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RESEARCH AND STATISTICS BRANCH

WORKING PAPER 04/2008

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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

The 1991 economic reforms in India resulted in large-scale foreign direct investment (FDI) inflows into various industries. FDI is also an important channel that influences R&D activities in an economy. The entry of foreign firms leads to increased competition in the domestic market. This forces domestic firms to undertake R&D activities or obtain technology from other sources so as to compete withmultinational corporations (MNCs). Against this backdrop, this study examines the relationship between FDI and R&D of the domestic firms after compensating for firm-specific variables, in the post-liberalization regime, using unbalanced panel data for 1,843 Indian manufacturing firms operating during the period 1994-2005. An important contribution of the paper is to correct for the self-selection problem by using a Heckman-two step procedure. The analysis involving full sample firms does not give a clear picture of the impact of FDI on the innovation strategies of domestic firms. However, when analysis is carried out according to different sub-samples—based on foreign-ownership and technology intensity of the industry, interesting results emerge. FDI inflow induces foreign-owned firms, irrespective of the extent of ownership—to invest in R&D. In all other specifications, FDI inflow does not have any impact on the selection equation. For the outcome equation, there is no impact of inflow. An important finding of the study is that technological efforts in the form of R&D have declined marginally for both categories of firms during the study period. The removal of restrictions on the imports during the reform period might have played a catalytic role in this phenomenon.

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 industrialized countries, technology was found to be an important catalyst in fostering their spectacular growth (Nelson and Pack 1999). Developing countries, such as 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 viewed solely from the angle of technology provider. Foreign firms can significantly contribute, directly or indirectly, to 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 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 foreign firms have access to 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, 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.

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1 A manifestation of this is increased R&D intensity, as defined as the ratio 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".

Empirical studies have found complementarity, as well as substitution, between the technology imports, FDI and R&D (see, for example, Pack and Saggi 1997 and the literature cited below). A large number of studies carried out for Brazil, China, Germany, India, Japan, etc. have found a complementary relationship between technology imports and R&D. See, for instance, Katrak (1985), Siddharthan (1992), Deolalikar and Evenson (1989), Kumar and Aggarwal (2005) for India, Odagiri (1983) for Japan, Braga and Wilmore (1991) for Brazil, Bertschek (1995) for Germany, Zhao (1995) and Hu *et al*. (2005) for China among others. The substitution effect of technology imports on domestic R&D was obtained by Kumar (1987), Basant and Fikkert (1996), Kathuria and Das (2005) for India, Veugelers 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 (2007) for China, among others. However, some studies, such as Kumar and Saqib (1996) and Katrak (1997), find neither substitution nor complementary effects in the technology imports-R&D relationship.

An important contribution of this 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. 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 that 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, 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. Therefore, use of Ordinary Least Squares (OLS) will yield estimates that

[3] There are a few firms in our sample that also 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, so we treat them as non-R&D units.

would be biased and inconsistent. Therefore, in this 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 those reserved for small scale industries or strategic reasons. As a result, competition in the domestic market has increased considerably. In order to thwart competition from foreign firms, domestic firms need either to 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. The investment in R&D is, however, essential to compete with the global players as well as to adapt the imported technology. Against this backdrop, the purpose of this study is to explore the nature of the relationship between FDI and R&D in the post-liberalization era.

Section 2 provides a brief literature review. Section 3 discusses FDI inflows into India and compares it with that into Brazil, Russian Federation, China and South Africa. Section 4 elaborates the hypothesis and model used to gauge 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. Section 7 presents the conclusions.

2. Literature Review

Numerous studies examining the relationship between FDI and technology imports on R&D exist. They are based on theoretical arguments regarding the potential effects of FDI on the host country. The most prominent among them are the works of authors such as Buckley and Casson (1976) and Dunning (1993). Buckley and Casson (1976) applied the transaction cost framework to understand the international production activities. They identified market imperfections as the main reason for internalization activities by MNCs. The most noteworthy aspect of the authors' analysis is the perception of MNC as an "international intelligence system for the acquisition and collation of basic knowledge relevant to R&D, and

[4] The bias caused by not reporting R&D data is partly taken care of 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 into India has increased from US$155 million in 1991 to US$2,514 million in 2006 (Data Source: Secretariat for Industrial Assistance (SIA) newsletters, various issues).

for the exploitation of the commercially *applicable knowledge generated by R&D*" (p. 35). Dunning (1993) formulated a framework, called the eclectic paradigm, to explain the motive for international production. According to it, the internationalization decision of the firms is based on 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 current 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. They mainly attempt 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 industry-level data for a period of three years (1975-77). The results of the study found a complementary relationship between technology imports and R&D.

