Determinants of R&D Behavior of Foreign Firms in India

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In the recent past researchers have observed paradigm shifts in the location and nature of R&D activities undertaken by multinationals in host countries. India is one of the host countries for the R&D activities of foreign firms from developed countries like the USA. Hence, the objective of this study is to understand the factors that determine the R&D behavior of foreign firms operating in India. The data used for the analysis is secondary data extracted from Prowess database of Centre for Monitoring Indian Economy. Econometric analysis is carried out on a panel data consisting of foreign affiliated firms for a period of five year from 2011 to 2015. The preliminary results of the random effects Tobit analysis indicate that the traditional variables like size of the firm and age of the firm are important in determining R&D intensity even in the case of foreign firms. Further analysis is carried out using Heckman two-step econometric specification to understand the factors that determine the decision to invest on R&D and the factors that affect R&D intensity of the foreign firms operating in India. The results of the econometric analyses reveal that other factors like labor intensity, sales and distribution intensity, outsourcing intensity are also relevant in determining R&D activities of the foreign firms.

Keywords

R&D intensity; Foreign firms; Outsourcing; India

Introduction

Over the last few decades, owing to the advances in transportation and communication technologies, many firms are distributing their value chains across the globe (Dunning and Lundan, 2009). The multinationals are increasingly engaging in vertical foreign direct investments (FDI) through which they spread across different locations the different activities that they perform, including research and development (R&D) (Hanson et al., 2005; Guillen and Garcia-Canal, 2009).

Thus, internationalization of R&D has become an important research theme as many multinational companies from developed countries are undertaking R&D activities outside their home country (Ito and Wakasugi, 2007; Kurokawa et. al., 2007). While deciding the location of R&D activity, the multinational firms consider the cost and benefits of R&D (Hu, 2004). The R&D activity may either be performed in the headquarters to have higher efficiency and scale economies or may be carried out in the overseas subsidiaries for product customization and to exploit the resources and incentives provided by host country (Caves, 1996; Hu, 2004).

With regards to nature of host country R&D, two types of activities are noticed. The first type is "home-base exploiting" as proposed by Kuemmerle (1997). It is also known as "asset exploiting" as per Dunning and Narula (1995). In this type of foreign R&D the multinational uses its existing R&D capabilities to support its overseas manufacturing activities. The second type is "home-base augmenting" as proposed by Kuemmerle (1997), which is also known as "strategic asset augmenting" as proposed by Dunning and Narula

(1995). In this type of foreign R&D the multinational tries to capture the knowledge available in foreign competitors and universities and thereby augmenting the capabilities at home.

Researchers like Hegde and Hicks (2008) have noted paradigm shifts in the constituents of R&D in host countries. During 1980s, R&D in the host subsidiaries were mainly concentrating on the development aspect, with the core sophisticated research part still remaining at home. In late 1980s and early 1990s it was observed that the foreign subsidiaries were engaging in sophisticated applied research and even acquiring foreign know-how. However, bulk of these overseas R&D investments undertaken by multinational companies from developed countries like the USA were located in other developed countries (Veliyath and Sambharya, 2011). More recently, multinationals have been seen to be engaging in R&D that can expand their home innovation capabilities. Thus, increasing shares of outbound R&D from USA are going to countries like Singapore, Israel, and India (Doh et al., 2005) in different industries from chemicals to computers (Hegde and Hicks, 2008). Although there has been an increase in multinational firms' R&D investments in developing countries, a large amount of overseas R&D investments by the multinationals are still located in developed countries (Veliyath and Sambharya, 2011).

Some researchers believe that the paths of evolution of FDI in R&D are different for industrialized and emerging countries (Vasudeva and Sonderegger, 2007). In the industrialized countries R&D centers were set up to have access to latest technologies and to exploit or adapt the firm's existing products to local conditions. However, in the case of emerging countries like India, R&D centers were set up with an exploratory approach to acquire and build on locally available knowledge.

Hence, in the light of paradigm shifts in the location and nature of R&D undertaken by multinational firms, the objective of the study is to understand the latest trends in in-house R&D investments by foreign firms in India. Further, the study attempts to understand factors that determine the inter-firm differences in R&D activities of the foreign firms operating in India. Here, foreign firms are the firms that are owned by foreigners including foreign government.

The following section presents a review of literature on the factors that can determine R&D activities of the firms. After that, the sample and methodology is discussed. Then, the next sub-section highlights the patterns in the R&D investments with respect to the foreign firms in the present sample. The subsequent section deals with the analysis and results of the econometric models. The final section gives the conclusion and implications of the study.

Literature Review on Factors determining R&D activities

The following sub-sections give a review of various factors that determine R&D activities of the firms, with focus on India context. These variables include size of the firm, age of the firm, capital intensity, labor intensity, selling and distribution intensity, outsourcing intensity, and import of technology.

Size of the Firm

Size of the firm has been used in innumerable empirical studies on firm behavior. It essentially acts as a proxy for the amount of resources available to the firms (Schumpeter, 1943). Basant (1997) found larger firm size to favorably affect the firm's chances of doing R&D. However, others believe that there is decreasing returns to scale in the production of innovations due to loss of managerial control and bureaucratization of innovative activity (Benvignati, 1982). Katrak (1989) found that larger enterprises invested proportionately less on R&D in Indian industries. Narayanan and Bhat (2009) observe that there is no consensus regarding the effect of size of the firm on innovative activities. Kumar and Siddharthan

(1997) observed that most of the studies on developing countries have found larger firms to be involved in more formal technological activities compared to the smaller ones.

Even in the context of multinationals, large scale operations in the host country increases the chances of better returns to R&D adaption to local market conditions (Belderbos, 2003). In another study Belderbos et al. (2008) found that foreign R&D of the multinationals increases with increase in the size of manufacturing operations in the host country. Hence, it is postulated that the effect of size of the firm on R&D activity is positive for the foreign firms operating in India.

Age of the Firm

Age of the firm captures the experiences and learning of the firm. Siddharthan (1992) noted that in case of Indian firms, the age of the R&D unit would indicate long run and sustained commitments of the units to R&D. The study found that older established firms undertook higher R&D activities. Similar results were found by Narayanan and Bhat (2009) in the case of Indian basic chemical industry. In the context of multinationals too, firms may consider internationalization of R&D only after they have built, over time, a strong business at home (Belderbos et al., 2013). In the case of Japanese multinationals, Ito and Wakasugi (2007) did find evidence that age of the affiliate in the host country has a positive effect on R&D activities of the affiliate in the host country. Hence, it is hypothesized that age of the firm has a positive effect on the R&D activities of even the foreign firms in India.

