INNOVATION BY FIRMS IN HIGH AND MEDIUM-HIGH TECHNOLOGY INDUSTRIES: AN INDIAN EXPERIENCE

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ABSTRACT

Innovation is vital in gaining advantage over other firms and to attain the competitive edge. An emerging economy like India needs to have an innovative industry with large R&D expenditure and patenting activity. The study thus focuses on nature of Indian investment on innovation through R&D and patenting activities. The data covers all the firms of high-tech and medium-high-tech sectors during a period of 1995-2011. We employ a recursive simultaneous equation where the R&D expenditure used as a dependent variable in R&D equation and as an independent variable in patenting equation. We use Heckman's two-step procedure in R&D equation and Hurdle count data model in patenting equation that taking care of heterogeneity and selection bias problem simultaneously. The study finds that patent policy significantly influences R&D and patenting intensity. After the patent policy changes foreign firms are relocating their R&D units into India and taking patent from Indian patent office. The study does not find any direct evidence of R&D oriented patenting activity in India.

Key words- R&D, Patent, Innovation, Emerging economy

1. INTRODUCTION

Schumpeter defines "innovation as the setting up of a new production function. This covers the case of a new commodity, as well as those of a new form of organization such as merger, of the opening up of new markets, and so on, [66]".These technological changes consisting of introduction of new product, process and management methods are the major determinants of the industrial changes. Innovation is the means through which firms compete and grow that leads to the innovation-led-growth. Empirical evidence shows that innovation increases the productivity and efficiency of firms [33]. Geroski et. al identify that innovating firms are growing more quickly and making higher profit than non-innovating firms [30].Innovation by a firm is thus vital in gaining the advantage over other firms and sustaining it for survival in a competitive industry. When firms are constantly pursuing new technologies that opening up new opportunities and provide stronger market positions. Consequently, innovation is expected to enhance the performance of the firms. Thus policy makers give much importance to innovation activities of firms.

The limited number of variables available for quantifying and qualifying the innovation process often lead to under estimate of the actual level of innovation occurring in an economy. However, economist derived some indicators from the available statistical data, perhaps the most important form for such information. The data on R&D expenditure and the patents are generally available information for innovation and technological analysis. Griliches shows the relevance of the patent data vis-à-vis R&D expenditure in capturing the innovation activity [35]. In this seminal paper, Griliches establishes that R&D is an input into the knowledge production function that leads to output in the form of patent.

There is extensive literature that studies the economic and social factors that influence innovation. However, most of these studies employ research and development (R&D) expenditure as a measure of innovation. Particularly, from an emerging economy's perspective, resources devoted by firms towards R&D and ensuing patenting activity both influence the global competitiveness of an economy. Therefore, it is pertinent to study the determinants of the R&D expenditure and the following patenting activity of the firms together. This is the key motivation behind this study where we bring together R&D and patent data of firms to gauge and analyze the innovative activity of these firms.

Emerging economy like India needs to maintain competitive edge at the global level. Therefore, having an innovative industry with large R&D expenditure and patenting activity is very important. This study gains further relevance in light of the following fact. India spends only 0.7- 0.9% of their GDP on R&D expenditure. This expenditure is not only low but also stagnant in the last few years whereas Indian Patent Office witnesses a remarkable progress in patent filing (on an average of 15% increase) during 2005-2011 i.e. after the recent institutional changes in Indian industrial policy and TRIPs agreement. The unexplored patent data at the firm level along with the R&D expenditure further increases the significance of the study in the Indian context. In the study we introduce institutional factors in order to account for policy changes.

The study focuses on the medium and high technology industries as these firms are relatively more intensive in research. Moreover, the statistics shows that Indian high-tech firms contribute, on an average, 84% of total manufacturing R&D (during 2006-2010) and 39% of the total patent granted (during 2006-2009). Importantly, the share of high-tech patent after the product patent introduction in all fields of technology is increasing tremendously. It was as low as 1% in 2003, 4% in 2005 and increased thereafter to the share of 30%, 49% and 57% in 2006, 2007 and 2008 respectively.

The reminder of the paper is structured as follows. After the introduction, Section 2 explains the conceptual model for the study and briefly reviews empirical literature on R&D and patenting. Section 3 discusses about the variables used in the study along with relevant literature. Section 4 provides information on the data for the analysis including the data sources, and the empirical strategy followed in the paper. Section 5 provides the results of the Heckit and count data models applied to the Indian firm’s data. The concluding Section 6 highlights the key findings of the study and the policy implications.

2. CONCEPTUAL FRAMEWORK

Pakes and Griliches use patent statistics as an indicator of innovative activity of a firm where patent is the output of the Knowledge Production Function (KPF)[1] with investment in R&D as an input [56].Later, Griliches shows the importance of patent data for capturing the innovative activity of a firm[35]. Both the studies explain the relationship through a statistical descriptive model known as the *simplified path analysis* that represents R&D and patents as the input and output of the KPF. KPF represents the net addition of knowledge (K) to the economy as a result of firm's investment in R&D. Since K is unobservable, patent[2] would serve as a measure of inventive output created through the knowledge generated in the R&D process. Therefore, R&D and patents data is estimated and analyzed to understand the factors influencing KPF of a firm. A group of factors classified as firm specific, industry specific, institutional, technology related and demand and supply side variables influence both R&D and patents.

The study by Ray and Bhaduri estimates a research production function for India providing developing country perspective. The study considers R&D stock as an input into the KPF and the number of product, process, publication of papers and books as the output. Further, the study covers electronics and pharmaceutical industries [59].