Kumar (1987) used cross-sectional data for 43 industries during the period 1978-81 to study the effect of technology imports on 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 of FDI and complementary effect in the case of licensing firms. Along similar lines, Siddharthan (1988) analysed the role of technology imports through licensing and lump sum payments for local R&D activities. The study was based on 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 (1989) 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 used patents as an indicator of technology imports. The empirical analysis was based on a demand system framework (generalized 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 variables. 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 82 firms electrical and electronics industries 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), by the Department of Scientific and Industrial Research. In-house technological efforts were measured by R&D expenditures and 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 R&D expenditures.

Basant and Fikkert (1996) analysed the role of technology purchase on in-house R&D activities. The study used 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.

The Kumar and Aggarwal (2005) study was one of the first attempts to understand the technology behaviour of MNCs and Indian firms during the reform period. They made use of firm-level data for the period 1992-1998. The panel data analysis revealed that there was a complementary relationship between technology imports and R&D during the liberalization period. Kathuria and Das (2005) explicitly took into consideration the role of FDI as a means of technology transfer to analyse R&D efforts of domestic firms. They used firm-level data for two time periods, 1996 and 2001. Additional analysis was carried out to understand the determinants of R&D efforts of domestic firms. The study found a substitution effect between FDI and R&D in the latter 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 were statistically insignificant for certain industries. Veugelers and van den Houte (1990) developed a game-theory approach to analyse R&D activities of domestic firms in the presence of foreign firms. They empirically verified the hypothesis of positive/negative effect on a sample of 47 Belgian manufacturing firms over a period of three years. The econometric estimations revealed a negative effect on domestic firms.

The Braga and Wilmore (1991) study, based on 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 determinants of R&D efforts and technology imports. They found that foreign equity participation was a significant variable in determining R&D efforts and technology imports, along with size and exports.

Using industry level data, Zhao (1995) analysed the indigenous technological efforts in and technology imports into China. The study used time-series data for the period 1960-1991. The empirical evidence provided support for complementarity between technology imports and indigenous technological efforts. The findings of the study pointed 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 was based on balanced panel data from 1,270 firms for the period 1984-1988. Unlike Veugelers 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 tried to rectify the sample selection problem by using appropriate econometric techniques. 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 recognized R&D units. The results of the study pointed 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 Province of China, 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 argued that the substitution effect might be due to the absence of any R&D by MNCs in the host country or acquisition of technology from the parent affiliate.

Hu *et al.* (2005) examined the relationship between foreign firms and 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.

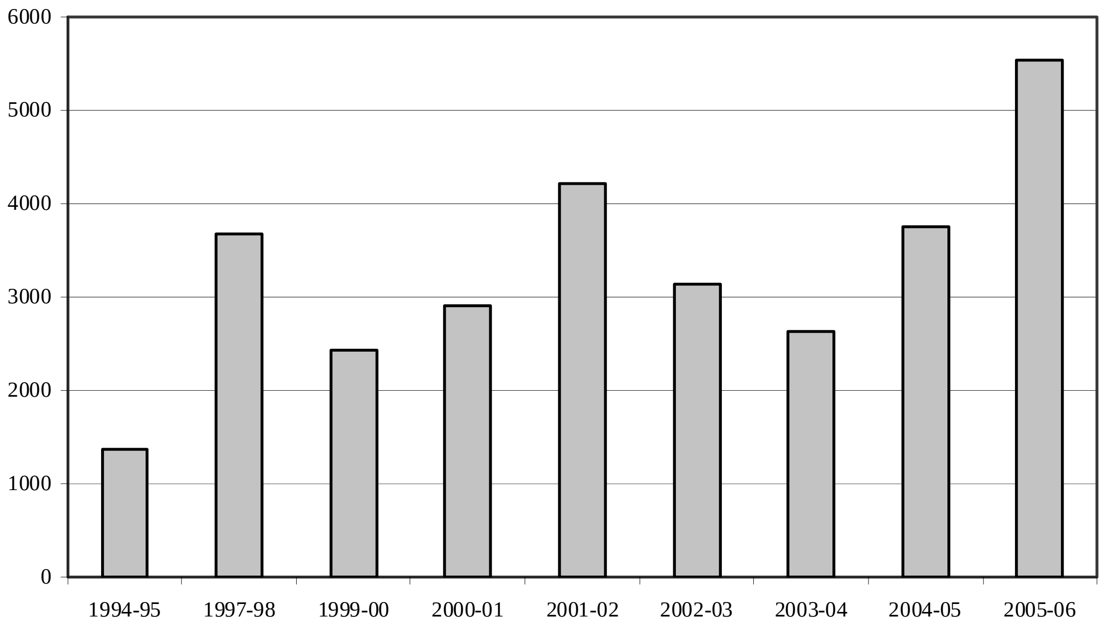
Fan and Hu (2007) analysed whether indigenous technological efforts increase or decrease as a result of FDI for a sample of 998 Chinese manufacturing firms for the period 1998-2000. The empirical results provided evidence of substitution effect between technology transfer through FDI and indigenous technological efforts.

