Total Factor Productivity, Foreign Ownership and Technology Import: Are These Crucial in Determining R&D Intensity in Indian Manufacturing?

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1. INTRODUCTION

This study explores a possible two-way relationship between Research and Development (R&D) and Total Factor Productivity (TFP) recognizing that the existing literature consider R&D as an important determining factor of Total Factor Productivity. In doing so, this study attempts to understand the impact of Total Factor Productivity on R&D intensity of Indian manufacturing firms during the post-reforms era. This paper also empirically investigates into the role of ownership and imported foreign technology in determining R&D intensity of Indian manufacturing at the firm-level.

With the study of Griliches (1958), a good amount of both theoretical and empirical studies enquiring into the R&D - Productivity relationship has emerged in the literature. The theoretical models of Griliches (1973) and Terleckyj (1974) suggest that R&D plays an important role in productivity growth. Empirical findings on the issue also indicate a positive and

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significant relationship between a firm's R&D investment and its productivity (Griliches and Mairesse, 1984; and Griliches, 1986, 1988). Mansfield (1980), shows that there exists a statistically significant and direct relationship between the R&D expenditure of a firm or an industry and its rate of increase in Total Factor Productivity using data across manufacturing industries of the US. However, this relationship is found to be weaker at the industry level than at the firm level (Zhang et al., 2003). Chuang and Lin (1999) using firm level data from Taiwan find that a one percent increase in R&D intensity generates a 19.1 percent to 41.7 percent increase in firms' productivity. Hanel (2000) also arrives at similar results. Coe and Helpman (1995) extend the idea further and suggest that a country's TFP not only depends on its own domestic R&D capital stock but also on the R&D capital stock of its trade partners.

Notwithstanding the above relationship between R&D and TFP, this paper aims to explore the existence of bidirectional relationship between the two. Literature, while discussing the relationship between TFP and R&D, identifies "the two faces of R&D" namely innovation and 'absorptive/'learning' capacity (Cohen and Levinthal, 1989) of firms. Such learning efforts or the absorptive capacity of domestic firms might occur as a result of technology transfer from foreign to domestic firms (Wang and Blomstrom, 1992). If productivity of a firm improves due to increase in its absorptive capacity, the firm might not be interested in spending on R&D as such expenditures are mostly sunk in nature and hence considered to be risky (see Miller and Bromily, 1990; Hoskinsson et al., 1993; Barker and Mueller, 2002; Chen and Miller, 2007; Devers et al., 2008 etc.). Thus, in a liberalized regime, the possibility of factor productivity impacting on technology decisions of firms becomes pertinent. This paper empirically investigates the role of TFP on firm-level R&D in Indian manufacturing during post reforms. This to the best of our knowledge has not been explored so far.

FDI inflows to the emerging market economies including India mostly occur through Multinational Enterprises (MNEs), whereby foreign firms acquire a substantial control over a host-country firm or set up a subsidiary in a host country (Markusen, 2002). The theory of the MNEs is based on the assumption of advantages that these entities have over the existing local enterprises (Hymer, 1976), in particular advantages arising from ownership, assets, knowledge and technology, risk taking behaviour and long-term financing decisions over the domestic counterparts (Caves, 1996). MNEs remain internationally competitive through a combination of technological innovation, access to frontier foreign technology and a variety of complementary assets. It has been increasingly recognized that presence of foreign firms contributes, directly or indirectly, to the performance and technological choices of host country firms.

With increase in MNE operations in India since 1991, the hitherto protected domestic firms facing competition had to review their technology strategies. As technology followers, on one hand, it was expected that there would be a huge dependence on imported technology. While on the other, 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, firms are likely to invest in local R&D as well. 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; 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). 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 studies of Ronstadt (2002), Pearce (1999), Birkinshaw and Morrison (1995), and 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. Further, Mukherjee and Sinha (2013) in a North-South trade model show that southern patent protection makes southern firms better off by increasing the southern firms' incentive to innovate and affecting the nature of competition in the world market. In sharp contrast to the conventional perception, the modern knowledge seeking R&D laboratories seek for geographically differentiated frontier technology with the motive to preserve the technological lead of the MNEs.

Findlay (1978), Das (1987), Wang and Blomstrom (1992), Perez (1997) contribute to the theoretical literature focusing on the effects of the presence of MNEs on the technology development of the host country. They emphasize on the fact that spillover benefits might increase with the technology gap between local recipient and foreign investors. Findlay (1978) formulates a dynamic model to analyze the role of MNEs in the process of technological transfer to the LDCs. Das (1987) extended Findlay's model, considering technological spillovers from the subsidiary to the host country firms, show higher productivity spillovers to the domestic firms resulting from higher production of the subsidiary. The firm's own capability is also crucial in making use of the knowledge that they can access (Blomstrom and Kokko, 2003; Keller, 1996; Rogers, 2004).

