FDI, Technological Choices and Spillovers in an Emerging Market Economy: A Study of Indian Manufacturing Industries

(Preliminary Draft)

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Abstract: With the inflow of FDI and MNE operations in the Indian Economy in the 1990s, the domestic firms had to face a very crucial issue of technological choices in the face of competition On one hand technology could be imported in both embodied and disembodied form, while on the other hand thrust could be given to develop local R&D. This paper tries to analyse the factors influencing the firms' technological choices across high-tech and medium-tech industries. A logit framework is constructed to empirically explore the technology choice determinants. Results suggest that foreign ownership and technological spillovers from both domestic and foreign firms have significant effect on the technology choice of most Indian manufacturing industries. Dependence on imported foreign technical know-how is also evident.

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1. *Introduction*

Technology is one of the major factors which aid growth in the developing economies. This is often sourced from abroad. In this context, Foreign Direct Investment (FDI) flows play an important role which together with technology brings other critical resources such as entrepreneurship and capital as catalysts of development (Kumar, 1996) .Since the mid 1980s as against arm's length licensing for technology transfer, there has been a rapid rise in the flow of FDI in emerging market economies like India. This is a major cause of optimism for these countries in terms of multiple benefits including technology transfers, market access and organizational skills associated with FDI. FDI has emerged as the major channel of technology transfers and international diffusion of knowledge and technology (Kumar,

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1995). FDI is associated with the large Multinational Enterprises (MNEs), which possess huge resource base and are important source of research and development activity. They also possess a higher level of technology than is available in the emerging market economies. Thus with the operation of the MNEs in these economies, there is a possibility of the knowledge pool to be transferred from the parent firm to the host firm which can potentially generate considerable technology spillovers. It is increasingly recognized that foreign firms can significantly contribute, directly or indirectly, to the innovative activities of the host country (Lall, 1993).

Since independence, India has been striving hard to promote technological advances. The 1970s and the early 1980s was a period of 'closed technology policy' with an emphasis on self reliance (Basant, 1997).With the economic liberalization in the 1990s, this restrictive technology regime came to an end with huge amount of FDI flowing in almost all the sectors. As a result, the domestic firms started facing considerable competition from the large MNEs. To survive in face of this competition from the foreign firms, the domestic firms were forced to review their technology strategies. There was a strong-felt need to either invest in indigenous R&D or to import foreign technology or do both. In this context of access to technology, two strands of arguments emerged. The first line of argument presumes that the emerging market economies are basically technology followers. Hence, it was expected that with the MNEs operating, there would be a huge dependence on technology imports in both embodied and disembodied form (Kumar and Saqib, 1996; Katrak, 1997; Evenson and Joseph, 1999; Aggarwal, 2000). On the other hand, it was also argued that the inward looking policies followed by India in the first three decades after independence have enabled the manufacturing industries to develop a high capital base. Hence, industries in the face of competition have also started producing their own technology (Kumar, 1996). Therefore, access to technology and its development in India across manufacturing sectors have evolved as a combination of production and purchase. Again, the choice of technology and the response in the presence of MNEs varied across the high end technological sectors and the medium/ low end technological sectors. Thus to understand the impact of the new policy regime which started in the 1990s, an in-depth analysis of the determinants of the firm level technology choices across sectors in the post liberalization phase is called for. This paper builds on the recent works of Basant, 1993; Basant and Fikkert, 1996; Fikkert, 1993; Kathuria, 2000 and tries to understand the role of ownership, technological spillovers (both domestic and foreign) among other variables in explaining technological choices at the firm level for the high-tech industries like chemicals, machinery, transport equipment as well as the medium-tech industries like food &beverages, metals and textiles. This is where the paper contributes to the existing literature.

There is a rich body of literature with regards to the impact of technology transfer via FDI. This 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. Since the work of J.A Schumpeter in the early twentieth century, innovation has continued to attract researchers as a driving force of economic growth. During the last few decades the works of Dahlman and Alii (1987), Evenson and Westphal(1995) have led to a better understanding of the main determinants and characteristics of technical innovation. It seems that in the emerging market economies new technologies are not developed. Their activities mainly consist of adaptation of transferred knowledge from the developed nations.

