ELSEVIER
www.elsevier.com/locate/worlddev

World Development Vol. 39, No. 7, pp. 1226–1239, 2011

0305-750X/$ - see front matter

doi:10.1016/j.worlddev.2010.05.012

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

SUBASH SASIDHARAN
Madras School of Economics, India

and

VINISH KATHURIA *
Indian Institute of Technology Bombay, India

Summary. — The entry of foreign firms in India since the reforms forces domestic firms to undertake R&D activities or import technology so as to compete with them. This study examines the relationship between FDI and R&D of the domestic firms in the post-liberalization regime. The study uses unbalanced panel data for 1,843 Indian manufacturing firms operating during the period 1994–2005 and corrects for the self-selection problem by using a Heckman-two step procedure. The analysis involving full sample does not give a clear picture of the impact of FDI on the innovation strategies of domestic firms. Interesting results emerge, when analysis is carried out according to different sub-samples—based on foreign-ownership and technology intensity of the industry. FDI and R&D are found to be complements when sample is divided on the bases of equity ownership. FDI inflow induces foreign-owned firms in high tech industries and firms in minority ownership to invest in R&D.

Key words — FDI, R&D, complementarities, substitution, India

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 & Pack, 1999). The role of technology has become more important in the present scenario as the world is moving toward knowledge economy and the only way countries can sustain growth is by aggressively promoting technological efforts of their domestic firms. 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 role of FDI in the host country cannot be viewed solely from the angle of technology provider. Recent attempts of studying the benefits from FDI have looked at the impact on domestic firms' productivity, technology transfer, exporting behavior *etc.* [2] The presence of foreign firms can also create positive externalities in the form of spillover effects to the domestic firms (Kathuria, 2000). [3] It is increasingly recognized that foreign firms can significantly contribute, directly or indirectly, to innovative activities in the host country (Lall, 1993). 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 (Kathuria, 2008). Similarly, in the case of domestic firms, the presence of foreign firms may force them to invest in innovative activities so as to enhance their technological capability (Helfat, 2000). 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 (Globerman and Meredith (1984), Fan & Hu, 2007). Since foreign firms have access to parent firms' technology, there is little incentive for them to undertake new technological efforts (Kathuria, 2008). 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.

Despite growing importance of the FDI and the impact on the indigenous technological efforts, studies exploring the issue using detailed firm level data are scarce. Using a rich firm level data for Indian manufacturing industries for the period

* The authors acknowledge the support provided by UNIDO to participate in the First Annual Conference of the Sanjaya Lall Programme for Technology and Management for Development (SLPTMD) "Confronting the Challenge of Technology for Development: Experiences from the B-RICS", University of Oxford, May 29–30, 2008. The authors wish to express their gratitude to Adamos Adamou and John T. Scott for the useful discussions and Dr. C. Veeramani for comments on an earlier draft. The authors would like to thank the conference participants and the two anonymous referees for very useful comments. The usual disclaimers nevertheless apply. Final revision accepted: May 20, 2010.

1994–2005, this study investigates the effects of FDI on indigenous R&D efforts.

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, 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. Analyzing 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 are 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 1% of their sales turnover. For adaptive R&D or shop floor modifications, R&D expenditure of firms is often <1%; hence, these firms do not report it. [4] This implies that the results of the previous studies (Kathuria & Das, 2005; Kumar & Aggarwal, 2005) based on only those firms which report R&D are biased. Therefore, use of Ordinary Least Squares (OLS) will yield estimates that would be biased and inconsistent. In this study, we correct for the problem of self-selection bias by applying Heckman's two-step procedure. [5]

Until 1991, India followed a restrictive policy on foreign capital (Rao, Murthy, & Ranganathan, 1999). The reforms undertaken during the early nineties have led to large inflows of FDI into the Indian economy. [6] 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 (Kathuria, 2008). 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 elaborates the hypothesis and model used to gauge the impact of FDI on R&D behavior. In Section 4, data sources and summary statistics of the key variables are given. Section 5 discusses the empirical results. Section 6 presents the conclusions.

2. LITERATURE REVIEW

The existing studies on effects of FDI have looked at a variety of issues such as FDI and productivity/technology spillover, exporting behavior, R&D investment, competitiveness *etc*. In this study, since our focus is on FDI and R&D, we confine literature survey to those studies looking into the effect of FDI/technology imports on R&D.

