FDI, TECHNOLOGICAL CHOICES AND SPILLOVERS IN AN EMERGING MARKET ECONOMY: A STUDY OF INDIAN MANUFACTURING INDUSTRIES

Maitri Ghosh* and Saikat Sinha Roy[1]**

Abstract: With inflow of FDI and MNE operations in the Indian economy since the 1990s, the domestic firms had to face a very crucial issue of technological choice in the face of competition. On one hand, technology could be imported in both embodied and disembodied form, while on the other; thrust could be given to develop local R&D. Again, there could also be a possibility of combining both. This paper tries to analyze the factors influencing the firms' technological choices across high technology, medium-high technology, medium-low technology and low-technology industries during post reforms. In this process, the role of the ownership of firms and technological spillovers is taken into account. A logit framework is constructed to empirically explore the technology choice determinants. Results suggest that foreign ownership and technological spillovers have significant effect on the technology choices of most manufacturing firms in India. Dependence on imported foreign technical know-how is also evident.

JEL Classification No.**:** F23, O33, C 33

Key words**:** FDI, Multinational Enterprises, Technological choices, Technological spillovers, Logit estimation.

1. Introduction

Foreign Direct Investment (FDI) flows together with technology play a critical role in improving international competitiveness and aiding growth in emerging market economies. For instance, Ghosh and Sinha Roy (2013), Kumar and Joseph (2005) have investigated the international competitiveness following increased FDI flows in India since 1991. FDI has emerged as the major channel of international diffusion of

[1] *Assistant Professor, Bethune College, 181 Bidhan Sarani, Kolkata – 700 006. INDIA. E-mail: maitri_ghosh@yahoo.com
**Associate Professor, Department of Economics, Jadavpur University, Kolkata – 700 032. INDIA. E-mail: saikat.sinharoy@gmail.com (Corresponding Author)
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knowledge and technology transfer (Kumar, 1995) as against transfer through arm's length licensing of technology. With FDI flows to developing countries mainly through Multinational Enterprises (MNEs), the knowledge pool of parent firms get transferred to the firm in host country which can potentially generate technology spillovers. It has been increasingly recognized that foreign firms contribute, directly or indirectly, to the innovative activities of the host country firms (Lall, 1993).

India pursued 'closed technology policy' with an emphasis on self reliance during the 1970s and the 1980s (Basant, 1997). This restrictive technology policy regime ended with economic reforms in the 1990s. With large volume of FDI inflows into the economy across sectors, domestic firms started facing considerable competition from the MNEs. In face of this competition from foreign firms, the domestic firms reviewed their technology strategies by either investing in indigenous R&D or importing foreign technology or both. In this context two strands of arguments emerged. First, in developing economies including India who are technology followers, it is expected that with the MNEs operating, there would be an increase in dependence on imported technology, embodied and disembodied (Kumar and Saqib, 1996; Katrak, 1997; Evenson and Joseph, 1999; Aggarwal, 2000); second, manufacturing industries in the face of competition, have to evolve their own technology (Kumar, 1995). Access to technology and its development across manufacturing sectors in India thus evolved as a combination of production and purchase. Again, following Basant (1997), the choice of technology and the response in the presence of MNEs vary across sectors. Thus, an analysis of the determinants of the firm-level technology choices across sectors during reforms is called for. This paper investigates into the role of ownership, technological spillovers (both domestic and foreign) among other variables in explaining technological choices at the firm level for some high technology, medium high technology, medium low technology and low technology industries[2]. This paper builds on the recent works of Basant (1993, 1997), Basant and Fikkert (1996), Kathuria (2000).

There is a rich body of theoretical and empirical literature with regards to the impact of technology transfer to host developing countries. Early theoretical literature on R&D activities of MNEs concentrated on product adaptation. This predominantly considered cross border transfer of mature technologies as the dominant motive for decentralization of R&D geographically [Vernon (1974), Caves (2006), Dunning (2000), Lall (1979)]. The determinants of such global spread of R&D activities of the MNEs can be traced into the two forces which on one hand, compel the MNEs to keep R&D as a headquarter function (centripetal factors) and those which pull it away from the centre into peripheral locations (centrifugal factors), Caves (2006). The centrifugal forces operate because there may be a need to adapt production processes and characteristics of products to meet local conditions. Again, MNEs may undertake R&D overseas in order to benefit from localized technology spillovers in these locations with a view to maintain a competitive edge. With the recent works of Ronstadt (1997),Pearce (1999), Bikinshaw and Morrison (1995), Vernon (2000) it is now being suggested that the technology seeking motive itself has become a significant contributor in disseminating R&D by MNEs particularly in the R&D intensive sectors. In sharp contrast to the conventional R&D departments to adopt established mature technology, the modern knowledge

[2] The classification of manufacturing industries into categories is based on R&D intensities (ISIC Revision 3). However, we have considered chemicals as high technology industry as it is inclusive of drug and pharmaceuticals.

seeking R&D laboratories seek for geographically differentiated frontier technology with the motive to preserve the technological lead of the MNE.

Along with the process of developing new technologies, MNEs form one of the major channels of technology spillovers. Findlay (1978), Das (1987), Wang and Blomstrom (1992) contributes to the theoretical literature focusing on the effects of the presence of the MNEs on the technology development of the host country. Findlay (1978) formulates a dynamic model to analyze the role played by the MNEs in the process of technological transfer to the LDCs. However, his model could not draw any welfare implications as the model did not consider any domestic welfare function. Das (1987) extended Findlay's model by considering that there are technological spillovers from the subsidiary to the host country firms which depend proportionally on the output level of the MNC subsidiary. So higher is the production level of the subsidiary, the higher is the productivity spillovers received by the domestic firms.