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 is a substitute of local R&D. On one hand it is recognized that foreign firms can significantly contribute directly or indirectly to the innovative activities of the host country as foreign firms may engage in technological activities to adapt to the host country conditions, while the domestic firms in presence of the foreign firms may invest in technological activities to improve their technical capacity. 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).Again as R&D is uncertain, involves huge costs and has gestational lags, domestic firms might not opt to do R&D. Instead they procure technology from abroad. So the question that remains is whether the import of foreign technology enhances or diminishes local R&D. Lall (1983) with Indian Engineering industries found a complementary relationship with adaptive R&D. Sasidharan and Kathuria (2011) show a positive relationship between FDI and R&D when sample is divided on the bases of equity ownership. Their results show that FDI inflow induces foreign owned firms in high tech 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. However, whether foreign firms invest or not the domestic firms in face of competition has to invest in R&D (Caves, 1974).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. Again, substitutability between technology imports and domestic R&D has been found by Kumar (1987), Basant and Fikkert(1996), Kathuria and Das(2005) for India, Veugeler and Van den Houte(1990) for Belgium, Lee (1996) for Korea, Fan and Hu (2007) for China etc. So the question remains whether imported technology in coming in the way of innovative capacity or paving the way of local R&D of the domestic firms. This is particularly true for the emerging market economies like India.

Empirical studies relating to productivity spillovers can be categorized into two basic sets:

- Studies which quantitatively measure the impact of foreign presence on Total Factor Productivity (TFP) or efficiency of local firms. The standard method is to use the Ollay Pakes or Levinsohn Petrin semi parametric estimation of TFP.
- Studies that use production function to analyze knowledge spillovers from technology imports. In most of the cases a Cobb Douglas production function is estimated.

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 to that of the foreign owned firms in twenty two digit Mexican industries for the period 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) tests the hypothesis of

FDI to be a channel of knowledge spillovers for Japanese manufacturing industries. Results show evidence of knowledge spillovers both from and to the investing Japanese firms. Yao and Wei (2006) tests the hypothesis 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. The results support the hypotheses. Haddad and Harrison (1991) found that FDI helped in reducing the productivity gap in low technology Moroccan industry. Chang and Chung (2007) examine the effects of technological spillovers from foreign to local firms and also distinguish between modernized local firms and other local firms. Positive productivity spillover on domestic firms is found with foreign presence. Strong spillover effects among local firms are also evident. Empirical analyses have also been done to the understanding of spillover effects on small and medium enterprises in developing countries (Nguyen et.al). Results suggest expansion of small and inexperienced domestic enterprises with FDI. Furthermore, larger and more productive firms reap the benefit of spillovers from the MNCs than the smaller firms (Bakes, Kleinert and Toubal, 2006).Again Feinberg and Majumder (2001) find R&D spillovers only to be between the MNCs 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) studies the impact of MNE entry on welfare, wages and occupational choice focusing on diffusion of knowledge spillovers through learning and worker mobility. Results show both formal and anecdotal evidence of knowledge spillovers from foreign firms. Spillover analyses have also been often done to understand the channel through which it happens. 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 knowledge spillovers are found to occur through backward linkages from foreign firms in upstream sectors to local firms in downstream sectors. So, vertical spillovers occur. Liu (2006) derives similar results for Chinese manufacturing.

The studies discussed so far mostly suggest that foreign investment creates spillover effects. However, there are studies which contradict this view. Aitken and Harrison (1999) using production function approach for some Venezuelan plants, find that the positive relationship between foreign equity share and the plants' productivity is present 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 could only partially explain the improvement of the performance of the US firms between 1982 to 1992.Cantwell (1989) found spillovers to be significant only in industries where the technology gap between local and foreign firms was low. Kokko (1994) divided his data sample into industries with lower and higher technologies and showed existence of spillovers in both the groups. However, when the cross item between FDI and the technology gap was added to the model, the spillover in the group with higher technology became insignificant. Kokko inferred that technology spillovers do not generally occur in technologically complex industries. Similar results were derived by Tsou and Liu (1994).

In the Indian context Goldar (1994) attempted to explain the total factor productivity growth attained by Indian enterprises from the period 1987-1990 in terms of their own R&D expenditure and technology imports apart from other factors. His results however did not explain the growth of the dependent variable through the technology variables. He suggested that Indian firms do not import technology to improve productivity rather to fulfill other objectives like expansion and diversification. Basant and Fikkert (1996) using panel data on Indian firms from 1974 -75 to 1981-82, provide estimates of the impact on output of Indian firms' R&D expenditures, technological purchases and international and domestic R&D spillovers. Their results show private returns to technology purchases to be high and significant 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 suggested 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.

