ARE FDI INFLOWS CRITICAL TO TECHNOLOGY CHOICE OF FIRMS?
An Exploration with Indian Manufacturing Industries

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Abstract: This paper explores firm-level technology choices of Indian manufacturing post reforms. With quantum inflow of Foreign Direct Investment across sectors, access to world class frontier technology became easier for the domestic Indian firms. As technology decisions are taken at the firm-level, the issue of technology choice of firms becomes a crucial issue. Based on a multinomial logit framework, the study reveals significant dependence on foreign technical know-how for firms to be technologically active. Foreign ownership, dependence on imported raw materials and technology spillovers from both domestic and foreign firms are found to be evident in making the firms technologically active.

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

JEL Classification No: *F21, F23, O33*

1. Introduction

Foreign Direct Investment (FDI) inflows play an important role in host country development, which together with technology brings other critical resources such as entrepreneurship and human capital. FDI supplements resource mobilization, facilitates access to world class technology, improves efficiency and productivity, and expands output. Further, in developing nations, Multinational Enterprises (MNEs) with R&D activity are often instrumental in technology spillovers to domestic firms. It has been increasingly recognized that presence of

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foreign firms contributes, directly or indirectly, to the technological choices of host country firms. This is particularly true as with increasing FDI inflows there will be transfer of both embodied and disembodied technology through internalized modes to MNE affiliates and externalized modes of joint ventures, franchising, licensing, arm's length sales of capital goods, technical assistance, subcontracting or original equipment manufacturing. The technology choice set for firms thus widens.

In India, firm-level R&D expenditure increased in high and medium technology industries along with quantum increase in imported raw materials across sectors during post-2000[1] (Ghosh and SinhaRoy, 2016). Again, imports of embodied technology, capital goods in particular, increased significantly during this period along with a rise in R&D stock and an increasing multinational R&D activity in India (Banerjee and Sinha Roy 2014). These have crucial implications for technological choices of firms. This paper builds on Basant (1997) and extends the framework in investigating the role of FDI in explaining firm-level technology choices of Indian manufacturing[2] as a whole post-reforms.

Technological choices of a firm can be influenced by a variety of industry specific or firm specific factors like size (Braga and Willmore, 1991; Toimura, 2003; Katrak, 1990), import of technology (Lall, 1983; Deolalikar and Evenson, 1989; Nelson, 2004; Kumar and Aggawal, 2005), ownership (Kumar and Saqib, 1996; Kumar and Aggarwal, 2005) and technology spillovers (Basant, 1997; Kathuria, 2001). Such variables determining technology choices of firms are expected to behave differently across sectors. The sectors in Indian manufacturing are heterogeneous and thus adhere to different modes of technological development. For instance, adaptation of foreign technology to suit Indian conditions constitute the major component of

[1] Import of raw materials has also aided improvements in India's international competitiveness across sectors.

[2] Basant (1997) considers two sectors namely non-electrical machinery and chemical.

indigenous technological effort in some sectors, while for others, imported technology may not need any modifications for local adaptations (Basant, 1997). In case of industries like chemicals and metals, 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 is likely to 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, as evident in literature are also likely to affect technological choices of firms across sectors. The study in particular, examines the role of ownership and technological spillovers from both domestic and foreign firms while investigating into the technological choices of firms. However, sector-specific analysis is not considered. This study adds to the literature by taking into account the changes in firm-level technology acquisition in Indian manufacturing during post-2000. This is how it also extends the findings of Basant (1997).

The paper is organized as follows. Section 2 puts forth the estimation model and the data. Section 3 analyses the paper. Section 4 summarises and concludes the paper. The empirical model that follows takes into account the nuances of technology choice of firms.