Based on this 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 have corrected for the possible selection bias.

3. Foreign Direct Investment in India

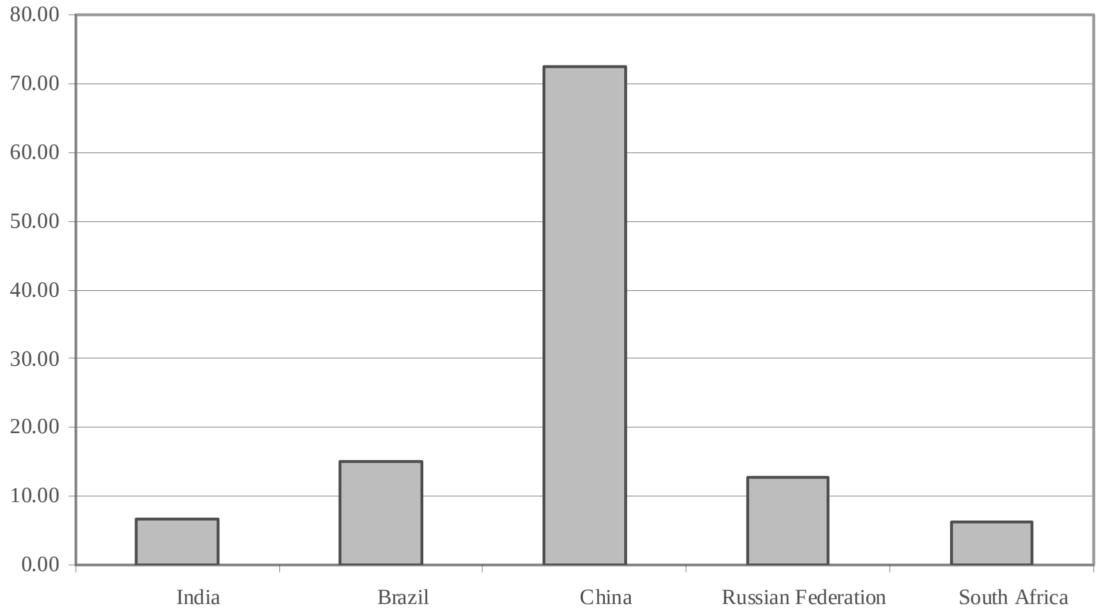
Until the late 1980s, Indian policy makers followed a restrictive attitude towards foreign firms. However, adoption of a liberal regime in the early 1990s marked a transition towards market economy. Since then, the Government has opened up the economy to foreign investors. The net effect has been a significant inflow of FDI in Indian economy. Figure 1 shows that inflows peaked in 2005. Although inflows have picked up momentum in recent years, India receives less FDI compared to other countries, especially BRICS (see Figure 2).