Theoretical and empirical arguments are made in favor and against complementarity of FDI and R&D. Those who argue in favor of complementarity are of the opinion that MNCs will have to undertake adaptive R&D to suit the local conditions (Nelson, 2004; Tomiura, 2003). According to Annique and Cuervo-Cazurra (2008), there are three distinct channels of accessing technological and scientific instruments of other countries, which result in a subsidiary of a foreign MNE spending less in R&D in the host country: (a) through its access to the parent firm located in a country with a well-developed technological infrastructure; (b) through its access to other MNE subsidiaries located in countries with highly developed technological capabilities; or (c) through its access to knowledge developed within the network of subsidiaries. On the other hand, investments in R&D being subjected to financial constraints, which a subsidiary of a foreign MNE may not face because the parent has better access to capital markets than domestic firms, hence may spend more on R&D (Annique, 2008).

Irrespective of whether foreign firms spend on R&D or not, the enhanced competition due to the entry of foreign firms has a direct bearing on the R&D efforts of the domestic firms (Caves, 1974). In order to face competition from MNCs, domestic firms may acquire technology either by sourcing it from outside/externally or undertaking own R&D. Domestic firms may not devote resources for R&D in the fear of lower profitability, gestation lag, and the risk associated with own research efforts (Veugelers & van den Houte, 1990). Therefore, firms consider technology import from abroad as a favorable option. However, technology import may still necessitate R&D to adapt the technology to local conditions. Similarly, absorption of spillovers may require spending on R&D by domestic firms (Feinberg & Majumdar, 2001; Kathuria, 2002).

Empirical studies have found both complementary, as well as substitution effect, between the technology imports, FDI, and R&D (see, for example, Pack & Saggi, 1997 and the literature summarized in Table 1). 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 WilLmore (1991) for Brazil, Bertschek (1995) for Germany, Zhao (1995) and Hu, Jefferson, and Jinchang (2005) for China among others. The substitution effect of technology imports on domestic R&D has been 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.

From the literature cited in Table 1 two gaps clearly emerge: (a) barring two (Lee, 1996; and Chuang & Lin, 1999), none of the studies correct for selection bias, and (b) most of the studies in the Indian context are for the period when the economy was not liberalized. The present study fills these obvious gaps in the literature.

3. 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, 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

Table 1. *Summary of the literature survey*

Author	Source of data	Dep. variable	Methodology	Results
Katrak (1985)	RBI and DST (1975–76 to 1977–78)	Expenditure on R&D	log-linear	R&D and import of technology—complementary
Deolalikar and Evenson (1989)	RBI industry data (1960–70)	Expenditure on R&D	Generalized cost function	Purchased technology and R&D—complementary
Kumar (1987)	RBI unpublished industry data (1976–77 to 1980–81)	R&D intensity	OLS	FDI and R&D are substitutes
Siddharthan (1992)	"MoST" publication on "compendium on inhouse R&D centres" (1985–86)	R&D intensity	OLS	Technology imports and R&D—Complementary
Kumar and Saqib (1996)	Firm level data from RBI (1977–78 to 1980–81)	Probability of undertaking and R& D intensity	Probit and Tobit models	Technology imports and R&D—neither substitutes nor complements
Basant and Fikkert (1996)	Annual reports (1975–76 to 1981–82)	Output	Fixed Effect(FE) & Random Effect (RE) model	R&D and technology purchases—substitutes
Feinberg and Majumdar (2001)	RBI firm level data (1971–75)	Value of production	FE model	Domestic firms experienced no spillovers from MNCs
Kumar and Aggarwal (2005)	Prowess (1996 and 2001)	R&D intensity	GLS model	Technology imports and R&D—complements
Kathuria and Das (2005)	Capitaline (1992–93 to 1998–99)	Probability of undertaking and R&D intensity	Probit and Tobit model	FDI and R&D are substitutes
Kathuria (2008)	Capitaline (1994–96 and 1999–2001)	Probability of undertaking and R&D intensity	Probit and Tobit model	FDI and R&D are substitutes in period 1 and no relation in period 2
Odagiri (1983)	Company financial reports, (1980)	R&D intensity	GLS	R&D and technology imports—complementary
Veugelers & van den Houte (1990)	Kompass register of industrial and survey data base Belgium and INCAP database, (1980–83)	R&D intensity	Pooled OLS	FDI and R&D are substitutes
Braga and WilLmore (1991)	Institute of administration, University of Sao Paulo, (1981)	R&D dummy	Logit model	Technology imports and domestic R&D efforts are complements
Bertschek (1995)	Ifo business survey, (1984–88)	Product/ Process innovation dummy	Chamberlain's RE Probit model	FDI and product and process innovations are complements
Zhao (1995)	Almanac of foreign trade in China, (1960–91)	Output & export value of heavy industry;R&D & tech. upgrading spending	Autoregression	Technology imports and domestic technological efforts are complements
Lee (1996)	Year book of Companies and Korean Ministry of Finance, (1985)	R&D dummy & R&D intensity	Heckman two stage estimation	Technology imports and domestic R&D efforts are substitutes
Chuang and Lin (1999)	Industrial and Commercial Census for Taiwan (1991)	R&D dummy & R&D intensity	Heckman two stage estimation	FDI and R&D are substitutes
Hu, Jefferson and Jinchang (2005)	Chinese National Bureau of Statistics (1995–99)	Value added	OLS and IV approach	Foreign technology transfer and in-house R&D are complements
Fan and Hu (2007)	World Bank firm level survey, (1988–2000)	R&D intensity & R&D manpower	OLS and FE models	Technology transfer and in-house R&D-substitutes