The empirical literature on the issue has spawned into two different directions. The first approach finds 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, 2005; Chuang and Lin, 1999; Fan and Hu 2007) foreign technology import substitutes local R&D. One school of thought establishes that foreign firms can contribute directly or indirectly to the technological activities in the host country in order to adapt to local conditions, while the domestic firms in presence of competition from foreign firms may invest in technological activities. Lall (1983), Nelson (2004), Toimura (2003), Kumar and Aggarwal (2005), Sasidharan and Kathuria (2011) and Basant and Mishra (2014) provide evidence on complementarity. The other view is skeptic about the technological efforts of foreign firms in the host country as MNEs have easy access to the parent firm's technology (Globerman and Meredith, 1984; Fan and Hu, 2007) and domestic firms' in-house R&D, given huge costs and gestational lags. 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. The evidence is thus not conclusive with regards to the relationship between imported technology and domestic R&D. This is particularly intriguing when there is a difference in the behavioral pattern of the MNEs and domestic firms, as observed by Caves (1974).

Any further research on the issue of R&D activities in an emerging economy such as India has to investigate the impact of TFP along with ownership and imported foreign technology on the local innovative activities at a further disaggregate level. This study precisely aims to understand these different dimensions impacting R&D intensity of Indian manufacturing at the firm-level during the post reforms era. This is where the paper contributes to the existing literature.

The paper is organized as follows. Section 2 puts forth some stylized facts on R&D in Indian manufacturing. Section 3 discusses the analytical framework and the empirical model. The database and method of estimation are discussed in section 4. Section 5 presents the empirical results. Lastly, section 6 summarizes the major findings of the paper.

2. SOME STYLIZED FACTS ABOUT R&D EXPENDITURE IN INDIA

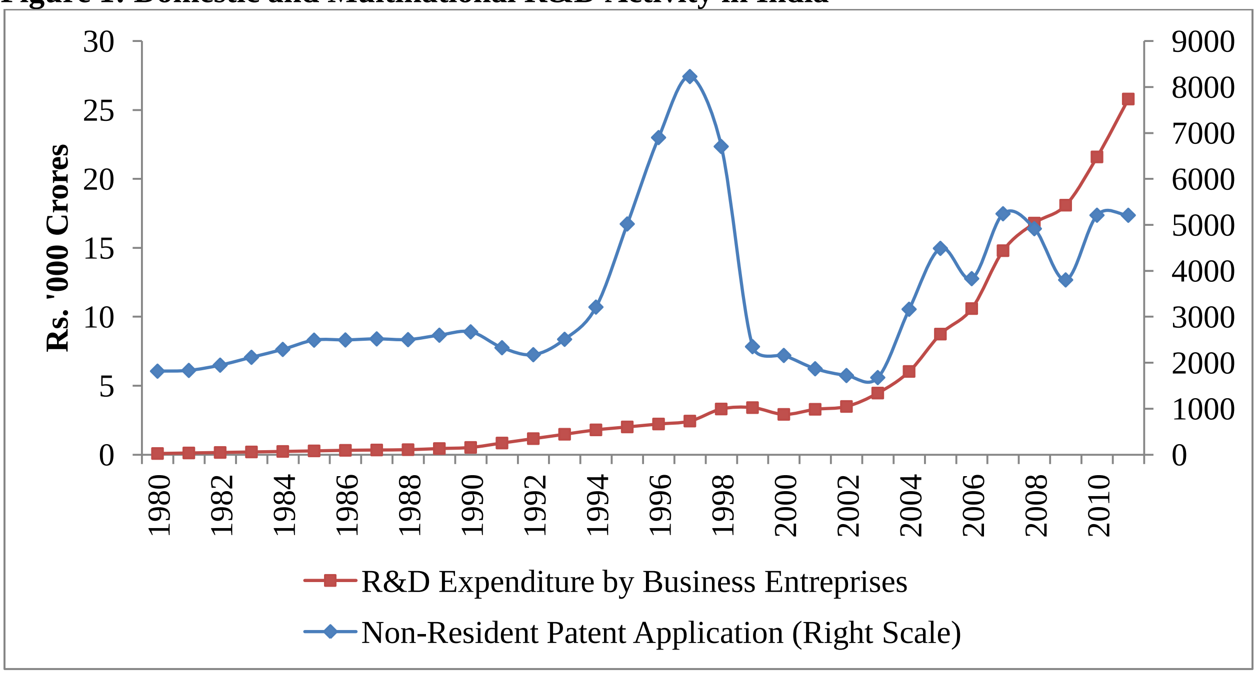
The comprehensive reforms process which began in the early 1990s in India, was actually initiated in the mid-1980s with liberalization of external trade. Wide ranging changes in India's industrial policy, especially with regards to foreign capital movements, were introduced in 1991 with complementary changes in other policies as well. India's foreign investment policy measures initiated in the 1990s, which mark a departure from those of the 1980s, made the economy more open and proactive to build strategic alliances and penetrate the world market (Ahluwalia, 2008). As a result, India witnessed quantum increases in FDI inflows since 1991[1].

FDI in many emerging market economies including India is encouraged, to gain international competitiveness. To gain international competitiveness, technology plays an important role along with FDI. The host economy gets access to world class technology with FDI inflows and foreign firms contributing, directly or indirectly, to the innovative activities of host country firms (Lall, 1993). The adoption of the WTO Agreement on the Trade Related

[1] Developing countries witnessed increasing foreign investment inflows since 1980s (UNCTAD, 1995).