We build our schematic framework based on Pakes and Griliches and Ray and Bhaduri [56] and [59]. We enhance the earlier frame work by introducing the factors keeping in view of the changes in the Indian economy. These additional factors include institutional aspects like patent policy changes, government incentives and other variables capturing the economic reforms. We use more internationally comparable variable for knowledge output i.e. the number of patent granted to different firms. An increase in the number of foreign owned companies further necessitates the use of patent as an outcome variable as these companies have been patenting at the Indian Patent Office (IPO). We bring together R&D and patent of all high-tech and medium-high-tech sectors together to understand knowledge generated in the Indian firm. These two variables are used independently in different studies to capture the innovation activity of the firms.[3] By bringing these two variables together we will be able to understand innovation activity of the Indian firms in a more comprehensive manner.

The proposed schematic framework for the KPF is given in Figure 1. Where K is the knowledge generated from the firm's investment in R&D which converts into an inventive output in the form of patent. The υ_{it} , ε_{it} and u_{it} are the unobserved factors that influencepatenting, K and R&D activity respectively. These unobserved factors are firm specific and time specific. For instance, firm's motivation may influence its KPF and its variable. In terms of time specific variables, for example it has been noted that R&D expenditure is cyclical in nature with the total amount increasing during boom and declining during recession.

[1]According to the authors, KPF is the mechanism through which past R&D expenditure together with unobservable random variables translates into invention.

[2]Note that all the knowledge generated through R&D need not be patentable and/or patented.

[3]For example see Kumar and Aggarwal [45] and Ghosh [31] etc. for R&D and innovation; Chadha[18]and Nair [54]etc. for patenting as a measure of innovation.

Based on the schematic frame work given in Figure.1 we estimate the following models.

R= f (Xβ+**u**) (1)

Where R is the n × 1 vector of R&D efforts by n number of firms, X is an n × k vector of explanatory variables, β is the coefficient matrix of order k × 1 and **u** is the matrix of error term.

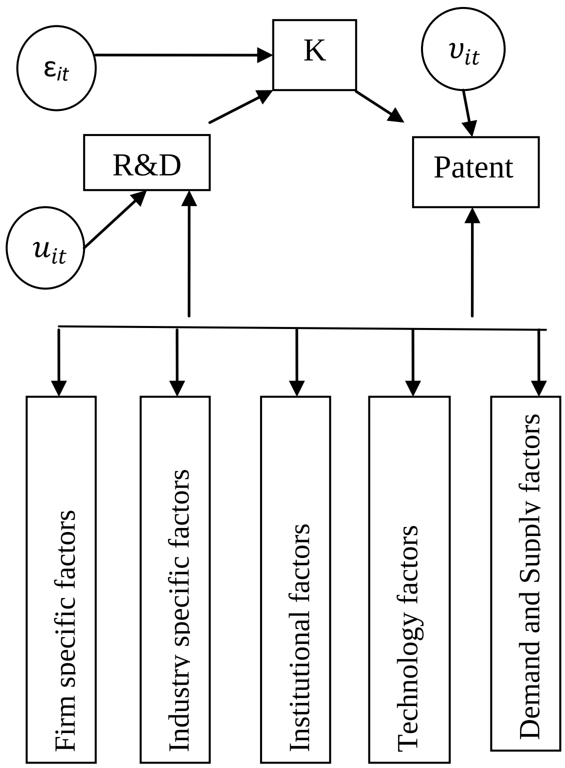

Figure 1: A Schematic Framework of the Knowledge Production Function

P= f (Z α+**v**) (2)

Where P is the n × 1 vector of patenting output, Z is an n × k matrix of explanatory variables, α is the coefficient matrix of order k × 1 and v is the matrix of error term.

3. VARIABLES

3.1. R&D Expenditure: An Input Measure

It is evident from the Figure1 that input of K and its output are determined by a set of factors like firm specific, industry specific, institutional, technological and demand and supply side factors. Now we will have a discussion on these factors.

Firm specific variables: While deciding the investment in R&D, firm specific variables like age, size and ownership category of firms play a vital role. Ray and Bhaduri find that initially R&D effort increases with size but at decreasing rate and fall after attaining an optimum firm size [59]. Kumar and Aggarwal study the R&D activity of Indian firm in the pre and post reform period. The study finds that R&D expenditure increases with firm size and the local firms primarily conduct R&D for the assimilation of imported technology [45]. Ghosh uses a panel of 800 companies for the time period 1995-2007 and finds that large size of the firm and foreign exchange earnings influences R&D expenditure of the companies [31]. Sasidharan and Kathuria find that FDI inflows influence R&D expenditure by the foreign-owned firms in high-tech industries [62].Many benefits accrue to the firm through economies of scale for firms with larger scale of operation. The returns of R&D are likely to be high due to spread of fixed cost of innovation over a large volume of sales [9].To capture the size aspect, we employ deflated sales (*SIZE*)[4].

Ownership, on the basis of domestic and foreign, also influences the investment decision. Foreign firms have several advantages over the domestic firms. They can easily avail the technology available with their parent company without any complex procedures. Further, these firms possess intangible assets like technical know-how, marketing and management skill, export contacts and reputation, which enable them to compete successfully with local firms. Therefore, we create a dummy variable of foreign ownership (*FOS*) given a value equal to one if the firm belongs to foreign and zero otherwise. All firms having foreign equity greater than 10% of the total equity are classified as foreign firms.

The experience of a firm has a bearing as the incentive to innovate. Age as an experience factor, helps firms to discover what they are good at and learn how to do things better [7]. Therefore, the study includes firm's age (*AGE*) as a control variable, where we consider the difference between the study year and incorporation year as the age of a firm.