Capital Intensity

Capital intensity, in terms of investment on plants and machinery as a proportion of sales, indicates the extent to which a company prefers automation of its processes. Capital investment may reflect the overall collateral value of the firm (Hottenrott and Peters, 2011), which may give confidence to the firms to invest more on risky R&D activities. In the case of Indian private corporate sector, Siddharthan (1992) found capital intensity to be unimportant in determining R&D intensity of the firms. However, there is evidence that multinationals in some industries in India like chemicals, pharmaceuticals, textiles, and computers acquire efficiency enhancing capital goods from local suppliers for process innovations (Franco et al., 2011). Hence, in the case of foreign firms in India, it is hypothesized that firms with higher capital intensity would tend to undertake more R&D activities.

Labor Intensity

Higher labor intensity can be a proxy for higher human skills in the firm. Lall (1983) found that technical employee skill has a positive effect on R&D in Indian engineering industry. Tan and Hwang (2002) also found skill to favorably affect the decision of the firms to undertake R&D in electronics industry in Taiwan. Firms from developed countries like the USA internationalize R&D or offshore innovation activities mainly to access qualified personnel (Baskaran and Muchie, 2008; Lewin et al., 2009). Hence, it is postulated that labor intensity as a proxy for skill will have a positive effect on R&D activities of the foreign firms in India.

Selling and distribution

According to Porter (1980), access to distribution channels is one of the barriers to entry into any industry. The foreign firms that invest high amounts on selling and distribution are likely to be the ones who are rigorously building the distribution channels for their existing products in India. Such firms may not be able to invest much on risky in-house R&D efforts during the same year. Hence, it is postulated that selling and distribution intensity may have a negative effect on the in-house R&D activities of the firm.

Outsourcing

Outsourcing, where all or part of a firm's activity is given to an outside vendor, is often considered to be an import tool to cut costs, improve performance, and refocus on the core business (Barthelemy and Adsit, 2003). Thus, the foreign firms that outsource their manufacturing activities may invest more on other activities including in-house R&D. Alternatively, if the outsourcing activity involves sourcing of new technologies from collaborators in India, the R&D activities may be undertaken outside the firm in dedicated R&D centers (Mrinalini and Wakdikar, 2008)

Import of technology

Import of technology can be in embodied form embedded in imported raw material or imported capital goods or can be in disembodied form like designs, drawings, blueprints and patents against royalty and technical fee payments (Basant, 1997). Often firms operating in developing countries like India are observed to be following the import and adapt strategy, where the firms import technology and use in-house R&D investments to the local environment (Katrak, 1985). Although, it is possible that foreign firms may import technology from their parent firms through intra-firm mode, the firms that do purchase technology through arms-length purchases may undertake in-house R&D to adapt the imported technology. Hence, it is hypothesized that import of technology (whether in embodied or disembodied form) has a positive effect on R&D activities of the foreign firms.

Sample and Methodology

The secondary data for the study is extracted from the Prowess database provided by Center for Monitoring Indian Economy (CMIE). The present study considers firms that are classified as foreign as per the database. These are the firms that are owned by foreigners including foreign government. After removal of firms with missing data and the outliers, the final balanced sample consists of data on 242 firms for a period from 2011 to 2015. The sample has both manufacturing and services firms. These firms are classified into different industries based on the two-digit classification (called Division) in 2008 National Industrial Classification (NIC) codes published by the Central Statistical Organization, Ministry of Statistics and Programme Implementation, Government of India.

To construct the variables, information on various firm characteristics has been extracted from the Prowess database. The definitions of the variables based on this information are presented in Table 1. Except SIZE and AGE variables, all other variables are normalized with respect to size of the firm by considering sales in the denominator. The variable outsourcing intensity (OSRCI), which considers only the manufacturing jobs that are outsourced, may be appropriate mainly for the manufacturing firms. Nevertheless, the variable has been introduced all the econometric models in this study as some of the services firms (mainly in publishing industry and wholesale industry) are also outsourcing manufacturing jobs.

Table 1: Definitions of the Variables

Sl.	Variables	Symbol	Definition
1.	Decision to invest on In-house R&D	$\mathbf{D_{RDI}}$	D_{RDI} = 1 if Research and development expenses (in Rs. Millions) > 0 D_{RDI} = 0 otherwise
2.	In-house R&D Intensity	**RDI**	Research and development expenses (in Rs. Millions) as a percentage of sales (in Rs. Millions)

3.	Size of the Firm	**SIZE**	Logarithm of sales (in real terms Rs. Millions)
4.	Age of the Firm	**AGE**	Year of observation – year of incorporation
5.	Capital Intensity	**CAPI**	Net investments on plant and machinery (in Rs. Millions) as a percentage of sales (in Rs. Millions)
6.	Labor Intensity	**LABI**	Investments on salaries, wages, bonus, ex gratia pf & gratuities (in Rs. Millions) as a percentage of sales (in Rs. Millions)
7.	Selling and Distribution Intensity	**SDI**	Selling and distribution expenses (in Rs. Million) as a percentage of sales (in Rs. Million)
8.	Outsourcing Intensity	**OSRCI**	Outsourced manufacturing jobs (in Rs. Million) as a percentage of sales (in Rs. Million)
9.	Import of Raw Materials Intensity	**IRAWI**	Import of raw materials (in Rs. Million) as a percentage of sales (in Rs. Million)
10.	Import of Capital Goods Intensity	**ICGI**	Import of capital goods (in Rs. Million) as a percentage of sales (in Rs. Million)
11.	Import of Disembodied Technology Intensity	**IRTI**	Forex spending on royalty/technical knowhow (in Rs. Million) as a percentage of sales (in Rs. Million)

Econometric Specifications

In the present study, the data is a panel data consisting of 242 firms (cross-sections) and 5 years (time periods) from 2011 to 2015. Since the dependent variable has many zero values, limited dependent data model specifications are considered to be appropriate. Two of the popular limited dependent data models are the Tobit model and the sample-selection model (Cameron and Trivedi, 2009).

Following Cameron and Trivedi (2009), a random effects Tobit model for i cross-sections and t time periods can be specified as,

$$RDI_{it}^{*} = \mathbf{X}_{it}\,\beta + \alpha_i + \varepsilon_{it} \qquad \text{---- (1)}$$

where RDI_{it}^{*} is the latent variable that depends on regressors ($\mathbf{X}_{it}$), an idiosyncratic error (ε_{it}), and an individual-specific error (α_i). If RDI_{it} is the observed variable, then

$$\begin{aligned} RDI_{it} &= RDI_{it}^{*} \text{ if } RDI_{it}^{*} > 0 \\ &= 0 \quad \text{if } RDI_{it}^{*} \leq 0 \end{aligned} \qquad \text{---- (2)}$$

Following Maddala (1983, p. 268), the sample selection model being analysed may be represented as[1]:

$$RDI = \mathbf{X}\beta + u \qquad \text{---- (3a)}$$
$$D_{RDI}^{*} = \mathbf{Z}\gamma - \varepsilon \qquad \text{---- (3b)}$$

[1] The sample is an unbalanced panel data where each observation may be considered as a separate data point. Hence, equation (3a) to equation (4) should ideally have subscript 'it' for RDI, X, D_{RDI}^{*}, Z, and D_{RDI}. However, subscript 'it' has been dropped from the equations for ease of notational representation.

where RDI is the regressand, **X** and **Z** are vectors of exogenous variables, β and γ are vectors of coefficients on **X** and **Z,** respectively, and u and ε are stochastic error terms.