Intellectual Property Rights (TRIPS) since the mid-1990s has significant implications for international technology markets and international technology transfer. India's technology indicators show improvements during post 1991 reforms (Ghosh and Sinha Roy, 2016). India's in-house R&D expenditure increased after 1991 along with an increase in non-residents patent applications in India during the same period, especially after 1999 (See Figure 1).

Figure 1: Domestic and Multinational R&D Activity in India



Further, as Banerjee and Sinha Roy (2014) show, imports of embodied technology, capital goods in particular, increased significantly during this period. A rise in the R&D expenditure is indicative of an enhancing domestic technological capability, a rise in non-resident patent application in India corroborates to increasing multinational R&D activity in India. Further, such a pattern of development of technological capability in India can be explained, following Dinopolous and Segerstorm (2010), in terms of technology transfer within multinationals when

IPR protection is strong in a southern country. FDI has thus emerged as the major channel of technology transfer and international diffusion of knowledge and technology in India (Kumar, 1995; Glass and Saggi, 2009).

R&D expenditure in India as a percentage of GDP, as reported in Table 1, is low as compared to developed and other emerging market economies such as China. Between 2001 and 2010, R&D expenditure as a percentage of GDP has increased from 0.72 to 0.80; whereas that of China has increased from 0.95 to 1.73. Although, India's R&D expenditure as a percentage of GDP has remain always lower than developed countries such as the US or Japan, or even OECD countries; it has performed substantially well vis-à-vis its regional counterparts.

Table 1: R&D Expenditure as per cent of GDP

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
India	0.72	0.71	0.71	0.74	0.81	0.80	0.79	0.84	0.82	0.80
China	0.95	1.06	1.13	1.22	1.32	1.38	1.38	1.46	1.68	1.73
BRICS	0.92	1.00	0.98	0.98	1.01	1.03	1.05	1.07	1.14	1.11
US	2.64	2.55	2.55	2.49	2.51	2.55	2.63	2.77	2.82	2.74
Japan	3.07	3.12	3.14	3.13	3.31	3.41	3.46	3.47	3.36	3.25
South Asia	0.58	0.58	0.59	0.63	0.69	0.70	0.71	0.73	0.71	0.69
OECD	2.17	2.14	2.15	2.12	2.15	2.19	2.23	2.31	2.36	2.33
World	1.55	1.54	1.54	1.52	1.54	1.55	1.57	1.61	1.65	1.63

Source: UNESCO's database of Science, Technology and Innovation

Table 2 below shows R&D expenditure in India across major economic activities. In terms of source of funding, R&D expenditure can be divided into two categories, namely public and private. It can be seen from the table that the R&D expenditure in the manufacturing sector accounts for only 21.29 per cent of the total R&D expenditure in the economy. However, almost half (46.12 per cent) of the total R&D expenditure funded by private sources goes to manufacturing sector. On the other hand, within the manufacturing sector 82.95 per cent of the total spending on R&D has been funded by private sources. These figures call for firm level studies to arrive at the determining factors of R&D intensity in Indian manufacturing sector.

Table 2: R&D Expenditure in Different Economic Activities (Rs. Crores) in 2009-10

NIC 2004	Economic Activity	Public	Private	Total
A+B+C	Agriculture, Forestry & Fishing, Mining & Quarrying	7047.1 {87.50} [21.54]	1006.72 {12.50} [4.96]	8053.82 {100} [15.19]
D	Manufacturing	1924.98 {17.05} [5.88]	9365.76 {82.95} [46.12]	11290.74 {100} [21.29]
E+F	Construction, Electricity Gas & Water Supply	3575.53 {96.83} [10.93]	117.12 {3.17} [0.58]	3692.65 {100} [6.96]
I	Transport & Communication	776.42 {12.66} [2.37]	5354.48 {87.34} [26.37]	6130.9 {100} [11.56]
L+O	Public Administration & Defense and Other Services	19397.18 {81.30} [59.28]	4462.6 {18.70} [21.98]	23859.78 {100} [44.99]
A+B+C+ D+E+F+I +L+O	Total	32721.22 {61.71} [100]	20306.67 {38.29} [100]	53027.89

Source: Authors' calculation on the basis of data obtained from Ministry of Science and Technology, Government of India. (Downloaded from www.indiastat.com).

Note: The first figure in a cell is the R&D expenditure measured in Rs. Crore. The second and the third figures are the sectoral share and share of that economic activity respectively.

Table 3 reflects expenditure on R&D across sectors in Indian Manufacturing. We find that R&D expenditure has increased across sectors as well as technology intensities in India from 2005-06 to 2009-10 and the total expenditure increasing from Rs 5193.23 crores to Rs 10377.1 crores during the period. Drug and Pharmaceuticals is the sector which is found to expend the most on R&D activities over years followed by Machinery and Equipment and Electrical Machinery and Apparatus. This is expected as these industries belong to the High/Medium High technology sector. In the Medium-low technology sector, Basic metals show the maximum R&D expenditure.