The empirical literature again has spawned into two different approaches. The first approach tries to find a link between technology imports and local R&D while the second relates to the diffusion of the imported technology through knowledge and productivity spillovers to the locally owned firms. The nature of the relationship between technology imports and local R&D has been a matter of debate. For some (Blumenthal 1979, Lall 1993, Katrak 1985), the relation is complementary while for some others (Kumar, 1987; Basant and Fikkert, 1996; Kathuria and Das, 1997; Chuang and Lin, 1999; Fan and Hu 2007) foreign technology import substitutes local R&D. On one hand it is recognized that foreign firms can contribute directly or indirectly to the innovative activities in the host country as foreign firms engage in technological activities to adapt to the host country conditions, while the domestic firms in presence of competition from foreign firms may invest in technological activities. On the other hand, there is some amount of skepticism about the technological efforts of foreign firms in the host country as MNCs have easy access to the parent firm's technology (Globerman and Meredith 1984, Fan and Hu, 2007).As R&D is uncertain, involving huge costs and gestational lags, domestic firms might not opt for in-house R&D, but procure technology from abroad. A large number of studies including Kumar (1987), Basant and Fikkert(1996), Kathuria and Das(2005) , Veugeler and Van den Houte (1990) , Lee (1996) , Fan and Hu (2007) among others find substitutability between technology imports and domestic R&D. Again, Lall (1983) found a complementary relationship with adaptive R&D in Indian Engineering industries. Sasidharan and Kathuria (2011) show that FDI inflow induces foreign owned firms in high technology industries and in firms in minority ownership to invest in R&D. Nelson (2004), Toimura (2003), argues in favor of complementarity with a view that MNCs will undertake R&D to suit to local conditions. Again, as R&D is expensive, MNE affiliates can bear it as their parent firm has easy access to capital market. Kumar and Aggarwal (2005), shows for India that the local firms' direct R&D activity is primarily towards the assimilation of imported technology and to provide a backup to their outward expansion via exports and FDI, while the MNEs focus on exploiting the advantages of India as an R&D platform. The evidence is thus not conclusive of whether imported technology in coming in the way of local innovation or paving the way of domestic R&D. This is particularly intriguing when there is a difference in the behavioral pattern of the MNEs and domestic firms. Such differences in technology behavior pattern between MNEs and domestic firms conform to the observations by Caves (1974). This is particularly true for emerging market economies like India.

While encouraging FDI, developing economies hope not only to import more efficient foreign technical expertise but also to generate technological spillovers for the domestic firms. Such spillovers might occur through the potential channels of demonstration effects, labor turnover or vertical linkages. The initial econometric studies consider presence of spillover if a positive correlation between FDI and productivity is found. Caves (1974) confirm positive spillover effect of FDI in Canadian and Australian manufacturing sector. Globerman (1979) also arrived at similar results using Canadian manufacturing industries. Blomstrom and Perssion (1983), using data on Mexican manufacturing industries, found a strong evidence of FDI spillovers. Blomstrom (1986) using data on Mexican manufacturing industries found that the foreign firms have significant effect on the average productivity of the industry. Further, Blomstrom and Wolff (1989) found increasing convergence of productivity levels of locally owned firms and foreign owned firms in Mexican industries during 1965-1984. The rate of productivity growth of local firms was found to be positively related to the degree of foreign ownership of an industry. Branstetter (2005) results provide evidence on FDI as a channel of knowledge spillovers for Japanese manufacturing industries. Yao and Wei (2006) find that FDI is the prime mover of production efficiency as it helps to reduce the gap between the actual level of production and the steady state production frontier and that FDI with high technology and knowledge is a shifter of the home country's production frontier. Haddad and Harrison (1991) found that FDI helped in reducing the productivity gap in low technology Moroccan industry. Chang and Chung (2007) focused of technological spillovers from foreign to local firms and also strong spillover effects among local firms. Again Feinberg and Majumder (2001), find R&D spillovers among the MNEs only in the Indian Pharmaceutical industry.

Spillover effects of FDI can also be observed by analyzing how technology import from the foreign firms affects the various industry characteristics. For instance, Blomstrom, Kokko and Zejan (1994) established a significant relationship between technology imported by the foreign affiliates and the local competitors' investment and output growth and labor skills. Dasgupta (2012) show diffusion of knowledge spillovers from foreign firms on welfare, wages and occupational choice. Javorcik (2012) investigates whether productivity of domestic firms is correlated with the presence of multinationals in downstream sectors or the upstream industries. Results show evidence of positive productivity spillovers taking place through contact of the foreign affiliates and their local suppliers. Bwalya (2006) studies the nature and significance of productivity externalities of FDI to local firms both in terms of intra industry and inter industry spillovers. Significant vertical knowledge spillovers are found to occur through backward linkages from foreign firms in upstream sectors to local firms in downstream sectors. Liu (2006) derives similar results for Chinese manufacturing.

The studies discussed so far suggest that foreign investment creates spillover effects. However, there are studies which present a more nuanced view. Aitken and Harrison (1999) using production function approach for some Venezuelan plants, find the presence of a positive relationship between foreign equity share and the plants' productivity only in small firms. When spillovers from joint ventures to firms with no foreign investment were tested, a spectacular negative effect was found on the domestic firms' productivity. Okamoto (1999) finds that the Japanese industries were less productive than their US counterparts and technology transfer from Japanese to US firms only partially explains the improvement of the performance of the US firms between 1982 and 1992.Cantwell (1989) found spillovers to be significant only in industries where the technology gap between local and foreign firms was low. Kokko (1994) shows the existence of spillovers in both low and high technology industries. Kokko inferred that technology spillovers do not generally occur in technologically complex industries. Similar results are arrived at by Tsou and Liu (1994).

In the Indian context, Basant and Fikkert (1996), using panel data on Indian firms from 1974 -75 to 1981-82, show high and significant private returns to technology purchases and the private returns to the firms' own R&D expenditures to be lower and insignificant. They also found evidence of both international and domestic R&D spillovers. Kathuria (2001) finds that the presence of foreign owned firms and disembodied technology import lead to higher productivity growth for domestically owned firms. The results thus suggest presence of knowledge spillovers from the foreign to the domestic firms belonging only to the 'scientific' sub sectors, provided the firms themselves engage in R&D activities. Marin and Sasidharan (2008), in terms of an alternative model, show that only creative MNE subsidiaries in India have positive effects on innovative capacity of host country firms. In all these models of international diffusion of technology and technology transfer, what stands out to be of importance is the individual firm's choice of technological activity.

This paper explores into firm-level technological choices in Indian manufacturing and the determining factors of such technological choices during post reforms. In this context, the role of ownership and technological spillovers is accounted for. The paper is organized as follows. Section 2 provides some stylized facts on the overall trends in technological choices of the Indian manufacturing industries during 1991-2010. Section 3 discusses the analytical framework, the empirical model and method and the database for analyzing the determinants and spillover effects of firm- level technological choices. Section 4 presents the empirical results. Section 5 summarizes the major findings of the paper stating the implications for policy.