Notes: Figures in parenthesis represent the study period; IV—Instrument variables.

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, Adkins, and Bender (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.

$$\begin{aligned} z_{\mathrm{it}}^{*} &= w_{\mathrm{it}}'\gamma + u_{\mathrm{it}} \\ z_{\mathrm{it}}^{*} &= 1 \quad \text{if } z_{\mathrm{it}}^{*} > 0 \text{ and } z_{\mathrm{it}}^{*} = 0 \quad \text{if } z_{\mathrm{it}}^{*} \leqslant 0 \end{aligned} \tag{1}$$

z_{it}^{*} is a latent variable, γ a $K \times 1$ vector of parameters, w_{it}' a $1 \times \mathrm{K}$ 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:

$$\begin{aligned} y_{\mathrm{it}}^{*} &= x_{\mathrm{it}}'\beta + v_{\mathrm{it}} \\ y_{\mathrm{it}} &= y_{\mathrm{it}}^{*} \quad \text{if } z_{\mathrm{it}}^{*} = 1 \text{ and } y_{\mathrm{it}} = 0 \quad \text{if } z_{\mathrm{it}}^{*} = 0 \end{aligned} \tag{2}$$

y_{it} is an observed variable, β a $M \times 1$ vector of parameters, x_{it}' a $1 \times M$ row vector of observations on M exogenous variables and v_{it} the random error term. We assume that the random error terms in Eqns (1) and (2) are normally distributed jointly:

$$\begin{bmatrix} u_i \\ v_i \end{bmatrix} \approx N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & \sigma_v^2 \end{pmatrix}\right] \tag{3}$$

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, that is, when $\mathrm{z}_{\mathrm{it}} = 1$, 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. $\lambda = \frac{\phi(w_i'\gamma)}{\Phi(w_i'\gamma)}$ where ϕ (.) and Φ (.) 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. 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 behavior of the firms are described below.

(a) *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 & 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 & Audretsch, 1988; Kumar & Aggarwal, 2005; Kumar and Saqib (1996); Pradhan, 2002; Siddharthan, 1988). Due to the large scale differences in the size of firms, our dataset 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 & Levinthal, 1989). Empirically, Braga and WilLmore (1991), in a study of Brazilian firms, found a positive relationship between export orientation and R&D intensity. 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.

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 technology of foreign firms. In the case of Indian enterprises, disembodied technology imports are mainly complementary (Aggarwal, 2000; Katrak, 1989; Siddharthan, 1992). 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 & 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. On the other hand, continuous reliance on imported raw material having more uncertainty in prices and availability may motivate the firm to invest in inhouse R&D so as to have a substitute for imported raw material. It will be interesting to see which of the two effects dominate. The variable is measured as raw material imports to sales, in percentage terms. 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.

Foreign affiliation: Studies about the innovative activities of MNCs reveal that most of their innovative activities are carried out in their home countries (Annique, 2008; Cantwell, 1989, cited in Gustavsson & Poldhal, 2003). A recent study, however, has found that many MNCs prefer R&D activities in host countries (Kumar, 2001), if supply of quality R&D personnel is available. 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.

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.

(b) *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 oligopolistic market structure—where few firms dominate—is conducive for innovative 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]

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 behavior. As hypothesized earlier, FDI influence on R&D investment behavior 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 any economy-wide shock affecting firms' decision to invest in R&D.

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

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

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

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

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.