Equation (3b) represents the selectivity criterion with D_{RDI}^{*} as the dependent variable that is not observed. Instead D_{RDI}^{*} has a dichotomous realization D_{RDI} that is related to D_{RDI}^{*} as follows:

D_{RDI} = 1 iff $D_{RDI}^{*} \geq 0$
= 0 otherwise ---- (4)

The dependent variable RDI is conditional on **X.** Furthermore, **Z** has a well-defined marginal distribution. However, RDI is not observed unless $D_{RDI}^{*} > 0$. Thus the observed distribution of RDI is truncated. The parameters can be estimated using the Heckman two-step procedure to ensure consistent estimates for the coefficients (Greene, 2002). Further, in order for the model to be identified it is important to identify at least one factor that affects the selection variable but not the level variable (Maddala, 1983). Furthermore, to ensure that the results are not affected by heteroskedasticity, robust standard errors have been calculated for both random effects Tobit models and Heckman two-step sample selection models through bootstrapping procedure (Horowitz, 2001) with 100 replications. All the statistical models have been estimated in STATA (version 10) statistical software.

Patterns in-house R&D investments by foreign firms in the present study

The pie chart in figure 1 shows the share of some of the industries in the present study sample. The sample has 190 manufacturing firms and 52 services firms. Most of the manufacturing foreign firms in this sample belong to the machinery & equipment industry (Division 28), followed by chemical & its products (Division 20). Around 4 percent firms belong to the pharmaceutical industry (Division 21) and another 4 percent firms belong to computer, electronic & optical products industry (Division 26). The services firms are spread across various industries including wholesale (Division 46), accommodation (Division 55), telecommunications (Division 61) and Computer programming, consultancy and related activities (Division 62).

Figure 1: Pie chart depicting the percentage share of different industries in the study sample

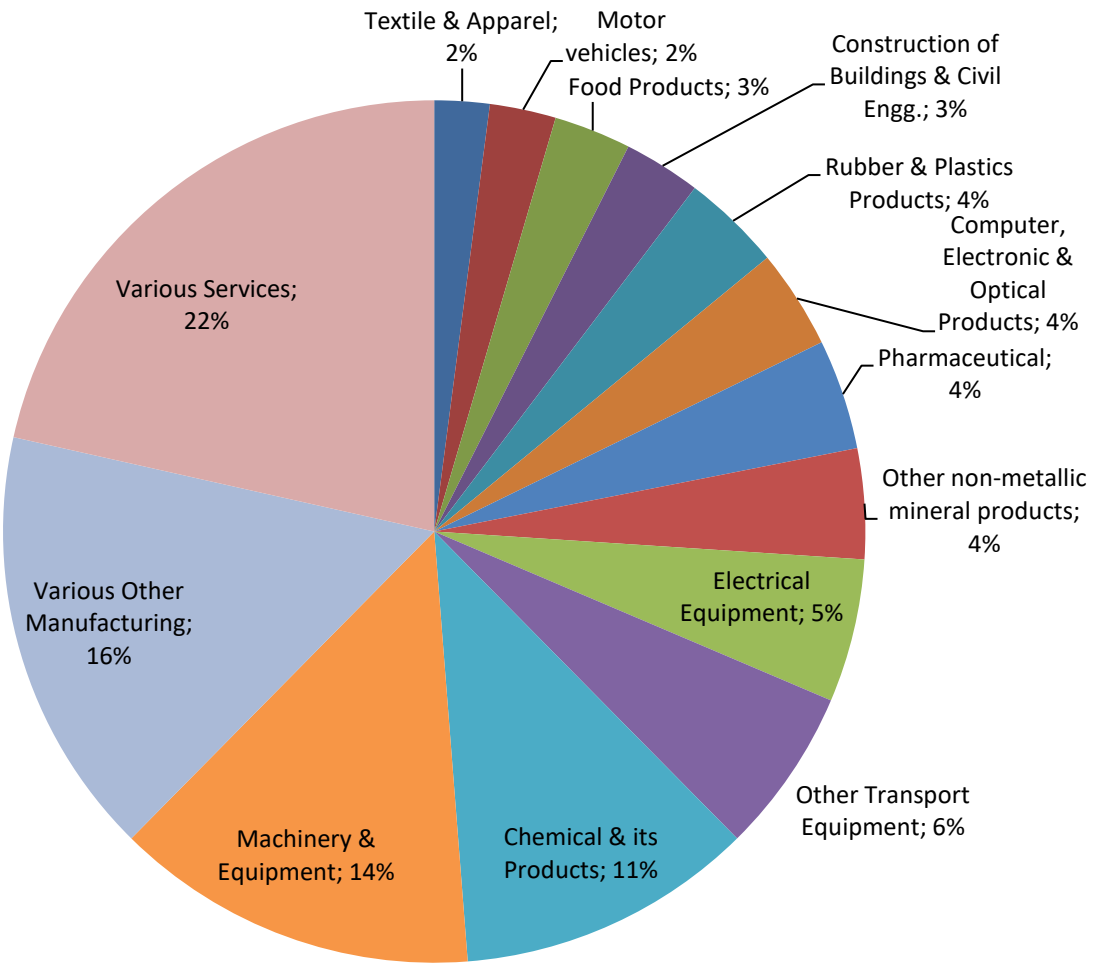
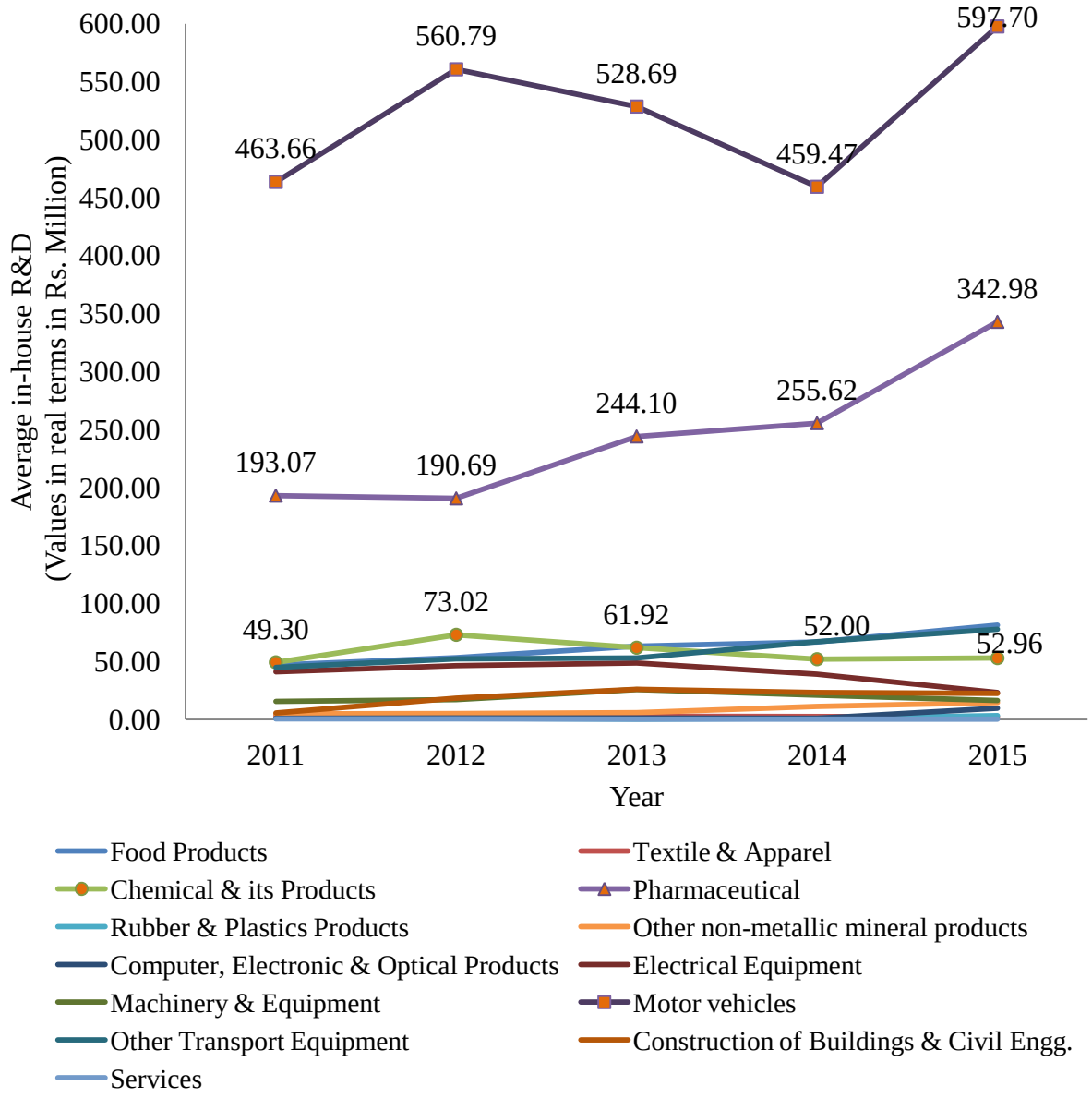