2. Technology Development in India since 1991

Technology acquisition pattern across Indian manufacturing firms has evolved with the technology policy framework. Changes in technology policies in India may be broadly understood in three distinct phases. Following a regulated regime of technology development till the 1980 and a phase of selective deregulation during 1980 to 1990, an open technology policy regime was pursued since 1991. In this last phase the thrust is on removal of reservations against foreign firms, thus enhancing the scope of the foreign firms to operate in the domestic market. This led to the expansion of the existing foreign enterprises and also allowed entry of new foreign firms into the Indian market. With increasing FDI inflows across manufacturing sectors, firms ought to have responded with regards to their technological choices.

With import of technology becoming cheaper and easier, firms can prefer technology imports instead of investing on R&D (Kathuria, 2008). Again, investment in indigenous R&D is essential to face competition in an open economy as well as to adapt imported technology. Hence the choice of "making" or "buying" technology or combining the two becomes crucial. To understand the patterns in firm level technological choices, we have looked at average R&D intensity, capital good import intensity, foreign technology intensity and raw-material import intensity of different sectors. This non-econometric analysis is done for the pre-and post-2000 phases as it is evident that FDI increased substantially between the two phases and it can be perceived that technology acquisition by firms also improved in a similar way.

Table 1 suggests that firm-level R&D intensity increased in the post 2000 period for all the high-technology and the medium-high technology industries like chemicals, machinery and transport equipments. The medium-low technology industries do not seem to expend on R&D on an average. For the low technology industries like the food and beverages, only a marginal increase in the R&D expenditure is noticed in the post 2000 period. Capital good import intensity on the contrary, shows a declining trend in the post 2000 period across sectors except machinery. This declining intensity as Pillai and Srinivasan (1987) argue, is largely on account of the pattern of use of such goods with relatively longer time span. With globalisation and the operation of the MNEs, the import of disembodied technology in the form of foreign technical knowhow, drawings, designs etc. is expected to increase due to increased access to global technology market. Table 1 suggests that for the industries like chemicals and transport equipment, foreign technology intensity increase in the post 2000 period. For the medium-low technology and the low technology industries, however, foreign technology intensity fell in the post 2000 scenario. This trend is constistent with the results of Pradhan and Puttaswamaiah (2005).Import of raw materials is one of the major sources of acquiring knowledge from rest of the world and in achieving cost competitiveness by using cheaper inputs. There has been a significant rise in the raw material import intensity across industries especially in case of transport equipments, machinery, textiles and metals in the post 2000 period.

Table 1: Expenditure on Technology as a Share of Sales (Pre and Post 2000)

High / Medium High-Tech Industries						
	Chemicals		**Transport Equipment**		**Machinery**	
	Pre 2000	*Post 2000*	*Pre 2000*	*Post 2000*	*Pre 2000*	*Post 2000*
R&D intensity	.001	.006	.0001	.0004	.0003	.001
Capital Good Import intensity	.007	.003	0.23	0.02	.006	.006
Foreign technology intensity	.0005	.019	0.002	.001	.002	.001
Raw material import intensity	.055	.074	1.29	9.96	2.21	20.12
Medium-Low/Low –Tech industries						
	Food and beverages		**Textiles**		**Metals**	
	Pre 2000	*Post 2000*	*Pre 2000*	*Post 2000*	*Pre 2000*	*Post 2000*
R&D intensity	.003	.005	neg	neg	neg	neg
Capital Good Import intensity	.007	.002	0.053	0.009	.004	.003
Foreign technology intensity	.0006	neg	0.022	0.001	.001	.0002
Raw material import intensity	.003	.005	2.59	16.80	1.97	21.36

Source: Calculations based on CMIE database; Note: neg denotes negligible

There are further nuances to these trends once we try to look into the expenditures of the domestic and foreign firms separately (Tables 2 and 3). For the chemical industry, R&D intensity, foreign technology intensity and raw material import intensity rise after 2000 for both domestic and foreign firms. However, capital good import intensity declines for domestic firms in contrast to rising intensity for foreign firms in this period

Table 2: Expenditure on Technology for the Domestic Firms

	Chemicals (Domestic)		Transport Equipment (Domestic)		Machinery (Domestic)	
High –Tech Industries						
	Pre 2000	*Post 2000*	*Pre 2000*	*Post 2000*	*Pre 2000*	*Post 2000*
R&D intensity	.001	.005	.001	.005	.003	.001
Capital Good Import intensity	.007	.003	.244	.019	.006	.006
Foreign technology intensity	.0005	.020	.002	.001	.002	.0008
Raw material import intensity	.056	.077	.021	.033	2.09	.001
Low/Medium –Tech industries						
	Food and beverages (Domestic)		**Textiles (Domestic)**		**Metals (Domestic)**	
	Pre 2000	*Post 2000*	*Pre 2000*	*Post 2000*	*Pre 2000*	*Post 2000*
R&D intensity	neg	neg	neg	.0001	neg	neg
Capital Good Import intensity	.007	.003	.052	.009	.005	.003
Foreign technology intensity	neg	neg	.021	.0009	.001	.0002
Raw material import intensity	.003	.005	.026	.0001	0.02	0.19

Source: Calculations based on CMIE database; Note: neg denotes negligible

Table 3: Expenditure on Technology for the Foreign Firms

High –Tech Industries						
	Chemicals (Foreign)		**Transport Equipment (Foreign)**		**Machinery (Foreign)**	
	Pre 2000	*Post 2000*	*Pre 2000*	*Post 2000*	*Pre 2000*	*Post 2000*
R&D intensity	neg	0.01	neg	neg	.0002	.0009
Capital Good Import intensity	.0008	.006	neg	0.04	.006	.004
Foreign technology intensity	.0001	.005	neg	.002	.004	.003
Raw material import intensity	.04	0.16	neg	0.09	2.78	22.6
Low/Medium –Tech industries						
	Food and beverages (Foreign)		**Textiles (Foreign)**		**Metals (Foreign)**	
	Pre 2000	*Post 2000*	*Pre 2000*	*Post 2000*	*Pre 2000*	*Post 2000*
R&D intensity	.0002	.0002	neg	neg	neg	neg
Capital Good Import intensity	.008	.003	.003	neg	neg	neg
Foreign technology intensity	.007	.001	.016	neg	neg	neg
Raw material import intensity	.015	.008	.64	neg	neg	.049

Source: Calculations based on CMIE database; Note: neg denotes negligible

for this industry. In case of the food and beverages industry, expenditure on local research and development and imported raw materials for the domestic firms increase during post 2000, while technology import intensity in both embodied and disembodied forms falls. For foreign firms in the food industry, all the variables show a declining trend excepting local R&D intensity. It is interesting to note that, expenditure on import of raw materials for the domestic firms decline in the machinery industry. However, the ratio for foreign firms increased from 2.78 in the 1990s to 22.6 in the 2000s.In case of the transport equipment industry R&D intensity and raw material import intensity show a rising trend for the domestic firms, while all the factors increase for the foreign firms in the decade of 2000. Capital good import intensity however falls for the domestic firms during this period. In case of the metal industry, raw material import intensity rises in the post 2000s for the domestic as well as the foreign firms. Local R&D as well as imported technology intensities for the domestic firms in metal industry declined during the period. Interestingly, in the textile industry there is a fall in all the factors for the domestic and foreign firms alike in the post 2000 period.