Table 3: Technology Intensity and R&D Expenditure in Indian Manufacturing Industries in 2005-06 and 2009-10

Manufacturing	NIC 2008	Technology Intensity (ISIC)	2005-06	2009-10
Drugs & Pharmaceuticals	21	High Tech Industry	3408.42	6475.92
Manufacture of Medical, Precision and Optical Instruments	26	High Tech Industry	58.16	67.37
Manufacture of Chemicals, Chemical Products & Fertilizers	20	Medium High Tech Industry	478.6	973.71
Manufacture of Electrical Machinery and Apparatus	27	Medium High Tech Industry	288.87	519.11
Manufacture of Machinery and Equipment	28	Medium High Tech Industry	458.45	1391.84
Manufacture of Coke, Refined Petroleum Products and Nuclear Fuel	19	Medium Low Tech Industry	147.44	349.75
Manufacture of Rubber and Plastic Products	22	Medium Low Tech Industry	58.45	125.46
Manufacture of other Non-Metallic Mineral Products	23	Medium Low Tech Industry	73.98	110.9
Manufacture of Basic Metals	24	Medium Low Tech Industry	154.54	278.12
Manufacture of Fabricated Metal Products	25	Medium Low Tech Industry	66.32	84.95
Manufacture of Food Products and Beverages	10+11	Low Tech Industry	210.1	437.25
Manufacture of Tobacco Products	12	Low Tech Industry	67.5	109.58
Manufacture of Textiles	13	Low Tech Industry	110.06	180.09
Manufacture of Wearing Apparel, Dressing and Dyeing of Fur	14	Low Tech Industry	20.21	30.46
Tanning and Dressing of Leather, Luggage Handbags etc.	15	Low Tech Industry	45.27	65.14
Manufacture of Wood and Products of Wood and Cork	16	Low Tech Industry	7.54	12.21
Manufacture of Paper and Paper Products	17	Low Tech Industry	40.43	78.88
Total R&D Expenditure (Rs Crore)			**5193.23**	**10377.1**

Interestingly, of the low technology sector, the expenditure on R&D of Food Products has more than doubled from Rs 210.1 crores in 2005-06 to Rs 437.25crores in 2009-10. Textiles also show considerable improvements in R&D expenditure during this period.

In this paper we have considered firms belonging to the Chemicals (including Drug and pharmaceuticals), Machineries, Basic metals, Food and beverages and textiles industries to understand the determining factors of R&D intensity in Indian manufacturing. We have also included firms belonging to the high-tech transport equipment industries for the purpose of analysis.

What follows next is the analytical framework of the study.

3. Analytical framework

3.1 The Theoretical Model

Suppose the production function of a representative firm is expressed as:

$$Y_{it} = A_{it} L_{it}^{\alpha} K_{it}^{\beta} I_{it}^{\gamma} \tag{1}$$

where Y_{it}, A_{it} , L_{it} , K_{it} and I_{it} are total sales, TFP , labour employed , physical capital stock and imported inputs (import of capital goods and raw materials) by the ith firm at time t.

Replacing K, L and I by their respective demand functions[2], the production function is derived as follows:

$$Y_{it} = A_{it} C_{it}^{\alpha+\beta+\gamma} \frac{1}{(\alpha+\beta+\gamma)^{\alpha+\beta+\gamma}} \left(\frac{\alpha}{w}\right)^{\alpha} \left(\frac{\beta}{r}\right)^{\beta} \left(\frac{\gamma}{e}\right)^{\gamma} \tag{2}$$

where C is the total cost, w, r and e are unit price of labour, capital and imported input respectively. The above equation is modified to get the cost function as follows:

[2] Input demand functions are obtained by maximizing production function subject to the cost constraint, $C_{it} = wL_{it} + rK_{it} + eI_{it}$. Sufficient conditions are examined.

$$C_{it} = (\alpha+\beta+\gamma)\left(\frac{Y_{it}}{A_{it}}\right)^{\frac{1}{\alpha+\beta+\gamma}}\left(\frac{w}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta+\gamma}}\left(\frac{r}{\beta}\right)^{\frac{\beta}{\alpha+\beta+\gamma}}\left(\frac{e}{\gamma}\right)^{\frac{\gamma}{\alpha+\beta+\gamma}} \quad (3)$$

Dividing both sides by Y_{it} an expression for ratio of cost to sales, denoted by C'_{it} is derived as :

$$C'_{it} = (\alpha+\beta+\gamma)\, A_{it}^{-\left(\frac{1}{\alpha+\beta+\gamma}\right)}\, Y_{it}^{\left(\frac{1}{\alpha+\beta+\gamma}-1\right)}\left(\frac{w}{\alpha}\right)^{\frac{\alpha}{\alpha+\beta+\gamma}}\left(\frac{r}{\beta}\right)^{\frac{\beta}{\alpha+\beta+\gamma}}\left(\frac{e}{\gamma}\right)^{\frac{\gamma}{\alpha+\beta+\gamma}} \quad (4)$$