Figure 2 depicts the trends in the average in-house R&D investment values (in real terms) during 2011 to 2015 for some of the industries in the present study sample. According to figure 2, foreign firms operating in motor vehicles are investing the highest amount on in-house R&D followed by those in pharmaceutical industries. The average in-house R&D investments undertaken by the multinationals in other industries are less than Rs. 100 million (in real terms).

In the present study, Mylan Laboratories Ltd. is the pharmaceutical firm that is one of the leading firms in terms of R&D investments (in real terms). The firm operates in India in several pharmaceutical segments like critical care, hepato care, HIV care, oncology care and women's care.[2] The firm claims to have more than 2,900 R&D and regulatory experts who work collaboratively across 10 different centers around the world. Further, about half of the scientific affairs workforce is based in India working at the firm's global R&D center of excellence in Hyderabad and other R&D centers in Bangalore and Ahmedabad.

Figure 2: Trends in average in-house R&D investments of the foreign firms in different industries in the present study during 2011-2015

[2] Information obtained from the website of the company http://www.mylan.in/ (accessed 27 August 2017)



Source: Author's calculations based on data from Prowess Database

In the automobile industry the leading firms in terms of real investments on in-house R&D are Maruti Suzuki India Ltd., Ashok Leyland Ltd. and Bosch Ltd. In the last six years Maruti Suzuki India Ltd. has launched 36 new and refreshed car models.[3] The firm has started a state-of-art R&D center in Rohtak, Haryana is equipped to design, develop and evaluate vehicles. Ashok Leyland Ltd. is a subsidiary of Hinduja Group that is headquartered in London, United Kingdom.[4] The company has a global R&D center at Chennai which has close to around 1000 engineers engaged in design and development of commercial vehicles and vehicle systems. In India, Bosch Automotive Aftermarket Division of Bosch Ltd. is responsible for the supply, sales and distribution of automotive parts for vehicle servicing;

[3] Information obtained from the website of the company https://www.marutisuzuki.com/technology.aspx (accessed 27 August 2017)

[4] Information obtained from the website of the company http://www.ashokleyland.com/ (accessed 27 August 2017)

diagnostics equipment for workshops (i.e. testing equipment), technical information, training, and consulting; and technical after-sales service for Bosch automotive products and systems.[5]

Analysis and Results

Table 2 presents the mean and standard deviation for the different variables in this sample. The table also indicates the number of observations that are undertaking R&D (represented by the dummy variable D_{RDI}). It is clear that hardly any foreign services firms claim that they undertake in-house R&D. In fact, in the present sample, the 12 non-zero observations on D_{RDI} for services is due to four firms undertaking R&D in various years. These four firms are Carrier Airconditioning & Refrigeration Ltd., Aimil Ltd., Kernex Microsystems (India) Ltd. and Lakeshore Hospital & Research Centre Ltd. It is visible that foreign manufacturing firms are having higher average in-house R&D intensity (0.33 percent) compared to foreign services firms (0.02 percent). The average age of the firms in the sample is around 35 years. With regards to embodied technology imports, the average raw material import intensity is higher for manufacturing firms at around 12 percent and the average capital goods import intensity is higher for services firms. Manufacturing firms on an average invest more on sales and distribution as a ratio of sales compared to the services firms. Foreign services firms have higher average labor intensity (19.45 percent) compared to the manufacturing firms (9.22 percent). Interestingly, both manufacturing and services firms are outsourcing manufacturing jobs. In the case of manufacturing, high OSRCI values are present mainly in construction industry and machinery & equipment industry. As mentioned earlier, in the case of services, high OSRCI values are present mainly in publishing industry and wholesale industry.