On the whole, local R&D intensity increased for the high technology and the medium-high technology industries in the post reforms period. Dependence on imported raw materials also increased significantly across sectors post 2000. For chemicals and transport equipment industries, disembodies technology purchase shows an improvement. However, import of capital goods declined across sectors during post 2000.

3. Analytical Framework

The role of technology in determining a country's international trade and competitiveness has been emphasized in the neo-technology theories of trade (Posner, 1961; Vernon, 1966; Krugman, 1979, among others). The emerging literature has often shown that new technology generation and technology transfer has often determined economic growth. Borensztein, Gregorio and Lee (1998) show that adoption and implementation of technology already in use in leading countries determine economic growth of the developing country. With the global economy becoming more open and interdependent, the role of technology has become even more important. Since the phase of rapid economic growth in the 1950s and the 1960s or during the phase of relatively lower growth rates in the 1970s the MNCs have been the major agents of organizing economic activities. They dominate the world's pool of technology and retain their global position through a combination of technological innovation and a variety of other complementary assets like marketing and distribution networks. Many theories on international production have assumed that a parent MNC begins with an individual act of technology which is diffused abroad through the operations of its foreign affiliates. Such technological transfers have attracted quite a good deal of attention particularly for the emerging market economies like India.

The theoretical literature on FDI and technology spillovers started to emerge from the late 1970s. In contrast to the Dependency school theory, the Industrial Organisation theory recognizes the role of spillover effects of FDI (Hymer 1976). It was emphasized that a firm in order to undertake FDI in a foreign country must possess some special ownership advantage than the domestic competitors (Caves, 1974). MNCs while operating in other economies thus entail a cross border transfer of a variety of resources including process and product technology, managerial skills, marketing and distribution networks etc. Most of the theoretical models on FDI and technology transfers have a common characteristic of considering technology transfers as an externality from the MNEs to the local firms in the host economy. However, they differ in terms of interpretation of technology. While in some models, technology of foreign firms is assumed to be a kind of public good which is transferred automatically, in some other models, foreign technology is treated as a private good which is costly. Hence, the extent of technology transfers depends on the capacity of the local firms and their interaction with the foreign firms.

Koizumi and Kopecky (1977) are the first to model FDI and technology transfer. They develop a model of international capital movements and technology transfers in a small open economy assuming that technology transfer takes place when foreign capital creates externality in technology to the host country. They find that an increase in the savings rate of the country reduces foreign capital and steady state capital intensity through its effects on technical efficiency. Das (1987) uses price leadership model of a duopoly to examine technology transfer from parent to subsidiary firms abroad. Results suggest that the domestic firms learn from subsidiaries and become efficient. De Mello (1997) analyses the externalities of FDI in the stock of technology of the host economy. The results suggest that growth rate of an economy is positively associated with higher level of FDI. Wang and Blomstrom (1992) analyze international technology transfer through MNC in a game theoretic framework. Technology transfer in this model is assumed to be a process by which the foreign technology acquired by the foreign subsidiaries gets diffused to the domestic firms. Kabiraj and Marjit (2003), considering a duopoly model where a foreign firm competes in a host country, show that imposition of tariff may induce technology transfer from foreign to local firms thereby making the consumers better off in the host country. The theoretical literature thus justifies the inflow FDI, MNE operations and technology transfers in the host economy. In this process of technology transfer, the role of innovation and imitation efforts become very crucial and the question of technological choice thus becomes pertinent.

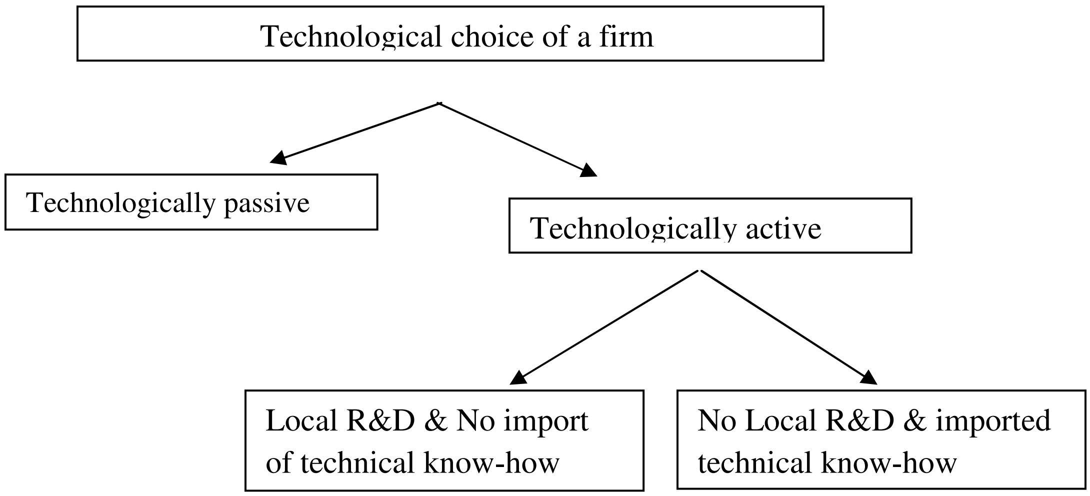
Technological choices of a firm can be influenced by a variety of factors. This paper studies industries which are hugely heterogeneous in nature and thus adhere to different technological paradigms. Hence the modes of technological choices vary widely across sectors. For some, adaptation of foreign technology to suit Indian conditions constitute the major component of indigenous technological effort, while for others, imported technology may not need any modifications at all (Basant, 1997). In case of industries like chemicals and metals, food and beverages where every technical operation maintains a rigid sequence, adaptation might not play a major role. However, for industries like machinery, transport equipments and textiles import of foreign designs and adaptation of the same might play a dominant role. Again firms within industries are heterogeneous and technological choices are expected to differ according to the firm ownership. Existence of spillovers both from foreign firms and indigenous technical efforts are also likely to affect the technological choices of firms across sectors. This is one such issue which is not much explored in the Indian context.