Figure 1: FDI flows into India 1994-2005 (US$ million)



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

Figure 2: FDI inflows to BRICS countries in 2005 (US$ billions)



Source: UNCTAD *World Investment Report* 2007 database

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. 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 total FDI stock by the end of 1990, fell to 48 per cent by the end of 1997 (Kumar 2005). It is revealing to examine the share of the sectors that have attracted the largest inflow of FDI for the period 1991-2005. From the Table 1, it can observed that some 17 per cent of total FDI inflows have gone into the electrical equipment industry (mainly software), followed by the transportation industry. From the state-wise distribution of FDI, three southern states (Andhra Pradesh, Karnataka and Tamil Nadu) and two Western states (Maharashtra and Gujarat) accounted for nearly 71 per cent of total FDI approvals during the period 1991-2005 (Nunnenkamp and Stracke 2007).

Table 1: Sectors attracting highest FDI flows (US$ millions)

Sector	Cumulative inflows (1991-Nov 2005)	Share of inflows (per cent)
1.Electrical equipment (including computer software and electronics)	4,266	16.62
2.Transport	3,070	10.39
3. Services	2,840	9.60
4.Telecommunications	2,730	9.53
5. Fuels	2,505	8.49
6.Chemicals (other than fertilizers)	1,818	5.92
7.Food processing	1,172	3.72
8.Drugs and pharmaceuticals	936	3.21
9.Cement and gypsum products	715	2.57
10.Metallurgy	544	2.13

Source: SIA newsletters (various issues)

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

4. Model Specification

4.1 Hypothesis

Based on the results of existing studies, there is lack of consensus as to whether FDI complements or substitutes for R&D. Theoretical arguments suggest either. Domestic firms will have to invest in R&D if they want to absorb the technology spillover effects from foreign ones. Similarly, as a result of the entry of foreign firms, domestic firms may loose market share and be forced to move up along the average cost curve. The easier way to recapture market share is to invest in technology import, which has sure and faster returns compared to 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 on the nature of the relationship a priori. With respect to foreign ownership, we expect that firms with foreign equity to undertake more R&D activities, so as to adapt 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 pools of financial resources from parent companies (Kumar and Aggarwal 2005). Data show that due to the availability of vast pools of scientific manpower and low-cost R&D personnel, several MNCs have recently set up R&D centres[6] in India (Kumar 2001). Therefore, we hypothesize that a higher percentage of foreign equity has a positive effect on R&D intensity.

4.2 Model

In any industry, not all firms undertake R&D. Firms self-select into R&D due either to the prevailing market structure or expected net gains from R&D. Therefore, using an OLS method to estimate 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 establishment of R&D labs and equipment, only a few firms decide to spend on R&D. Therefore, the whole process can be visualized in two stages: the decision to undertake R&D,

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

as stage 1 (i.e., selection stage) and how much resources need to be spent 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 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.

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

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

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

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

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

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

$$y_{it} = y^*_{it} \qquad \text{if} \quad z^*_{it} = 1$$

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

y_{it} is an observed variable, β a M x 1 vector of parameters, x'_{it} a 1 x M row vector of observations on M exogenous variables and v_{it} 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 a 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 (Heckman 1979). In order to obtain unbiased estimates, we need to use the two-step estimation of Heckman, popularly known as HECKIT. The first step of this involves estimating the selection equation parameters (γ) using the 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.

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

$\phi(.)$ 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 Mill's ratio to the response equation (i.e., R&D intensity equation) to obtain consistent estimates using the OLS method.

4.3 Description of variables

The literature has identified a number of firm- and industry-specific factors influencing a firm's decision to invest in R&D and the extent of investment. These factors and how 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 large sales volume due to the availability of greater financial resources. Likewise, they can hedge uncertainty and risk of failure by undertaking a variety of R&D. However, empirical studies investigating the effect of firm size on innovation have brought out a variety of patterns between the two. Although 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 2002; Kumar and Aggarwal 2005). Due to the large scale differences in the size of firms, our data set includes 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 a firm's sales to the median sales in the industry.

Export intensity: 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 hypothesize a positive relationship between the two.[7]

Vertical integration: A firm having large-scale activities organized within it will have a greater possibility of appropriating the benefits of innovation. This would give an incentive to firms to invest in R&D. Therefore, we assume that a firm with higher value-added to sales will have a greater inclination to invest in 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 firms to invest in R&D.

Technology imports: In developing countries, the major source of technology transfer is through import of technology. They can either be in the form of embodied or disembodied means. Embodied technology consists of imports of capital goods. Disembodied technology refers to royalties, licensing and technical fees paid by domestic firms for using the

[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.

technology of foreign firms. Similar to investment in R&D, the impact of technology imports can be either complementary or substitutional. In the case of Indian enterprises, disembodied technology imports are mainly complementary (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 imports, 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.