Dimelis and Louri (2004*)* look at technology spillovers from yet another angle. They analyse the net efficiency benefits stemming from FDI in the particular case of Greece with a distinction between spillovers from different types of multinationals. More specifically they address questions like how differentiated such effects are according to the size of domestic firms and foreign firms and according to the degree of ownership involvement in the foreign partner. A Cobb-Douglas type production function is estimated and the results show that while it is the large majority held foreign firms that exhibit higher productivity, spillovers are important for small domestic firms. Marin and Sasidharan (2008) create an alternative model where the local innovative activity of the subsidiaries plays a critical role in accounting for the possibility of positive and negative effects. Results suggest that in case of country like India only creative subsidiaries have positive effects on host country firms.

This paper explores the firm level technological choices of the Indian manufacturing and the determining factors of such technological choices in the post reforms era. In this process 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 the 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 and implications for policy.

2. Technology Acquisition in the Post Reform period, 1991-2010: Trends and patterns

Since economic reforms, FDI inflows increased substantially across Indian manufacturing sectors, though there have been drastic changes in the sectoral composition overtime. With changes in the FDI stimuli across sectors, the response has been varied with respect to their technological choices. With liberalization import of technology has become cheaper and easier. Thus, firms can prefer technology imports instead of investing on R&D (Kathuria, 2008). Again, investment in indigenous R&D is essential to face the competition from the large MNEs as well as to adapt imported technology. Hence the choice of "making" or "buying" technology or combining the two becomes crucial. To understand the trends and patterns in these technological choices across sectors, this paper investigates into the broad changes in the average R&D intensity[2] (RDI), import of capital good intensity [3](KI), forex payment for technical know-how and royalty[4] (FPTR) and import of raw-material intensity[5] (IMPR) of different sectors in the pre 2000 and the post 2000 scenario (See Table 1).

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

High –Tech Industries						
	Chemicals		**Transport Equipment**		**Machinery**	
	Pre 2000	***Post 2000***	***Pre 2000***	***Post 2000***	***Pre 2000***	***Post 2000***
Expenditure on R&D	**.001**	**.006**	**.0001**	**.0004**	**.0003**	**.001**
Expenditure on import of capital goods	**.007**	**.003**	**0.23**	**0.02**	**.006**	**.006**
Forex payment for technical know how and royalty payments	**.0005**	**.019**	**0.002**	**.001**	**.002**	**.001**
Expenditure on import of raw materials	**.055**	**.074**	**1.29**	**9.96**	**2.21**	**20.12**
Low/Medium –Tech industries						
	Food and beverages		**Textiles**		**Metals**	
	Pre 2000	***Post 2000***	***Pre 2000***	***Post 2000***	***Pre 2000***	***Post 2000***
Expenditure on R&D	**.003**	**.005**	**0.000**	**0.000**	**0.000**	**0.000**
Expenditure on import of capital goods	**.007**	**.002**	**0.053**	**0.009**	**.004**	**.003**
Forex payment for technical know how and royalty payments	**.0006**	**0.00**	**0.022**	**0.001**	**.001**	**.0002**
Expenditure on import of raw materials	**.003**	**.005**	**2.59**	**16.80**	**1.97**	**21.36**

Note: Calculations based on CMIE database

[2] RDI is measured as the ratio of R&D expenditure to sales
[3] KI is measured as the ratio of imports of capital goods to sales
[4] FPTR is measured as the ratio of technical fees and royalties paid abroad to sales
[5] IMPR is measured as the ratio of imports of raw materials to sales

Developing indegenous technological capabilities is very crucial in a globalised economy to stand the competition from the global market in the liberalised regime (Lall, 2001). A complex debate exists in literature regarding the relationship between imports of foreign technology and undertaking R&D by the manufacturing enterprise. Some studies explain a complementary relationship while others argue substitution (Kumar and Aggarwal, 2005). It is believed that when knowledge is imported, further research is taken up by the enterprises to absorb and adapt the imported knowledge. This is particularly true for the high tech industries. Table 1 suggests that the expenditure on R&D has increased in the post 2000 period for all the high- tech industries like chemicals, machinery and transport equipments. The medium tech industries do not seem to expend on R&D on an average except for the food and beverages industry, where, only a marginal increase in the R&D expenditure is noticed in the post 2000 period. Import of capital good intensity shows a declining trend in the post 2000 period for almost all the sectors excepting the machinery industry. With the removal of trade restrictions, an instant demand for foreign capital goods was felt immediately after liberalization. However, as Pillai and Srinivasan (1987), argue that most capital goods have a certain life time. Once the capital goods are bought, the firms are expected to use the same for a certain period of time. This might be one of the reasons which explain the declining average expenditure on capital goods in the post 2000 phase. With globalisation and the operation of the MNEs, the import of disembodied technology in the form of foreign technical know how, drawings and designs etc. is expected to increase due to increased access to global technology market. Table 1 suggets that for the high tech industries like chemicals and transport equipment, forex payment for technical know-how and royalty shows a rising trend in the post 2000 period. However for the low/medium tech industries, forex payment for technical know-how and royalty payments falls steadily in the post 2000 scenario. This trend is constistant with the results of Pradhan and Puttaswamaiah (2005) and Choragudi (2008) who argued that the expenditure on disembodied technology has been decling in the post liberalisation period. 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 very significant rise in the import of raw material intensity in all the industries in the post 2000 period. The increase in the expenditure on imported raw materials is quite drastic for the industries like transport equipments, machinery, textiles and metals.