Assuming $Y_t = \sum_i Y_{it}$ (the total industry output at time t) equal to 1, Y_{it} is interpreted as the size of the firm. Logarithmic transformation of the above equation is as follows:

$$\ln C'_{it} = \ln\varphi - \left(\frac{1}{\alpha+\beta+\gamma}\right)\ln A_{it} + \left(\frac{1}{\alpha+\beta+\gamma} - 1\right)\ln Y_{it} + \left(\frac{\alpha}{\alpha+\beta+\gamma}\right)\ln w + \left(\frac{\beta}{\alpha+\beta+\gamma}\right)\ln r + \left(\frac{\gamma}{\alpha+\beta+\gamma}\right)\ln e \quad (5)$$

In the literature[3], the evolution of R&D capital stock over time is described as follows:

$$R_{it} = \sum_{k=1}^{n} \mu_k E_{t-k} + (1-\delta)R_{i,t-1} \quad (6)$$

R&D of the i^{th} firm at time t is the sum of all past R&D expenditures and depreciated R&D capital at time t-1. Here, μ_k is a distributed lag and δ is the rate of depreciation of R&D capital. However, this study considers R&D as the current period expenditure on R&D. As measuring the growth of R&D expenditure for a firm (Mansfield, 1980) is complex, it is assumed that a firm's expenditure on R&D during a particular year is approximately equal to the year's change in the firm's stock of R&D capital, rate of depreciation being significantly small (Griliches, 1980; Terleckyj, 1973). Hence, it is assumed that the change in current year's R&D stock is approximately equal to current year's expenditure on R&D. This assumption does not substantially differ from Griliches (1980), Terleckyj (1973) and Mansfield (1980). Apart from production cost, the study incorporates two other costs components, viz. marketing cost (C'^{M}_{it}), and cost of R&D (C'^{R}_{it}) . Hence, equation (5) can be rewritten as:

[3] See Griliches (1980), Nadri (1980) and Goto and Suzuki (1989) for example.

$$\ln C'^{R}_{it} = \ln\varphi - \ln C'^{M}_{it} - \left(\frac{1}{\alpha+\beta+\gamma}\right) \ln A_{it} + \left(\frac{1}{\alpha+\beta+\gamma} - 1\right) \ln Y_{it} + \left(\frac{\alpha}{\alpha+\beta+\gamma}\right) \ln w + \left(\frac{\beta}{\alpha+\beta+\gamma}\right) \ln r + \left(\frac{\gamma}{\alpha+\beta+\gamma}\right) \ln e \tag{7}$$

The estimable model, presented in the following subsection is obtained.

3.2 The Estimation Model

The estimation model, in its general form, is:

$$R\&D_{it} = \alpha_0 + \alpha_1(R\&D_{t-1}) + \alpha_2(\mathrm{size}_{it}) + \alpha_3(\mathrm{age}_{it}) + \alpha_4(\mathrm{mktcost}_{it}) + \alpha_5(\mathrm{fortech}_{it}) + \alpha_6(\mathrm{TFP}_{it}) + \alpha_7(\mathrm{own}_{it}) + +u_{it} \tag{8}$$

Where the variables[4] are constructed as follows:

R&D: Ratio of R&D expenditure to sales.

size: Ratio of firm sales to industry sales.

age: Absolute age of the firm in number of years[5]

mktcost: Ratio of summed up advertising expenditure, marketing expenditure and distribution expenditure to sales.

fortech: Ratio of the sum of expenditure on import of capital good, import of raw materials and import of foreign technical know-how to sales.

TFP: Total Factor Productivity measured by the semi-parametric method of Levinsohn-Petrin[6].

own: A dummy variable, taking the value 1 if the firm is foreign, and 0 otherwise.