Raw material imports: Since firms operate under severe budget constraints (Kathuria and Das 2005; Mytelka, 1987), any increases in raw material imports limit resources to invest in R&D. The relevance of this variable has increased in the post-1991 period, as firms are freer to import raw materials. The sample data show that a large number of firms have imported raw materials in the past four to five years, and domestic firms have high raw material-import intensity. Hence, raw material imports to sales, in percentage terms - are expected to have a negative coefficient on in-house R&D decisions.

Foreign affiliation: Studies about the innovative activities of MNCs reveal that most of their innovative activities are carried out in their home countries (Cantwell 1989, cited in Gustavsson and Poldhal 2003). A recent study, however, has found that many MNCs prefer R&D activities in host countries (Kumar 2001), if they supply quality R&D personnel. At the same time, foreign firms may carry out R&D activities in host countries to adapt products to local conditions. An earlier study by the same author (Kumar, 1987) however, found that foreign firms investing in Indian industries do not invest in R&D, since they have access to parent firms' technology. Hence, both arguments are valid, in support of and against carrying out R&D in the host country. The post-1991 reform situation is much different, as demonstrated by establishment 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.

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

Age: Age variable often proxies for learning. Due to the accumulated experience, older firms are assumed to have an edge over new entrants. Therefore, it is posited that, with their experience, older firms are able to make decisions enabling them to earn more return on their R&D per unit of investment. However, newer firms are able to obtain the latest technology through inter-firm technology transfer (Katrak 1997). Therefore, any R&D investment is to assimilate technology, rather than to further their technological advancement. Thus the extent of R&D investment by newer firms would be less. We expect a positive relationship between age of firms and R&D.

Location: The new economic geography literature provides evidence of a 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, which takes the value one for those firms located in an industrial estate and zero otherwise.

Industry-specific factors

Competition Effect: The empirical literature has attempted to examine the relationship between 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 R&D activities. The study attributes this phenomenon to lack of competition and entry barriers. The situation may be altogether different in the post-1991 period, where opening up and delicensing has resulted in increased competition from imports as well as entry of foreign and domestic firms. Thus, the effect could be positive. In the present exercise, we use the Hirschman-Herfindhal index (HHI) as a measure of concentration to evaluate the effect of competition.[9]

[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, the situation may have changed due to emergence of some of the technology-oriented industries such as biotechnology, nano-technology and information technology (IT). Since our data set does not contain these industries, simultaneity bias may not exist.

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

In addition to these variables, we include 25 three-digit industry-specific dummies to capture inter-industry differences. We also include time dummies to capture year-to-year variations. Thus, the selection model with R&D dummy (DRD) as the dependent variable is:

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

The 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 from the latter. While considering the econometric issues, the next subsection highlights the need for choosing an extra variable. Table 2 gives the definition of different variables and the expected sign.

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 firms' sales to 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 Centre for Monitoring Indian Economy (CMIE) publications	+
Age	Number of year since incorporation of the firm	+

Econometric issues

Estimation of the 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 the process involved in selection and response are identical (Vella 1998; Puhani 2000). In our model specification, we include an additional variable, location, which guides the decision to invest in R&D but not R&D intensity. The variable is defined as a dummy, which takes the value 1 if the firm is located in an industrial estate and 0 otherwise. An industrial estate comprises a large number of firms located in a small geographical area and whose employees meet more often then when units are dispersed. This implies that the information flow between them should be faster (Stewart and Ghani, 1991). Being located on an industrial estate may force firms to undertake R&D, so as to benefit from knowledge spillovers or as other firms on the estate may be spending on R&D. However, it may not affect the amount spent on R&D, as this is primarily a function of market structure.