(c) *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

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	+

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 (Puhani, 2000; Vella, 1998). 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 than when units are dispersed. This implies that the information flow between them should be faster (Stewart & 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, Hill *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. The wide spectrum of companies in the database constitutes 70% of the economic activity of the organized industrial sector. [10] 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 behavior, 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 dataset 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% 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. [11]

Table 3 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: 100% 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 toward lean and flexible manufacturing but is a disincentive for R&D investment. Only three firms have vertical integration >25%. [12]

(a) *Comparison: foreign vs domestic firms*

We carried out a test for the differences in mean between foreign and domestic firms. Columns 3 and 4 of Table 3 report 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). 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 *vis*-a-*vis* domestic ones. Lastly,

Table 3. *Summary statistics and Testing for difference in means for domestic and foreign firms*

	Variable	All firms		Domestic firms	Foreign firms
		Mean	Range		
1	Size (SIZE)	3.27 (9.14)	0.00013–186.47	2.72* (7.68)	8.59* (15.76)
2	Export intensity (EXPINT)	8.87 (18.73)	0.00–100.00	7.95* (18.31)	1.19* (4.57)
3	Capital goods imports intensity (IMPCGI)	1.02 (4.52)	0.00–76.32	0.75* (3.37)	0.37* (0.83)
4	Disembodied technology imports intensity(DISTECH)	0.15 (1.07)	0.00–34.25	0.11* (1.09)	5.96* (10.38)
5	Raw material imports intensity (IMPRM)	3.40 (8.86)	0.00–79.07	3.47* (8.89)	0.68* (0.90)
6	R&D intensity (RDINT)	0.96 (2.64)	0.00–51.00	1.09* (2.67)	0.50* (0.50)
7	Vertical integration (VI)	0.25 (0.54)	0.001–37.91	0.25 (0.74)	0.24 (0.13)
8	Age (AGE)	24.95 (21.27)	1–136	24.83* (20.83)	27.91* (20.95)

Notes: Figures in parenthesis are standard deviation.
* Indicates significant differences in mean values, based on the *t*-test with unequal variances.

no systematic differences exist between the two groups of firms regarding their vertical integration (row 7).

There exists explanation suggesting why the behavior of MNEs in Indian context (or for that matter, in any big economy) might be different. Many of the foreign firms have invested in India so as to cater to the local market. In that scenario MNEs export intensity will be low. Similarly, exporting activity might necessitate technology import so as to produce quality product. Such a compulsion may not be there for a firm catering to the domestic market. Study by Aggarwal (2002) has also found the similar conclusion. Further, MNCs have access to the centralized research labs of their parent firms, therefore, they are unlikely to spend on R&D. Apart from adapting products to the local market, they may not incur large expenses. Studies by Globerman and Meredith (1984) for Canada, Fan and Hu (2007) for China and Kumar and Aggarwal (2005) for India have come up with same conclusions.

Table 4. *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*

* Indicates significant differences in mean values, based on the *t*-test with unequal variances.

Since our main concern is evaluating R&D behavior of firms, we provide details of the R&D intensity of foreign and domestic firms for the period 1994–2005 (Table 4). For both groups, there does not exist any trend in R&D intensity, though it has declined marginally for 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.

6. RESULTS AND DISCUSSION

In order to understand the role of FDI in influencing R&D behavior, 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 (Eqns 1 and 2) based on Heckman's two step self-selection model. All the estimations have been carried out using the

Table 5. *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: standard errors are generated using Bootstrap with 1,500 replications.
* Denotes 10% level of significance respectively.
** Denotes 5% level of significance respectively.
*** Denotes 1% level of significance respectively.

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.

(a) *Full sample*

In Table 5, 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. 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.

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 3). This can be attributed to the fact that foreign firms obtain more technology through imports (row 4, Table 3), 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 (Feinberg & Majumdar,

Table 6. *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 chi^2	596.19***		823.4***		70.27**	
25	Industry dummy	Yes		Yes		Yes	
26	Time dummy	Yes		Yes		Yes	
27	No. of observations	1992		424		249	

Notes: standard errors are generated using Bootstrap with 1,500 replications.
* Denotes 10% level of significance respectively.
** Denotes 5% level of significance respectively.
*** Denotes 1% level of significance respectively.

2001)[13] 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) favor 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.[14] 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'.[15]

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.

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 & Audretsch, 1988; Pradhan, 2002; Kumar & 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 behavior. 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% and 0.51% of their sales turnover on R&D.[16] 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.

(b) *Classification according to industrial groupings*

Technological opportunities vary by industry. To appropriate those opportunities, R&D intensity of firms may differ accordingly (Nelson & Wolff, 1997). Firms in high technology industries have greater opportunity and capacity to absorb external knowledge. We expect that firms in high technology industries invest more in complementary in-house R&D. On the other hand, for firms in the low-technology industries, where production process is fairly standard, there is less incentive to spend on R&D. Therefore, it is important to investigate the R&D behavior of firms belonging to technologically homogenous groupings. For this purpose, we divide the entire sample into high-, medium- and low-tech industries. The classification is as per the OECD classification, which classifies industries on the basis of their R&D intensities. Table 6 presents the results.