Industry specific variables: According to Schumpeter, existence of large firms in an industry is conducive for technical progress [67]. The idea is that firms are raising their control in a concentrated industry through innovation and these monopoly firms have more resources to conduct in-house R&D. Archibugi and Piantausing new technological indicator test the hypothesis and find that size and concentration is positively related in Italian manufacturing sectors [5]. Benavente confirms the Schumpeter's view in a study conducted in Chile [11]. However, as a contrary to this result Mukhopadhyay (1985) and Audretch andAcs report a negative relationship between concentration and investment in R&D[53] and [8]. Researchers have combined these two possible patterns (positive and negative) and identify an inverted U shape relationship between innovation and competition which implies that neither perfect competition nor monopoly is conducive for innovation [64], [49], [14] and [3].

In the context of India, Desai finds that market structure with a limited number of firms (2 to 6) is more conducive for innovation [26]. Kumar and Saqib based on RBI data from 1966-81 identifies that Schumpeterian hypothesis is not significant in the Indian context since these industries are protected from domestic as well as foreign competition [46]. Prasad in a firm level study shows the negative relationship between market concentration and investment whereas Subodh shows that market concentration has no influence on the decision to perform R&D and on R&D intensity [58] and [70]. Basant and Mishra study

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[4]Note that in many studies number of employees represents the size of the firm, for example see [1]. But in the present case most of the firms in India do not report employee's data in CMIE prowess data.

the potential market concentration as a determinant of the innovative efforts by a firm. The study finds that firms in industries with greater R&D efforts in the past spend more on innovation. However, the study fails to produce a significant effect of market concentration on innovation [9].

The discussion on market structure and innovative activities of firms that is started by Schumpeter is still active [66]. The literature on concentration versus competition incentives of firm on investment remains inconclusive. Therefore, the present study uses Hirschman- Herfindahl index (*HHI*) to capture the market structure. At the same time, the monopolistic nature of industry necessitates the firms to spend more on investment and advertising. Therefore, the model includes advertising intensity (*ADVI*) that captures product differentiation aspect of the industry.

Institutional Factors: India along with other member states of WTO considered National Innovation System approach as an important tool of local institutional frame work for shaping the pace of innovation [52] and [22].In order to comply with Trade related Intellectual property rights (TRIPs) agreement, India made extensive changes in her IPR policy especially in patent policy. As a first move, in 1999 an amendment to Indian Patent Act (1970) makes provision for receiving product patent in the field of pharmaceutical and agricultural chemicals. In the second amendment, in 2003 the patent protection was extended up to 20 years in all fields of technology. The third amendment of 2005 brings significant changes in the patent field as the introduction of product patent in all field of technology[5].The impact of institutions such as intellectual property protection is tested and validated in developed nations. However, the impact of same on developing nation is in debate, therefore there is a need to look in to it.

As an institutional frame work the impact of IPR on innovation has two sided view. One view is that as property right become stronger, firms can appropriate their return on investment, thus facilitate R&D [24] and [27]. On the contrary to this, monopoly power effect of IPR reduces the incentives of firms to invest or update their existing technologies [60]. The effect of IPR on the R&D activities of developed as well as developing countries are also different. Allred and Park argue that standards of patent protection influence negatively the R&D activity of developing firms and positively in case of developed nations[4]. Therefore, to see the impact of the protection on innovation the study uses a patent policy index[6] (*PATPOL*) known as Ginarte and Park index which is further updated by [57]. We construct an interaction variable of patent policy index with foreign licensing (*FTM*) payment which indicates the market for foreign technology under the strict property regime that may have negative impact on the in-house R&D.

India is one of the countries offering numerous incentives to firms for investing in R&D. Department of Science and Industrial Research (DSIR) is the nodal agency providing such support to firms. It is mandatory that all firms that have in-house R&D units to register with DSIR. Therefore, we create a dummy of government incentives (*GID)* which equals one if the firm is registered with DSIR and zero otherwise. Siddharthan also used the same set of industries in his paper [68].

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[5]For more detailed description of Indian patent policy changes see Sharma (2012) an unpublished Indian Council of Social Science Researches (ICSSR) project report.

[6] Patent policy index consists of duration of protection, enforcement mechanism, membership in international agreement and coverage.

Technology Related Variables: A firm's success largely depends on its technological effort, either through the internal efforts of in-house R&D activities or acquisition of the same through dis-embodied technological purchase through licensing. The positive relationship between R&D expenditure and firm's output growth and productivity has already been established in the literature [34] and [38]. R&D not only enhances the productivity but also is critical to the absorptive capacity of a firm [21]. The produced technology may complement the purchased technology or could substitute the same [2]. Therefore, we include foreign royalty payment (*FLP*) represents all payment made to foreigner for licensing the technology.

High capital intensity (*CI*) encourages a firm towards in-house R&D which enhances the firm's ability to appropriate new technology. CI is measured through the percentage of net fixed asset to sales of the firm. Foreign firm possess intangible assets like technical know-how, marketing and managerial ability that enable them to compete successfully with domestic firms, these intangible assets, because of their non-rival and partial excludable nature, spillovers to local firms. We thus include a spillover variable (*SPILL*) which measures the difference between a firm's own R&D expenditure and total industrial R&D in the present study.

Demand and Supply side factors: The demand forces that affect the expected profit from an invention play a leading role in determining both the direction and magnitude of innovative activity [65]. With the increasing globalization the demand factors are spread beyond national borders. Zimmerman finds stronger impact of the demand created by exports as compared to the domestic demand [73]. Further, exporting companies are aware of the international technology trends and are more likely to adopt the same [29].Therefore, export intensity (*EXPI*) measured through the percentage of export to total sales becomes an important component. Along with the international market growth, growing domestic market also contributes to the innovation activities [68] and [2].Therefore, to capture this aspect, we include market growth rate (*MGR*) measured as the sales growth rate in each industry as a control variable.

