Technological capability in Indian manufacturing firms: A study of the determinants of R&D

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Abstract

This paper explores determinants of R&D, an important indicator of technological capability, of Indian manufacturing firms. The manufacturing firms are grouped according to their technology level. We employed Probit and Tobit regression models respectively for each technology group to analyse the relation between the determinants and R&D activity. We consider the period from 1994 to 2010 for our study. We find variation in relation between explanatory variables and R&D activity across different technology groups. Among the explanatory variables size of the firm, age of the firm, export status of the firm and imported disembodied technology are playing an important role in determining domestic in-house R&D activity of manufacturing firms. Among them, from a policy perspective, disembodied technology is playing a crucial role by working as a catalyst for the domestic R&D and also helping in-house R&D activities to assimilate and adapt the imported technology according to local conditions.

Keywords: Technological capability, R&D determinants, Level of technology, Indian manufacturing firms, Probit and tobit

Introduction

India, as one of the fastest growing economy in the world, is going through various levels of transformations and facing different developmental challenges in the process. The development of a competitive manufacturing sector is very crucial in this regard, given its importance in foreign trade and in the development of other sectors.

After liberalisation of the economy manufacturing sector experiencing a relative stagnation. From the trade perspective, India's export structure of manufacturing products is shifting towards higher technology intensive industries from the traditional low technology-labour intensive sectors. Technological capability is considered to be one of the important factors which can help to overcome the industrial stagnation as well as can help to sustain the changing export structure. This technological capability is a 'must' element for 'catching up' with the developed world.

According to Lall (1987), "the general ability to undertake broad range of tasks" including innovation, adoption, assimilation, alteration of exiting technology according to local need etc comes under technological capability especially for a developing country. In the literature there are large discussions on various dimensions and indicators of technological capability. Nonaka and Takeuchi (1995) and Kim

(1997), put technological capability simply as the ability to innovate. Research and development (R&D) is considered as one of the important indicator of technological capability. In the present study we will try to find the determinants of R&D of the manufacturing firms of India.

According to the R&D statistics published by Department of Science and Technology (DST)(2013)[1], R&D expenditure at the national level is increasing. During 1990-91 R&D as a percentage of Gross Domestic Product (GDP) was 0.75%. It increased to 0.87% in 2009-10. As a percentage of sales turn over R&D was 0.82 % for the private sector and 0.27% for the public sector during 2009-10 (DST). Private firms are investing more in innovative activities compared to the public enterprises and it is occurring more in the manufacturing sector (Mani, 2009)[2].

Blumenthal (1979) stressed upon the fact that technological level of a country depends upon domestic R&D and imported technology and an optimal technological strategy depends upon the relation between the two. Most of the time developing countries could not afford the ability to get proper return from new technology and innovations and thus rely on the development of R&D activity that can assimilate and adapt imported foreign technologies according to their need and local conditions (Braga and Willmore, 1991). It seems that the innovativeness of India has increased after 1991 which is evident from the total factor productivity (TFP) of industrial sector (Mani, 2009). Correspondingly the report of the Global Innovation Index (2013) confirms that India is making significant progress in innovativeness and is among the top performers in innovation efficiency among the lower-middle-income countries during 2012[3]. Domestic firms are engaged in procuring foreign technology[4] especially after liberalisation of the economy although Mani (2009) found that from 2005 onwards, on the technology balance of payments indicator, India has become a net exporter of technology from a net technology importer[5].

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[1]Accessed through the following link
http://www.nstmis-dst.org/SnT-Indicators2011-12.aspx

[2]According to the DST report during 2009-10 private investment was higher on R&D as a percent of sales turnover was on drugs and pharmaceuticals, scientific instruments and transport equipment which belong to either HT or MHT group.

[3]Global Innovation Index Report 2013 accessed through the following link
http://www.globalinnovationindex.org/content.aspx?page=gii-full-report-2013#pdfopener

[4] Technology can be bought in disembodied or embodied form. Embodied form comes with new machinery from abroad and intermediate inputs (Pavitt, 1984). Disembodied technology can be in the form of transfer of technology, blueprints, royalty payments etc.

[5] In this regard it is important to mention that after 2000, theGovernment of India has unrestricted FDI flow in most of the sectors which attracted foreign players and gradually we can see the growing

The present paper examines the influences of firm level and market level factors (imported technology[6], firm size, market concentration, leverage, export status and foreign firm status) on R&D decisions and R&D intensities of manufacturing firms. In relation to it will test three hypotheses which are based on existing literature on R&D in developing as well as developed countries. The hypotheses are (1) the relationship between R&D and firm size is inverted U shaped, (2) R&D is positively related with market concentration and (3) disembodied technology import is positively related to R&D activity. In the next sections we will discuss relevant literature, data source and methodology, regression results followed by conclusion.

Review of literature

There is a distinction between the innovative or R&D activity of developing countries and that of the developed countries. In the developed country it is either of process or product innovation but for the developing countries it is mostly engagement with the process of adaption or assimilation of the technology sourced from developed countries.

A great attention was paid on the size-market competition relation with innovation following Schumpeter (1942). Schumpeter observed considerable differences between innovative activities of small firms and large organisations. The empirical literature following his arguments interpreted that there is a continuous and positive relation between innovation and the size of the firm, implying large firms are more suitable for better innovations (Cohen and Levin, 1989).

There are large numbers of studies which either supported this view or have found opposite results. Thus the relation is somewhat inconclusive in nature. Earlier studies on developed nations by researchers like Horowitz (1962), Hamberg (1964) found a positive relation between R&D intensity (measured as a ratio of R&D investments to sales of the firm) and firm size. Mansfield (1964) did a study on a small number of chemical, petroleum, drug, steel and glass firms of USA and found that large firms are not spending more than the small firms on R&D activities except for the chemical industries. Soete (1979) also confirmed a positive relation between

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presence of foreign firms or Multi National Enterprises (MNEs) in most of the manufacturing industries. The MNEs are setting up many Research and Development (R&D) facilities in India which are mostly subsidiaries of US based firms (Basant and Mani, 2012)[5].