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

5. Data Source and Descriptive Statistics

For this study, we have used firm level data, Prowess from CMIE. Prowess provides annual report data for nearly 10,000 firms listed on the Bombay Stock Exchange (BSE), of which some 5,000 firms belong to the manufacturing sector. For our purposes, we cleaned the data following three truncation rules. First, we dropped those firms reporting zero sales or negative value-added. Secondly, given the objective of finding the role of FDI in influencing

R&D behaviour, we dropped those industries without any foreign presence. Thirdly, firms should not belong to any industry reserved for small-scale sectors such as leather. After the cleaning process, our final data set consisted of an unbalanced panel of 1,850 firms belonging to 26 three-digit manufacturing industries spanning 12 years, from 1994 to 2005. The number of foreign firms in our data varied from 234 to 293 (i.e., 12-15 per cent of the total) during the study's period. The Prowess data base is based on the National Industrial Classification (NIC) 1998. For FDI in industry, we have used data from the Secretariat of Industrial Approvals (SIA). The SIA classification is different from that of NIC. Since it is the only source for obtaining FDI approvals data at sectoral level, we have matched NIC with SIA classification, so as to obtain the total FDI approved in each of these 26 three-digit manufacturing sectors. Use of approvals, however, may create bias, as approval is different from actual investment. 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 projects never take place. Therefore, approvals data do not necessarily reflect actual FDI inflows. Hence, we have tried to investigate how approvals differ from actual investment in our sample industries. We find the ratio fairly consistent 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 like vegetable oils and vanaspati, textiles, and cement and gypsum products, they are at the fringe with a presence of less than five per cent.

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

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	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
Fertilizers	2 (9.1)	1 (4.5)	2 (9.1)	22	22	22
Drugs and 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 and 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 and gypsum products	1 (2.4)	1 (2.4)	1 (2.4)	41	42	42
Metallurgy	18 (8.6)	18 (8.4)	17 (7.9)	210	215	216
Prime movers other than electrical and 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 equipment such as lamps	26 (21.8)	26 (21.8)	23 (19.2)	119	119	120
Medical and 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 transport such as 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**

Table 3: Distribution of firms according to industry classification

Note: Figures in parenthesis indicate percentage of 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. In our sample, there are both categories of firms: hundred per cent export-oriented units as well as those that cater only to the domestic market (row 2). Pertaining to the sources of technology, 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 share. From the mean age (row 8), firms operating during the study period are fairly experienced. Lastly, the firms in our sample are not highly vertically integrated (row 7). This is consonant with the global trend towards lean and flexible manufacturing but is a disincentive for R&D investment. Only three firms have vertical integration greater than 25 per cent[11].

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: foreign vs domestic firms

We carried out a test for the differences in mean between foreign and domestic firms. Table 5 reports the results. On an average, foreign firms are larger (row 1). The share of disembodied technology imports (row 4) is greater for those firms that have foreign equity participation, while domestic firms exhibit higher capital goods imports intensity (row 3). Similarly, greater dependence on embodied technology import has resulted in large imports of raw materials by the domestic firms (row 5). Innovative efforts (R&D intensity) of foreign-owned firms (row 6) are lower compared to domestic ones. However, there is 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 Mean (Std. dev.)	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 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). For both groups, there does not exist any trend in R&D intensity, though it has declined marginally for

[11] Based on the authors' calculations from the Prowess data base.

both the groups. R&D intensity of foreign firms is lower than that of domestic ones. However, the differences are statistically significant only for the year 1994 and 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 mean values, based on the t-test with unequal variances

6. Results and discussion

In order to understand the role of FDI in influencing R&D behaviour, we have carried out an 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 the 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 one per cent for all the specifications, thereby indicating that independent variables explain for the variations in R&D intensity. The Lambda value (inverse Mill's ratio) is negative and significant. This implies that sample selection bias exists. Without correcting for it, the OLS estimates of the coefficients will tend to be overestimated. Findings from the estimations for the full sample are summarized below.

Export orientation (row 15) of a firm 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 those that cater to the domestic market. However, once an export-oriented firm decides to invest on R&D, given the fact that it is competing on an outside front, it needs to invest considerably in R&D.

Similarly, a firm that imports technology (row 16) is less likely to opt for R&D. However once the decision is taken, the extent of R&D is more for technology importing firms (row 5). This is consonant with our conjecture that technology importing firms tend to complement 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). From the results, we can deduce that larger size drives 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	Size having linear relation		Testing for non-linearity of size	
		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: * ten per cent level of significance; standard errors are generated using Bootstrap with 1,500 replications.