The relationship between R&D and profitability is a debatable issue. Firms are likely to prefer internal source including retained earnings or internally generated funds to finance R&D expenditure. Since, R&D expenditure involves extreme riskiness, moral hazard problem, and extensive transaction costs firms rely on internal resources for funding innovative activities. However, Basant and Mishra do not find any statistical significant impact of profitability on innovation; rather they find a negative relationship [30] and [9]. We use profitability (*PBTI*) measured through percentage of profit before tax to sales represents the supply side factor.

3.2. Patents: An Output Measure

In our schematic framework, patenting is considered as an imperfect measure of output function of the KPF, because not all inventions are patented and/or patentable. There are certain strategic motives behind patenting; patent use improves the reputation of the company, the company is in better position while negotiating with other companies and it reflects on the performance of the company [13].Among the firm specific variables, firm size plays an important role in determining the number of patents [63].Levin et.al and Griliches argues that for small firms patent may be the relatively effective means of appropriating their R&D return. As a well-established major firm does not consider patent as a mechanism of survival or market position, thus propensity to patent among large firm tend to be low[49] and [35]. Cincera in a study of 379 Belgian manufacturing firms during the period of 1994-95 finds that larger firms are more likely to apply for patent [20]. Later, Makinen in a study of Finland finds a U shape relationship between firm size and propensity to patent [50]. Thus, the literature gives ambiguous result of the influence of firm size on patenting.

In terms of industry specific factors, empirical evidence suggests that a difference in technological opportunities and incentive peculiar to individual industry is the major reason for the variability among the sectors [63] and [71].Mansfield shows that in some industries for instance, motor vehicle industries, patents are ineffective in appropriating their return. However, about 60 percentages of patentable inventions are patented as the industry considers protecting their technological knowledge as an important competitive tool [51]. Brouwer and Kleinknecht find a significant difference in patenting propensity among the sectors, where high technology sectors tend to have higher propensity than low technology sectors [16]. Van den berg in a study of Dutch manufacturing industry finds that firms are unlikely to patent in a concentrated industry [72]. Similarly, Arundel and Kabla also find that higher degree of competition is beneficial for higher propensity to patent [6].

In terms of technological factors, research efforts of a firm significantly contribute to the patenting [23] and [55].Some researchers argue that in-house R&D greatly influences the patenting activity [12], whereas some others argue that it is contracted R&D that influences the patenting propensity of a firm [61] and [43]. Gurmu and Sebastian apply different count data models to US firms data from 1982-1992[36]. The analysis mainly intends to identify the lag between R&D and patenting but find a strong contemporaneous relationship between them. To analyze the influence of R&D on patenting activity we have three variables of R&D. R&D stock (*RDS*)[7] is used as an important variable as it represents expenditure incurred over a period of time to innovate new products and processes. R&D intensity (*RDI*) measures the percentage of R&D expenditure to sales. Foreign R&D (*FRD*) is an interaction variable of foreign dummy and RDS which analyses foreign firms R&D impact on innovation of the domestic firms.

Studies provide mixed result in terms of influence of institutional factors on the patenting activity of firms. Hall and Ziedonis study of U.S. semiconductor firms during 1979-1995 finds that firms do not heavily rely on patents to appropriate their return from R&D. However, the study suggest that strengthening of patent right in 1980 leads to the remarkable hike in patent filing among the firms in U.S. [39].Cohen et.al also finds the same result for the U.S firms in 1994 [74].Studies of Branstetteret.al and Chan do not provide any evidence of a significant impact of patent protection on firm's propensity to patent [15] and [19]. In Indian context, Deolalikar and Roller (1989) study the patenting activity of firms during the weak patent regime (1975-76 to 1979-80). The study finds that patenting leads to significant

[7]R&D stock is calculated using perpetual inventory method using depreciation rate of 15% [37] and [10]. An R&D deflator (base year 1993-94=1) is constructed as a weighted average of the WPI for machinery and Consumer Price Index. The weights are calculated on the basis of the ratio of the current and capital R&D expenditure in total. The current R&D expenditure mostly includes wages and salaries paid to researchers and in case of most industries contributes more than 80% of the combined data series.

gains in terms of total factor productivity [25]. Chadha and Nair show that after complying with TRIPs, the tendency of patenting among pharmaceutical firm has increased considerably [18] and [54].

The above discussion shows that there is no unanimous opinion among the researchers about the factors influencing the R&D and patenting behavior of firms. Firstly, it shows that there is an ambiguity among the researchers about the size of the firm, market concentration and IPR policy particularly in developing country perspective. Secondly, there is no study that brings together the R&D and patenting behavior of firm together in the Indian context. One such exception is Ray and Bhaduri study, but their data covers 1992-1994 only [59]. Thereafter Indian economy has introduced a lot of changes in her industrial policy. Finally, after complying with TRIPs there is no study on the larger set of industries. The studies of Chadha and Nair considered only pharmaceutical industry [18] and [54]. Therefore, the present study attempts to bridge the gap by bringing R&D and patenting activity of firm together for high-tech and medium-high-tech industries.

From the above discussion we are estimating the following models by using different econometric tools

RD= f(AGE,FOS,PBTI,SIZE,CI,SPILL,FTM,HHI,ADVI,EXPI,GID,PATPOL,TAR,MGR) (3)

PT= f(AGE,FOS,PBTI,SIZE,CI,SPILL,HHI,ADVI,EXPI,RDI,FRD,PATPOL,TAR,MGR,) (4)