[6] We have considered the disembodied technology as imported technology following Kumar and Siddharthan (1994).

size and innovation in a cross section framework. In a study on more than 400 US firms, Scherer (1965) found that the inventive output and firm size has a less than proportional relation, which gave a clear indication of an inverted U shaped relation. Scherer (1984) in another study found that there was a little impact of size on R&D and opined that small firms might be more interested to engage in innovative activities in US than the big sized firms. Bound *et al.*, (1984) in a cross sectional analysis of a quite large sample of US manufacturing firms in 1976 found that very small and very large sized firms are more R&D intensive compared to the average sized firms. Cohen at al., (1987) says that there may be no relation existing between size and R&D when inter-industry differences of R&D investments were taken care of and outliers are excluded from the data of US manufacturers. Thus a contradicting result to Schumpeterian hypotheses was found. They applied Tobit and Probit models and found that business units rather than the firm as a whole have some impact on the decision to engage in R&D activity. Pavitt et al., (1987) found that very small and very big firms are engaged in innovation activities in UK.

Braga and Willmore (1991) in a study on Brazilian manufacturing firms found that size and R&D expenditure are having a positive relation but there is no such threshold effect present. Lee (1996) found that there is no such size-R&D relation existing in Korean manufacturing firms.

Thus it is evident there is a lack of consensus regarding the firm size-R&D relation at the firm level in the literature. Cohen and Levin (1989) tried to address this issue. According to them there could be few reasons like the issue of measurement of R&D[7], have sample selection bias or collinearity.

According to Acs and Audretsch (1987) the relation between firm size and innovation of large and small firms depends upon market structure and conditions of the industry. They found that small firms are more innovative in a market which has less concentration and the opposite is true for the larger firms.

Studies made on Indian enterprises (Lall, 1983; Katrak, 1985; Kumar and Saqib, 1996; Goldar and Renganathan, 1997; Kumar and Aggarwal, 2005) found positive relation between firm size and R&D activities. Katrak (1985) studied the relation on 300 top Indian enterprises and found that there is a less than proportional relation between size and expenditure on R&D. A study by Tan and Hwang (2002) on

[7] Different studies have taken different measures of measurements. Some considered sales of the firm, other considered man power engaged in innovation activities of the firm.

Taiwanese electronic industry found similar results. Jefferson et al., (2006) observed that in Chinese manufacturing industries highest R&D is occurring in the capital intensive sectors where large firms are operating[8]. According to them the reason could be the presence of substantial scale economies and minimum economies of size in the Taiwanese electronic firms. Kumar and Saqib (1996) confirmed the size threshold effect in Indian industries by analysing 221 firms. On the contrary Siddharthan (1988) found a U shaped relation for Indian manufacturing firms in a cross sectional analysis. According to him this could be due to the fact that small firms do not have the financial strength to undertake R&D investments as with size the capability to undertake investments increases.

Kumar and Aggarwal (2005) found a cubic relation between size and R&D intensity by analysing Indian manufacturing firms from 1992-93 to 1998-99. According to them this cubic relation says that for very small firms the R&D intensity is very high, after that it declines up to a threshold level, beyond that it increases again to an another threshold and after that it again declines. Thus they found two threshold levels in their study. Some of the new studies like Kumar and Pradhan (2003) and Ghosh (2009) found inverted U shaped relation using CMIE-Prowess data on Indian manufacturing firms.

Another aspect emphasised by Schumpeter was the market power[9] or presence of monopoly structure which, according to him, is essential incentive for a firm to invest in R&D. According to Schumpeter (1942), "Large firms operating in a concentrated market are the most powerful engines of growth" and thus market concentration gives impetus for innovation activities. Cohen and Levin (1989) discussed two themes regarding Schumpeterian assumption of market concentration and innovation. The first theme states that firms need some form of short-term market power which can give them incentive for investment in R&D activities[10]. The other theme says that in an oligopolistic market structure the firms can predict each other's actions and thus making stable behaviour clears the uncertainty and leads to incentive for invention. There are contradictory views on this issue of impact of market concentrations upon innovation activity. Arrow (1962) said that under the condition of competitive structure firms can gain more from innovative activity than under a

[8]In his study he also observed that in the low technology intensive industries R&D activity is also low.
[9]This is the basis for current patent laws (Cohen and Levin, 1989).
[10] A monopolistic market structure can give the firm required amount of financial resources that can be utilised for innovative activity.

monopoly structure. Scherer (1980) opined that a non-competitive structure can discourage innovation by the involvement of unnecessary bureaucratic procedures. Earlier studies like Horowitz (1962), Hamberg (1964), Scherer (1967), Mansfield (1964) found a positive relation between market concentration and innovation in US firms. Williamson (1965) studied US firms and from least-square estimates on the data he found that as the monopoly power in the industry, measured by concentration ratio, increases the largest firms' innovation contribution decreases. In one another study on US firms, Mukhopadhyay (1985) also found a similar type of result. He divided the firms in three categories on the basis of R&D intensity and found negative effect of market concentration on R&D in the technologically progressive industries[11]. Some studies on Indian firms also confirm such relation (Kumar, 1987; Kathuria, 2008). Kumar (1987) reported a negative relation between seller concentration and R&D intensity in Indian Firms. According to him, the then prevailing public policy deterring new entry in industries was behind such result.

Scherer (1967) in his study on US firms found that technology intensive firms (electrical and chemical) have higher concentration on an average to other firms[12]. He tested a nonlinear relationship between size (measured by technical employment) and concentration in the traditional industries and found that firms' 'technological vigour' increases with market concentration up to a threshold level and after that it declines According to him this supports the neo-Schumpeterian hypothesis of oligopolists behaviour where firms may need some degree of concentration required for innovation activities before going into price-competition. A Study by Lunn and Martin (1986) on US firms also found a positive effect of market power in firms having low technological opportunities. Braga and Willmore (1991) also found a non-linear relation between market concentration and technological activity in Brazilian firms. According to them, non-price competition increases up to a concentration and then it declines due to collusive behaviour. Other studies on developing countries found a positive relation of market concentration on innovative activity. Lee (2004) in Malaysian manufacturing industries, Lin and Yeh (2005) in non-FDI Taiwanese firms found positive relation of market concentration on innovative activity. In Korean

[11]According to him in USA the net entry rate of firms are much higher in technologically progressive industries.

[12]He explained that there could be a causal relation between concentration and technological progressiveness. Opportunities for better technological innovations and subsequent patenting of the technologies might have facilitated the market concentration in those technologically advanced industries. But he was not sure about the direction of causality.

manufacturing industries Lee (2005) found a positive relation between R&D and market concentration in low technology intensive industries “where market concentration supplements low R&D appropriability” and found an inverted U shaped relation in industries with higher “appropribility”.