Before we discuss the results, it needs to be mentioned that behavior of some of the drivers inducing firms to invest in R&D may be different depending upon the technology intensity of the industry, yet there can be some common factors influencing this decision. These include the size, age, and the extent of competition. Domestic competition to a large sized, and an old firm may force a firm to be more inclined to do R&D, but extent of investment may differ depending on the technology intensity of the industry. Factors like embodied or disembodied technology import, export intensity, and vertical integration may be more relevant for firms in the high technology intensity industries.

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 extent of R&D investment if firms belong to the high-tech sector. For the medium-tech sector, the R&D intensity declines as size increases (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. This might be due to the nature of the sector, which has standardized production process.

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. This implies that if a foreign subsidiary is in high technology intensive sectors, it needs to invest in R&D so as to adapt the technology to local conditions, but the extent of investment declines with rise in foreign equity points that overall investment may be in line with the philosophy of parent firm of relying on centralized labs. 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?

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 in contrast to what Kumar and Siddharthan (1994) found in their study. 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.

(c) *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 extent of ownership of foreign firms. Ownership determines the residual control rights, that is, who has the right to use assets beyond what is stipulated in a contract. These rights influence surplus sharing and investment decisions (Gonzalez Perez, 2005). An industry dominated by majority-owned foreign firms would expect greater involvement of parent companies. This is likely to result in a significant increase in total investments, in investments in embodied and disembodied technology, in the use of automatic and computerized equipment, an improvement in the skill profile of the workers, as well as increase in R&D investment (*ibid.*). The implication of this would be larger spillver potential for local firms.

On the other hand, there are reasons why R&D orientation of majority-owned foreign firms should be less than that of minority-owned ones. Majority-owned firms, though are likely to generate more spillover effects (Javorcik & Spatareanu, 2005), have an access to parents' technology and R&D decision of these firms is often dictated by parent firm's policy as well as governed by host country's patents laws. Since India had weak intellectual property right regime until recently (Feinberg & Majumdar, 2001), both of these would have an attenuated effect on R&D decision of majority-owned firms. 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. Thus, which of the two effects dominate in the Indian case needs to be seen. The univariate comparison reveals that

Table 7. *Heckit estimation results with firms classified based on ownership*

Sl. No.	Variable	Majority ownership (>50)		Minority ownership (<50)	
		Coeff. (1)	Std. err. (2)	Coeff. (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: standard errors are generated using Bootstrap with 1,500 replications.
* Denotes 10% level of significance respectively.
** Denotes 5% level of significance respectively.
*** Denotes 1% level of significance respectively.

minority-owned[17] 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 7 lists the results of the estimations for both categories of firms depending on the extent of foreign ownership.

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 later 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. This is in line with what Annique (2008) found in their study. 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 behavior, 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 behavior. If firms are exporting to countries less developed than India, export may have limited or no influence on R&D behavior. 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 and R&D are complements for domestically owned firms when sample is divided based on equity ownership of foreign firms. FDI, however, induces foreign firms in high technology intensive sectors and those having minority share to invest in R&D. Majority equity ownership and R&D decision of firms is found to be substitute in nature. In all other specifications, FDI inflow does not have any impact in both selection and outcome equations. 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. 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 examined the relationship between FDI inflow and R&D behavior 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 corrected for the self-selection problem by using a Heckman-two step procedure.

Descriptive statistics show that the technological efforts in the form of R&D have declined marginally for both categories of firms during the study period. We also find that firms are increasingly depending on technology imports. The removal of restrictions on the imports during the reform period might has played a catalytic role in this phenomenon. The econometric analysis involving full sample firms failed to produce a clear picture of the impact of FDI on the innovation strategies of domestic firms. However, when analysis was carried out with sample bifurcating in two categories depending on ownership of foreign firms, FDI inflow and R&D decision of domestic firms was found to be complementary in nature. FDI, however, induces foreign firms in high technology intensive sectors and those having minority share to invest in R&D. Majority equity ownership and R&D decision of firms are found to be a substitute in nature giving credence to the conjecture that having access to parent's technology acts as disincentive for foreign firms to invest in R&D. FDI inflow does not have any impact on the extent of R&D in most specifications.