4. DATA SOURCES AND ECONOMETRIC STRATEGY

4.1. Data sources

The main sources of data for the study are the website of Controller General of Patent Design and Trade mark (CGPDT) and CMIE Prowess for patent and firms specific variables respectively. The prowess data base of the Centre for Monitoring Indian Economy (CMIE) contains 27183 companies of data from 1990 onwards. R&D expenditure and patent granted to the Indian high-technology and medium-high-technology industries at Indian Patent Office (IPO) during the 1995-2010 are considered as two measures of innovation (List of industries given in Appendix 1). R&D expenditure of the firms is also collected from Department of Science and Industrial Research (DSIR), to fill the missing numbers in the CMIE prowess database and to perform cross-check. The present study considers only those firms which are active and producing consistent data during 1995-2010. We removed all manufacturing firms without a consistent sales data. A close examination of the data further necessitates dropping of firms with high negative profitability. After the cleanup process, we have a panel of 554 firms from four high-technology and five medium-high-technology sectors from 1995-2010 and 8864 firm level observations. A major challenge in any study that examines the patenting behavior of firms over time is identifying the patents that are assigned to individual firms in a given year. The present study consists of exclusively those patents that were assigned in the firm’s own name[8]. On the basis of literature review, the study classifies all the variables under the five categories namely, firm specific, industry specific, technology related,

[8]Patents are assigned to firms under variety of names such as their own name and their subsidiaries.

institutional factors and demand and supply side factors. Finally, the average applied tariff rates were collected from UNCTAD TRAINS database.

All the variable series are adjusted for inflation using the wholesale price index of respective industries based on 1993-94 prices. Further, all variables (except AGE and PATPOL) are in first difference form after taking the logarithm. A summary of all variables used is given in Table1.

4.2 Econometric Strategy

The model as given by equation 1 and 2 in section 2 and further extended in equation 3 and 4 can be estimated by recursive simultaneous equation because the dependent variable of RDI (equation1) comes as an independent variable in patenting equation (equation 2).

$$R_{it} = x_{it}\,\beta + c_{it}\,, \quad i=1,\ldots,N \text{ and } t=1,\ldots,T, \qquad (5)$$

Where R_{it} denotes R&D efforts by firms which is considered as research inputs, x_{it} is the vector of explanatory variable that have impact on the research activity, β is the coefficient and c_{it} is the error terms.

$$P_{it} = z_{it}\,\alpha + \upsilon_{it}\,, \quad i=1,\ldots,N \text{ and } t=1,\ldots,T, \qquad (6)$$

Where P_{it} denotes innovation output of the firms measured by patent granted, z_{it} is the vector of explanatory variables that influences the patenting activity, α is the coefficient and υ_{it} is the error terms.

Each of these models has its own specialties and has to be dealt carefully. In case of equation (1) a firm's decision to invest in R&D depends on several factors including demand, supply and technology related aspects. Factors like profit, advertisement and export orientation, foreign and domestic spending on royalties, competitive pressure, appropriability condition and the ownership position of a firm affects the decision to invest. Apart from introducing these aspects in the model, we find that for each country there could be peculiar data related aspects. For instance, in India, most of the

Table 1. Summary of variables

Category	***Variable name***	***Measurement***
Depended variables	RDD	Decision to invest. If a firm has a positive R&D takes the value 1 and zero otherwise
	RDI	Percentage of R&D expenditure to sales
	PATCOUNT	Number of patent granted to each firms
Independent variables		
Firm specific variables	AGE	Age is the difference between present year and the year of incorporation
	SIZE	Deflated sales value
	FOS	A dummy for ownership that takes value 1 if it is a foreign firm and zero otherwise
Industry Specific	HHI	Sum of the square of the sales' share of each firm in a year
	ADVI	Advertisement expenditure as a percentage of sales
Technology related	RDS	Stock of R&D
	FRD	Interaction variable of foreign dummy and R&D expenditure
	CI	Percentage of net fixed asset to sales
	SPILLFLP	Difference between total industry R&D and a firm's R&D Royalty and Licensing payment made by firms in India to foreign firms(as a percentage of sale)
Institutional factors	PATPOL	Patent policy index developed by Ginarte and Park
	FTM	Interaction variable of foreign licensing and patent policy index
	GID	A dummy for DSIR registered companies, which takes a value 1 if they are registered in DSIR and zero otherwise
	TAR	Average applied tariff rate
Demand and supply side	EXPI	Export as a percentage of sale
	PBTI	Profit before tax as a percentage of sales
	MGR	Market growth rate

firms do not report their R&D expenditure in their balance sheet if the R&D expenses are below 1% of their sales turn over. R&D expenditure of firms is often less than 1% of sales turn over; hence these firms do not report it. Further, R&D activity is observed only for those firms that decide to invest in R&D. Hence, a problem of selection occurs as R&D data is missing non-randomly. Failure to account for this sample selection problem not only leads to inconsistent estimation of parameters but also inability to generalize the inferences drawn based on sample for the population. To correct for the problems of self-selection bias and heterogeneity researchers applies Heckman's two-step procedure [62]. This model is applied on a panel data and its details follow.

Heckman's procedure: To look into the aspect of selection bias, a selection equation can be stated as:

$$s_{it} = x_{1it} \ ' \Upsilon_i + c_{i1} + \upsilon_{it1} \text{ i=1..., N and } t\text{=1... T,} \quad (7)$$

$$s_{it} = \begin{cases} 1 = \ if \ y_{it} > 1 \\ 0, \quad otherwise \end{cases} \quad (7.1)$$

Where s_{it} is the latent variable of decision to invest, which will be observable only if there is a positive R&D. Therefore, s_{it} takes a value equal to 1 if there is a positive R&D and 0 otherwise. Individual unobserved effects like motivation, endowments, ability and/or effort of a firm influence its decision to invest in R&D. Such influences lead to the issue of heterogeneity in the model that is denoted byc_i and c_{i1} in equation 5 and 7 respectively. The estimation procedure that does not take into account this heterogeneity may cause upward bias in the coefficients. For instance, if a high ability firm has more incentive to invest than the low ability firms; OLS estimates coefficients will have upward bias [28]. Thus, one of the focus in modeling is the potential correlation between dependent variable and unobserved individual firms characteristics,c_i.Hausman and Taylor suggest transformation of the data in to deviations from individual means to remove the individual effects[40]. The estimates of the transformed data have two important problems; firstly, all the time invariant variables are eliminated. Secondly, the estimator is also not fully efficient because it ignores the variation across individuals in the sample. However, the model requires that the explanatory variables be strictly exogenous. Therefore, we made a Hausman-Taylor test for endogenity. The result (given in Appendix 2) confirms no endogenity of profit and sales variable (there is no statistical difference between the coefficient of OLS and Htaylor). Therefore, following Hill, Adkin and Bender, Green and Sasidharan and Kathuria we can estimate a model consisting of two equations through Heckman's two step procedure (popularly known as Heckit method)[41], [32] and [62]. We have two equations; a selection equation (7) and an equation of interest (5), known as primary equation.