In the literature, the relation between R&D and technology import is reported as either of a substitute or a complementary (Kumar, 1987). The relation is substitutive when the firm’s in-house R&D declines with imported technology and it is of complementary nature when in-house R&D is used to assimilate and adapt the imported technology according to local conditions and often this foreign technology acts as a catalyst for domestic R&D (Braga and Willmore, 1991; Lee, 1996; Tan and Hwang, 2002). Studies in various countries, starting from developed to developing, often found the relation to be complementary (Odagiri, 1983; Lall, 1983; Siddharthan, 1988, Braga and Willmore, 1991). Few studies have reported substitutive relation. Lee (1996) found a substitutive relation between technological cooperation and R&D efforts in Korean firms. Kumar (1987) found a substitutive relation between FDI mode of technology import and R&D expenditure in Indian manufacturing firms in pre reform period. Kumar and Aggarwal (2005) found a complementary relation between embodied technology and R&D behaviour and a substitutive relation between disembodied technology and R&D behaviour in post reform period in Indian manufacturing firms.

The mode of importation of technology also determines the nature of the relation depending upon whether technology is imported under licensing agreement by local firms or technology is imported through FDI package (Kumar, 1987). Regarding foreign technology adoption or acquisition, firms may differ depending upon their attitude Porter (1980)(as mentioned in Lee, 1996). The methods of getting foreign technology could be through importing capital goods which embodies foreign technology or through royalty payments, licensing etc. (disembodied technology)[13]. Firms which are technology importers and firms which are R&D performers usually

[13]Lee (1996) pointed out that there are informal methods of acquiring technology like by imitating product or process innovation of larger firms by the small firms or by reverse engineering of foreign technology by domestic firms, literature regarding inventions in foreign countries, inspecting production sites of foreign firms etc. In the developing country a very less number of firms are engage in importing technology. Rest of them tries to imitate or reverse engineer foreign technology. For an example we can mention the Chinese manufacturing firms where counterfeit products ranges from 10% to 20% and according to Chinese government report these counterfeit products outnumbers original product by 2:1 (Minagawa et al., 2007).

come from the same group. The reason behind the fact is that R&D activity and importing technology, both need considerable amount of finance, high administrative and technical cost and risk (Lee, 1996)[14]. Firms having such capabilities can do R&D activity and subsequently import technology. In the relevant literature emphasis was given to the R&D activities by foreign firms or MNE's as they always have the capability to develop advance technology and thus enjoy monopoly over the technology paradigm (Kumar, 1987). Kumar and Aggarwal (2005) in a study of Indian manufacturing firms' R&D activity in post reform period found that MNE's are more active in R&D activity by exploiting local resources.

Data Source and Methodology

This section discusses the classification of manufacturing industries, followed by present analyses. After that the data source and methodology of the analysis are discussed.

Classification of manufacturing industry according to technology level

There are many ways to distinguish or categorise products according to their technology levels. Usually the R&D level associated with the product development is the distinguishing factor.

For our analysis we classified the manufacturing firms into four groups depending upon their main products into four technology groups following the classification provided by Hatzichronoglou (1997):

(i) Low-technology industries (LT industries): food, beverages and tobacco, wood products and furniture, textiles and apparel, leather, paper products, printing.

(ii) Medium-low-technology industries (MLT industries): ferrous and non-ferrous metal products, non-metallic mineral products, refined petroleum products, rubber and plastic products, ship building and repairing, other manufacturing.

(iii) Medium-High-technology industries (MHT industries): mainly transport and automotive products, chemicals (excluding drugs), electrical and electronic products.

[14] Lee (1996) found that in the Korean manufacturing industries technology importing firms are more active in R&D activity than the non-importer ones.

(iv) High-technology industries (HT industries): pharmaceuticals, complex electrical and electronic machinery (office, computing, radio, TV etc.), aerospace.

The dataset for Indian organised manufacturing firms for the firm level study is compiled from the Prowess database which maintains income statements and balance sheets of the companies enlisted with the Bombay Stock Exchange. This database is maintained and provided by CMIE. This data base has data on large number of firms (both private and public sector enterprises) of India. The firms covered in Prowess account for about three fourth of all corporate taxes collected by the Government of India . This data set provides data on a panel of firms over a long period but it does not considers very small scale firms.

The dataset in our study covers the period 1994 – 2010[15]. It provides quantitative information on a wide range of variables like sales, age (this data set does not provide exact age as the firms are not in any legal obligation to report their entry and exit date to the data collecting agency), GFA, export sales, expenditure on R&D and imports of capital and intermediate goods, profit, advertisement expenditure of the firm, consumption of raw material and energy, compensation to employees etc.

For cleaning the data set we have excluded those firms which do not have continuous information on key variables (sales, wage and GFA) for less than 5 years. After cleaning the data set we have 5501 firms in our sample. It is a longitudinal dataset with unbalanced panel. We deflated the variables using WPI corresponding to each product taking 1993-94 as base year[16].

Determinants of R&D in manufacturing sector

We collected data for this study from CMIE-Prowess data base.

Following are the explanatory variables used in the analysis

Size

Schumpeter(1942) in his famous book *Capitalism, Socialism and Democracy* discussed the innovative behaviour of small and big enterprises. According to him

[15] Adequate amount of firm level information from the data base was only available since 1994. One another reason to choose a post liberalization period of 15 years was due to the assumption (widely discussed in literature on economic reforms) that integration with the world economy actually influences various firm level factors over the years.