The literature on R&D spillovers examines the issue of whether knowledge created by firms' R&D and patenting activities enhances the productivity of other firms *via* a spillover process. It is now well documented that the Indian policy goals of industrial development, growth, and equity in sixties and seventies resulted in a weak R&D appropriability regime. The situation was more or less same till India embarked on a newer patent regime in 2005. In such an environment, this would have led to significant spillovers from technological development activities if firms were willing to undertake R&D activities. But such a policy environment also limited the activities MNCs could undertake in the local market, thereby attenuating the spillovers. The results obtained can thus be looked in this broader perspective of whether opening of foreign investment policy in the restricted appropriability regime led to a commensurate increase in spillovers or not.

Another important policy implication of the present study is can we have single policy toward FDI when response of firms to R&D decision is different depending upon the nature of industries? The investment in R&D being one of the surest ways of increasing the absorptive capacity having direct implication for competitiveness and spillover absorption potential of the firms. Since FDI is not affecting R&D behavior of all the domestic firms, more directed incentives are needed for the firms to invest in R&D to increase their competitiveness and 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.

The study though has come up with important policy implications, opens up a number of avenues for future research. A limitation of the present study is the use of only stock exchange-listed firms. There are few large Indian firms that are not listed but may have responded to foreign firm by investing in R&D. Since ownership is a key determinant of investment decision (Gonzalez Perez, 2005), from property rights theory, 100% foreign subsidiaries especially in industries that rely on technological innovations may be more inclined to do R&D in the new patent and liberalized regime. The present analysis need to be extended to include those firms to give a complete picture of manufacturing industries. 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 these R&D centers on the behavior of other domestic firms. Another direction of future research is inclusion of small and privately-owned firms. Evidence exists that some of the 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 behavior in the post-1991 scenario.

NOTES

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. See Görg and Greenaway (2004) for an excellent survey of literature.

3. 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".

4. 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.

5. 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.

6. The magnitude of FDI inflows into India has increased fifteen fold from US$ 155 million in 1991 to US$ 2,514 million in 2006 (Data Source: Secretariat for Industrial Assistance (SIA) newsletters, various issues).

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

8. We define foreign firms as those having foreign promoters' share $\geqslant$10%. This is consistent with the definition of foreign firms as given by the Reserve Bank of India.

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 Saqib (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 dataset does not contain these industries, simultaneity bias may not exist.

10. The PROWESS database has been widely used in studies to analyze different issues pertaining to FDI (see for example, Kathuria (2002), Kumar and Aggarwal (2005). At the outset, we would like to mention that there are certain closely held domestic firms and 100% foreign subsidiaries which are unlisted and may be doing R&D. These firms are not included in the PROWESS data base. This is one of the limitations of the present study.

11. In this context, even if actual entry does not take place, the threat of potential entry is enough to change firms' behavior (Schumpeter, 1942; Dunning 1993).

12. Based on the authors' calculations from the Prowess data base.

13. 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.

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

15. Based on the authors' own calculations from the Prowess data base.

16. Source: own calculations from the Prowess data base.

17. In the present study, firms with more than 50% promoters' share have been designated as majority-owned firms, whereas firms with <50% promoters' share are designated 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.

REFERENCES

Acs, Z. J., & Audretsch, D. B. (1988). Innovation in large and small firms: An empirical analysis. *American Economic Review, 78*(4), 678–690.

Aggarwal, A. (2000). Deregulation, technology imports and in-house R&D efforts: An analysis of the Indian experience. *Research Policy, 29*(9), 1081–1093.

Aggarwal, A. (2002). Liberalization, multinational enterprises and export performance: Evidence from indian manufacturing. *Journal of Development Studies, 38*(2), 119–137.

Amemiya, T. (1984). Tobit models: A survey. *Journal of Econometrics, 24*(1–2), 3–61.

Annique, U. A., & Cuervo-Cazurra, A. (2008). Do subsidiaries of foreign MNEs invest more in R&D than domestic firms?. *Research Policy, 37*(10), 1812–1828.

Basant, R. (1997). Technology strategies of large enterprises in Indian industry: Some explorations. *World Development, 25*(10), 1683–1700.

Basant, R., & Fikkert, B. (1996). The effects of R&D, foreign technology purchase, and domestic and international spillovers on productivity in Indian firms. *Review of Economics and Statistics, 78*(2), 187–199.

Beers, V. (2004). Multinationals and the knowledge economy in small countries. *Economic Bulletin, 41*(6), 205–208.

Bertschek, I. (1995). Product and process innovation as a response to increasing imports and foreign direct investment. *Journal of Industrial Economics, 63*(4), 341–357.

Braga, H., & Willmore, L. (1991). Technological imports and technological effort: An analysis of their determinants in Brazilian firms. *Journal of Industrial Economics, 39*(4), 421–432.

Cantwell, J. (1989). *Technological Innovations and Multinational Enterprises*. Oxford: Basil Blackwell.