There are further nuances to these trends once we try to look into the expenditures of the domestic and foreign firms separately (Table 2 & 3). For the chemical industry, expenditure on R&D, forex expenditure on technical know-how and expenditure on imported raw materials rise in the post 2000s for both the domestic and the foreign firms. However, import of capital good falls for the domestic firms and rises for the foreign firms in this period for this industry. In case of the food and beverages industry, expenditure on local research and development and imported raw materials rises in post 2000 for the domestic firms, while technology imported in both embodied and disembodied form falls. For the foreign firms in the food industry, all the variables show a declining trend excepting RDI. It is interesting to note that, expenditure on import of raw materials shows a decline for the domestic firms in the machinery industry. However for the foreign firms, it has increased drastically from 2.78in the 1990s to 22.6 in the 2000s.In case of the transport equipment industry research and development intensity and import of raw materials show a rising trend for the domestic firms, while all the factors increase for the foreign firms in the decade of 2000. Import of capital goods however, fall for the domestic firms during this period. In case of the metal industry, import of raw material intensity rises in the post 2000s for the domestic as well as the foreign firms. Expenses on local research and development as well as on imported technology fall for the domestic firms on the other hand for this industry. 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.

Table: 2 Expenditure on Technology as a Share of Sales for the Domestic Firms (Pre and Post 2000)

High –Tech Industries						
	Chemicals (Domestic)		**Transport Equipment (Domestic)**		**Machinery (Domestic)**	
	Pre 2000	***Post 2000***	***Pre 2000***	***Post 2000***	***Pre 2000***	***Post 2000***
Expenditure on R&D	**.001**	**.005**	**.001**	**.005**	**.003**	**.001**
Expenditure on import of capital goods	**.007**	**.003**	**.244**	**.019**	**.006**	**.006**
Forex payment for technical know how and royalty payments	**.0005**	**.020**	**.002**	**.001**	**.002**	**.0008**
Expenditure on import of raw materials	**.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***
Expenditure on R&D	**.000**	**.000**	**.000**	**.0001**	**.000**	**.000**
Expenditure on import of capital goods	**.007**	**.003**	**.052**	**.009**	**.005**	**.003**
Forex payment for technical know how and royalty payments	**.000**	**.000**	**.021**	**.0009**	**.001**	**.0002**
Expenditure on import of raw materials	**.003**	**.005**	**.026**	**.0001**	**0.02**	**0.19**

Note: Calculations based on CMIE database

Table: 3 Expenditure on Technology as a Share of Sales for the Foreign Firms (Pre and Post 2000)

High –Tech Industries						
	Chemicals (Foreign)		**Transport Equipment (Foreign)**		**Machinery (Foreign)**	
	Pre 2000	***Post 2000***	***Pre 2000***	***Post 2000***	***Pre 2000***	***Post 2000***
Expenditure on R&D	**0**	**0.01**	**0**	**.000**	**.0002**	**.0009**
Expenditure on import of capital goods	**.0008**	**.006**	**0**	**0.04**	**.006**	**.004**
Forex payment for technical know how and royalty payments	**.0001**	**.005**	**0**	**.002**	**.004**	**.003**
Expenditure on import of raw materials	**.04**	**0.16**	**0**	**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***
Expenditure on R&D	**.0002**	**.0002**	**0**	**0**	**0**	**0**
Expenditure on import of capital goods	**.008**	**.003**	**.003**	**0**	**0**	**0**
Forex payment for technical know how and royalty payments	**.007**	**.001**	**.016**	**0**	**0**	**0**
Expenditure on import of raw materials	**.015**	**.008**	**.64**	**0**	**0**	**.049**

Note: Calculations based on CMIE database

2. *Analytical framework*

Technological choices of a firm can be influenced by a variety of factors. The industries studied in this paper 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 much of a 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.

