Firm-Specific Determinants of R&D Behaviour of Foreign Affiliates in India

Savita Bhat

1 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) and spreading across various locations all over the globe their different activities, including research and development (R&D) activity (Hanson et al. 2005; Guillen and Garcia-Canal 2009).

Thus, internationalization of R&D has become an important research theme for many research articles (Ito and Wakasugi 2007; Kurokawa et al. 2007). It is observed that the multinational firms often evaluate the cost and benefits of undertaking R&D at the potential locations before finalizing the R&D location (Hu 2004). The multinationals have the options to perform their R&D activities either at the headquarters in their home country or at the overseas subsidiaries in the host countries (Caves 1996; Hu 2004). It is believed that the companies that choose to locate R&D in home countries do so to have higher efficiency and scale economies. Others who choose to locate R&D in the overseas subsidiaries often do so to customize their products for local needs and to exploit the resources and incentives provided by the host countries.

Researchers like Hegde and Hicks (2008) have observed paradigm shifts in the constituents of R&D in host countries. During the 1980s, R&D in the host subsidiaries was mainly focused on the development aspect, with the core sophisticated research part still remaining at home. In the late 1980s and early 1990s, it was observed that the foreign subsidiaries engaged in sophisticated applied research and even acquired foreign know-how. More recently, multinationals have been seen engaging in R&D that can expand their home innovation capabilities.

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Further, initially, overseas R&D investments undertaken by multinational firms from developed countries like the USA were located in other developed countries (Veliyath and Sambharya 2011). However, during the 1990s, the pattern changed and increasing shares of outbound R&D from USA were going to countries like Singapore, Israel, and India (Doh et al. 2005). These R&D activities were in different industries including chemicals and computers (Hegde and Hicks 2008).

Researchers have observed that multinational firms from developed countries often invest on frugal innovations in the developing countries to eliminate the non-value adding functions from the original complex product existent in the developed countries (Simula et al. 2015). This type of R&D helps the multinational firms to create a product design with minimal features that is found to be more economical by the consumers of the low-income emerging markets. Subsequently, these innovative products are introduced in the developed countries to cater to the needs of the cost-aware consumers in developed countries. In such instances, the multinational firms can be considered to be setting up R&D centres in the emerging countries like India to acquire and build on locally available knowledge (Vasudeva and Sonderegger 2007). This type of R&D that is undertaken in the emerging economies to create products that are eventually diffused into developed markets is termed as reverse innovation (Immelt et al. 2009; Govindarajan and Ramamurti 2011; Simula et al. 2015).

Thus, the research focus in the area of innovation is now increasingly shifting towards the R&D activities of multinational firms in developing countries like India (Brem and Wolfram 2014). However, although there is an increasing trend in the amount of R&D investments by the multinationals going to the developing countries, a large amount of overseas R&D investments by the multinationals are still located in developed countries (Veliyath and Sambharya 2011).

Given the fact, the objective of this study is to understand the latest trends in in-house R&D investments by foreign affiliates in India. Further, the present study attempts to understand the firm-specific factors that determine the R&D behaviour of foreign affiliates operating in India. Here, foreign affiliates are the firms that are owned by foreigners including foreign government. It should be noted that determinants of in-house R&D by firms is a well-researched topic. However, there are limited studies in the recent past that have examined the factors that affect the in-house R&D activities of foreign affiliates in India. The present study tries to fill this gap in recent literature in the area of innovation.

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 are discussed. Then, the next subsection highlights the patterns in the R&D investments with respect to the foreign affiliates 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.

2 Literature Review on Factors Determining R&D Activities

The following subsections give a review of literature on various factors that determine R&D activities of firms in general. The relevance of these variables to the R&D behaviour of foreign affiliates is particularly focussed. These variables include size of the firm, age of the firm, capital intensity, labour intensity, selling and distribution intensity, outsourcing intensity and import of technology.

2.1 Size of the Firm

Size of the firm has been used in innumerable empirical studies on firm behaviour. It essentially acts as a proxy for the amount of resources available to the firms (Schumpeter 1943). Basant (1997) found a larger firm size to favourably 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. Nevertheless, 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.