Kyriazidou suggests first differencing of the observable variable to remove the individual effects [47]. Hence, the selection equation parameter $'\Upsilon_i$ in equation (7) can be estimated using the probit model[9]. The estimation gives inverse Mill's ratio 'τ' from the selection equation.

$$\lambda_{it} = \frac{\o(z_{it} \ '\Upsilon_i)}{\Phi(z_{it} \ '\Upsilon_i)} \quad (8)$$

Where ø (.) and Φ (.) are the probability density function and the cumulative distribution function for a standard normal random variable. In the second step, author suggests to add the inverse Mill's ratio to the primary equation to obtain consistent estimates using OLS method. Additionally, we employ 'exclusion principle' which states that the selection equation should contain an additional variable which does not directly influence the outcome of the primary model and DSIR is that additional variable. As being a registered company firm may decide to invest or not but having decided that it may not influence the amount of R&D expenditure.

The particular nature of patenting equation (6) is that the dependent variable is count data. Considering discrete non-negative nature of patent counts we use Hurdle two part model. This mode

[9]We employ Stata version 11 for the analysis. However, it does not have a direct command of Heckman model for panel data. Therefore, we follow two step procedures of probit and simple OLS.

relaxes the assumption that the zeros and the positives values comes from the same data generating process [17].The two parts of the model are functionally independent, one corresponding to the zeros and other to the positives. The first step model involves estimating the parameters of a binary outcome model through a 'logit' model (equation 6). The second step estimate the parameters through zero truncated negative binomial model, where the equation estimates only if there is a positive patent application.

5. RESULTS AND DISCUSSION

Appendix 3 provides a summary statistics of the key variables used in estimating the regression model. This shows that the mean age of firms is 30. The average number of patent granted to all high –tech and medium-high-tech sector's firms are 0.44 with a variance of 19.42. The number of patents granted to each firm in a particular year varies from 0 to 232. All firms in high-tech and medium high-tech sectors together contribute 0.5 percentage of their income to R&D that ranges between 0 to 40.5 percentages. We also find that high-tech market grows at an average rate of 13.02 per year. To know the aspects of multicollinearity we perform a correlation test, the results given in Appendix 4. The correlation matrix rules out the possibility of multicollinearity because none of the variables are highly correlated except the SPILL and CI. To capture the time and group effects we introduce time and sector dummies in the model. The log likelihood ratio test indicates that the introduction of time and group dummies adds to the explanatory power of the model.

As a preliminary evaluation, the relationship between market concentration and R&D expenditure is given in Table 2. The table gives four combination of R&D intensity (high and low) and market concentration (high and low) measured through HHI. Interestingly, only pharmaceutical sector perform well in R&D with low market concentration. The result is matched with Pavitt taxonomy where only pharmaceutical sectors considered patent as an effective mechanism to protect their innovation [75]. Since patent provides a temporary monopoly firms in pharmaceutical sector are capable to make profit from their innovation. Industries like RTC and MOTOR spend more on R&D where market is highly concentrated. On the other hand, even though the market is highly concentrated, firms in OAC and MPO do not invest in R&D. Finally, rail road and transport equipment and machinery equipment firms are the poor performers of R&D even if market is highly competitive.

The results of R&D and patenting equations are discussed in subsections 5.1 and 5.2 respectively. Table 3 provides results based on R&D intensity while Table 4 gives the result based on R&D stock. In each part, we have applied different model, however, our discussion of results is primarily based on the Heckit method that are given in column (5 and 6) in Table 3.

5.1 R&D as an Innovation input

Initially R&D activity of firms is estimated through a Tobit regression that gives random-effect estimates. The result are given in Table.3. As of now, there does not exist sufficient statistics allowing the fixed effects in tobit regression. Honore has developed a semi parametric estimator for fixed-effect Tobit model, but the unconditional fixed effect estimates are biased and cannot take account of the selection problem [42].Therefore, R&D activity of the Indian firms is estimated through Heckit method, which comprises of two parts, the probit model and the OLS.

Table 2. R&D intensity market concentration matrix

		HHI	
		Low	High
RDI	High	Pharmaceuticals(PHA)	Radio, T.V and communication equipment(RTC); Motor vehicles, trailers and semi-trailers(MOTOR)
	Low	Rail road equipment and transport equipment(RTE); Machinery and equipment (ME)	Office, accounting and computing machinery (OAC); Medical precision and optical instruments (MPO); Electrical (EL)

Note: Since the HHI of chemical sector is equal to the average of total industry, it is not included in any of the category

The probit model explains the probability of R&D decision whereas the OLS method explains the determinants of the investment based on the firms that have already decided to invest in R&D. The results of which given in Table 4 where we introduce time dummies (column 1 and 2) and industry dummies (column 3 and 4) separately. And in column (5 and 6) both dummies are introduced together. The current R&D as a measure of innovative activity has been criticized on the ground of capital expensed [59]. Therefore, as an alternative measure, we produce results of the R&D activity with R&D stock as a dependent variable in Appendix 5. Among these Tables, we concentrate on the Column 5 and 6 of the Table 4 for discussion.