For the selection equation, we find a positive influence from 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 the outcome equation. This implies that firms with foreign ownership tend to invest less in R&D (row 6, Table 4). This can be attributed to the fact that foreign firms obtain more technology through imports (row 4, Table 4), which needs to be adapted to local conditions. Since the climate of the host country may be different than that of the countries producing technology, this implies that the technology needs 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[12] and long gestation of investment. Similarly, firms that are vertically integrated (rows 21 and 9) have a positive and significant effect on 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), the former affects negatively the decision to undertake R&D, whereas the latter has no impact. But once firms decide to spend on R&D, the firms that opt for capital goods imports tend to have greater R&D intensity (rows 5 and 6). Thus, for capital goods imports and R&D intensity, we find a complementary relationship. Contrary to our expectation, 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 younger firms are more R&D-intensive (row 11) than older firms. As mentioned, the R&D spending of new firms is mainly on adaptation of imported technology. This is confirmed when comparing the technology imports intensity of old and new firms.[13] The average capital goods imports intensity of new firms is significantly higher than that of old firms. New firms have an import intensity of 1.14, compared to 0.94 for older firms'.[14]

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

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[12] The argument lost ground in the recent past, especially after 2005, as India is in the process of reforming its intellectual property laws. Since the current study is up to 2005, the argument will be valid for the analysis.

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

[14] Based on the authors' own calculations from the Prowess data base.

Previous studies related to Indian manufacturing have found either U or inverted U-shaped or horizontal S-shaped relationships 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 present 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 have the same sign and significance level.

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

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 sectors will be devoting more resources to R&D activities. This is well supported by the data. Compared to an average of 1.22% R&D intensity for firms belonging to high-tech sectors, firms in low- and medium-tech sectors spend only 0.33 per cent and 0.51 per cent of their sales turnover on R&D.[15] Similarly, the extent of foreign ownership may also play an important role in determining R&D intensity. The main motive for FDI, itself, is to exploit firm-specific knowledge. In the case of majority-owned foreign firms, it can fully internalize the gains from 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 degree of foreign ownership. In so doing, we are able to capture the considerable heterogeneity of the sample firms.

6.2 Classification according to industrial groupings

Technological opportunities vary by industry. To appropriate those opportunities, R&D intensity of firms may differ accordingly. Therefore, it is important to investigate the R&D behaviour of firms belonging to technologically homogenous groupings. For this purpose, we

[15] Source: own calculations from the Prowess data base

divide the entire sample into high-tech, medium-tech and low-tech industries. The classification is as per the OECD classification, which classifies industries on the basis of their R&D intensities. Table 8 presents the results.

Similar to the results for the full sample, older (row 21) and large-sized firms (row 12), irrespective of their industrial grouping, are more inclined to undertake R&D. However, size and vintage (rows 2 and 10, column 1) are a deterrent for R&D investment if firms belong to the high-tech sector. For the medium-tech sector, size discourages them to invest highly in R&D (column 3), whereas age (row 10) has no impact. For firms belonging to the low-tech sector, neither size nor age (column 5) has any influence on 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) are different for the three groups in the selection as well in the outcome equation. Though FE participation encourages firms in the high tech sector to undertake R&D, it negatively impacts on investment. For medium-tech industries, foreign equity participation discourages investment in R&D, whereas for low-tech firms equity participation does not influence the decision to invest but is a significant predictor of the extent of investment. The results raise two 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 firms in medium-tech sectors?

Sl. No	Variable	High-tech Coef. (1)	Std. err. (2)	Medium-tech Coef. (3)	Std. err. (4)	Low-tech 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	

Table 8: Heckit estimation results - Firms classified based on technology opportunity of industry

Notes: * same as for Table 6.

Results show that for medium-tech firms, export orientation is also motivating them to invest in R&D. The extent of investment is influenced only in the case of high-tech firms. This is entirely different from 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.