2. Empirical model and Data

An indirect profit function V_i for a firm i can be derived from maximization of a constrained profit function. V_{ij} is the maximum profit attainable for firm$i$ if it chooses jth technological status. This indirect profit function takes the form:

$V_{ij} = \beta_j X_i + \epsilon_{ij}$, where X is the vector of firm and industry characteristics like size, R&D intensity, foreign technology import intensity, capital good import intensity, raw material import intensity, technology embodied in domestic inputs, foreign technology spillovers and domestic

technology spillovers. The probability that the $i\ th$ firm will choose the $j\ th$ technological state is given by:

$P_{ij} = \Pr\ (V_{ij} > V_{ik})\ for\ k \neq j.$

A representative firm's strategy is considered 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

ii. Knowledge purchased by the firm

iii. Knowledge spillovers from other firms

Knowledge generated by the firm comes from 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 inputs available domestically and purchase of foreign inputs. Again, knowledge acquired through spillover can be either from other domestic firms or foreign firms. Following Basant (1997), a multinomial logit model of the firm's choice is designed as follows:

Firm's Choice: { Remaining technologically passive; Doing only local R&D; Choosing only foreign technical know-how; Doing both

In such structure, the model essentially computes the probability of a firm to choose a particular technological strategy, under certain given conditions. The estimation of the above model is carried out using STATA 13.

2.1 The Data

[3] Technology licenses are not considered in this analysis on account of data unavailability.

Firm-level data are obtained from Prowess Database published by the Centre for Monitoring Indian Economy for the period 1991-2010. PROWESS provides information from audited financial statements of companies and thereby uses company balance sheets and income statements as sources of information. The database covers both listed and unlisted firms from a wide cross-section of manufacturing, services, utilities and financial industries covering 60-70 per cent of organized sector in India, 75 per cent of corporate taxes and 95 per cent of excise duties collected by the Government of India (Goldberg et al., 2010). However, the database has some limitations especially with regards to this analysis. First, an important step involves identifying the firms according to ownership or finding the "FDI firms"[4] as against "non-FDI firms". PROWESS provides data for foreign promoter's equity holdings. If for a company, equity holding of the foreign promoter exceeds 25 percent, it is classified as a foreign owned firm or a "FDI firm". However, foreign promoter's equity holdings are reported in the database only for post 2001 period. As this study covers a twenty-year period (1991 to 2010), the information on equity holdings to identify company ownership cannot not be used. Further, numerous missing values of equity participation also reduces the sample size in a big way. The database instead provides separate information on the ownership group of firm in the sense of whether a firm is 'Private Indian', 'Private Foreign' or a 'State-run' enterprise. This information is used in the study to identify domestic and foreign ownership of firms. Such an ownership classification however does not differentiate between MNE affiliates and licensees of foreign firms as in Siddharthan and Nollen (2004), between wholly owned foreign enterprises and joint ventures, nor between foreign investment firms and investment-from-Mauritius firms, as is often done in the literature.

[4] Statistical information on India's overseas FDI can be availed. However, the database does not provide any information on source- and destination-wise FDI. As a result, the database does not provide any scope to arrive at re-directed investment and hence, estimates of "actual" foreign investments in India.

Second, the information on firms used in the study, being based on balance sheet of firms, are not product-specific. Thus it is not possible to carry out an analysis for multi-product firms. The comparison between MNEs and domestic firms considered are not product specific, even though most firms are multi-product by nature. Instead, mainly on account of non-availability of detailed product-wise data for individual firms, broad product groups are considered to analyse Indian manufacturing as a whole. The problems with data notwithstanding, the study include 8220 firms for the purpose of analysis. 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.

In what follows is a discussion of the estimation results.

3. Analysis

The results of multinomial logit estimation are represented in Tables 3.1, 3.2 and 3.3. The results suggest that foreign ownership of a firm plays a crucial role in the firm's decision to depend on only foreign technology as against remaining technologically passive. Foreign ownership also significantly increases the possibility of the firms to involve in local R&D as well as use foreign technology simultaneously as against remaining passive. However, foreign ownership diminishes the firm's possibility to engage in only local R&D though not significantly. The marginal effects suggest that ownership play a crucial role in making a firm technologically active as against remaining passive. Again, the elasticity relationship reflects the dependence of foreign technology of firms with foreign ownership. This relationship suggests that MNE affiliates may have a lesser necessity for in-house R&D given access to the R&D laboratories of their parent firms. This result is in conformity with Sasidharan and Kathuria (2011). Size of a firm plays a significantly positive role in the firm's possibility to become technologically active as against remaining passive. Size of a firm increases the probability of a firm to engage in local R&D, to use foreign technology as well as involve in local and foreign technology simultaneously. This is an expected result as one of the most important determinants of innovative activities of firms is firm size which arises from the Schumpeterian notion of existence of economies of scale (Cohen and Levinthal, 1989). Large firms have greater financial resources and are capable of hedging the risk and uncertainty of undertaking variety of innovative activities.