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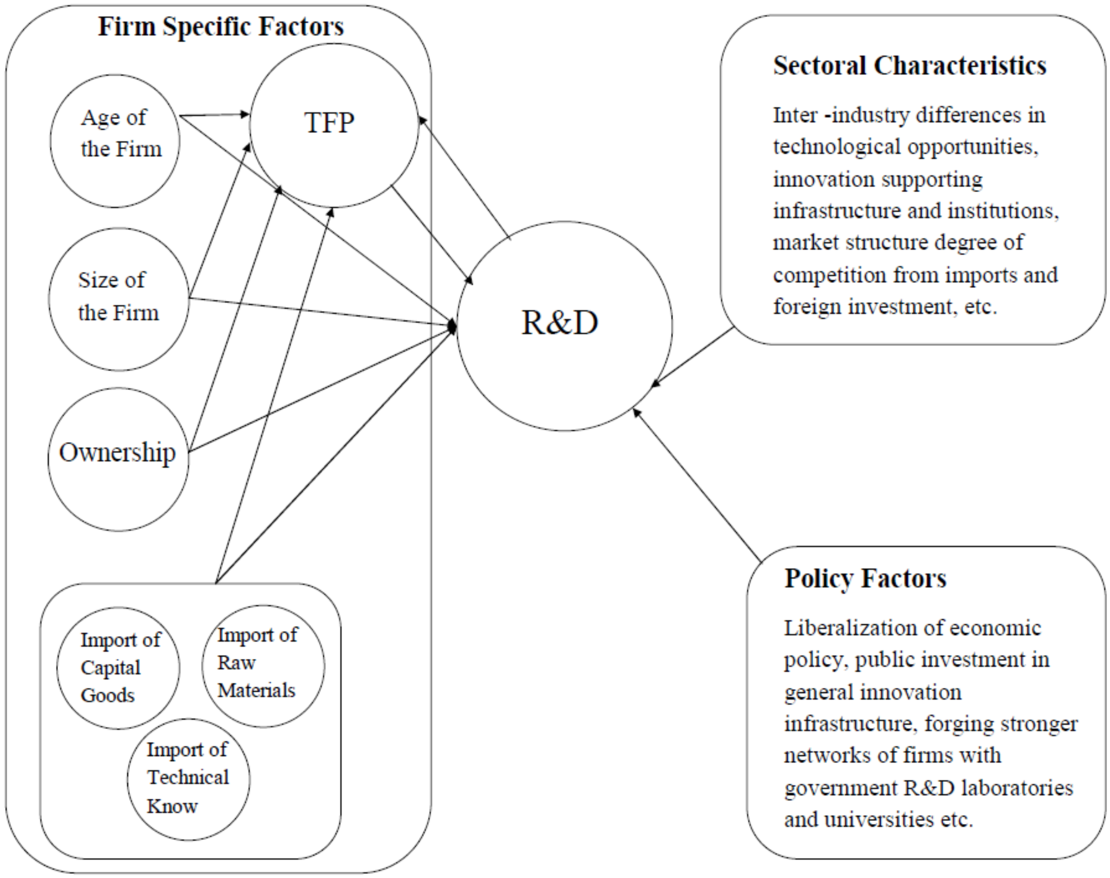
[4] See Appendix 1 for the correlation matrix.
[5] A better estimate of 'Age' in this context could be the numbers of years under present management. However, the database used for the purpose of analysis does not provide such data. Hence, the absolute age of the firm since incorporation has been considered to construct the variable.
[6] See Notes in Appendix 2 for details.

Figure 1: A Schematic Framework of the factors determining R&D intensity of firms



4. Method of Estimation and Data:

The study uses system estimator as suggested by Blundell and Bond (1998). Dynamic relationship among economic variables is identified by the presence of a lagged dependent variable among regressors. In a panel data set up this can be discerned by the presence of autocorrelation and other individual effects account for heterogeneity among individuals:

$$y_{it} = \delta y_{i,t-1} + x'_{it}\beta + u_{it} \quad i = 1, 2,\ldots\ldots, N;\ t = 1,2,\ldots\ldots, T \tag{9}$$

where δ is a scalar, x'_{it} is a 1 x K vector of strictly exogenous regressors and β is a K x 1 vector of coefficients. Here u_{it} is assumed to follow a one-way error component model as:

$$u_{it} = \mu_i + v_{it} \quad (10)$$

where μ_i and v_{it} are independent of each other and IID with mean 0 and variance σ_μ^2 and σ_v^2 respectively. The unavoidable correlation between $y_{i,t-j}$ i.e., the lagged dependent variables with u_i i.e., the unobserved panel level effects makes OLS estimator biased and inconsistent even though v_{it} is not serially correlated. Anderson and Hsiao (1981) show that first differencing of the model can give consistent estimator. But this does not necessarily produce efficient estimator. A generalized method of moments (GMM) procedure suggested by Arellano and Bond (1991) gives a consistent estimator.

Based on the study by Arellano and Bover (1995), Blundell and Bond (1998) have developed an estimator by assuming absence of autocorrelation in the idiosyncratic errors and no correlation between panel-level effects and the first difference of the dependent variable. Blundell and Bond (1998) by making this additional assumption increase efficiency by introducing more instruments. This method is called the system GMM dealing with a system of two equations namely the original and the transformed equation. This system GMM estimator not only improvises precision but also reduces finite sample bias even when the covariates are weakly exogenous. With large cross section units observed for a small number of time periods, difference GMM estimators have often been found to produce unsatisfactory results (Mairese and Hall, 1996). System GMM turns out to be a better choice in this case.

Despite limitations, firm-level data across sectors are obtained from Prowess Database published by the Centre for Monitoring Indian Economy (CMIE) for the period 2001-2010. In this study, the firms were identified according to ownership i.e. the “FDI firms” 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, PROWESS reports data on foreign promoter’s equity holdings only for post 2001 period. However, numerous missing values of equity participation do not auger well with the empirical analyses being carried out. The database 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 etc. This information is used in the study to identify domestic and foreign ownership[7] of firms. We use a dummy variable indicating ownership taking the value one if the firm is foreign and the value zero if the firm is domestic.