[16] Ministry of Commerce and Industries, India publishes the WPI series. http://eaindustry.nic.in/Download_Data_9394.html

there is a positive relationship between innovation and firm size. There are several studies on this issue. Cohen and Levin (1989) reported few arguments discussed in the existing literature on the relation between innovation and firm size following Schumpeterian hypothesis. One of the arguments is that big size firms have advantage of securing funds generated through capital market imperfections as firm size have "correlation with availability and stability of internally generated funds"[17]. This way they can afford to hire highly skilled researches and invest in risky innovative projects. Another argument is that economies of scale are associated with R&D technology. If there is higher volume of sales then the returns from R&D activity also becomes higher as the fixed cost of innovation can be spread over that larger sales value. R&D activity can become more productive as due to the presence of "complementary relation between R&D and nonmanufacturing activities" like financial decisions and marketing, which can be provided well by big sized firms. Studies made on Indian enterprises (Lall, 1983; Katrak, 1985; Kumar and Saqib, 1996; Goldar and Renganathan, 1997; Kumar and Aggarwal, 2005) found positive relation between firm size and R&D activities. Studies by Scherer (1965), Bound et al., (1984), Acs and Audretsch(1991), Kumar and Saqib (1996), Pradhan (2003), Ghosh (2009) found inverted U shaped relation. One reason could be that a threshold size is essential before taking up R&D activity due to the presence of fixed costs in performing R&D (Kamien and Schwartz, 1975). One another reason could be that, this nonlinear relation between R&D or R&D productivity and size could be due to "fishing out effect" which says that innovations becomes difficult with the advancement of technology (Aghion and Howitt, 2007) simply because of easiest innovations are already done in the past and discovering new technology is becoming tough job for researchers (Lee Sung, 2005) or the reason could be that after a certain size, firms grip over managerial activities becomes loose which deters the firms to gain from R&D activities (Cohen and Levin, 1989). Following these arguments we expect an inverted relation between size and R&D activity and beliving they are still true for Indian firms.

Market concentration

Market concentration on innovative behaviour is a contested issue in R&D literature. Market concentration is measured by Herfindahl Hirschman Index (HHI) in

[17]Larger firms having larger assets can be used as collateral for loans (Rogers, 2004).

this study. According to Schumpeter (1942), "Large firms operating in a concentrated market are the most powerful engine of growth" and thus market concentration gives impetus for innovation activities. Cohen and Levin (1989) discussed two themes regarding Schumpeterian assumption of market concentration and innovation. One says that firms need some form of short-term market power which can give them incentive for investment in R&D activities[18]. The other theme says that in an oligopolistic market structure the firms can predict each other's actions and thus making stable behaviour which clears the uncertainty and leads to incentive for invention. Studies in this field reported both negative (Kumar, 1987; Scherer, 1992; Kathuria, 2008) and positive relation (Scherer, 1967) between innovation and market concentration. In this study it is assumed that monopoly structure has a positive impact on R&D activity of the firm.

Imported disembodied technology

Importing technology and its impact on domestic R&D activities are usually studied on LDC firms as they need international technology more to produce internationally competitive products to compete in the world market. Technology import could be of two types. Embodied technology import and another is the disembodied technology import. Some argue that it is a complementary relation between imported technology and R&D and the other is in support of a substitutive nature relation. According to Lee (1996) its substitutive nature may be up to the point where the firm can make choice between purchasing any technology from abroad and developing it by their own. On the other hand complementary relation could be due to the fact that imported technology may be work as a catalyst for the domestic technology and innovation. A developing country which is importing technology can face adaptive R&D or "dependence culture". Studies like Lall (1983), Katrak (1985), Siddharthan (1988), Braga and Willmore (1991), Kumar and Aggarwal (2005) found positive relation between the two. We expect a positive relation between disembodied technology import (DEMTI) and R&D efforts.

Age

Age of the firm is an important variable which represents knowledge accumulation and experience and it is a proxy for efficiency differences (Ghosh , 2009). With age of the firm its administrative and technical capability increases (Lall,

[18]A monopolistic market structure can give the firm required amount of financial resources that can be utilised for innovative activity.

1983). According to Kumar and Saqib(1996) a firm which has a long engagement with the production process will have more incentive to invest in R&D as the accumulated learning may help in future technological activity and thus up gradation in quality of the product. This is also needed by exporting firms to remain in the international competition. Age of the firm is measured by the number of years the firm is active in the market[19] since its incorporation. We expect a positive relation with the R&D activity of the firm.

Leverage Ratio

R&D activities are highly dependent on financing. Bah and Dumontier (2001) discussed the issue of financing R&D at a great detail. There are four options according to them. Investing in a risky R&D project is guided by the future return from the innovation. The return from it is expected to be more than the reimbursement value of the debt taken to finance the project otherwise the shareholders of the firm may prefer to liquidate the firm. Thus it is always preferable to keep low level of leverage or debt. According to the 'asset substitution' hypothesis equity financing is more preferred to the debt financing one by the R&D intensive firms[20]. Asset substitution theory suggests that firms involved in R&D activity would prefer asset financing[21] to debt financing[22]. We expect a negative sign for the leverage ratio (Leverage).

Export orientation

Firms engaged in export activity need to compete in the world market. To meet the nature of foreign market demand, foreign standards, tastes etc. firms need to adapt product and process innovations (Kumar and Aggarwal, 2005). For this reason

[19]For the firms which are still active in the market we considered 2010 as their last year as it is the highest maximum year we are considering in this study.

[20] R&D activity is a specialised job and it produces unique products which are not easy to substitute or duplicate. In a situation of liquidation of the firm the customers and workers of that firm may find it harder to shift. In such a situation to avoid bankruptcy low debt and high equity financing is preferable. . Because of the presence of rivalry between the R&D firms they sometime do not expose their research detail which is necessary to get external funding. In such case having limited access to security markets firms are often dependent upon own financing. As R&D activity has significant opportunity of growth in future, leverage is expected to be low and short-term debt should to be high.

[21]Using balance sheet assets (such as accounts receivable, short-term investments or inventory) to obtain a loan or borrow money - the borrower provides a security interest in the assets to the lender. This differs from traditional financing methods, such as issuing debt or equity securities, as the company simply pledges some of its assets in exchange for a quick cash loan (Investopedia). Accessed through the following link
http://www.investopedia.com/terms/a/assetfinancing.asp

[22]Firm raises money for working capital or capital expenditures by selling bonds, bills, or notes to individual and/or institutional investors. In return for lending the money, the individuals or institutions become creditors and receive a promise that the principal and interest on the debt will be repaid.

they need quality products which can be produced with better R&D inputs. According to Zimmerman (1987), as export increases the size of the market for the firm it has a positive impact on the R&D investments by increasing the returns on it. Developing country or less developed country firms with export activity need more R&D activity than the domestically oriented firms to meet the challenging requirements abroad (Braga and Willmore, 1991). Studies by Braga and Willmore (1991), Kumar and Saqib (1996), Tan and Hwang (2002), Kumar and Aggarwal (2005) found positive relation between export and R&D decisions. Following the literature we also expect a positive relation between export and R&D activity of the firms. We have taken a dummy for the export status ($Export_{dummy}$)