Though it is often discussed that as firms operate under severe budget constraints (Kathuria and Das, 2005), investment in imported raw materials might reduce the firms' probability to invest in R&D activities, this is not found to be the case for Indian manufacturing. On the contrary, dependence on imported raw materials is evident from the estimation result for a firm to be technologically active. Irrespective of the firm's choice to engage in only local R&D

or only foreign technology or doing both, imported raw materials significantly increase the probability to become technologically active as against remaining passive. Continuous dependence on imported raw materials which is subjected to availability and fluctuating prices might be one of the reasons for the firms to invest in innovative activities to create substitutes. Again, as imported raw materials are of better quality and often require technology for assimilation and adaptation of the same, firms might engage in innovative activities with increased import of raw materials. However, import of capital goods (technology in embodied form) significantly reduces the firm's probability to be technologically active. This might suggest adaptation of foreign embodied technology. Hence, the firm's choice to spend further on local R&D or foreign technical knowhow (disembodied technology) comes down. Similar is the case of domestic inputs. Such a result is expected as the firms do not have any need to adapt the technology in this case. Hence, they choose to remain technologically passive. Spillover effects have significant implications for technology choices. Both domestic and foreign spillovers increase the firm's probability to become technologically active both in engaging in local R&D and investing in both local research activities and foreign technological know-how. This might be because of the fact that to gain from technology spillover, the host country firms must have a critical level of technical know-how. Hence they tend to decide to remain technologically active. Further, adapting foreign technology spillovers to local conditions requires investment in technology. With such investments in adaptation of foreign spillovers effects, the firm's choice to depend on only foreign technology significantly diminishes.

Table 3.1 Results of Multinomial Logit estimation

Regressors	Technologically Passive	Only Local R&D	Only Foreign Technology	Both Local and Foreign Technology

Ownership		-0.0865	1.2840***	0.5869***
		(-0.63)	(11.75)	(3.84)
Size of the firm		0.3524***	0.9240***	0.9241***
		(3.90)	(13.22)	(13.42)
Import of raw materials		1.1929***	1.3586***	1.2753***
		(6.46)	(7.42)	(6.90)
Import of capital goods		-0.3128***	-0.0002	-0.3689**
		(-2.90)	(-0.01)	(-2.54)
Technology embodied in domestic inputs		-0.0547*	-0.0374	-0.1708***
		(-1.86)	(-1.27)	(-4.12)
Domestic spillover		0.0533***	0.0057	0.1162***
		(16.43)	(0.91)	(36.25)
Foreign spillover		0.0098***	-0.0170***	0.0118***
		(5.40)	(-4.22)	(6.35)
Constant		-1.7130***	-2.1007***	-2.8916***
		(-35.41)	(-30.23)	(-43.54)
No. of Obs	8220			
LRChi-Square	2381.43***			

***, ** and * imply significance at 1%, 5% and 10% level, respectively. Estimated 'z' ratios are given in the parentheses.

Table 3.2 Estimated Marginal Effects of Multinomial logit estimation

Regressors	Technologically Passive	Only Local R&D	Only Foreign Technology	Both Local and Foreign Technology
Ownership	-0.1417***	-0.0563***	0.1631***	0.0349**
	(-6.34)	(-3.51)	(8.96)	(2.26)
Size of the firm	-0.1517***	0.0204	0.0672***	0.0641***
	(-8.98)	(1.59)	(11.82)	(11.92)
Import of raw materials	-0.2963***	0.1359***	0.0871***	0.0733***
	(-7.21)	(5.61)	(6.79)	(6.06)
Import of capital goods	0.0579***	-0.0417**	0.0092***	-0.0254**
	(3.60)	(-2.56)	(2.92)	(-2.14)
Technology embodied in domestic inputs	0.0184***	-0.0047	-0.0007	-0.0130***
	(3.53)	(-1.08)	(-0.29)	(-3.97)
Domestic spillover	-0.0132***	0.0061***	-0.0015***	0.0088***
	(-18.39)	(12.52)	(-2.99)	(26.31)
Foreign spillover	-0.0008*	0.0016***	-0.0018***	0.0010***
	(-1.92)	(6.26)	(-5.23)	(7.08)

***, ** and * imply significance at 1%, 5% and 10% level, respectively. Estimated 'z' ratios are given in the parentheses.