The PROWESS database provides information on salaries and wages and provides no information on the number of employees. In order estimate Total Factor Productivity, labour data was required. The Annual Survey of Industries (ASI) database of the Central Statistical Organization (CSO) is used to mitigate the problem. The data on Total emoluments and Total persons engaged for the relevant industry were collected from the ASI database. This requires data matching. Such matching has been done at the two digit level. Since the time period under consideration is 2001 to 2010, concordance between NIC 1998, NIC 2004 and NIC 2008 classification of industries at two-digit level has been done. A total of 3840 observations include both domestically owned and foreign owned firms[8].

[7] As the study explores the impact of foreign ownership on R&D intensity of firms, the ‘ownership’ variable does not take into account the differences between public and private enterprises or proprietary and partnership enterprises.

[8] Sector-wise analysis of the relationship between R&D intensity of firms and the other variables can give a better insight as technology opportunities are likely to vary across sectors and R&D intensities would vary accordingly. However, this study considers Indian manufacturing as a whole. This is precisely because of the fact that number of foreign firms in certain sectors are too less as compared to the domestic firms and does not auger well for econometric estimation.

5. Estimation Results

Estimation results of Equation (8) presented in Table 1 suggest that foreign ownership plays a positive and significant role in determining firm-level R&D intensity in Indian manufacturing. It is often suggested that MNEs carry out their innovative activities in their home countries (Annique and Cuervo-Cazurra, 2008) rather than in their host countries. However, with establishment and improvement of R&D labs in the post-1991 era the situation is much different (Sasidharan and Kathuria, 2011). In the Indian context, the result of this study is in conformity with Kumar (2001) suggesting that MNEs play an important role in determining R&D activities in the host country. The results further suggest a significant path dependence of firm-level R&D intensity, implying that the past year's expenditure on R&D has a strong impact on the R&D expenses of the current year. This also shows the extent of a firm's learning experience leading to greater experimental and tacit knowledge (Bhaduri and Ray, 2004).

It is found that higher total factor productivity of a firm significantly reduces its R&D intensity. This is suggestive of the fact that as firms with higher TFP have a competitive edge over other firms, they might not be interested in investing further in R&D which is sunk in nature. Hence, there exists a significant negative relationship between TFP and R&D intensity at the firm-level. This also suggests that firm heterogeneity not only determines firm-level performance, but also a factor explaining technology choices of firms.

Table: 4 Blundell–Bond (System GMM) Estimation Results of factors determining Firm-level R&D intensity

Table : Estimation Results

	Dependent variable R&D
Variables↓ Method	System GMM
R&D L1	0.6303359*** (0.0601315)
R&D L2	-0.124838* (0.0646184)
R&D L3	0.1372679** (0.0695254)
Age	0.0141544 (0.0087272)
Ownership	1.577941*** (0.5207738)
Size	19.36425*** (5.668709)
Size Square	-19.38069*** (6.695841)
ln TFP	-0.0711189*** (0.0239204)
ln Fortech	-0.1453943** (0.0585175)
ln Marketing Cost	0.0854666 (0.1217983)
Constant	-2.403408*** (0.6531816)
N	251
Wald χ^2	229.47***
Observations	3840

Note: (a) Model is estimated considering ln TFP as endogenous;
(b)L1, L2 and L3 are first, second and third lags respectively.
(c) Standard Errors are reported in parentheses;
(d) *** implies significance at 1% level; ** implies significance at 5% level; * implies significance at 1% level;

In most emerging economies including India import of raw materials, capital goods and foreign technical knowhow by firms is one of the major sources of acquiring knowledge from rest of the world. The existing literature in this context initiate debate on the issue of complementarity (Deolalikar and Evenson, 1989; Siddharthan, 1992; Aggarwal 2000) and substitutability (Fikkert 1993, Blumenthal 1979, Katrak 1990, and Kumar and Siddharthan 1997) between R&D intensity and imported technology. This study suggests a negative significant relationship between imported foreign technology with that of firm-level R&D intensity implying substitutability.

As expected, large sized firms also invest in R&D as size is found to be significantly affecting the R&D intensity of firms. This is an expected result as firm size is often considered to be a proxy for resource base, risk perception and economies of scale that crucially determines R&D activities of a firm (Kumar and Pradhan, 2003). A significant non-linearity also exists in this case. Age of a firm and marketing costs, however, remain insignificant in explaining firm-level R&D intensity.

6. Conclusion

Literature suggests that MNEs form one of the major channels of developing new technologies in host economies. Thus, ownership is likely to impact on the technology choices of firms. With the operation of MNEs, access to foreign technology becomes easier, which also might have an impact on a firm's innovative activities. Importantly, as firms are heterogeneous and technology decisions are taken at the firm-level, impact of such heterogeneity on firm-level R&D intensity turns out to be an important research question. This paper empirically investigates the role of these factors determining R&D intensity of Indian manufacturing at the firm-level during post-reforms. Dynamic Panel data estimation for the period 2001-2010 suggests that foreign ownership, large size and previous experience of firms positively explain R&D intensity of firms in Indian manufacturing. Importantly, total factor productivity is found to have a significant negative impact on innovative activity at the firm-level. Estimation results further suggest a significant substitutability between imported technology and local R&D. Age of firms and marketing costs do not create any significant impact. Such evidence is indicative of the continuing existence of various constraints operating in Indian manufacturing post reforms, which by itself creates a case for industrial policy interventions.