With respect to technology import variables, IMCGI and DISTECH, in the case of high-tech firms, the import of capital goods discourages R&D (row 14) but plays a positive role in influencing R&D investment (row 4). For medium-tech firms, disembodied technology imports (row 5, column 3) have 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, decreases in the case of high-tech sectors if the industry has high HHI (row 7). This suggests that, if the market is concentrated in a 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 on any 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 selected variables with R&D activities in regard to majority-owned foreign firms and minority-owned foreign firms. The sample is divided into two categories. Category A consists of firms with more than 50 per cent promoters' share, designated as majority-owned firms. Category B consists of the firms with less than 50 per cent promoters' share, designated as minority-owned firms. Foreign promoters are defined as ownership (ten per cent 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 ones. In the case of minority ownership, firms bear the risk of monitoring and coordinating activities with local firms (Caves 1996). The parent firm may be reluctant to transfer state-of-the-art technology in a joint venture where the 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 imports. Since 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 reveals that minority-owned foreign firms are more R&D-intensive and CG import-oriented than majority-owned firms. In the case of minority-owned firms, average R&D intensity is 0.86 and CG imports intensity 1.71, whereas, in the case of majority foreign-owned firms, it is 0.060 and 1.16 respectively. Table 9 lists the results of the estimations for both categories of firms depending on the extent of foreign 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

Table 9: Heckit estimation results with firms classified based on ownership

Notes: same as for Table 6

Irrespective of the extent of foreign ownership, older (row 21) and big firms (row 12) are more inclined to spend on R&D, though size (row 2) and age (row 10) do not influence R&D intensity. The extent of ownership (row 11) has a differential impact on the probability of undertaking R&D investment. In support of our conjecture, FE in the minority-owned firms motivates them to undertake R&D, whereas the parent firm's high ownership acts as a deterrent to majority-owned firms to R&D investment in the host country. The differential impact vanishes when comparing the effect on R&D investments, as ownership (row 1) has no statistically significant effect on either category. Export intensity (row 13) has a negative and significant influence on 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, we are aware that the export orientation of the majority of foreign-owned firms is based on the parent firms' strategy. The direction of exports can shed additional light on such R&D behaviour. If firms are exporting to countries less developed than India, export may have limited or no influence on R&D behaviour. However, we need data to substantiate this.

Concentration in an industry affects only 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, although vertical integration does not influence the probability to invest in R&D for either category, it has a positive effect on R&D expenditure of minority-owned firms (row 8). Investments in disembodied technology imports (row 15) are found to have a complementary effect for minority-owned foreign firms in undertaking R&D. Regarding our main variable of interest, sectoral FDI inflow induces both majority- and minority-owned foreign firms to invest in R&D (row 19), the motivation possibly being different, but has no impact on extent of investment (row 9). In other words, there is a complementary relationship between R&D decision and FDI inflow.

Based on overall and category-wise results, FDI inflow induces only foreign-owned firms to invest in R&D. In all other specifications, 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, such as technology import or outward orientation or market concentration, only selectively affect probability and R&D intensity.

7. Concluding Remarks and Issues for Future Research

One of the objectives of the economic reforms undertaken in India since 1991 is to open the doors to foreign firms for investment in the country. As a result, the last 17 years have witnessed large-scale FDI inflows into various industries in the Indian economy. Apart from the direct effect of bringing capital and technology, FDI is also an important channel that influences R&D activities in an economy. The entry of foreign firms leads to an increase in competition in the domestic market. To compete with them, domestic firms have to undertake R&D activities or obtain technology from other sources. Against 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 that report R&D, thereby creating the self-selection bias. This paper corrects for the self-selection problem by using a Heckman-two step procedure. To realize the objective, we have used unbalanced panel data for 1,843 Indian manufacturing firms operating during the period 1994-2005. The FDI approvals were used as a proxy for FDI inflow. 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 failed to produce a clear picture of 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, the results proved more promising. FDI inflow induces foreign-owned firms, irrespective of the extent of ownership to invest in R&D. In all other specifications, 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, such as technology import, outward orientation and market concentration, only selectively affect probability and R&D intensity. An important finding of the current 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 policy makers. We also find that firms are increasingly depending on technology imports. The removal of restrictions on the imports during the reform period might have played a catalytic role in this phenomenon.

In regard to the policy perspectives, the following salient points can be gauged, based on the results of the study. Since FDI is not affecting 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 tailored to 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 centres 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 inclusion of small and privately-owned firms. The current study covers firms listed on the stock exchange, whereas evidence exists that small and private-owned firms are equally dynamic with respect to R&D. The conjecture is supported by the fact that, of the eight recipients of the 2003 national award for outstanding in-house R&D achievements in different fields, seven were small and medium in size and not listed on stock exchange. Thus, the study can be extended to look into their R&D behaviour in the post-1991 scenario.

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