Firstly, the lambda value (coefficient of the mill's ratio) is negative and significant that shows negatively biased selection problem. It means that if we do not consider the selection problem the result would be negatively biased. The probit estimation of the selection equation (column 5 of table 4) shows that the variables like AGE, FOS, GID and PATPOL are positively and significantly influencing the R&D decision of firms. It implies that experienced firms and foreign firms are actively engaged in R&D activity. According to neo-classical theory, ownership per se is not expected to play any role in their R&D decision. Ray and Bhaduri find inter-industry differences of ownership effect on R&D [59]. Kumar and Aggarwal also shows that foreign affiliates tend to do little R&D in the host country because of their captive access to the laboratories of their parent company in the home [45]. However, contrary to these results we find stronger evidence that foreign firms R&D activity is highly significant. As we concentrate on high-tech and medium high-tech industries and as the IPR becomes stronger in India, foreign firms are able to make profit from their investment. The positive and significant effect of PATPOL further confirms the explanation. To examine the influence of liberalization policies we have introduced the variable TAR, however, though the influence of TAR is positive, it is insignificant. Therefore, patent policy seems to be one of the most influential variables in the R&D decision process. Kanwar also finds a positive influence of patent policy on innovative activity of Indian firms; however the study does not take in to account the effect of liberalized regime [44]. Further, the government incentives are highly significant showing that the government incentives in terms of tax rebate and tax holidays have a significant impact on the probability of conducting R&D by firms. It is important to note the experts' opinion here that not because of the innovative thrust but to avail the government sops firms are actively engaging in R&D

activities. Therefore, even if there is a vast investment in R&D hardly it comes out as output of investment.

The influence of CI, ADVI, TAR and MGR is positive but not significant. R&D decision by firms seems to be unaffected by market concentration though the sign of HHI is negative. The result is not surprising in the sense that Levin et.al and Basant and Mishra have already established that industry concentration has no effect on the innovation [49] and [9]. Further, Aghion et.al also show that it is only for new firms that the market competition is a matter of concern for innovation[3].All the remaining variables in case of R&D decision are insignificant.

OLS estimation results given in Column (6) of Table 4 shows that variable like CI and ADVI are positively and significantly influencing the R&D expenditure of firms. Once the firm decides to invest in R&D and it is capital intensive then that firm spends more on R&D. Our result corroborate with findings of Basant and Mishra where they find that industries with higher capital intensity invest more on innovation [9]. R&D stock model also confirms the influence of CI on R&D. However, in case of advertising, the study by Basant and Mishra finds a negative relationship where as in case of present study we find that advertising firms are investing more on innovation. This clarifies the product differentiation aspect where the monopolistic nature of the market necessitates firms to invest more on innovation. As every new invention gives a temporary monopoly power to firms and it is able to make profit from their investment.

The negatively significant coefficient of HHI shows that the absence of competitive pressure reduces the intensity of firms to undertake R&D because existing firms are free from competition threat. However, findings of Kumar and Saqib show that in the absence of competition, firms decision to invest in R&D is affected negatively with no impact on the intensity of R&D The result may vary in the sense that the study by Kumar and Saquib captures the aspect of R&D activity in early 1990s where the changes made in Indian economy after the liberalisation and TRIPs agreement are not fully covered [46].

The size of the firm (SIZE) negatively influences the R&D intensity. It implies that small firms are the major investors in R&D. In order to survive, such firms need a continuous flow of R&D effort, whereas for large firms because of their technological capability an adoption process need not be concentrated on continuous innovation for survival and market possession. We do not find any significant impact of AGE, FOS, PBTI, SPILL, FTM, EXPI and PATPOL. A few of these variables have significant impact on the earlier decision by the firm to invest or not.

5.2 Patenting as an innovation output

We use hurdle count data model that comprises of two parts to know the determinants of patenting activity of Indian firms. In the first part, we do regression with logit model (column1) which tells us about the probability of patenting while the second part (column 2) of zero truncated negative binomial model (ztnb) shows the determinants of patenting activity after taking care of the selection problem.

Table 3. R&D analysis through Tobit model

	(10)	(11)	(12)
AGE	0.067(3.1)*	0.058(2.71)*	0.070(3.27)*
FOS	0.029(1.69)***	0.028(1.63)	0.028(1.66)*
PBTI	-0.002(-0.26)	-0.002(-0.26)	-0.001(-0.19)
SIZE	-0.012(-1.39)	-0.012(-1.35)	-0.011(-1.27)
CI	-0.059(-1.56)	-0.058(-1.54)	-0.057(-1.53)
SPILL	0.036(1.05)	0.035(1.03)	0.036(1.05)
FTM	-0.003(-0.42)	-0.003(-0.42)	-0.004(-0.49)
HHI	0.016(0.67)	0.016(0.65)	0.010(0.45)
ADVI	-0.005(-0.59)	-0.005(-0.6)	-0.004(-0.46)
EXPI	-0.001(-0.13)	-0.001(-0.15)	-0.001(-0.13)
PATPOL	-0.244(-0.78)	-0.281(-0.89)	-0.005(-0.12)
TAR	-0.188(-0.92)	-0.191(-0.93)	-0.082(-0.79)
MGR	0.000(0.13)	0.000(0.28)	0.001(1)
Constant	0.013(0.07)	0.056(0.3)	-0.108(-3.46)
ID	Yes	No	Yes
TD	Yes	Yes	No
Log Likelihood	-7427.41	-7430.42	-7435.35
Observation	8310	8310	8310

Note: z statistics are in parenthesis. *,*** are 1% and 10% level significantly.