3.1 The Empirics

Following Basant (1997), we construct a model of a firm's strategy in the discrete choice framework. This is shown in Figure 1. As can be seen from the figure, the technical knowledge available to a firm can be broadly divided into three sources:

i. knowledge generated by the firm on its own
ii. knowledge purchased by the firm
iii. knowledge spillovers from other firms

Figure 1: A Schematic Framework of the technological choices of a firm



Knowledge generated by the firm on its own is basically its own R&D efforts. Knowledge purchased by the firm can be acquired through purchase of domestic technical knowhow[3], purchase of foreign technical knowhow, purchase of domestic inputs and purchase of foreign inputs. There can be knowledge spillovers from domestic firms and foreign firms.

3.2. The logit model

We analyze the firms' strategy assuming that a firm takes decision regarding its own R&D and import of foreign technology simultaneously. We consider two binary choices. This is done in two steps. First, considering all firms in each industry, we consider that firms can be technologically either active or passive. This binary choice of a firm takes the form[4]:

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[3] We are not dealing with technological licenses in this analysis due to data unavailability.

[4] The caveat in the analysis is that we have constructed a binary choice logit model instead of nested logit model.

S: Remaining technologically passive (neither LRD nor FPTR):0

Remaining technologically active (either LRD, or FPTR or both):1

Again, considering only the firms that are involved in technological activity we further construct a binary choice of technology of the firms in the following form:

M: Doing local R&D (LRD>0) and not importing foreign technical know-how (FPTR=0): 0

Not doing local R&D (LRD=0) and importing foreign technical know-how (FPTR>0):1

We, thus, construct a firm's binary response model[5] of the form:

$$P(y=1|x)= G(\beta_0+ \beta_1 x_1+\ldots\ldots+ \beta_k x_k)= G(\beta_0+\mathbf{x}\beta),$$

where $0<G(z)<1$, for all real numbers z and $\mathbf{x}\beta= \beta_1 x_1+\ldots\ldots+ \beta_k x_k$.

In the logit model, G is the logistic function:

$G(z) = \exp(z)/ [1+\exp(z)] = F(z)$, which is between 0 and 1 for all real numbers z. Hence, $\log F(z)/1-F(z)=z$. This kind of a logit model can be derived from an underlying latent variable model. Let y^* be an unobserved latent variable determined by: $y^*=\beta_0+\mathbf{x}\beta+e$, $y=1[y^*>0]$, where 1[.] defines a binary outcome. It is an indicator function which takes the value 1 if $y^*>0$ and 0 otherwise.

Again, e follows a standard logistic distribution. The latent variable formulation gives an impression that we are primarily interested in the effects if each x_j on y^* (Woolridge, 2006). For empirical comparisons we have computed the marginal effects which are the partial effects of the continuous variables to the response probability. If

[5] Statistical software used is STATA 10.

x_j is a continuous variable, its partial effect on p(x) =P(y=1|x) is obtained from the partial derivative: $\delta p(x)/\delta x_j = g(\beta_0 + \mathbf{x}\beta)\beta_j$, where, g(z)=dG(z)/dz, g(z)>0 for all z. In this kind of a structure, the model essentially computes the probability of a firm to choose a particular technological strategy, under certain given conditions.

Firm-level data is obtained from Prowess Database published by the Centre for Monitoring Indian Economy (CMIE) for the period 1991-2010 for the food and beverages, textiles, chemicals, metal and metal products, machinery and transport equipments industries. For the empirical estimation of the first binary choice, a total of 624 observations for the food & beverages industry, 1223 observations for the textiles and garments industry, 3231 observations for the chemicals industry, 637 observations for the metal and metal product industry, 1942 observations for the machinery industry and 592 observations for the transport equipments industry are obtained. For the analysis of the second binary choice, the sample size is restricted to the firms which are engaged in some form of technological activity. Thus 97 observations for the food and beverages industry, 307 observations for the textiles and garments industry, 911 observations for the chemicals industry, 89 observations for the metal and metal product industry, 583 observations for the machinery industry and 187 observations for the transport equipments industry are obtained. These observations include both domestically owned and foreign owned firms. We have constructed two period dummies Y1 and Y2 for the pre 2000 and post 2000 period.

The following variables have been constructed to capture the effects:

Firm Size (SIZE): Ratio of firm sales to industry sales.

Firm's own technological effort (LRD): Ratio of the R&D expenditure of the firms to sales.

Foreign technology purchase (FPTR): Ratio of forex payment for technical know-how and royalty to sales.

Technology purchase through capital import (KI): Ratio of imports of capital goods to sales

Technology purchase through raw materials (IMPR): Ratio of imports of raw materials to sales.

Technology embodied in domestic inputs (DOMIN): Technology embodied in domestic inputs measured by adding the domestic expenses on raw materials and domestic payment for technical know-how and royalty.

Foreign Technology Spillovers (FORSPILL): The foreign technology spillover variable for a particular firm has been constructed by aggregating foreign technology purchase at the industry level and subtracting foreign technology purchase expenses at the firm level.

Domestic Technology Spillovers (DOMSPILL): The total expense made on local R&D by the industry to which the ith firm belongs minus the local R&D expenses of the ith firm is the measure of domestic spillovers for the ith firm.

*MNC participation (*OWN): Dummy variable taking the value 0 if the firm is domestic and 1 if the firm is foreign.

Y1: Dummy taking the value 1 for the time period 1991-1999 and 0 for the time period 2000-2010.

Y2: Dummy taking the value 1 for the time period 2000-2010 and 0 for the time period 1991-1999.

In what follows is a discussion of the estimation results of the model across sectors.

4. The Empirical Results

Logit model estimation results showing the determinants of firm-level technological choices in India are presented in the Tables A.1-A.7 (See Appendix). Considering the Indian manufacturing as a whole (Table A.1), we find that foreign ownership, large size of firms, import of raw materials and spillovers from domestic as well as foreign firms play a very significant role in explaining the binary choice of the firms to become technologically active as against remaining passive. Results further suggest that foreign ownership, large size and import of capital goods significantly explain the probability of the firms to depend on disembodied foreign technology as against engaging themselves in local R&D. Domestic and foreign spillovers on the contrary significantly diminishes the probability to depend on foreign technical know-how for the Indian manufacturing as a whole. However, such results ought to be very industry specific. The various factors that explain the firm-level technological choices across industries are as follows.