Caves, R. E. (1974). Industrial organisation. In J. H. Dunning (Ed.), *Economic analysis and the multinational enterprise*. Allen & Unwin: London.

Caves, R. E. (1996). *Multinational enterprise and economic analysis* (2nd Edition). Cambridge, MA: Cambridge University Press.

Chuang, Y., & Lin, C. (1999). Foreign direct investment, R&D and spillover efficiency: Evidence from Taiwan's manufacturing firms. *Journal of Development Studies, 35*(4), 117–137.

Cohen, W. M., & Levinthal, D. A. (1989). Innovation and learning: The two faces of R&D. *Economic Journal, 99*(397), 569–596.

Deolalikar, A. B., & Evenson, R. E. (1989). Technology production and technology purchase in Indian industry: An econometric analysis. *Review of Economics and Statistics, 71*(4), 687–692.

DST (2006), *Research and Development in Industry—2005–06*, Department of Science and Technology, New Delhi.

Dunning, J. H. (1993). *Multinational enterprises and the global economy*. Addison-Wesley, Reading.

Fan, C. S., & Hu, Y. (2007). Foreign direct investment and indigenous technological efforts: Evidence from China. *Economics Letters, 96*(2), 253–258.

Feinberg, S. E., & Majumdar, Sumit. K. (2001). Technology spillovers from foreign direct investment in the indian pharmaceutical industry. *Journal of International Business Studies, 32*(3), 421–437.

Feldman, M. P. (2000). Location and innovation: The new economic geography of innovation, spillovers, and agglomeration. In G. Clark, M. Feldman, & M. Gertler (Eds.), *Oxford Handbook of Economic Geography*. Oxford: Oxford University Press.

Globerman, S., & Meredith, L. (1984). The foreign ownership-innovation nexus in Canada. *Columbia Journal of World Business, 19*(4), 53–62.

Gonzalez Perez-, F. (2005) The impact of acquiring control on productivity, working paper, Columbia University (also available at http://catalogue.polytechnique.fr/site.php?id=332&fileid=2272 accessed on April 15, 2010).

Görg, H., & Greenaway, D. (2004). Much ado about nothing? do domestic firms really benefit from foreign direct investment?. *World Bank Research Observer, 19*(2), 171–197.

Greene, W. (2003). *Econometric Analysis* (5th ed.). New York: Prentice Hall.

Gustavsson, P. and Poldhal, A. (2003), "Determinants of firms R&D: evidence from Swedish firm level data", *FIEF Working Paper No. 190*, Stockholm School of Economics and Trade Union Institute for Economic Research.

Heckman, J. J. (1979). Sample selection bias as a specification error. *Econometrica, 47*(1), 153–161.

Helfat, C. E. (2000). Guest editor's introduction to the special issue: The evolution of firm capabilities. *Strategic management Journal, 21*(Summer special issue), 955–959.

Hill, R. C., Adkins, L., & Bender, K. (2003). Test statistics and critical values in selectivity models. In T. B. Fomby, & R. C. Hill (Eds.), *Advances in econometrics: Maximum likelihood estimation of misspecified models: Twenty years later*. Elsevier Science: Amsterdam.

Hu, A. G. Z., Jefferson, G. H., & Jinchang, Q. (2005). R&D and technology transfer: Firm-level evidence from Chinese industry. *Review of Economics and Statistics, 87*(4), 780–786.

Javorcik, B. S., & Spatareanu, M. (2005). Disentangling FDI spillover effects: What do firm perception tell us. In T. H. Moran, E. Graham, & M. Blomstrom (Eds.), *Does foreign direct investment promote development?*. Washington: Institute for International Economics.

Kathuria, V. (2000). Productivity spillovers from technology transfer to Indian manufacturing firms. *Journal of International Development, 12*(2), 343–369.

Kathuria, V. (2001). Foreign firms, technology transfer and knowledge spillovers to Indian manufacturing firms—a stochastic frontier analysis. *Applied Economics, 33*(5), 625–642.

Kathuria, V. (2002). Liberalisation, FDI and productivity spillovers an analysis of Indian manufacturing firms. *Oxford Economic Papers, 54*(4), 688–718.

Kathuria, V. (2008). The impact of FDI inflows on R&D investment by medium- and high-tech firms in India in the post-reform period. *Transnational Corporations, 17*(2), 45–66.

Kathuria, V., & Das, S. (2005). Impact of FDI on R&D strategies of firms in the post-1991 era. *IIMB Management Review, 17*(2), 17–28.

Katrak, H. (1985). Imported technology, enterprise size and R&D in a newly industrialising country: The Indian experience. *Oxford Bulletin of Economics and Statistics, 47*(3), 213–230.