With regard to the size of foreign affiliates, relatively large sized ones would possibly have more resources and be forced by the host country institutions to incorporate local requirements in their operations (Rottig 2016). Moreover, the multinationals that have successfully introduced products and captured markets in the host developing countries would be interested in investing further on R&D for reverse innovation. Hence, the effect of size of the foreign affiliates (in terms of sales) is hypothesized to have a positive effect on R&D activities of the firms in India.

2.2 Age of the Firm

Age of the firm captures the experiences and learning of the firm. Siddharthan (1992) noted that in the 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 case of foreign affiliates too, the firms that have been operating in the host developing countries for some time and gained knowledge about consumer preferences would be more confident of investing successfully on R&D in those

countries. There is evidence that, as time progresses, the small investments in import-and-adapt R&D of foreign firms evolve into more significant investments in local R&D for local product development (Motohashi 2015). Hence, it is hypothesized that the age of the firm has a positive effect on the R&D activities of even the foreign affiliates in India.

2.3 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. However, in the case of Indian private corporate sector, Siddharthan (1992) found capital intensity to be unimportant in determining R&D intensity of the firms.

The parents of the foreign affiliates operating in developing countries are generally from advanced countries where capital-intensive automated processes are more popular. Hence, the foreign affiliates are likely to have greater affinity towards adopting capital-intensive techniques for their different activities including R&D. Thus, due to the possibility of higher overall collateral value, the capital-intensive foreign affiliates are hypothesized to undertake more R&D investments.

2.4 Labour Intensity

Higher labour 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 favourably affect the decision of the firms to undertake R&D in electronics industry in Taiwan.

Many of the foreign affiliates are increasingly locating their R&D centres to developing countries like India to exploit the skills of the abundant human capital (Haakonsson and Ujjual 2015). The foreign affiliates that invest higher amounts on the wages and salaries of employees are likely to utilize their capabilities for improving the operations of the company including for in-house R&D activities. Hence, it is postulated that labour intensity as a proxy for skill will have a positive effect on R&D activities of the foreign affiliates.

2.5 Selling and Distribution

According to Porter (1980), access to distribution channels is one of the barriers to entry into any industry. The foreign affiliates may invest large amounts on selling and distribution activities to create this competition barrier for their existing products in the host developing countries. In other words, the foreign affiliates that give high priority to market expansion in the host countries are likely to give less preference to investments on in-house R&D activities in those countries. Hence, it is postulated that selling and distribution intensity of the foreign affiliates may have a negative effect on the in-house R&D activities of the firm.

2.6 Outsourcing

Outsourcing, where all or part of a firm's activity is given to an outside vendor, is often considered to be an important tool to cut costs, improve performance and refocus on the core business (Barthelemy and Adsit 2003). It is well known that many multinationals locate their subsidiaries in developing countries due to cost considerations. Hence, the foreign affiliates that outsource their manufacturing activities may invest more on other activities including in-house R&D in the host developing counties. However, if the outsourcing activity involves sourcing of new technologies from collaborators in India, then most of the R&D activities may be undertaken outside the firm in dedicated R&D centres rather than in-house (Mrinalini and Wakdikar 2008). Due to lack of empirical evidences with regard to the effect of outsourcing on in-house R&D of foreign affiliates in India, it is difficult to postulate the effect of outsourcing on in-house R&D activities of these firms in India.

2.7 Import of Technology

Import of technology can be in the 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). It is possible that foreign affiliates may import technology from their parent firms through intra-firm mode. Nevertheless, the firms that do import technology through arms-length purchases may undertake some 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 affiliates.

3 Sample and Methodology

The secondary data for the study is extracted from the Prowess database provided by Centre 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 can be 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 in 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.

3.1 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,

$$\mathrm{RDI}_{it}^{*} = \mathbf{X}_{it}\,\boldsymbol{\beta} + \alpha_i + \varepsilon_{it} \tag{1}$$

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

$$\begin{aligned} \mathrm{RDI}_{it} &= \mathrm{RDI}_{it}^{*} \text{ if } \mathrm{RDI}_{it}^{*} > 0 \\ &= 0 \quad \text{if } \mathrm{RDI}_{it}^{*} \leq 0 \end{aligned} \tag{2}$$

Table 1 Definitions of the variables

Sl. No	Variables	Symbol	Definition
1	Decision to invest on in-house R&D	D_{RDI}	$D_{\text{RDI}} = 1$ if Research and development expenses (in Rs. millions) > 0 $D_{\text{RDI}} = 0$ 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	Labour 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 know-how (in Rs. million) as a percentage of sales (in Rs. million)

