDI on R&D behaviour, we controlled for various firm and industry specific attributes that can affect R&D propensity and investment. These include size, foreign ownership, exports, technology imports, vertical integration, age, and market concentration.

In the first stage, the analysis involving full sample firms produced no clear picture about the impact of FDI on the innovation strategies of domestic firms. In the second stage, when analysis was carried out according to different sub-samples, we find some interesting results. FDI inflow induces foreign-owned firms irrespective of the extent of ownership to invest in R&D. In all other specification, FDI inflow does not have any impact. FDI inflow does not have any impact in any specification on the outcome equation. Among other firm specific variables size (large firms) and age (older firms) consistently influence the probability to invest in R&D. All other variables like technology import or outward orientation or market concentration, only selectively affect the probability and R&D intensity. An important finding of the present study is that the technological efforts in the form of R&D have declined marginally for both categories of firms during the study period. This is a cause of concern for the policy makers. We also find that firms are increasingly depending on technology imports. The removal of restriction on the imports during the reform period might have played a catalytic role for this phenomenon.

Based on the results of the study, in respect of the policy perspectives, the following salient points can be gauged. Since FDI is not affecting the R&D behaviour of domestic firms, more directed incentives for the firms to invest in R&D to enable them to absorb the technology spillovers from FDI. In this connection, sector specific policies depending on technological intensity of the industry have to be designed in order to encourage setting up of in-house R&D units.

In the recent period, India has witnessed many MNCs locating R&D centers in India. As a future work, it will be interesting to examine the impact of FDI in R&D on the behaviour of other domestic firms. Another direction of future research is including small and privately-owned firms. As mentioned, the present study covers firms which are listed in the stock-exchange, whereas evidence exist that small and private-owned firms are equally dynamic with respect to R&D. The conjecture gets support from the fact that of the eight recipients of 2003 national award for outstanding in-house R&D achievements in different fields, seven are small and medium in size and are not listed in stock-exchange. Thus the study can be extended to look into their R&D behaviour in the post-1991 scenario.

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