Foreign firms

Foreign affiliates are usually subsidiaries of foreign firms operating in a country and they always have an edge over the domestic firms on various fronts. They have more financial resources which provide them the courage to take risks to do high end research. They have better networks in the world market and thus can have better knowledge on advance R&D activity. An increased share of skilled workers and enhanced competition in a host country can accelerate the foreign firms R&D decisions (as mentioned in Kumar and Aggarwal, 2005). A firm makes investments abroad with some motivations. According to efficiency seeking motives (neo-classical) a firm invests abroad to increase efficiency, or for market seeking motives, or to access resources from abroad (resource-seeking), or to enrich domestic products by exploiting knowledge pool from abroad (asset seeking/evolutionary economics) (Arvanitis and Hollenstein, 2006). In a post reform Indian economy the large number of foreign firms will certainly invest more on R&D activities. We expect a positive relation between the two. We have taken a dummy for the foreign firms ($Foreign_{dummy}$).

We have discussed the measurement of the variables in the table below.

Table: 1 Variable measurement for R&D determinants analysis	
Dependent Variables	
RND*	In the Probit model the variableis a binary dummy variable taking value 1 if the firm is making positive R&D expenditure and zero otherwise.

RNDT*	In the Tobit model the dependent variable is a binary one and is the ratio of R&D expenditure to sales of the firm. It is taking value zero when the firm is not making any R&D investment.
Explanatory Variables	
Age	Number of years the firm is active in the market.
Size	It is the value if sales of the firm in real terms.
Size2	It is the square term of the size.
Leverage	It is the ratio of the borrowing and total asset of the firm.
DEMTI	It is representing disembodied technology import. It is the payments made on account of royalty, technical fees abroad by the firm as a proportion of its sales value.
HHI	Herfindahl Hirshman Index measured as $HHI = \sum_{i=1}^{n} \left(\frac{x_i}{X}\right)^2$ Where x_i represents the sale of the *i*th firm and X represents the total sales of the industry the firm belongs to.
Export dummy	Dummy variable for export activity. It takes value 1 for firms engaged in export activity and 0 otherwise.
Foreign dummy	Dummy variable for foreign firms. It takes value 1 for foreign firms and 0 otherwise.

Empirical model

We employ both Probit and Tobit model respectively to find the probability and intensity of R&D investments. In the Probit model the dependent variable is a binary value taking 1 if the firm has made investment in in-house R&D activity and 0 if it does not. This model says about the conditional probability of a firm making R&D expenditure given the explanatory variables. Thus the model can be represented by the following equation:

$$RND^{*}_{ijt} = \beta_0 + \beta_1 Age_{ijt} + \beta_2 Size_{ijt} + \beta_3 size^{2}_{ijt} + \beta_4 Leverage_{ij\,(t-1)} + \beta_5 DEMTI_{ij\,(t-1)} + \beta_6 HHI_{ijt} + \beta_7 Export_{dummy} + \beta_8 Foreign_{dummy} + \mu_{ijt} \;, \quad (1)$$

where, $\beta_1, \ldots, \beta_8$ are unknown parameters and μ is the error term. Here, i =firm and *t*=time.In the equation the variable Leverage and DEMTI is lagged one year to overcome the endogeneity problem. $Export_{dummy}$ and $Foreign_{dummy}$ are two dummy variables that take the following values.

$Export_{dummy}$ = 1 when the firm is engaged in export activity.

= 0 otherwise, and

$Foreign_{dummy}$ = 1 when the firm is a foreign firm,

= 0 otherwise.

Here RND^{*}_{ijt} is a latent variable. The decision of RND (R&D) depends upon this latent or unobservable variable. Here RND^{*}_{ijt} is dependent upon explanatory variables. The dummy variable RND which is observable takes the value

RND_{ijt} =1, if $RND^{*}_{ijt} > 0$,

=0, otherwise.

The above Probit model only explains the probability of R&D decisions by the firms. To know about the intensity of R&D expenditure of the firms we need to apply a Tobit model. The Tobit model can be explained with the following equation:

$$RNDT^{*}_{ijt} = \beta_0 + \beta_1 Age_{ijt} + \beta_2 Size_{ijt} + \beta_3 size^{2}_{ijt} + \beta_4 Leverage_{ij\,(t-1)} + \beta_5 DEMTI_{ij\,(t-1)} + \beta_6 HHI_{ijt} + \beta_7 Export_{dummy} + \beta_8 Foreign_{dummy} + \mu_{ijt} \;, \quad (2)$$

where, $\beta_1, \ldots, \beta_8$ are unknown parameters and μ is the error term. Here, i =firm and *t*=time. In the equation the variable Leverage and DEMTI is lagged one year to overcome the endogeneity problem. $Export_{dummy}$ and $Foreign_{dummy}$ are two dummy variables that take the following values.

$Export_{dummy}$ = 1, when the firm is engaged in export activity.

= 0, otherwise, and

$Foreign_{dummy}$ = 1 when the firm is a foreign firm,

= 0 otherwise.

Here $RNDT^{*}_{ijt}$ is a latent or unobserved variable. The observed dependent variable takes the value such that:

$$RNDT_{ijt} = 0, \text{if} RNDT^{*}_{ijt} \leq 0,$$

$$= RNDT^{*}_{ijt}\ , \text{ if } RNDT^{*}_{ijt} > 0.$$

Empirical results

Following Probit regression results are based on the equation no. (1). Table: 10 to Table: 13 show results of Probit regression for HT, MHT, MLT and LT industries. The tables show the factors that are influencing the probability of R&D decisions by the Indian manufacturing firms. The models are statistically significant at one percent level of significance showing by the respective Chi-square statistic[23] distribution. Table: 14 to Table: 17 represent the results of the Tobit models for the technology groups. Tobit regressions are based on equation no. (2).

Age variable representing experience is highly significant at 1% level of significance in all the technology groups implying that with age the firms are more interested in making expenditure in R&D activities. In the R&D intensity analysis the age variable representing the level of experience is significant for all technology groups except HT group. It seems unlike MHT, MLT and LT, experience is not a big factor for the R&D intensity of HT firms. The result clearly says that the firms with more experience on market as well as production is tend to associate more with R&D activities or initiatives.