Table 3.3 Estimated Elasticities of Multinomial logit estimation

Regressors	Technologic	Only Local	Only Foreign	Both Local

	ally Passive	R&D	Technology	and Foreign Technology
Ownership	-0.0124*** (-4.46)	-0.0189** (-2.33)	0.0846*** (11.88)	0.0319*** (3.14)
Size of the firm	-0.0626*** (-8.57)	0.0274 (1.62)	0.1734*** (13.91)	0.1777*** (14.17)
Import of raw materials	-0.0560*** (-7.07)	0.0835*** (5.76)	0.1029*** (7.15)	0.0932*** (6.38)
Import of capital goods	0.0084*** (3.62)	-0.0197** (-2.53)	0.0084*** (2.96)	-0.0247** (-2.11)
Technology embodied in domestic inputs	0.0134*** (3.54)	-0.0111 (-1.08)	-0.0034 (-0.29)	-0.0633*** (-3.87)
Domestic spillover	-0.0926*** (-16.95)	0.1379*** (13.20)	-0.0681*** (-2.87)	0.4099*** (34.47)
Foreign spillover	-0.0173*** (-1.91)	0.1162*** (6.28)	-0.2487*** (-5.06)	0.1432*** (7.20)

***, ** and * imply significance at 1%, 5% and 10% level, respectively. Estimated 'z' ratios are given in the parentheses.

In sum, ownership plays a significant role in explaining the choice of a firm to become technologically active as against remaining passive in Indian manufacturing. Ownership also plays a significant role in explaining the firm's choice of depending on foreign technical knowhow. Dependence on imported raw materials and technology spillovers from both domestic and foreign firms are important determinants in making the firms technologically active. However, import of capital goods and technology embodied in domestic inputs do not increase the probability of firms to engage in innovative activities for Indian manufacturing as a whole. Dependence on foreign technical know-how is evident from the estimates.

3. Conclusion

With quantum FDI inflows across sectors in Indian manufacturing, access to frontier technology became easier for the domestic Indian firms, thus widening the technology set available to each firm. With such access to world class technology, the firms faced a crucial

technology choice problem. This paper builds on Basant (1997) and constructs a multiomial logit model of technology choice of a representative firm in Indian manufacturing during post reforms. In understanding the technology decision of firms, factors like firm ownership, size, import of raw materials, imported embodied technology and spillovers from domestic and foreign firms are considered. Results suggest significant dependence on foreign technical know-how. Foreign ownership plays a significant role in explaining the choice of a firm to become technologically active as against remaining passive. Dependence on imported raw materials and technology spillovers from both domestic and foreign firms are evident in making the firms technologically active. However, import of capital goods and technology embodied in domestic inputs do not increase the probability of firms to engage in innovative activities for Indian manufacturing.

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APPENDIX

Alternative models:

Alternative model I

Note: In this model import of raw materials and import of capital goods have been taken together as import of embodied technology.

Table A.1 Results of Multinomial Logit Estimation

Regressors	Technologically Passive	Only Local R&D	Only Foreign Technology	Both Local and Foreign Technology
Ownership		-0.0582 (-0.42)	1.3121*** (12.04)	0.6146*** (4.03)
Size of the firm		0.3595*** (3.98)	0.9290*** (13.24)	0.9457*** (13.44)
Import of embodied Technology		-0.0817* (-1.67)	0.0198 (0.92)	-0.0967** (-2.41)
Technology embodied in domestic inputs		-0.0625* (-1.99)	-0.0350 (-1.10)	-0.1827*** (-4.31)
Domestic spillover		0.0512*** (15.88)	0.0040 (0.64)	0.1139*** (35.80)
Foreign spillover		0.0107*** (5.76)	-0.0142*** (-3.43)	0.0126*** (6.64)
Constant		-1.6227*** (-34.95)	-2.0256*** (-28.80)	-2.7878*** (-42.97)
No. of Obs	8243			
LRChi-Square	2381.68***			

***, ** and * imply significance at 1%, 5% and 10% level, respectively. Estimated 'z' ratios are given in the parentheses.