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

$$\text{RDI} = \mathbf{X\beta} + u \tag{3a}$$

$$D^*_{\text{RDI}} = \mathbf{Z\gamma} - \varepsilon \tag{3b}$$

[1]The sample is an unbalanced panel data where each observation may be considered as a separate data point. Hence, Eqs. (3a)–(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 explained variable, **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:

$$\begin{aligned} D_{\text{RDI}} &= 1 \text{ iff } D^*_{\text{RDI}} \geq 0 \\ &= 0 \text{ otherwise} \end{aligned} \tag{4}$$

The dependent variable RDI is conditional on **X**. Furthermore, **Z** has a well-defined marginal distribution. However, RDI is not observed unless $D^*_{\text{RDI}} > 0$. 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 introduce 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.

4 Patterns in in-House R&D Investments by Foreign Affiliates in the Present Study

Figure 1 shows the share of some of the industries in the present study sample of firms with foreign affiliation. The sample has 190 manufacturing firms and 52 services firms. Most of the manufacturing foreign affiliates in this sample belong to the machinery and equipment industry (Division 28), followed by chemical and its products (Division 20). Around 4% firms belong to the pharmaceutical industry (Division 21) and another 4% firms belong to computer, electronic and 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 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 Fig. 2, foreign affiliates 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).

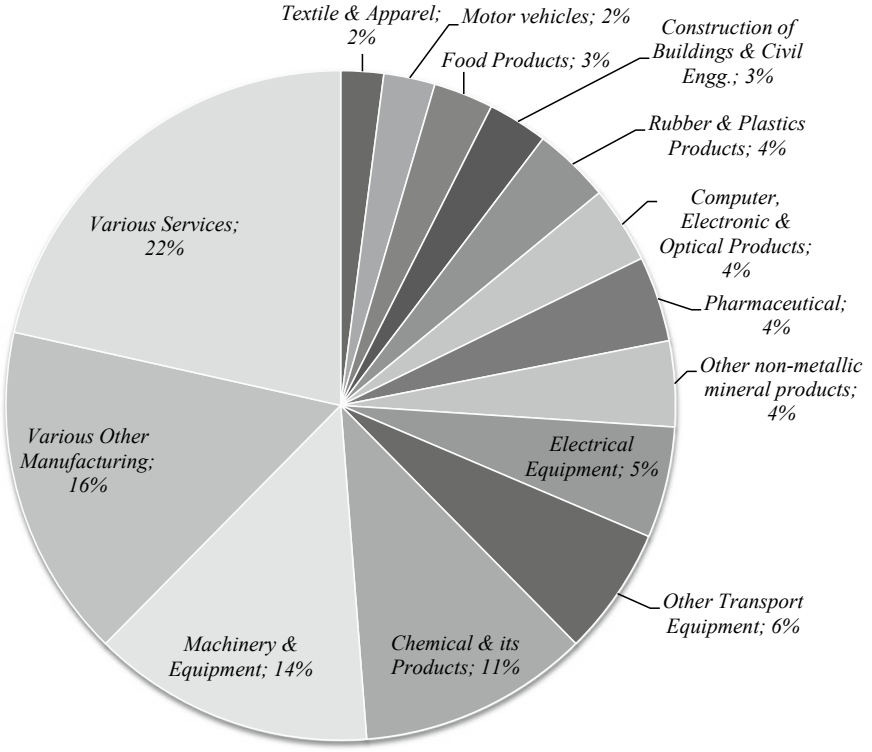

Fig. 1 Pie chart depicting the percentage share of different industries in the study sample

In the motor vehicles 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.[2] The firm has started a state-of-the-art R&D centre 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, UK.[3] The company has a global R&D centre 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; diagnostics equipment for