Table 2: Descriptive Statistics*

Sl.	Variables	Full Sample	Manufacturing	Services
1.	D_{RDI}	Value of 1= 483 Value of 0 = 727	Value of 1 = 471 Value of 0 = 479	Value of 1 = 12 Value of 0 = 248
2.	RDI	0.26 (0.79)	0.33 (0.87)	0.02 (0.13)
3.	SIZE	7.75 (1.91)	8.01 (1.78)	6.78 (2.06)
4.	AGE	35.50 (21.22)	38.7 (20.86)	23.83 (18.25)
5.	CAPI	19.84 (36.66)	18.03 (32.13)	26.46 (49.34)
6.	LABI	11.41 (10.88)	9.22 (6.57)	19.45 (17.67)
7.	SDI	4.88 (5.51)	5.44 (5.74)	2.84 (3.93)
8.	OSRCI	1.24 (3.30)	1.46 (3.48)	0.45 (2.38)
9.	IRAWI	9.84 (12.59)	12.06 (12.91)	1.70 (6.67)
10.	ICGI	1.87 (21.21)	1.21 (3.06)	4.29 (45.37)
11.	IRTI	0.57 (1.03)	0.66 (1.10)	0.22 (0.64)
Number of Observations		1210	950	260

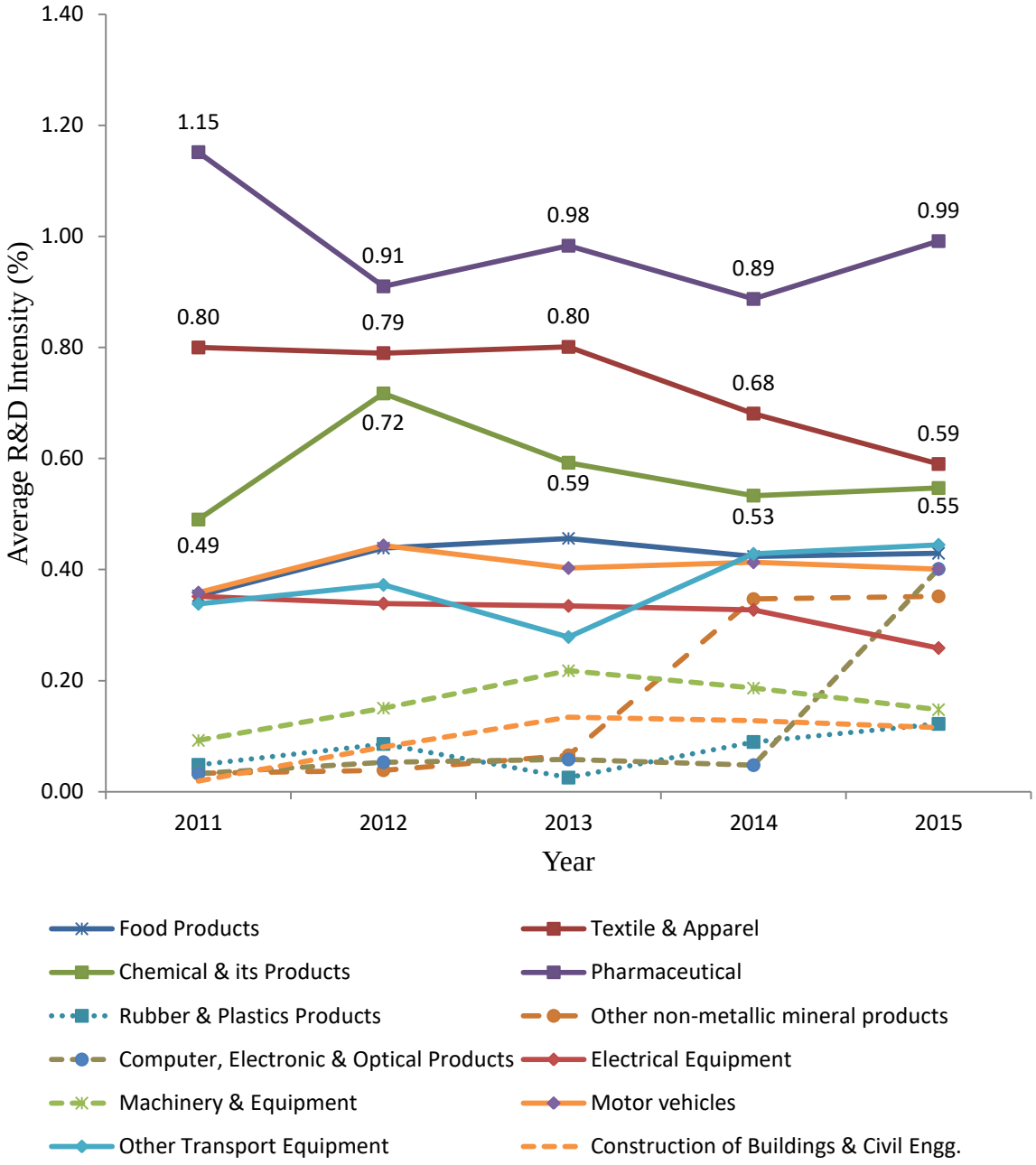
* Mean with standard deviation in parenthesis for the variables from Sl. 2. to 11.

Although foreign firms in motor vehicles industry are leading in terms of average real investments on in-house R&D (figure 1), the trends for the average in-house R&D intensities (figure 3) is different. The highest R&D intensity is observed in the case of the high-tech industry, pharmaceuticals. Interesting the next highest R&D intensity is found in the firms

[5] Information obtained from the website of the company http://www.boschindia.com/en/in/our_company_5/business_sectors_and_divisions_5/automotive_aftermarket_5/automotive-aftermarket.html (accessed 27 August 2017)

belonging to relatively lower technology group, namely, textile and apparel, followed by those belonging to chemical and its products.

Figure 3: Trends in average in-house R&D intensity of the foreign firms in different manufacturing industries in the present study during 2011-2015



Source: Author's calculations based on data from Prowess Database

In the present sample, Voith Paper Fabrics India Ltd. is the firm in the textile and apparel industry with high R&D intensity. The firm is a subsidiary of VP Auslandsbeteiligungen GmbH, which belongs to the Voith Group of Companies, Germany.[6] The firm's focus is on paper machine clothing (PMC), fiber-cement sheet making felts and hi-tech textile processing felts. The firm undertakes research and development activities for

[6] Information obtained from the website of the company https://voith.com/vpf-india-en/ (accessed 27 August 2017). Felt is a textile material that is produced by matting, condensing and pressing fibers together.

improving the quality of its products to meet the expectations of customer and for developing indigenous resources for import substitution. Another firm, Indian Card Clothing Co. Ltd., is into manufacturing of metallic yarn. The firm is promoted by Mauritius based Multi Act Industrial Enterprises Limited (MAIL). The firm undertakes in-house R&D to improve its products and processes in the area of metallic card clothing and card wire. It has ISO 9001:2008 certification.[7]

Surprisingly, in another high-tech industry, namely, computer, electronic and optical products, the average in-house R&D investments (figure 2) as well as average in-house R&D intensity (figure 3) of the foreign firms is relatively low. In this industry, the average R&D intensity improved to around 0.4 percent in 2015 from 0.05 percent in 2011 (figure 3) mainly due to relatively high investments on in-house R&D during the year by Panasonic A V C Networks India Co. Ltd.

Table 3 and Table 4 present the correlation matrix for the variables for the full sample and for the manufacturing firms, respectively. The variables SIZE, AGE, IRAWI and IRTI are positively correlated with RDI. However, the magnitude of correlation coefficient is low in all the cases. The magnitudes of the correlation coefficients between all other variables are also low in both table 3 and table 4. Hence, there are less chances of multicollinearity problem in the present study.