Firm size

Size is considered to be one of the major determinants of technological activities of a firm (Sasidharan and Kathuria, 2010). Large firms have greater financial resources and higher scale of operations. Hence they are capable of undertaking a variety of research and development activities. Our estimation results suggest that a large firm size significantly increases the probability of the firms to be technologically active as against remaining passive. This is true for all industries excepting the food and beverages where the odds ratio does not reveal any significant influence of size on the choice of being technologically active relative to being technologically passive. Size of a firm also significantly increases the probability of importing foreign technical know- how relative to doing local R&D for the industries like chemical and transport equipment as well as the food and beverages and metal industries. Size of the firm however does not play any significant role in explaining the dependence on foreign technology for the textiles and machinery industries. This may be because of the fact that both textiles and machinery industries involve subcontracting where the parent firm provides the necessary raw materials to the small firms which in turn gives the product its final shape with indigenous technique and little capital.

Technology purchased through capital imports

In the developing economies, one of the major sources of technological transfer is through import of foreign technology. Import of capital good is import of technology in embodied form. Estimation results reveal that, in the post reforms period, import of capital goods do not play much of a role in explaining both the binary technological choices of most of the industries. The only exception is the metal industry. In this industry, import of capital good (KI) significantly affects the choice of a firm to be technologically active rather than being passive. Since 2006 India has been a very important exporter of iron and steel particularly to China. The possibility is that India possesses the world class raw material but probably not the world class technology. Hence, technology imported in embodied form provides a platform to invoke local innovation which in turn promotes exports. Again, for the machinery industry, with the import of capital goods, the probability of expending on foreign technical know-how increases significantly relative to expending on local R&D. Hence foreign technology in embodied form substitutes local R&D in this industry. This result is expected in the case of the medium-high technology industries like machinery as the processes are stringently sequenced and there is not much scope left for adaptation. Thus, often the firms do not have any incentive to further invest in local R&D. Again, as better process technology tend to be difficult to imitate or adopt from inspection of the final good, first-hand experience of the technology may be required. So expenses on domestic R&D are likely to come down. However, for the Indian manufacturing as a whole, import of technology in embodied form significantly increases the probability to import technology in disembodied form.

Technology purchase through raw materials

The probability of remaining technologically inactive steadily declines with the import of raw materials (IMPR) for the chemical, food and beverages, textile, transport equipment and machinery industries. The only exception is the metal industry, where the marginal effects show a fall in the probability of being technologically active with import of raw materials though not significantly. Interestingly, however, the dependence on foreign technical know- how significantly declines with import of raw materials for the chemical industry. This is because of the fact that for the Indian basic chemical industry as a whole, technology imports either in embodied or disembodied form and local R&D are substitutes. Most active firms focus on investing on only one of the technological strategies rather than investing in both simultaneously. In the transport equipment industry, on the other hand, import of raw materials significantly improves the probability to buy foreign techniques. In this case the Indian firms mostly being assemblers seem to have a strong dependence on foreign technical know-how as against the chemical industry which depends on adaptive technology.

Technology embodied in domestic inputs

The odds ratios suggest that the technology flows through domestic inputs purchases do not have much of a significant effect on the choice of becoming technologically active for almost all the industries. For the chemical, food and beverages and the textile industries technology flows through domestic inputs significantly diminish the probability to become technologically active as against remaining technologically passive. However, for chemical industry, technology purchased through domestic inputs significantly diminishes the probability to import foreign technological know–how.

Technology spillovers

Estimation results suggest that foreign technology spillovers significantly affect the technological choice of only the textile industry to become technologically active. Foreign technological spillovers however do not have any significant effect on this binary choice of the other industries. Interestingly, for the chemical industry, the choice to import foreign technical know-how substantially decreases with foreign technological spillovers. This however does not hold good for the other industries where positive effect of foreign spillovers is not noticed. Spillovers from domestic firms significantly increase the probability of the firms in the high tech industries like chemical and machinery and the medium tech industry like textile to be technologically active relative to the reference state of remaining technologically inactive. The marginal effects reveal that with an increase in spillovers in domestic firms, the choice of buying foreign technology significantly increases in the chemical and metals industry. However, domestic spillovers significantly diminishes the probability to expend on foreign technical know-how for the medium-high technology industries like machinery and transport equipment as well as the low technology industry like textiles. At the aggregative level both domestic and foreign spillovers significantly affect the choice of the firms to become technologically active. However, the choice to depend on foreign technical know-how significantly diminishes with both spillovers for Indian manufacturing.

Ownership*: *Participation of Multinationals

Foreign ownership plays a very significant role in the technology choice of becoming technologically active for the chemical and the machinery industries. This is particularly important in the choice of purchase of foreign technique as against doing local research and development in the chemical and the machinery industry. The low technology industries however, respond differently. Interestingly, for the food industry, with foreign ownership, the probability to become technologically active falls significantly. Again, for the textiles industry, the marginal effects reveal that with increase in foreign ownership, there is a significant fall in the firms' choice to become technologically active.

In our study we have used two time period dummy variables explaining the pre 2000 and post 2000 phases. The Logit estimation reveals that in case of the chemical industry, given the base pre 2000 period there has been a significant rise in the probability of the chemical firms to be technologically active as against remaining passive in the post 2000 period. However, a significant fall in the probability to import foreign technical knowhow by the firms actively engaged in some form of technological activity is noticed in the post 2000 period as against the pre 2000s. This is also true for the machinery and textile industries. Given the base pre 2000 period there has been a significant fall in the probability of the machinery and textile firms to be technologically active as against remaining passive in the post 2000 period. For the transport equipment and the food and beverages industry, the post 2000 period does not mark any effect on the binary choices of the firms.

5. Summary of Findings

During post-reforms, with increasing FDI across sectors and hence operation of the MNEs, access to foreign capital and technology has become far easier. FDI has become an important channel that influenced domestic R&D activities (Sasidharan and Kathuria, 2011). The technological choices made by the firms and the factors influencing such choices in different industries have become very crucial. This study has investigated into the proximate factors underlying the firm-level technological choices in Indian manufacturing in the post reforms period.