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

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

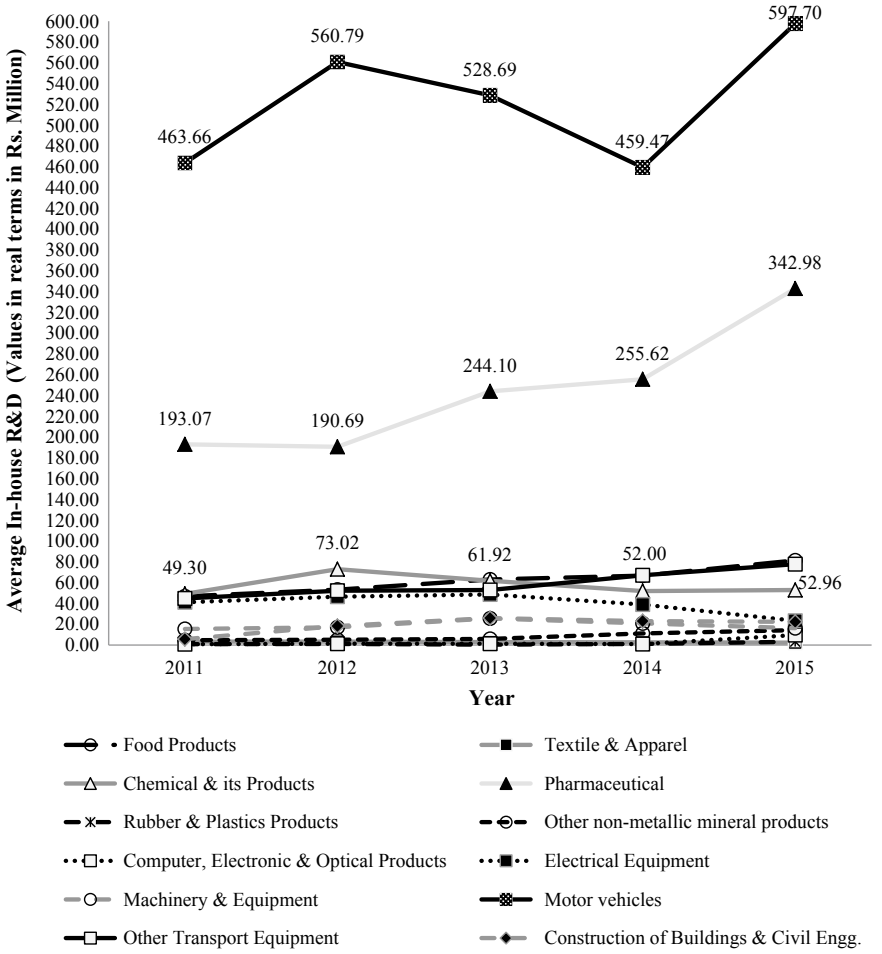

Fig. 2 Trends in the average in-house R&D investments of the foreign affiliates in different industries (*Source* Author's calculations based on data from prowess database)

workshops (i.e. testing equipment), technical information, training and consulting; and technical after-sales service for Bosch automotive products and systems.[4]

In the case of pharmaceutical industry, Mylan Laboratories Ltd., is the leading pharmaceutical firm in terms of R&D investments (in real terms). The firm operates in India in several pharmaceutical segments like critical care, hepatic care, HIV care, oncology care and women's care.[5] The firm claims to have more than 2900 R&D

[4]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).

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

and regulatory experts who work collaboratively across 10 different centres around the world. Further, about half of the scientific affairs workforce is based in India working at the firm's global R&D centre of excellence in Hyderabad and other R&D centres in Bangalore and Ahmedabad.

5 Analysis and Results

Table 2 presents the mean and standard deviation for the different variables in this sample. The table also indicates a 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%) compared to foreign services firms (0.02%). The average age of the firms in the sample is around 35 years. With regard to embodied technology imports, the average raw material import intensity is higher for manufacturing firms at around 12% 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 labour intensity (19.45%) compared to the manufacturing firms

Table 2 Descriptive statistics

Sl. No.	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. No. 2 to 11

(9.22%). 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 and equipment industry. As mentioned earlier, in the case of services, high OSRCI values are present mainly in publishing industry and wholesale industry.