2.1 *The Empirics*

Following Basant, 1997, we construct a model of a firm's strategy in the discrete choice framework where the technical knowledge available to a firm can be broadly divided into three sources:

i. Knowledge generated by the firm on its own (LRD)
ii. Knowledge purchased by the firm (TP)
iii. Knowledge spillovers from other firms(TS)

Knowledge generated by the firm on its own is basically its own R&D efforts. Knowledge purchased by the firm can be further subdivided into:

DPTR: acquired through domestic technical knowhow and royalty payment[6].

FPTR: acquired through foreign technical knowhow and royalty payment

DOMIN: acquired through purchase of domestic inputs

FORIN: acquired through purchase of foreign inputs

Again, knowledge acquired through spillover (TS) can be subdivided into knowledge spillovers from domestic firms (DOMSPILL) and spillovers from foreign firms (FORSPILL).

3.2. *The logit model*

We analyze the firms' strategy in a discrete framework and assume that a firm takes decision regarding doing its own R&D and importing foreign technology simultaneously. We consider two binary choices. This is done in two steps. Firstly, considering all the firms in each industry, we consider that firms can be technologically active as against being technologically passive. Hence, the binary choice takes the form:

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

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

Now, considering the firms which are actively engaged in some kind of technology (Local or Foreign) 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

Hence, we construct a binary response model[7] of the form:

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

$P(y=1|x)= G(\beta_0+ \beta_1x_1+\ldots\ldots+ \beta_kx_k)= G(\beta_0+\mathbf{x\beta})$, where $0<G(z)<1$, for all real numbers z and $\mathbf{x\beta} = \beta_1x_1+\ldots\ldots+ \beta_kx_k$. 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, $\log F (z)/1\text{-}F(z)=z$. 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 basically the partial effects of the continuous variables to the response probability. If 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 particular technological strategy, given the levels of the explanatory variables. 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

[7] Statistical software used is STATA 10.

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 findings of the estimation of the model for the chemicals, food and beverages, textile, machinery, metal and transport equipment industries.

3. *The Empirical results*

Logit model estimation results showing the determinants of firm-level technological choices are presented in the Tables 1-6 (See Appendix). The results suggest that with inflow of FDI, participation of the MNEs, import of capital and import of raw materials as well as technological spillovers have significant effect on the technological choices of the Indian manufacturing. 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 high-tech industries like chemical and transport equipment as well as the medium-tech 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.

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, KI does not play much of a role in explaining both the binary technological choices for 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. 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 high tech industries like machinery as the processes are stringently sequenced and often the firms do not have any incentive to further invest in local 9R&D. So expenses on domestic R&D are likely to come down. However, this is not true for the other industries studied.

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. In the transport equipment industry, on the other hand, import of raw materials significantly improves the probability to buy foreign techniques.

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 the chemical industry, the technology purchased through domestic inputs significantly diminishes the probability to import foreign technological know how as against doing local R&D and not importing foreign technical know how.

Technology spillovers

Estimation results suggest that foreign technology spillovers (FORSPILL) significantly affect the technological choice of 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 technical spillovers. This however does not hold good for the other industries where positive effect of FORSPILL is not noticed. Spillovers from domestic firms(DOMSPILL) 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 high tech industries like machinery and transport equipment as well as the medium tech industry like textiles.

Participation of the 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 medium tech 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.