The size variable is significant at 1% level of significance for all the technology groups except MLT, saying that larger firms have ability to set about R&D decisions. This result is also in line with our hypothesis based on Schumpeterian assumption on size. The quadratic term of the size variable is negatively significant for all the technology groups, except MLT, showing an inverted U shaped relation between R&D decisions and size of the firm. This particular relation says that large firms have the probability of undertaking R&D activities up to a certain size or threshold level and after that it declines. For determining the R&D intensity, size

[23]Chi-square statistic belongs to the Wald test. Under the null hypothesis the Chi-square distribution says that all the explanatory variables are equal to zero.

variable is only significant for the HT group (Table: 14) supporting Schumpeterian hypothesis. For the rest of the technology groups there is no significant impact of size on R&D. The quadratic term of the size variable is not significant in any of the technology groups showing that there is no non-linear relation between R&D intensity and size. It seems that unlike the probability of venturing into R&D activity, the intensity of R&D is related linearly to their size linearly and that is only in HT firms. A study by Kumar and Saqib (1996) found a similar type of result though it was based on the whole manufacturing sector of India and not on technology categories. The aspect of big firms having greater financial resources and risk taking capability may have made them capable to undertake R&D projects.

Leverage, which is a ratio of borrowing and total asset, shows the financial constraint of the firm. Firms with greater financial risk and constrained resources reflected in a greater leverage ratio will spend less on R&D (Cumming and McIntosh, 2000). The regression result supporting this hypothesis shows a negative relation between leverage ratio and R&D decisions in the HT and MHT industries (Table: 10 and Table: 11). For the MLT and LT industries leverage ratio has no significant effect on R&D decisions. The leverage ratio failed to show any significant impact on R&D intensity across technology group.

The disembodied technology import variable has no statistically significant impact on R&D decisions by firms of any of the technology groups. On the other hand disembodied technology import plays an important role as a determinant of the R&D intensities for HT and MHT firms. It is statistically significant at 1% level of significance in these two groups but insignificant in the other two groups. From the results it can be said that it has important as a determinant but it cannot influence the R&D decisions.

The result shows that disembodied technology import is having a complementary relation with the R&D intensities in HT and MHT firms in India (Table: 14 and Table: 15). In developing countries the result is in line with the literature (Lall, 1983; Siddharthan, 1988, Braga and Willmore, 1991). The literature is divided upon the type of relation (complementary or substitute) between technology import and R&D activity (Kumar, 1987). The complementary relation says that in the HT and MHT firms this disembodied technology is actually helping the in-house R&D activities to assimilate and adapt the imported technology according to local conditions.

The Herfindahl Index (HHI) showing the degree of market concentration is statistically significant in the HT group (Table: 10) and LT group (Table: 13) but with opposite sign respectively in the Probit analysis. In the HT group the sign of the coefficient of HHI is negative and significant at 1% level of significance. On the other hand it is positively significant in the LT group at 10% level of significance. According to Schumpeter (1942), a monopoly industrial structure with large firms is ideal for R&D activities. The LT industries are supporting this hypothesis whereas the HT industries are following an opposite relation. Mukhopadhyay (1985) also found a similar type of result on US firms and Kumar (1987) on Indian firms.

According to Mukhopadhyay (1985) entry rate of firms is much higher in technologically progressive industries which are behind such relation. Here the same reason may be working in HT group. The Concentration in the industry represented by the Herfindahl index (HHI) has no statistically significant impact on R&D intensity in any of the technology groups.

The two dummy variables, dummy for the export firms and dummy for the foreign firms, considered in the Probit models shows how the foreign firms and the exporter firms behave regarding R&D decisions. The export dummy is significant at 1% level for the HT and MHT groups (Table: 10 and Table: 11). It has 5% level of significance for the MLT firms but it has no significant role in the LT group firms (Table: 12 and 13).

From the result it seems that the exporter firms in the HT and MHT firms are more interested and have higher probability to engage in R&D activities. The probability declines for the next technology groups. On the other hand export status represented by the export dummy variable is statistically significant for all the technology groups except MHT firms in the Tobit result. This suggests that exporting status is important for both the probability and intensity of investments in R&D as exporting activity means diversification in the international market essentially needs technology inputs of the firms (Kumar and Saqib, 1996). Foreign firm status represented by the foreign dummy is highly significant for the MHT firms at 1% level in the Pobit result (Table: 11). It is significant at 10% level for the MLT firms (Table: 12). It has no statistically significant relation with R&D decisions in HT and LT groups (Table: 10 and 13). This shows that foreign firms in these MHT and MLT categoriesare more interested to make investment in R&D activity compared to the domestic firms. In the Tobit regression foreign dummy is significant in MHT firms

(Table: 15). In the relevant literature emphasis was given to the R&D activities by foreign firms or MNE's as they always have the capability to develop advance technology and thus enjoys a monopoly over the technology paradigm (Kumar, 1987) and it seems very true for MHT and MLT firms in India.

Conclusion

In this paper the main objective was to find the relevant determinants of R&D, an important indicator of technological capability, at the firm level. In this context we had three hypotheses to test: first, the relationship between R&D and firm size is inverted U shaped; second, R&D is positively related with market concentration and third, disembodied technology import is positively related to R&D activity.

From the analysis it is evident that there are differences in the relation between the explanatory variables and the dependent variable across technology groups. We find that the firm size has a nonlinear relation with the probability to undertake innovative activity in all industries except MLT. It implies that in those technology groups size has a threshold effect on R&D. In HT firms, size has a positive and linear relation with the R&D intensity. The result supports Schumpeter's size-innovation hypothesis but with exception. The result may also imply that size in a high technology intensive firm can impact the R&D when certain firm specific technological competence is conducive to utilise the situation by investing more in R&D[24].

Market concentration, another important aspect of Schumpeter's hypothesis, has a positive relation with the probability of R&D activity in LT but a negative relation in HT. In other technology groups there is no significant relation between them. Market concentration does not have any impact on R&D intensity. The result shows that, in the LT group market concentration is helping R&D activity but in the HT group it has a negative relation with R&D. Following Mukhopadhyay (1985) we can draw a conclusion that may be entry rate of firms is much higher in technologically progressive industries which is behind such relation. Further study is required to find the possible reason(s).