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

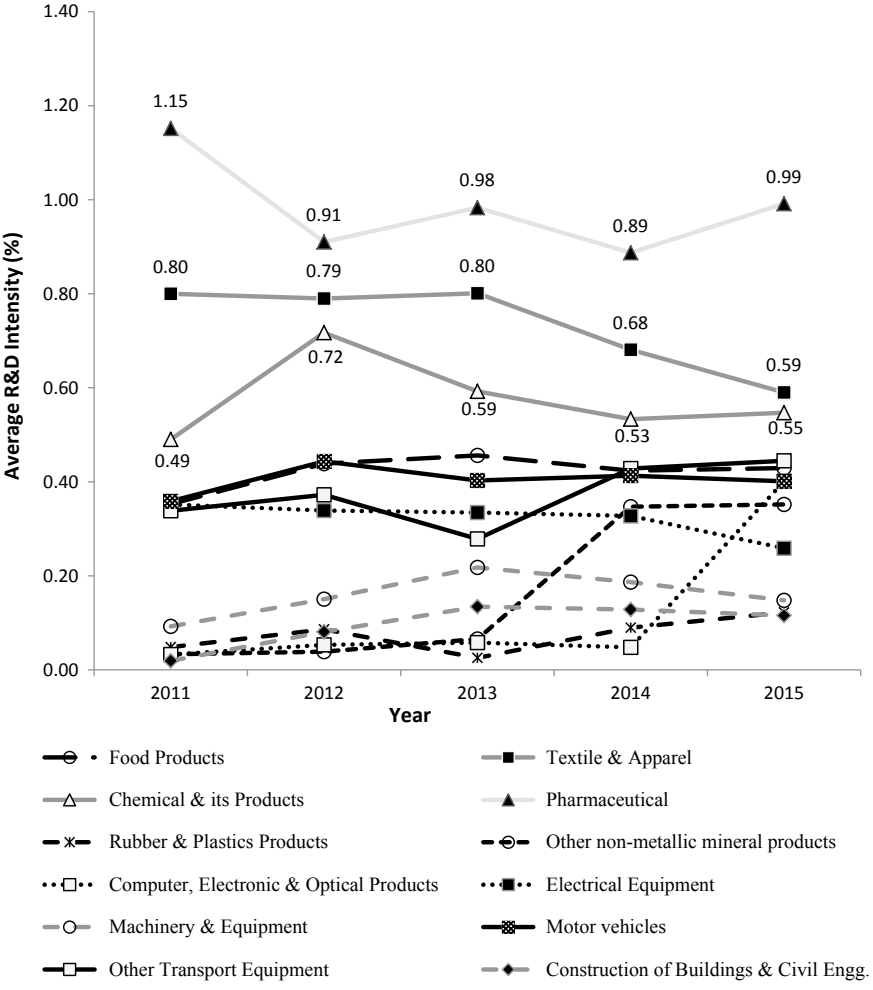

Fig. 3 Trends in the average in-house R&D intensity of the foreign affiliates in different manufacturing industries (*Source* Author's calculations based on data from prowess database)

R&D intensity is found in the firms belonging to relatively lower technology group, namely textile and apparel, followed by those belonging to chemical and its products.

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), fibre-cement sheet making felts and hi-tech textile processing felts. The firm undertakes research and development activities for 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 (Fig. 2) as well as average in-house R&D intensity (Fig. 3) of the foreign affiliates are relatively low. In this industry, the average R&D intensity improved to around 0.4% in 2015 from 0.05% in 2011 (Fig. 3) mainly due to relatively high investments on in-house R&D during the year by Panasonic A V C Networks India Co. Ltd.

Tables 3 and 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 Tables 3 and 4. Hence, there are less chances of multicollinearity problem in the present study.

5.1 Results of Random Effects Tobit Econometric Models

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, additional dummy variables (D_{pharma}, D_{textile}, and D_{chem}) have been introduced in the econometric Model 2 and Model 4 to represent the firms belonging to the top three industries in terms of average R&D intensity in the present sample (Fig. 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 affiliates are likely to undertake more R&D. None of the other variables are statistically significant.

[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 fibres together.

[7]Information obtained from the 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).

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% 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% level

Table 5 Results of random effects Tobit econometrics models 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

Robust standard errors have been calculated using bootstrapping procedure with 100 replications
[a,b,c]Indicate statistical significance at 1%, 5% and 10% respectively. z-statistics in parenthesis

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.

5.2 Results of Heckman Two-Step Econometric Models

In the present study, Heckman two-step estimation models that can incorporate differing effects of the factors on decision and level parts have also been estimated. Tables 6 and 7 present the results for the same. While Table 6 (Models 1–4) gives the results for full sample, Table 7 (Models 1–4) gives the results for manufacturing firms. As mentioned earlier, for the Heckman two-step econometric models to be identified, it is important to introduce at least one factor that affects the selection variable but not the level variable (Maddala 1983). Hence, industry dummy variables (D_{pharma}, D_{textile}, and D_{chem}), which represent the firms belonging to the top three industries with respect to average R&D intensity in the present sample (Fig. 3), have been introduced in only the selection part of Model 1 in Tables 6 and 7.