Table A.2 Estimated Marginal Effects

Regressors	Technologically Passive	Only Local R&D	Only Foreign Technology	Both Local and Foreign

				Technology
Ownership	-0.1475*** (-6.60)	-0.0500*** (-3.17)	0.1642*** (8.95)	0.03329** (2.38)
Size of the firm	-0.1478*** (-8.85)	0.0235* (1.88)	0.0669*** (11.28)	0.0574*** (10.97)
Import of embodied technology	0.0132** (2.01)	-0.0110 (-1.55)	0.0039* (1.95)	-0.0061** (-2.20)
Technology embodied in domestic inputs	0.0189*** (3.58)	-0.0060 (-1.36)	-0.0005 (-0.20)	-0.0123*** (-4.72)
Domestic spillover	-0.0120*** (-16.57)	0.0059*** (12.11)	-0.0014*** (-2.78)	0.0076*** (19.05)
Foreign spillover	-0.0010** (-2.47)	0.0016*** (6.37)	-0.0015*** (-4.38)	0.0008*** (6.92)

***, ** and * imply significance at 1%, 5% and 10% level, respectively. Estimated 'z' ratios are given in the parentheses.

Table A.3 Estimated Elasticities

Regressors	Technologically Passive	Only Local R&D	Only Foreign Technology	Both Local and Foreign Technology
Ownership	-0.0124*** (-4.73)	-0.0168** (-2.04)	0.0867*** (12.14)	0.0340*** (3.31)
Size of the firm	-0.0586*** (-8.57)	0.0329 (1.92)	0.1780*** (13.93)	0.1823*** (14.18)
Import of embodied technology	0.0043** (2.02)	-0.0125 (-1.54)	0.0083** (2.00)	-0.0157** (-2.08)
Technology embodied in domestic inputs	0.03560*** (3.68)	-0.0401 (-1.32)	-0.0067 (-0.20)	-0.1858*** (-4.03)
Domestic spillover	-0.08124*** (-15.11)	0.1397*** (13.12)	-0.0639*** (-2.68)	0.4099*** (34.39)
Foreign spillover	-0.0216** (-2.46)	0.1233*** (6.43)	-0.2141*** (-4.24)	0.1491*** (7.26)

***, ** and * imply significance at 1%, 5% and 10% level, respectively. Estimated 'z' ratios are given in the parentheses.

Alternative model II

Note: In this model, domestic disembodied technology is considered in the left hand side. So the choice becomes local R&D against disembodied technical know-how (both domestic and foreign).

Table A.4 Results of Multinomial Logit Estimation

Regressors	Technologically Passive	Only Local R&D	Only Foreign Technology	Both Local and Foreign Technology
Ownership		-0.267**	.815***	0.258
		(-1.75)	(6.66)	(1.39)
Size of the firm		0.215***	.266***	0.263***
		(9.13)	(11.76)	(11.48)
Imported embodied technology (Lagged)		-.021	-.218	-.188
		(-0.36)	(-0.97)	(-0.68)
Time dummy		.577***	.179**	.780***
		(6.83)	(2.11)	(6.39)
Domestic Raw material		-.107	-.001	-1.11
		(-1.26)	(-0.l8)	(-5.89)
Domestic spillover		.004	0.04***	.101***
		(0.60)	(5.55)	(11.27)
Foreign spillover		.019***	-0.022***	-0.074***
		(5.85)	(-5.32)	(-10.80)
Constant		-2.03***	-1.57***	-1.827***
		(-21.66)	(-18.34)	(-14.67)
No. of Obs	6048			
LRChi-Square	854.19***			