The disembodied technology import or 'arm's length purchase' of technology has a complementary relation with the R&D intensity of firms in higher technology

[24] For this particular conclusion we followed a study on Korean firms by Lee and Sung (2005).

intensive industries (HT and MHT). This relation implies that disembodied technology is actually working as a catalyst for the domestic R&D and also helping in-house R&D activities to assimilate and adapt the imported technology according to local conditions. There is a need to encourage policies or activities which brings disembodied technology in the domestic industries. There is no impact of disembodied technology import in the probability of undertaking R&D activity.

Leverage indicating the financial constraint of a firm has a negative relation with the probability of R&D activity in HT and MHT only. This relation is supporting our hypothesis which says that firms with greater financial risk and constrained resources reflected in a greater leverage ratio will spend less on R&D (Cumming and McIntosh, 2000). There was no relevant relation found between leverage and R&D intensity across technology groups.

We found that experience measured by the age of the firm has positive impact on R&D intensity with an exception to HT group and also on the probability of undertaking R&D activity. This simply says that the firms with longer association with production process and market experience are willing to undertake R&D activity may be because they realised the importance of becoming more competitive and productive.

Export status provides incentive to enhance R&D activity in the firms due to the fact that it helps the exporting firms to get a competitive edge in the world market. Foreign firm status is also found to be engaged more in R&D activity, but only in MHT and MLT, compared to domestic firms. The reason could be that in these technology group foreign firms getting better technological opportunities and thus the return of their investment in R&D is much higher compared to other technology groups[25]. Foreign firms are interested to increase their R&D activity as for them it's an opportunity to utilise the resources of the host country. In this process they usually try to engage in better R&D activity compared to their counter parts in the domestic country[26].

The results have important implications. Different firm level characteristics or factors are affecting R&D activity in different ways across different technology groups. Thus these factors should be addressed accordingly considering the fact that

[25]Kumar and Aggarwal (2005) reached to similar conclusions but only for chemical and engineering industries which is mostly included in our MHT group.
[26] Lall (1987) pointed out that in developing countries firms mostly concentrate on the development part than the research part of R&D.

these firms are from different technology intensive industries[27]. India as a developing country can only achieve better competitive edge if these dimensions are considered to enhance technological capability while formulating industrial policies.

[27] In recent economic literature, firms are considered to be different from each other following their heterogeneous attributes. Technological level is one of them and from our analysis we can say that various firm level factors are impacting the R&D activity in various degrees following the heterogeneous level of technology of the firms.

Table: 2
Summary statistics of Probit and Tobit analysis of R&D of HT industries

Variable	Obs	Mean	Std. Dev.	Min	Max
Age	6128	20.04439	13.74137	1.00E+00	80
Size	6178	0.013786	0.0488167	1.00E-06	1.45754
Size2	6178	25.7273	374.5937	1.00E-08	21244.23
Leverage_1	5813	0.443287	0.8934206	0.000045	23.6154
DEMTI_1	696	0.078432	1.06687	0.000035	25.037
HHI	6178	0.051507	0.0401772	0.0211291	0.184039

Source: Calculated using CMIE-Prowess data.

Table: 3
Correlation coefficients in Probit and Tobit analysis of R&D of HT industries

	Age	Size	Size2	Leverage_1	DEMTI_1	HHI
Age	1					
Size	0.1066	1				
Size2	0.0333	0.8821	1			
Leverage_1	-0.1757	-0.039	0.0056	1		
DEMTI_1	-0.0603	-0.024	-0.0106	0.0452	1	
HHI	-0.125	0.1739	0.1835	-0.0213	0.031	1

Source: Calculated using CMIE-Prowess data.

Table: 4
Summary statistics of Probit and Tobit analysis of R&D of MHT industries

Variable	Obs	Mean	Std. Dev.	Min	Max
Age	19303	23.88515	15.29138	1	80
Size	19392	0.022479	0.101187	0	3.49309
Size2	19392	107.4354	2020.206	0	122016.8
Leverage_1	18416	0.452558	1.056839	0.00003	61.2857
DEMTI_1	4053	0.079538	3.143323	-0.01166	182
HHI	19392	0.042988	0.026795	0.018622	0.133085

Source: Calculated using CMIE-Prowess data.

Table: 5
Correlation coefficients in Probit and Tobit analysis of R&D of MHT industries

	Age	Size	Size2	Leverage_1	DEMTI_1	HHI
Age	1					
Size	0.2203	1				
Size2	0.119	0.8832	1			
Leverage_1	-0.0805	-0.1174	-0.0749	1		
DEMTI_1	-0.0211	-0.0064	-0.0021	-0.0072	1	
HHI	-0.0076	0.0116	0.0392	-0.0803	-0.0134	1

Source: Calculated using CMIE-Prowess data.

Table: 6
Summary statistics of Probit and Tobit analysis of R&D of MLT industries

Variable	Obs	Mean	Std. Dev.	Min	Max
Age	15229	21.8665	14.18428	1.00E+00	80
Size	15323	0.023114	0.1242582	1.00E-06	4.87125
Size2	15323	159.7335	3702.494	1.00E-08	237290.8
Leverage_1	14861	0.518127	1.047725	2.90E-05	74.4858
DEMTI_1	1516	1.465143	32.07952	1.18E-06	1081.5
HHI	15323	0.051708	0.0326636	0.0330682	0.925816

Source: Calculated using CMIE-Prowess data.

Table: 7
Correlation coefficients in Probit and Tobit analysis of R&D of MLT industries

	Age	Size	Size2	Leverage_1	DEMTI_1	HHI
Age	1					
Size	0.1837	1				
Size2	0.1263	0.8826	1			
Leverage_1	-0.0724	-0.0759	-0.07	1		
DEMTI_1	-0.0093	-0.0124	-0.0055	-0.0346	1	
HHI	0.1362	-0.0311	-0.027	-0.1115	0.0137	1

Source: Calculated using CMIE-Prowess data.