Table 3: Correlation matrix for full sample

Variables	RDI	SIZE	AGE	CAPI	LABI	SDI	OSRCI	IRAWI	ICGI	IRTI
RDI	1.00									
SIZE	0.15*	1.00								
AGE	0.10*	0.30*	1.00							
CAPI	-0.06	-0.21*	-0.11*	1.00						
LABI	-0.05	-0.35*	-0.08*	0.02	1.00					
SDI	0.01	0.29*	0.25*	-0.08*	-0.20*	1.00				
OSRCI	0.03	-0.03	-0.02	-0.06*	-0.04	-0.03	1.00			
IRAWI	0.15*	0.12*	-0.04	-0.16*	-0.22*	-0.10*	-0.04	1.00		
ICGI	-0.01	-0.03	-0.05	0.01	-0.03	-0.03	-0.01	-0.01	1.00	
IRTI	0.15*	0.30*	0.09*	-0.11*	-0.17*	0.15*	-0.02	0.17*	0.07*	1.00

***** Statistical significance at 5 percent level

Table 4: Correlation matrix for manufacturing firms

Variables	RDI	SIZE	AGE	CAPI	LABI	SDI	OSRCI	IRAWI	ICGI	IRTI
RDI	1.00									
SIZE	0.13*	1.00								
AGE	0.06*	0.32*	1.00							
CAPI	-0.05	-0.16*	-0.13*	1.00						
LABI	0.02	-0.40*	0.08*	-0.04	1.00					
SDI	-0.02	0.31*	0.22*	-0.04	-0.17*	1.00				
OSRCI	0.01	-0.08*	-0.04	-0.04	-0.004	-0.06*	1.00			
IRAWI	0.11*	0.03	-0.17*	-0.16*	-0.14*	-0.21*	-0.10*	1.00		
ICGI	0.02	0.04	-0.04	0.09*	-0.07*	-0.01	0.06	0.11*	1.00	
IRTI	0.13*	0.33*	0.05	-0.12*	-0.16*	0.13*	-0.09*	0.11*	0.07*	1.00

***** Statistical significance at 5 percent level

Results of random effects Tobit econometric models

[7] Information obtained from annual report of the company present in Bombay Stock Exchange website http://www.bseindia.com/bseplus/AnnualReport/509692/5096920313.pdf (accessed 27 August 2017) and ICRA report https://www.icra.in/Rationale/GetRationaleFile/27861 (accessed 27 August 2017)

The results of the random effects Tobit econometric models for the full sample and the manufacturing firms are presented in Table 5. To explore industry specific effects on R&D, in the econometric models 2 and 4, additional dummy variables (D_{pharma}, $D_{textile}$, and D_{chem}) have been introduced for the firms belonging to the top three industries with respect to average R&D intensity in the present sample (figure 3). Size of the firm and age of the firm is statistically significant with positive sign in all the four econometric models. This implies that the older and larger foreign firms are likely to undertake more R&D. None of the other variables are statistically significant. This may be because the factors that affect the decision to undertake R&D may be different from the factors that affect in-house R&D intensity. Hence, Heckman two-step estimation models have also been formulated and the results of the same are presented in Table 6.

Table 5: Results of random effects Tobit econometrics model with In-house R&D intensity (RDI) as explained variable[*]

	Model 1	**Model 2**	**Model 3**	**Model 4**
	Full Sample	**Full Sample**	**Manufacturing Firms**	**Manufacturing Firms**
Constant	-2.59 (-4.06)[a]	-2.60 (-4.36)[a]	-2.36 (-3.24)[a]	-2.40 (-3.54)[a]
SIZE	0.13 (2.43)[b]	0.14 (2.70)[a]	0.14 (2.01)[b]	0.15 (2.41)[b]
AGE	0.02 (4.96)[a]	0.02 (3.98)[a]	0.02 (3.31)[a]	0.02 (3.50)[a]
CAPI	-0.002 (-0.69)	-0.001 (-0.44)	-0.001 (-0.30)	-0.001 (-0.26)
LABI	-0.01 (-1.57)	-0.01 (-1.32)	0.002 (0.23)	0.002 (0.14)
SDI	-0.002 (-0.20)	-0.01 (-0.81)	-0.01 (-0.89)	-0.02 (1.18)
OSRCI	-0.01 (-0.64)	-0.01 (-0.47)	-0.02 (-0.84)	-0.01 (-0.79)
IRAWI	0.01 (1.12)	0.01 (0.99)	0.003 (0.51)	0.003 (0.46)
ICGI	-0.005 (-0.57)	-0.005 (-0.76)	-0.003 (-0.43)	-0.003 (-0.58)
IRTI	0.03 (0.62)	0.04 (0.81)	0.04 (0.69)	0.04 (0.77)
D_{pharma}	-	1.42 (1.48)	-	1.23 (1.38)
$D_{textile}$	-	1.48 (0.23)	-	1.13 (0.13)
D_{chem}	-	0.59 (1.34)	-	0.50 (1.06)
Wald Chi^2	33.93[a]	33.21[a]	28.16[a]	36.67[a]
Log Likelihood	-616.18	-608.33	-575.97	-570.09
No. of Obs.	242 × 5 = 1210	242 × 5 = 1210	190 × 5 = 950	190 × 5 = 950

[a, b, c] indicate statistical significance at 1%, 5% and 10% respectively. z-statistics in parenthesis.

[*] Robust standard errors have been calculated using bootstrapping procedure with 100 replications.

Results of Heckman two-step econometric models

Table 6 (models 1-4) presents the results for full sample and table 7 (models 1-4) presents the results for manufacturing firms. As mentioned earlier, for the Heckman two-step econometric models to be identified it is important to identify at least one factor that affects the selection variable but not the level variable (Maddala, 1983). Hence, in only the selection part of model 1 in table 6 and table 7, industry dummy variables (D_{pharma}, $D_{textile}$, and D_{chem}) have been introduced for the firms belonging to the top three industries with respect to average R&D intensity in the present sample (figure 3). However, it is clear from the results of model 1 in both the tables that the variables representing technology imports (IRAWI, ICGI and IRTI) are not statistically significant in the level parts. Hence, the variables representing import of technology in embodied (IRAWI and ICGI) and disembodied (IRTI) forms are introduced only in the selection models in the other three econometric models in both the tables. The

assumption for doing so is that any technology that is imported may require some amount of R&D to adapt it to local condition. Hence, the firms importing technology are likely to undertake R&D. However, imported technology may not affect R&D intensity of the firms if the foreign firms are engaging in explorative R&D activities based on locally available technologies as suggested by Vasudeva and Sonderegger (2007). In the present study this seems to be the case since technology imports are not statistically significant in the level part of the Heckman two-step model.