4. *Conclusion*

Since economic liberalization in 1991, India opened doors for foreign investment in the country. With the inflow of FDI across sectors and the operation of the MNEs, access to foreign capital and technology became far easier. Again, FDI became an important channel that influenced the domestic R&D activities (Sasidharan and Kathuria, 2011). Hence, the technological choices made by the firms and the factors influencing such choices in different industries became very crucial. The present study explores the trends in the technological choice-variables in the post liberalization period and tries to determine the factors underlying the firm-level technological choices in Indian manufacturing in the post reforms period (1991-2010). We find that there has been a rise in the domestic research and development intensity of the firms across most industry groups in the post 2000 period. However, it is to be noticed that 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 techniques, designs and royalty payments saw a fall in the post 2000s. However, for the domestic firms in the chemical industry the dependence on foreign disembodied technology shows a rising trend in the post 2000s. Import of raw materials increased drastically 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. Such stylized facts led 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 that large firm size has a very significant effect on the binary choice for almost all industries except food and beverages to be technologically active as against remaining technologically passive. This is expected as larger firms with good resource base can exploit economies of scale, while smaller firms with their resource constraints are mostly scale inefficient. Results also imply that that the probability of relying on foreign technical know-how rises with increase in size for all the high-tech industries excepting machineries. For the medium–tech industries like food and beverages and metals dependence on imported disembodied technology rather than investing in local R&D also rises for large sized firms. With raw materials import becoming cheaper in the liberalized regime, the import of raw materials has significantly increased in the post 2000s in Indian manufacturing across sectors. Estimation results suggest that excepting the metal industry, with the increase in the expenditure on the import of raw materials the probability to become technologically active significantly rises for all the high-tech and medium-tech industries alike. Again, the choice of depending on foreign technical know-how significantly declines with increase in imported raw materials for the Chemical industry. The transport equipment industry on the other hand is in sharp contrast to this where the probability of the firms to invest in domestic R&D significantly falls with imported raw materials. Import of capital good does not affect the choice of Indian manufacturing to become technologically active as against remaining passive. The only exception is the metal industry where imported capital good is noticeably important in making this sector technically active. For the machinery industry the probability of the dependence on foreign technical know-how significantly increases with imported capital good. This is probably because of the fact that machinery firms seek product technology from abroad which has less scope of local adaptation. Thus with import of embodied capital, dependence on foreign technical know-how significantly increases. MNE participation significantly increases the probability of the high tech industries like chemicals and machinery to be technologically active. It also significantly increases the probability to import foreign technical know-how for these two high-tech sectors. Interestingly this is not the case with the transport equipment industry. In the textile industry however, the marginal effects reveal that with an increase in MNE participation in this industry, the firms would significantly become technologically active Spillover effects from domestic firms play quite a significant role in explaining the technological choices of firms across sectors. Technology spillover from domestic firms is found to significantly increase the probability to become technologically active as against remaining technologically passive for the chemicals, machinery and textile industries. It is further important to note that such spillovers significantly reduce the firms' choice to become technologically active in the food and beverages and metal industry. Spillovers from the domestic firms also significantly increase the possibility to buy foreign technology in the chemical industry while for the machinery, textile and transport equipment industries dependence on imported technology significantly falls. Foreign spillovers do not seem to affect the choice of becoming technologically active for most industry groups excepting the textile industry. However, with foreign spillovers the probability to depend on foreign technology is found to significantly for the chemicals, textiles and transport equipment industries.

Thus, with the inflow of FDI and MNE participation in the post liberalization era, spillover effects and foreign ownership have significantly affected the technological strategies of Indian manufacturing industries. Further, a complex relationship exists between the choice of local R&D and foreign technology purchase for both the high-tech and the medium-tech industries. Results do not reveal much of a clear picture regarding the complex debate existing in literature regarding substitutability and complementarity between the two choices. However dependence on foreign technology seems to be evident across industries. This leaves enough scope for future policy endeavor.

Appendix

Table: 1A Odds Ratio and estimated Marginals of binary choice Logit estimates, Chemicals

S	Odds ratio	dy/dx	Odds ratio	dy/dx
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:1B Odds Ratio and estimated Marginals of binary choice Logit estimates, Chemicals

M	Odds ratio	dy/dx	Odds ratio	dy/dx
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: 2. Odds Ratio and estimated Marginals of binary choice Logit estimates, Machinery

	S		**M**	
	Odds ratio	**dy/dx**	**Odds ratio**	**dy/dx**
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: 3 Odds Ratio and estimated Marginals of binary choice Logit estimates, Transport Equipments

	S		M	
	Odds ratio	**dy/dx**	**Odds ratio**	**dy/dx**
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: 4 Odds Ratio and estimated Marginals of binary choice Logit estimates, Food and Beverages

	S		M	
	Odds ratio	**dy/dx**	**Odds ratio**	**dy/dx**
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: 5 Odds Ratio and estimated Marginals of binary choice Logit estimates, Textiles

	S		**M**	
	Odds ratio	**dy/dx**	**Odds ratio**	**dy/dx**
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: 6 Odds Ratio and estimated Marginals of binary choice Logit estimates, Metals

	S		M	
	Odds ratio	**dy/dx**	**Odds ratio**	**dy/dx**
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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