Table: 8
Summary statistics of Probit and Tobit analysis of R&D of LT industries

Variable	Obs	Mean	Std. Dev.	Min	Max
Age	16035	22.39214	17.27222	1.00E+00	117
Size	16277	0.012113	0.0484763	1.00E-06	2.31151
Size2	16277	24.96534	663.8445	1.00E-08	53430.79
Leverage_1	15646	0.670783	2.345303	0.000034	105.335
DEMTI_1	569	0.118836	1.307008	0.0000105	21
HHI	16277	0.027043	0.064837	0.0081522	0.65407

Source: Calculated using CMIE-Prowess data.

Table: 9
Correlation coefficients in Probit and Tobit analysis of R&D of LT industries

	Age	Size	Size2	Leverage_1	DEMTI_1	HHI
Age	1					
Size	0.2977	1				
Size2	0.151	0.8701	1			
Leverage_1	-0.293	-0.1182	-0.0951	1		
DEMTI_1	-0.0765	-0.0607	-0.028	-0.0121	1	
HHI	0.373	0.2112	0.1115	-0.1572	0.0358	1

Source: Calculated using CMIE-Prowess data.

Table: 10
Probability of undertaking R&D activity in HT industries

Explanatory Variables	
Age	0.0389482***
	(2.96)
Size	9.386816***
	(2.76)
Size2	-0.0004639*
	(-1.89)
Leverage_1	-1.702331***
	(-3.21)
DEMTI_1	-0.0401363
	(-0.24)
HHI	-12.26635***
	(-3.27)
Export_dummy	1.500227***
	(4.59)
Foreign_dummy	0.2455847
	(0.44)
Constant	-0.5220038
	(-1.07)
Wald Chi square	(54.89)***
Log likelihood	-267.54561
Observations	655

Significant at (***) 1%, (**) 5%, (*) 10%. Z values are given in the parentheses.

Table: 11
Probability of undertaking R&D activity in MHT industries

Explanatory Variables	
Age	0.0505113*** (7.85)
Size	5.538084*** (4.87)
Size2	-0.0001401*** (-3.88)
Leverage_1	-0.583955** (-2.21)
DEMTI_1	0.4026178 (1.07)
HHI	-2.281993 (-0.88)
Export_dummy	0.4145772*** (3.26)
Foreign_dummy	1.193982*** (4.21)
Constant	-2.069057*** (-7.57)
Wald Chi square	(179.97)***
Log likelihood	-1473.766
Observations	3845

Significant at (***) 1%, (**) 5%, (*) 10%. Z values are given in the parentheses.

Table: 12
Probability of undertaking R&D activity in MLT industries

Explanatory Variables	
Age	0.0454695*** (5.80)
Size	0.3983082 (0.61)
Size2	-1.80E-06 (-0.06)
Leverage_1	-0.1758022 (-0.45)
DEMTI_1	-2.760469 (-0.66)
HHI	-1.24709 (-0.49)
Export_dummy	0.5801095** (2.55)
Foreign_dummy	0.6405738* (1.77)
Constant	-2.488989*** (-6.12)
Wald Chi square	(64.48)***
Log likelihood	-592.15778
Observations	1455

Significant at (***) 1%, (**) 5%, (*) 10%. Z values are given in the parentheses.

Table: 13
Probability of undertaking R&D activity in LT industries

Explanatory Variables	
Age	0.0489039*** (2.86)
Size	35.25822*** (3.33)
Size2	-0.0064339* (-1.73)
Leverage_1	-0.2007418 (-0.19)
DEMTI_1	-0.9280601 (-0.21)
HHI	8.162815* (1.68)
Export_dummy	0.0072393 (0.01)
Foreign_dummy	1.072074 (1.04)
Constant	-4.209603*** (-4.97)
Wald Chi square	(35.79)***
Log likelihood	-183.75747
Observations	548

Significant at (***) 1%, (**) 5%, (*) 10%. Z values are given in the parentheses.

Table: 14
Determinants of R&D intensity in HT industries

Explanatory Variables	
Age	0.0004388 (1.15)
Size	0.1755541** (2.28)
Size2	-8.85E-06 (-1.22)
Leverage_1	-0.0203109 (-1.20)
DEMTI_1	0.00718*** (3.29)
HHI	-0.1855268 (-1.57)
Export_dummy	0.04804*** (3.97)
Foreign_dummy	-0.0140159 (-0.77)
Constant	-0.0461*** (-2.64)
Wald Chi square	(38.49)***
Log likelihood	463.5432
Observations	655

Significant at (***) 1%, (**) 5%, (*) 10%. Z values are given in the parentheses.

Table: 15
Determinants of R&D intensity in MHT industries

Explanatory Variables	
Age	0.0005364*** (6.40)
Size	0.0063695 (0.70)
Size2	-3.29E-08 (-0.11)
Leverage_1	0.0031378 (0.77)
DEMTI _1	0.0016891*** (4.27)
HHI	-0.0384896 (-1.01)
Export_dummy	0.0029984 (1.39)
Foreign_dummy	0.0099031** (2.48)
Constant	-0.0368313*** (-9.15)
Wald Chi square	(88.97)***
Log likelihood	3979.5689
Observations	3845

Significant at (***) 1%, (**) 5%, (*) 10%. Z values are given in the parentheses.

Table: 16
Determinants of R&D intensity in MLT industries

Explanatory Variables	
Age	0.0002211*** (4.23)
Size	0.0045822 (1.26)
Size2	-9.73E-08 (-1.05)
Leverage_1	-0.0000153 (-0.00)
DEMTI _1	-0.0175952 (-1.03)
HHI	-0.0226773 (-0.92)
Export_dummy	0.0047522** (2.22)
Foreign_dummy	0.0024328 (0.92)
Constant	-0.0213677*** (-6.18)
Wald Chi square	(48.24)***
Log likelihood	1405.6275
Observations	1455

Significant at (***) 1%, (**) 5%, (*) 10%. Z values are given in the parentheses.

Table: 17
Determinants of R&D intensity in LT industries

Explanatory Variables	
Age	0.0004771*** (2.34)
Size	0.11583 (1.25)
Size2	-3E-05 (-1.14)
Leverage_1	-0.01796 (-1.23)
DEMTI _1	-0.09462 (-1.02)
HHI	0.01168 (0.33)
Export_dummy	0.0145397* (1.65)
Foreign_dummy	0.00279 (0.23)
Constant	-0.05175 (-4.38)
Wald Chi square	(20.77)***
Log likelihood	395.842
Observations	548

Significant at (***) 1%, (**) 5%, (*) 10%. Z values are given in the parentheses.

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