Table 6: Results of Heckman two-step model with Decision to undertake in-house R&D (D_{RDI}) and In-house R&D intensity (RDI) as explained variables for full sample[*]

	Model 1	**Model 2**	**Model 3**	**Model 4**
	Full Sample	**Full Sample**	**Full Sample**	**Full Sample**
	Selection	**Selection**	**Selection**	**Selection**
Constant	-3.20 (-13.15)[a]	-3.20 (-11.14)[a]	-3.08 (-12.69)[a]	-3.20 (-11.54)[a]
SIZE	0.21 (7.51)[a]	0.21 (7.37)[a]	0.20 (7.46)[a]	0.21 (8.14)[a]
AGE	0.03 (13.65)[a]	0.03 (12.35)[a]	0.03 (13.02)[a]	0.03 (11.75)[a]
CAPI	-0.002 (-1.44)	-0.002 (-1.47)	-0.002 (-1.53)	-0.002 (-1.38)
LABI	-0.01 (-2.00)[b]	-0.01 (-2.08)[b]	-0.01 (-1.62)[c]	-0.01 (-1.86)[c]
SDI	-0.004 (-0.48)	-0.004 (-0.49)	0.003 (0.33)	-0.004 (-0.47)
OSRCI	-0.01 (-1.13)	-0.01 (-1.10)	-0.02 (-1.42)	-0.01 (-0.98)
IRAWI	0.01 (4.52)[a]	0.01 (4.29)[a]	0.02 (5.71)[a]	0.01 (4.45)[a]
ICGI	-0.001 (-0.05)	-0.001 (-0.08)	-0.0003 (-0.04)	-0.001 (-0.06)
IRTI	0.11 (2.90)[a]	0.11 (2.42)[b]	0.09 (2.01)[b]	0.11 (2.66)[a]
D_{pharma}	1.05 (3.95)[a]	1.05 (4.00)[a]	-	1.05 (4.42)[a]
$D_{textile}$	1.34 (3.79)[a]	1.34 (5.27)[a]	-	1.34 (4.36)[a]
D_{chem}	0.18 (1.24)	0.18 (1.24)	-	0.18 (1.45)
	Level	**Level**	**Level**	**Level**
Constant	2.84 (2.87)[a]	2.73 (3.72)[a]	1.87 (2.72)[a]	1.82 (2.54)[a]
SIZE	-0.04 (-0.94)	-0.03 (-0.81)	0.004 (0.09)	0.02 (0.37)
AGE	-0.03 (-3.30)[a]	-0.03 (-3.75)[a]	-0.02 (-3.04)[a]	-0.02 (-3.79)[a]
CAPI	0.004 (1.06)	0.002 (0.87)	0.001 (0.27)	0.003 (0.78)
LABI	0.03 (3.08)[a]	0.03 (2.66)[a]	0.03 (2.58)[a]	0.04 (2.74)[a]
SDI	-0.02 (-2.25)[b]	-0.02 (-2.15)[b]	-0.02 (-2.30)[b]	-0.03 (-3.12)[a]
OSRCI	0.12 (3.49)[a]	0.12 (3.12)[a]	0.12 (2.77)[a]	0.11 (3.81)[a]
IRAWI	-0.0005 (-0.09)	-	-	-
ICGI	-0.02 (-1.16)	-	-	-
IRTI	0.02 (0.25)	-	-	-
D_{pharma}	-	-	-	0.43 (1.30)
$D_{textile}$	-	-	-	0.10 (0.26)
D_{chem}	-	-	-	0.48 (2.45)[b]
Wald Chi^2	23.57[a]	17.88[a]	18.91[a]	33.49[a]
Mills λ	-1.29[a]	-1.25[a]	-0.79[b]	-0.91[a]
No. of Obs.	1210	1210	1210	1210

[a, b, c] indicate statistical significance at 1%, 5% and 10% respectively. z-statistics in parenthesis.

[*] Robust standard errors have been calculated using bootstrapping procedure with 100 replications.

Table 7: of Heckman two-step model with Decision to undertake in-house R&D (D_{RDI}) and In-house R&D intensity (RDI) as explained variables for manufacturing firms[*]

	Model 1	Model 2	Model 3	Model 4
	Manufacturing Firms	Manufacturing Firms	Manufacturing Firms	Manufacturing Firms
	Selection	Selection	Selection	Selection
Constant	-3.16 (-9.22)[a]	-3.16 (-9.06)[a]	-3.08 (-10.95)[a]	-3.16 (-10.17)[a]
SIZE	0.24 (6.39)[a]	0.24 (5.81)[a]	0.23 (8.07)[a]	0.24 (7.37)[a]
AGE	0.03 (9.21)[a]	0.03 (10.41)[a]	0.03 (11.57)[a]	0.03 (10.42)[a]
CAPI	-0.002 (-1.43)	-0.002 (-1.49)	-0.002 (-1.37)	-0.002 (-1.43)
LABI	0.02 (0.22)	0.002 (0.21)	0.01 (1.05)	0.002 (0.21)
SDI	-0.01 (-1.63)[c]	-0.01 (-1.64)[c]	-0.01 (-0.99)	-0.01 (-1.57)
OSRCI	-0.03 (-2.51)[b]	-0.03 (-2.88)[a]	-0.04 (-3.12)[a]	-0.03 (-2.73)[a]
IRAWI	0.01 (1.56)	0.01 (1.66)[c]	0.01 (1.97)[b]	0.01 (1.57)
ICGI	0.02 (0.93)	0.02 (1.03)	0.02 (0.93)	0.02 (0.94)
IRTI	0.08 (1.76)[c]	0.08 (1.48)	0.06 (1.18)	0.08 (1.68)[c]
D_{pharma}	0.86 (3.11)[a]	0.86 (3.68)[a]	-	0.86 (3.53)[a]
$D_{textile}$	1.05 (3.43)[a]	1.05 (3.12)[a]	-	1.05 (3.73)[a]
D_{chem}	0.16 (1.28)	0.16 (1.13)	-	0.16 (1.05)
	Level	**Level**	**Level**	**Level**
Constant	3.23 (3.17)[a]	3.45 (3.62)[a]	1.67 (1.76)[c]	2.00 (2.09)[b]
SIZE	-0.07 (-1.35)	-0.08 (-1.66)[c]	0.01 (0.19)	0.005 (0.08)
AGE	-0.03 (-3.50)[a]	-0.03 (-3.25)[a]	-0.02 (-2.98)[a]	-0.02 (-3.44)[a]
CAPI	0.004 (1.04)	0.001 (0.30)	-0.001 (-0.23)	0.002 (0.48)
LABI	0.02 (2.03)[b]	0.02 (1.94)[c]	0.02 (2.28)[b]	0.03 (2.10)[b]
SDI	-0.01 (-1.31)	-0.01 (-1.58)	-0.02 (-2.05)[b]	-0.03 (-2.69)[a]
OSRCI	0.14 (3.35)[a]	0.14 (3.38)[a]	0.12 (3.18)[a]	0.13 (3.39)[a]
IRAWI	0.006 (0.99)	-	-	-
ICGI	-0.03 (-1.37)	-	-	-
IRTI	0.03 (0.38)	-	-	-
D_{pharma}	-	-	-	0.50 (1.39)
$D_{textile}$	-	-	-	0.22 (0.55)
D_{chem}	-	-	-	0.50 (2.07)[b]
Wald Chi^2	24.97[a]	21.86[a]	18.21[a]	26.20[a]
Mills λ	-1.54[a]	-1.56[a]	-0.68[c]	-0.99[b]
No. of Obs.	950	950	950	950

[a, b, c] indicate statistical significance at 1%, 5% and 10% respectively. z-statistics in parenthesis.