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Appendix 1

Table A.1: Classification Concordance between NIC 1998, NIC 2004 and NIC 2008

Description	NIC 1998 2-digit	NIC 2004 2-digit	NIC 2008 2-digit
Chemical and Chemical Products	24	24	20+21
Basic Metals	27	27	24
Food Products and Beverages	15	15	10+11
Motor Vehicles, Trailers and Semi Trailers+Other Transport Equipment	34+35	34+35	29+30
Textile Products+Wearing Apparel, Dressing and Dyeing of Fur	17+18	17+18	13+14
Machinery and Equipment NEC +Accounting and Computing Machinery	29+30	29+30	26+27+28

Table A.2: Correlation Matrix

	R&D	Age	Size	Marketing Cost	TFP	Fortech
R&D	1					
Age	-0.0701**	1				
Size	-0.019	0.1886***	1			
Marketing Cost	-0.0232	-0.0784**	0.1502***	1		
TFP	0.008	0.0028	0.0356	0.0823**	1	
Fortech	-0.0223	0.0166	0.0079	0.0398	-0.009	1

Note: *** implies significance at 1% level; ** implies significance at 5% level; * implies significance at 1% level.

Appendix 2

Notes on the calculation of total factor productivity:

Recently, econometricians doing micro-econometric research have paid great attention to the problem of measuring total factor productivity. Presence of correlation between unobservable productivity shocks and input levels make OLS estimator biased. Use of investment as a proxy for these unobservable shocks might help (Olley and Pakes, 1996). However, this may produce inconsistent estimator especially when investments of firms are lumpy. In a semi-parametric model, using intermediate inputs instead of investment, Levinsohn and Petrin (2003) have addressed this simultaneity problem described by Marschak and Andrews (1944). Using intermediate input proxies instead of investment has many advantages. Since intermediate inputs are not state variables, it renders a simple link between the estimation strategy and the economic theory. From a practical point of view, one may say that use of intermediate inputs as proxies avoids truncating all the zero investment firms, as investment proxy is only valid for firms reporting nonzero investment. In our study, presence of large number of zero observation on investment impelled us to use Levishon-Petrin (2003) method to estimate total factor productivity considering use of energy as the proxy for unobservable productivity shocks. The brief idea of the estimation technique is as follows:

The logarithmic version of a Cobb-Douglas type production function is as follows:

$$\ln Y_t = \beta_0 + \beta_1 \ln L_t + \beta_2 \ln K_t + \beta_3 \ln M_t + \omega_t + \eta_t \tag{A.1}$$

where Y_t is the firm's output, commonly measured as the gross value added; L_t and $M_t$are labour and intermediate inputs respectively; and K_t is the use of capital. The two components of the error – the transmitted productivity component and the other component that is uncorrelated with input choices are denoted by $\omega_t$and η_t respectively. OLS estimation technique ignores correlation between ω_t, a state variable with other state variables considered in the production function engendering inconsistent results. Demand for intermediate input m_t[9] can be expressed as a monotonically increasing function of ω_t:

[9] Variable written in small letters is the logarithm of the actual variable

$$m_t = m_t(k_t, \omega_t) \tag{A.2}$$

To get the function for the unobserved productivity term, the above function can be inverted as follows:

$$\omega_t = \omega_t(k_t, m_t) \tag{A.3}$$

Finally imposing an identification restriction following Olley and Pakes (1996) that productivity is governed by a first order Markov process:

$$\omega_t = E[\omega_t|\omega_{t-1}] + \xi_t \tag{A.4}$$

where ξ_t is an innovation to productivity that is uncorrelated with k_t but not necessarily with l_t.

Now, equation (1) can be rewritten as:

$$\begin{aligned} y_t &= \beta_0 + \beta_1 l_t + \beta_2 k_t + \omega_t + \eta_t \\ &= \beta_1 l_t + \phi_t(k_t, \omega_t) + \eta_t \end{aligned} \tag{A.5}$$

where $\phi_t(k_t, \omega_t) = \beta_0 + \beta_2 k_t + \omega_t(k_t, m_t)$. Estimation is carried out in two stages. In the first stage, replacing $\phi_t(k_t, \omega_t)$ by a third order polynomial, equation (5) is estimated using OLS technique. In the second stage, estimated value of $\phi_t(k_t, \omega_t)$, say $\widehat{\phi}_t$ and hence $\widehat{\omega}_t$ are calculated. Then, to calculate SEs of $\widehat{\beta}_1$ and $\widehat{\beta}_2$ a Bootstrap approach is used. Then finally appropriate moment conditions are used to estimate $\widehat{\beta}_0$ and $\widehat{\beta}_3$. When all $\widehat{\beta}$ are estimated, the estimated values of TFP from the following equation are derived as follows:

$$\ln TFP_t = \ln Y_t - \widehat{\beta}_1 \ln L_t - \widehat{\beta}_2 \ln K_t - \widehat{\beta}_3 \ln M_t - \widehat{\beta}_4 \ln E_t$$