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

Robust standard errors have been calculated using bootstrapping procedure with 100 replications
[a,b,c]Indicate statistical significance at 1%, 5% and 10% respectively. z-statistics in parenthesis

Table 7 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 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

Robust standard errors have been calculated using bootstrapping procedure with 100 replications
[a,b,c]Indicate statistical significance at 1%, 5% and 10%, respectively. z-statistics in parenthesis

It is clear from the results of Model 1 in Tables 6 and 7 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 these 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 conditions. Hence, the firms importing technology are likely to undertake R&D. However, imported technology intensities may not affect R&D intensity of the firms if the foreign affiliates are engaging in explorative R&D activities or reverse innovation, which focuses on utilizing locally available technologies. Since technology imports are not statistically significant in the level part of the Heckman two-step model, there is a possibility that foreign affiliates in India are engaging in R&D investments for reverse innovation.

As is clear from the results of the econometric models (Tables 6 and 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 affiliates. Further, the results of Heckman two-step models (Tables 6 and 7) differ from those of random effects Tobit models (Table 5). Thus, the results of the Heckman two-step econometric models (Tables 6 and 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 affiliates, 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 affiliates 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 affiliates with high labour intensity do not invest in 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 labour intensities favourably affect in-house R&D intensities. In other words, higher investments in skilled labour are required to undertake more rigorous R&D activities.

The coefficient of the variable SDI is negative when it is statistically significant in the econometric models. Thus, as hypothesized, sales and distribution intensity

(SDI) and in-house R&D activities seem to be substitutes of each other. In other words, the firms that invest more on sales and distribution in a given year are more interested in capturing markets rather than spending on innovative efforts.

The results with regard 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, the level estimates in all the econometric models of Tables 6 and 7 indicate higher outsourcing intensities favourably affect in-house R&D intensities. 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 centre. 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. Such firms with high outsourcing intensities seem to be subcontracting the routine tasks in their production processes to focus on more challenging design and innovative activities.

With regard to import of technology, the results of the present study are not reliable. 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. However, in the case of sample with only manufacturing firms, the two technology import variables (IRAWI and IRTI) are statistically significant with positive sign in only some models. Further, in line with the findings of Siddharthan (1992) in the context of private corporate sector in India, capital intensity (CAPI) is not important in determining in-house R&D even in the case of foreign affiliates operating in India.

With regard to industry dummy variables, the firms belonging to pharmaceutical industry and textile & apparel industry are more likely to undertake R&D as compared

[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).

to other industry firms. However, the firms that belong to chemical industry are more likely to be R&D intensive compared to firms that belong to other industries. As environmental regulations across the world are becoming more stringent (TSMG 2014), perhaps the firms in the chemical industry are investing rigorously on in-house R&D to create new products that conform to these regulations.

6 Conclusion and Implications

The present study attempted to understand the latest trends in the in-house R&D investments by foreign affiliates 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 affiliates. These foreign affiliates have also set up R&D centres in India. With regard to trends in average R&D intensities of foreign affiliates, pharmaceutical industry was on the top followed by textile and apparel industry, and chemical and related products industry, respectively.

The econometric analysis indicates that even in foreign affiliates, size of firm and experience of the firm 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 wherein the recently established foreign affiliates are encouraged to undertake joint R&D activities with other Indian firms or Indian research centres to create innovative products of global standards through mutual sharing of knowledge.

In the case of foreign affiliates, higher labour intensities have a positive effect on in-house R&D intensities. By paying high salaries and wages to their employees, 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 a light on the factors other than high salaries and wages that attract the skilled workforce of India to work for multinational firms.

In the foreign affiliates, import of technology through arms-length purchases is hardly important in determining in-house R&D intensity. However, outsourcing of manufacturing jobs is favourable for in-house R&D intensity. Further, the firms that are outsourcing as well as doing in-house R&D have dedicated R&D centres in India. Thus, one can presume that the foreign affiliates in India are indeed engaged in explorative R&D activities or reverse R&D where they would like to source and build on locally available knowledge to provide innovative products for their home market. An in-depth study on the intention of R&D activities of foreign affiliates in India can confirm this.

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