[*] Robust standard errors have been calculated using bootstrapping procedure with 100 replications.

As is clear from the results of the econometric models (table 6 and table 7), the factors that determine the decision to invest on R&D are quite different from the factors that determine the R&D intensity of the foreign firms. Further, the results of Heckman two-step models (table 6 and table 7) differ from those of random effects Tobit models (table 5). Thus, the results of the Heckman two-step econometric models (table 6 an table 7) may be more relevant in giving useful insights in the present study. Furthermore, as per Wald Chi^2 statistics, the best of the four models is model 4 in both the tables. This is the case where the technology import variables (IRAWI, ICGI and IRTI) are introduced only in the selection part and the three industry dummy variables are introduced in both the selection and level parts.

In both tables 6 and 7 (except model 2 of table 7), the coefficient of size of the firm is statistically significant with positive sign only in the selection step. This implies that in the case of foreign firms, larger firms are more likely to undertake in-house R&D activity.

However, size of the firm may not matter in determining the level of R&D intensity of these firms. Interestingly, sign on the coefficient of AGE is different in selection step (where it is positive) and level step (where it is negative) in all the results. Thus, more experienced foreign firms are more likely to undertake in-house R&D. However, younger firms rather than the older ones invest more amounts (as a proportion of sales) on R&D activities.

The coefficient of the variable LABI is statistically significant with a negative sign in the selection part in table 6, suggesting that foreign firms with high labor intensity do not invest on R&D activities. However, this negative coefficient on LABI is present only in the case of full sample (table 6) and not in the case of manufacturing firms (table 7), where the coefficient is statistically insignificant. The full sample includes those software and services firms that have high LABI values but low (and even zero) values on in-house R&D activities, which may be influencing the results. However, as is clear from the level results in all the four econometric models in both the tables, higher labor intensity favorably affects in-house R&D intensities. In other words, higher investments on skilled labor may be required to undertake higher investments on R&D as a proportion of sales.

The coefficient of the variable SDI is negative when it is statistically significant in the econometric models. This implies that sales and distribution intensity (SDI) and in-house R&D activities are substitute of each other. In other words, in a given year, the firms that investment more on sales and distribution tend to undertake less of in-house R&D activities.

The results with regards to another variable, outsourcing of manufacturing jobs (OSRCI) is interesting. In the case of full sample (table 6) the coefficient of OSRCI is not statistically significant in the selection part. However, in the case of manufacturing firms (table 7) the coefficient of OSRCI is negative and statistically significant in the selection part. This implies that the manufacturing firms that outsource are not undertaking R&D activities. In the sub-sample of manufacturing firms, there are firms like Coretec Engineering India Pvt. Ltd. (produces industrial machinery), Sobha Ltd. (operates in real estate construction), I T D Cementation India Ltd. (operates in other infrastructure construction) and Toyo Engineering India Pvt. Ltd. (involved in construction of other industrial plants) that operate in engineering and construction industry and outsource a large portion of their operations. These firms hardly undertake any in-house R&D activities. However, as the level estimates in all the econometric models of table 6 and table 7 indicate, the firms that have high outsourcing intensity tend to undertake higher levels of in-house R&D. The manufacturing firms that undertake R&D and also outsource manufacturing jobs belong to different industries. For example, Nalco Water India Ltd. is based in Pune and is a subsidiary of Nalco Holding Co. that produces specialty chemicals including water treatment chemicals.[8] The Pune facility serves as headquarters for sales, marketing and supply chain for the company and also has a state-of-the-art technology and innovation center. Another firm, G M M Pfaudler Ltd. is an Indian subsidiary of Pfaudler Inc of USA and is a leading supplier of engineered equipment and systems for critical applications in the global chemical and pharmaceutical markets and works closely with its customers to provide solutions.[9] Mylan Laboratories Ltd., the leading pharmaceutical firm in terms of R&D investments also has high outsourcing intensity.

With regards to import of technology, in the case of full sample (table 6 all four econometric models), the firms that import raw materials and the firms that import disembodied technologies are more likely to invest on R&D activities. This result is more likely because the full sample includes service firms that hardly import raw materials and import technology against royalty and technical fees. Hence, in the case of manufacturing

[8] Information obtained from the website of the company http://www.nalco.com/aboutnalco/india.htm (accessed 27 August 2017)

[9] Information obtained from the website of the company http://www.gmmpfaudler.com/index.php (accessed 27 August 2017)

firms the two technology import variables (IRAWI and IRTI) are statistically significant with positive sign in only some models. With regards to industry dummy variables, the firms belonging to pharmaceutical industry and textile & apparel industry are more likely to undertake R&D as compared to other industry firms. However, the firms that belong to chemical industry are more likely to invest more amounts (as a ratio of sales) on R&D activities compared to firms that belong to other industries.

Conclusion and implications

The present study attempted to understand the latest trends in the in-house R&D investments by foreign firms in India. Further it tried to explore the factors that explain the inter-firm differences in R&D activities of these firms in India. The study used random effects Tobit model and Heckman two-step technique for a sample of 242 firms for the period of five years from 2011 to 2015.

With regards to the latest trends, motor vehicles and pharmaceuticals are the leading industries in terms of average R&D investments by foreign firms. These foreign firms have also set up R&D centers in India. With regards to trends in average R&D intensities of foreign firms, pharmaceutical industry followed by textile and apparel industry and chemical & related products industry.

The econometric analysis indicates that even in foreign firms, size of firm and experience are essential for the firms to be confident enough to invest on in-house R&D activities in India. However, it is the relatively younger firms that are willing to undertake higher intensities of in-house R&D. The Government of India can try to bring in policies where the recently established foreign firms can be encouraged to undertake joint R&D activities with Indian firms or research centers so as to distribute the risks associated with R&D activities.

The foreign firms that invest higher proportions on skilled workforce invest more on in-house R&D. These firms are likely to attract the cream of the talent, who may contribute many-folds to the intellectual property creation for the multinational firms. An in-depth comparative study on the corporate culture of leading corporate firms in India and the multinationals may be required to shed light on the factors other than high salaries and wages that attract the skilled workforce of India to work in multinational companies.

In the foreign firms, import of technology through arms length purchases hardly important in determining in-house R&D intensity. However, outsourcing of manufacturing jobs is favorable for in-house R&D intensity. Further, the firms that are outsourcing as well as doing in-house R&D have dedicated R&D centers in India. Thus, in line with the view of Vasudeva and Sonderegger (2007), it is possible that the foreign firms in India are indeed engaged in explorative R&D activities where they would like to source and build on locally available knowledge.

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