We find that there has been a rise in domestic research and development intensity of firms across high technology and medium high technology industry groups in the post 2000 period. However, the rise has been only marginal and that too for the foreign owned firms. Import of foreign technology both in terms of import of capital goods and foreign knowledge, designs and royalty payments saw a fall in the post-2000. Domestic firms in the chemicals industry are an exception to this pattern: the dependence on foreign disembodied technology of these firms shows a rising trend after 2000. Import of raw materials increased in the post 2000 scenario across sectors. Interestingly, for the machinery industry, expenditure on imported raw materials declined for the domestic firms while for the foreign firms there has been a very sharp rise. These stylized facts led us to inquire into, in particular, whether firm level choice of technique have been affected by foreign direct investment in presence of the MNCs. The factors including spillovers responsible for such choices have been investigated.

In this paper, we assume that firms face binary choices with regard to technology. A firm might decide to remain technologically active as against remaining technologically passive. Again the firms that engage themselves in some form of technological activity might buy foreign technology and not engage in domestic R&D as against engaging themselves in their own research and development and not depending on foreign technology. Evidence from the logit estimation suggests, with the inflow of FDI and increasing MNE participation across sectors since 1991, spillover effects and foreign ownership have significantly impacted on the technological strategies of firms in Indian manufacturing industries. Further, a varying relationship exists between the choice of local R&D and foreign technology purchase for firms in high technology, high-medium technology industries as well as the low technology industries. Results do not reveal much of a clear picture regarding substitutability and complementarity of the two choices except for the high technology industry like chemicals. However, dependence on foreign technology seems to be evident across industries. This leaves scope for separate policy initiatives across sectors.

Appendix

Table: A.1 Odds Ratio and estimated marginals of binary choice Logit estimates,

All industries

	S		**M**	
	Odds ratio	**Estimated marginals**	**Odds ratio**	**Estimated marginals**
Size	**1.19*** (15.47)	**.04*** (15.18)	**28813.67*** (2.09)	**2.37*** (6.50)
Impr	**2.77*** (5.69)	**.24*** (5.65)	1.09 (0.38)	.02 (0.38)
KI	.93 (-1.01)	-.015 (-1.01)	**29.08*** (3.01)	**.77*** (2.97)
Domin	**.94*** (-2.80)	**-.013*** (2.81)	.99 (0.01)	.00003 (-0.01)
Forspill	**1.01*** (5.75)	**.002*** (5.74)	**.97*** (-5.27)	**-.006*** (-5.33)
Domspill	**1.07*** (26.95)	**.017*** (26.30)	**.95*** (-6.22)	**-.009*** (-6.36)
Y2	1.01 (0.32)	.004 (0.32)	**.33*** (-10.38)	**-.25*** (-10.47)
Own(base=0)	**2.23*** (9.21)	**.198*** (9.38)	**5.43*** (10.67)	**.39*** (12.31)
Log likelihood	-4754.29		-1166.47	
Chi- Square	1468.63		536.04	
N	8220		2174	

Note: 1. z values are provided in parentheses
2. * denotes 1% level of significance, ** denotes 5% level of significance, *** denotes 10% level of significance

Table: A.2 Odds Ratio and estimated Marginals of binary choice Logit estimates, Chemicals

S	Odds ratio	Estimated marginals	Odds ratio	Estimated marginals
Size	**1.45*** (9.04)	**.08*** (8.75)	-------	-----
Impr	**1.95**** (2.49)	**.14**** (2.49)	**1.95**** (2.49)	**.14**** (2.49)
KI	.91 (-0.56)	-.20 (-0.56)	.91 (-0.56)	-.20 (-0.56)
Domin	**.71**** (-2.02)	**-.07**** (-2.02)	**.71**** (-2.02)	**-.07**** (-2.02)
Forspill	1.00 (0.55)	0008 (0.55)	1.00 (0.55)	.0008 (0.55)
Domspill	-------	------	**1.51*** (9.04)	**8.28*** (8.75)
Y2	**1.53*** (4.93)	**.093*** (5.07)	**1.53*** (4.93)	**.093*** (5.07)
Own(base=0)	**1.56*** (2.78)	**.10*** (2.67	**1.56*** (2.78)	**.10*** (2.67
Log likelihood	-1911.85		-370.45	
Chi- Square	264.78		135.95	
N	**3230**		**911**	

Note: 1. z values are provided in parentheses
2. * denotes 1% level of significance, ** denotes 5% level of significance, *** denotes 10% level of significance

Table A.2.1: Odds Ratio and estimated Marginals of binary choice Logit estimates, Chemicals

M	Odds ratio	Estimated marginals	Odds ratio	Estimated marginals
Size	**1.08*** (2.65)	**.01*** (2.63)	-------	-----
Impr	**.20**** (-2.04)	**-.22**** (-2.03)	**.20**** (-2.04)	**-.22**** (-2.03)
KI	.21 (-0.72)	-.21 (-0.72)	.21 (-0.72)	-.21 (-0.72)
Domin	**.076*** (-4.16)	**-.36*** (-3.95)	**.076*** (-4.16)	**-.36*** (-3.95)
Forspill	**.96**** (-2.02)	**-.004**** (-2.03)	**.96**** (-2.02)	**-.004**** (-2.03)
Domspill	-------	**------**	**3181.5*** (2.65)	**1.13*** (2.63)
Y2	**.32*** (--5.37)	**-.18*** (-4.87)	**.32*** (--5.37)	**-.18*** (-4.87)
Own(base=0)	**6.04*** (6.20)	**.36*** (5.36)	**6.04*** (6.20)	**.36*** (5.36)
Log likelihood	-1911.85		-370.45	
Chi- Square	264.78		135.95	
N	**3230**		**911**	

Note: 1. z values are provided in parentheses
2. * denotes 1% level of significance, ** denotes 5% level of significance, *** denotes 10% level of significance

Table A.3: Odds Ratio and estimated Marginals of binary choice Logit estimates, Machinery