Katrak, H. (1989). Imported technology and R&D in a newly industrialising country: The experience of Indian enterprises. *Journal of Development Economics, 31*(1), 123–139.

Katrak, H. (1997). Developing countries imports of technology, in-house technological capabilities and efforts: An analysis of the Indian experience. *Journal of Development Economics, 53*(1), 67–83.

Krugman, P. (1991). Increasing returns and economic geography. *Journal of Political Economy, 99*(3), 483–499.

Kumar, N. (1987). Technology imports and local R&D in Indian manufacturing. *Developing Economies, 25*(3), 220–233.

Kumar, N. (2001). Determinants of location of overseas R&D activity of multinational enterprises: The case of US and Japanese corporations. *Research Policy, 30*(1), 159–174.

Kumar, N., & Aggarwal, A. (2005). Liberalisation, outward orientation and in-house R&D activity of multinational and local firms. *Research Policy, 34*(4), 441–460.

Kumar, N., & Saqib, M. (1996). Firm size, opportunities for adaptation, and in-house R&D activity in developing countries: The case of Indian manufacturing. *Research Policy, 25*(5), 712–722.

Kumar, N., & Siddharthan, N. S. (1994). Technology, firm size and export behavior in developing countries. *Journal of Development Studies, 31*(2), 288–309.

Lall, S. (1993). Promoting technology development: The role of technology transfer and indigenous effort. *Third World Quarterly, 14*(1), 95–108.

Lee, J. (1996). Technology imports and R&D efforts of Korean manufacturing firms. *Journal of Development Economics, 50*(1), 197–210.

Moran, T. (1998). *Foreign direct investment and development: The new policy agenda for developing countries and economies in transition*. Washington DC: Institute for International Economics.

Mytelka, L. K. (1987). Licensing and technology dependence in the Andean group. *World Development, 6*(4), 447–459.

Nelson, R. R. (2004). The challenge of building an effective innovation system for catch-up. *Oxford Development Studies, 32*(3), 365–374.

Nelson, R. R., & Pack, H. (1999). The Asian miracle and modern growth theory. *Economic Journal, 109*(458), 416–436.

Nelson, R. R., & Wolff, E. (1997). Factors behind cross-industry differences in technical progress. *Structural Change and Economic Dynamics, 8*(2), 205–220.

Odagiri, H. (1983). R&D expenditures, royalty payments and sales growth in Japanese manufacturing corporations. *Journal of Industrial Economics, 32*(1), 61–71.

Pack, H., & Saggi, K. (1997). Inflows of foreign technology and indigenous technological development. *Review of Development Economics, 1*(1), 81–98.

Pradhan, J. P. (2002). Liberalization, firm size and R&D performance: A firm level study of Indian pharmaceutical industry. *Journal of Indian School of Political Economy, 14*(4), 647–656.

Puhani, P. A. (2000). The Heckman correction for sample selection and its critique. *Journal of Economic Surveys, 14*(1), 53–68.

Rao, K. S., Murthy, M. R., & Ranganathan, K. V. K. (1999). Foreign direct investment in the post-liberalisation period: An overview. *Journal of Indian School of Political Economy, 9*(2), 423–454.

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy, 98*(5), S71–S102.

Schumpeter, J. A. (1942). *Capitalism, socialism and democracy*. New York: Harper and Row.

SIA (2002), *SIA Newsletter—Annual Issue*, Ministry of Commerce and Industry, Government of India, New Delhi.

Siddharthan, N. S. (1988). In-house R&D, imported technology and firm size: Lessons from Indian experience. *Developing Economies, 26*(3), 212–221.

Siddharthan, N. S. (1992). Transaction costs, technology transfer, and in-house R&D: A study of the Indian private corporate sector. *Journal of Economic Behaviour and Organization, 18*(2), 265–271.

Stewart, F., & Ghani, E. (1991). How significant are externalities for development?. *World Development, 19*(6), 569–594.

Tomiura, E. (2003) "Firm-level relationship between technological capability and foreign direct investment", No 138, Discussion Paper Series from Research Institute for Economics & Business Administration, Kobe University.

Vella, F. (1998). Estimating models with sample selection bias: A survey. *The Journal of Human Resources, 33*(1), 127–169.

Veugelers, R., & van den Houte, P. (1990). Domestic R&D in the presence of multinational enterprises. *International Journal of Industrial Organisation, 8*(1), 1–15.

Zhao, H. (1995). Technology imports and their impact on the enhancement of China's indigenous technological capability. *Journal of Development Studies, 31*(4), 585–602.