	S		M	
	Odds ratio	Estimated marginals	Odds ratio	Estimated marginals
Size	**2.12*** (10.73)	**.18*** (0.15)	.97 (-1.12)	-.005 (-1.12)
Impr	**7.01*** (3.62)	**.47*** (3.62)	6.12 (1.49)	.39 (1.48)
KI	.83 (-1.44)	-.04 (-1.44)	**316647.4**** (1.97)	**2.72**** (2.04)
Domin	.99 (-0.01)	-.0003 (-0.01)	1.39 (0.46)	.072 (0.46)
Forspill	.99 (-0.14)	-.0001 (-0.14)	1.004 (0.48)	.0009 (0.48)
Domspill	**3.68*** (3.95)	**.32*** (3.95)	**.003*** (-6.77)	**-1.19*** (-6.34)
Y2	**.59*** (-3.67)	**-.12*** (-3.06)	.54 (-1.62)	**.129***** (-1.66)
Own(base=0)	**2.02*** (5.39)	**.17*** (5.49)	**3.18*** (4.50)	-.129 (-1.66)
Log likelihood	-1096.22		-287.48	
Chi- Square	356.76		187.06	
N	**1941**		**583**	

Note: 1. z values are provided in parentheses
2. * denotes 1% level of significance, ** denotes 5% level of significance, *** denotes 10% level of significance

Table: A.4 Odds Ratio and estimated Marginals of binary choice Logit estimates, Transport Equipments

	S		M	
	Odds ratio	Estimated marginals	Odds ratio	Estimated marginals
Size	**1.53*** (7.54)	**.100*** (9.59)	**1.02***** (1.67)	**.004***** (1.71)
Impr	**75.8*** (4.12)	**1.01*** (4.06)	**3227.63*** (2.63)	**1.28*** (3.07)
KI	.39 (-0.84)	-.22 (-0.84)	62.04 (0.85)	.654 (0.85)
Domin	.99 (-1.050	-.002 (-1.04)	1.007 (0.09)	.001 (0.09)
Forspill	1.04 (0.68)	.010 (0.68)	**.804**** (-1.91)	**-.03**** (-1.91)
Domspill	44.8 (1.43)	.89 (1.43)	**.471**** (-1.96)	**-1.19**** (-1.96)
Y2	.79 (-0.82)	-.054 (-0.83)	.68 (-0.70)	-.05 (-0.74)
Own(base=0)	1.34 (0.60)	.06 (0.62)	.751 (-0.27)	-.048 (-0.25)
Log likelihood	-303.15		-90.54	
Chi- Square	172.95		34.02	
N	568		187	

Note: 1. z values are provided in parentheses
2. * denotes 1% level of significance, ** denotes 5% level of significance, *** denotes 10% level of significance

Table: A.5 Odds Ratio and estimated Marginals of binary choice Logit estimates,

Food and Beverages

	S		**M**	
	Odds ratio	**Estimated marginals**	**Odds ratio**	**Estimated marginals**
Size	9.30 (1.27)	.29 (1.27)	**1.20***** (2.37)	**.030***** (2.28)
Impr	**277089.4*** (3.16)	**1.67*** (3.14)	15.30 (0.52)	.433 (0.51)
KI	.000015 (-1.46)	-1.47 (-1.51)	**1.33***** (1.81)	.046 (1.51)
Domin	**.46*** (-3.10)	**-1.02*** (-2.90)	.137 (-1.37)	-.31 (-1.42)
Forspill	.883 (-0.43)	-0.16 (-0.43)	1.51 (-1.91)	.065 (0.71)
Domspill	**.49**** (-2.55)	**-0.94**** (-2.59)	1.64 (0.84)	.079 (0.84)
Y2	1.12 (0.43)	0.15 (0.43)	1.80 (0.61)	.089 (0.65)
Own(base=0)	**.064**** (-2.26)	**-.16*** (-6.37)		
Log likelihood	-256.02		-39.04	
Chi- Square	59.43		20.62	
N	**623**		**97**	

Note: 1. z values are provided in parentheses
2. * denotes 1% level of significance, ** denotes 5% level of significance, *** denotes 10% level of significance

Table: A.6 Odds Ratio and estimated Marginals of binary choice Logit estimates,

Textiles

	S		**M**	
	Odds ratio	**Estimated marginals**	**Odds ratio**	**Estimated marginals**
Size	**1.28*** (5.04)	**.017**** (2.11)	.981 (-0.23)	.345 (1.30)
Impr	**66.2**** (2.55)	**.28*** (5.89)	1.13 (1.16)	.032 (1.15)
KI	9.27 (0.25)	.15 (0.26)	1.27 (1.18)	6.03 (1.03)
Domin	**.63*** (-2.68)	**-.031***** (-1.73)	1.25 (1.62)	.056 (1.59)
Forspill	**1.004**** (2.30)	**.0003**** (1.75)	.999 (-0.08)	-.00006 (-0.08)
Domspill	**1.08*** (6.39)	**.005*** (2.35)	**.947***** (-1.67)	**-.013***** (-1.65)
Y2	**.59**** (-2.28)	**-.033**** (-1.73)	.951 (-0.10)	-.012 (-0.10)
Own(base=0)	3.93 (1.60)	**.054*****	4.78 (1.16)	.345 (1.30)
Log likelihood	-607.58		-118.78	
Chi- Square	133.32		25.24	
N	**1222**		**307**	

Note: 1. z values are provided in parentheses
2. * denotes 1% level of significance, ** denotes 5% level of significance, *** denotes 10% level of significance

Table: A.7 Odds Ratio and estimated marginals of binary choice Logit estimates,

Metals

	S		M	
	Odds ratio	**Estimated marginals**	**Odds ratio**	**Estimated marginals**
Size	**1.38*** (8.75)	**.04*** (7.49)	**1.36**** (2.09)	.005 (0.40)
Impr	.55 (-0.63)	-.083 (-0.64)	18.30 (0.79)	.052 (0.42)
Ki	**1267.23**** (2.21)	**1.01**** (2.09)	75428.98 (0.52)	.204 (0.92)
Domin	1.57 (0.70)	.064 (0.7)	86.52 (1.34)	.081 (0.42)
Forspill	.95 (-0.96)	-.006 (-0.96)	.848 (-1.13)	-.002 (-0.41)
Domspill	**.512*** (-3.88)	**-.09*** (-3.98)	**24.28**** (2.23)	.058 (0.46)
Y2	1.28 (0.56)	.03 (0.58)	.655 (-0.34)	-.007 (-0.28)
Own(base=0)	-----	**------**	--------	-----------
Log likelihood	-202.03		-25.67	
Chi- Square	242.25		61.01	
N	629		89	

Note: 1. z values are provided in parentheses
2. * denotes 1% level of significance, ** denotes 5% level of significance, *** denotes 10% level of significance

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