Although we are concentrating on the hurdle count data model to interpret our results, estimates of other regression (Poisson. Negative binomial, Zip and zinb) are also given in Table 5. As a robustness check, we perform an OLS regression where we use logarithm of patent intensity as a dependent variable, the result of which are given in Table 6.

While discussing the probability of going for a patent, AGE, FOS, FRD and MGR are significant among the firms registered in India (Column1 and 2 of Table5). As in case of R&D, experienced firm has a tendency to patent more as it has better knowledge about the patenting activity. Similarly, foreign firms also have a higher tendency to patent. The changes in Indian patent policy have created confidence among the foreign firms that are operating in India as these firms are taking the advantage of patent protection in India. Not only because of this, the results show that foreign firms are patenting aggressively in Indian market to capture either the growing market size and seeking benefit from rapidly growing Indian market. As growth rate in market (MGR) is one of the factors that influences significantly the patenting decision.

The R&D stock of foreign firm (FRD) also contributes to the probability of patenting. This implies that foreign component in any form (either foreign equity or their R&D stock) is significantly influencing patenting decision of a firm. As we expected, market concentration negatively affects the patenting behavior of firms. Since the industry that lacks the competition the incumbent firm does not have any threat on their profit margin and no motivation to patent.

Table4.Decision and determinants of R&D

	(1)	(2)	(3)	(4)	(5)	(6)
AGE	0.793	-0.016	0.812	-0.002	0.823	-0.003
	(15.89)*	(-0.33)	(16.05)*	(-0.03)	(16.17)*	(-0.07)
FOS	0.407	0.009	0.413	0.011	0.412	0.009
	(10.37)*	(0.29)	(10.51)*	(0.34)	(10.46)*	(0.29)
PBTI	-0.005	-0.009	0.001	-0.003	-0.006	-0.009
	(-0.31)	(-0.56)	(0.07)	(-0.2)	(-0.33)	(-0.56)
SIZE	-0.013	-0.085	-0.010	-0.078	-0.014	-0.087
	(-0.66)	(-4.81)*	(-0.5)	(-4.43)*	(-0.71)	(-4.87)*
CI	0.134	0.301	0.131	0.305	0.133	0.298
	(1.54)	(3.15)*	(1.51)	(3.2)*	(1.52)	(3.12)*
SPILL	-0.064	-0.087	-0.061	-0.092	-0.062	-0.085
	(-0.81)	(-1.02)	(-0.78)	(-1.08)	(-0.79)	(-0.99)
FTM	-0.007	0.007	-0.002	0.005	-0.008	0.007
	(-0.36)	(0.49)	(-0.11)	(0.34)	(-0.37)	(0.49)
HHI	-0.025	-0.084	-0.055	-0.094	-0.021	-0.084
	(-0.44)	(-1.7)***	(-1.06)	(-2.11)**	(-0.36)	(-1.71)***
ADVI	0.028	0.040	0.026	0.043	0.028	0.039
	(1.38)	(1.86)***	(1.28)	(2.0)***	(1.37)	(1.85)***
EXPI	-0.009	0.010	-0.005	0.012	-0.009	0.010
	(-0.59)	(0.69)	(-0.34)	(0.82)	(-0.57)	(0.69)
GID	1.894	---	1.815	---	1.884	---
	(34.99)*		(33.99)*		(34.73)*	
PATPOL	1.243	(-0.677	-0.381	-0.056	1.348	-0.634
	(1.75)***	-1.13)	(-4.24)*	(-0.73)	(1.9)***	(-1.06)
TAR	0.068	---	0.607	0.435	0.070	---
	(0.14)		(2.42)**	(2.11)**	(0.14)	
MGR	0.001	0.002	-0.001	0.001	0.001	0.000
	(0.66)	(0.11)	(-0.75)	(0.45)	(0.45)	(0.02)
LAMDA		-0.114		-0.103		-0.11)
		(-3.29)*		(-2.98)*		(-3.13)*
Constant	-2.315	0.258	-1.274	-0.037	-2.443	0.204
	(-5.58)*	(0.73)	(-17.4)*	(-0.42)	(-5.85)*	(0.57)
TD	Yes	Yes	No	No	Yes	Yes
ID	No	No	Yes	Yes	Yes	Yes
Log likelihood	-4585.48		-4614.21		-4580.63	
Observation	8310	4216	8310	4216	8310	4216
Model	*Selection*	*Outcome*	*Selection*	*Outcome*	*Selection*	*Outcome*
	Probit	OLS	Probit	OLS	Probit	OLS

Note: z statistics and t statistics are in parenthesis for selection and outcome equations.*.,**.,*** are 1%,5% and 10% level respectively.TD represents time dummies and ID represents industry dummy in the entire model.

In case of the intensity of patenting (column.2 of Table.5) we observe that PATPOL is a major variable that determines firms' patenting level. The result indicates that as property rights become stronger, the intensity of firm to patent also increases. In the present scenario, this result highlights the benefits from strengthening patent right in India. Column numbers 1-4 of Table (6) also show that patent policy is significant in all the models. The influence of patent policy upon the patent intensity is obtained after controlling for the liberalization aspect. Though the coefficient of TAR is positive, it is not significant in the present model. Therefore, the influence of patent policy on patent intensity is validated here.

The results also show that foreign owned firms do more patenting after the TRIPs. It could be inferred that under the strict regime of property protection, firms in India are able to make profit arising from the temporary monopoly assigned to them for their inventions. Therefore, foreign owned firms are showing interest in taking patent from Indian patent office. Further, the study reveals that after the TRIPs, strategy of foreign firms has changed considerably. Instead of directly purchasing technology from their parent company, firms are conducting R&D activity within the domestic territory of India. The positive and significant aspect of interaction variable FRD shows that, R&D stock of foreign firm has a positive influence on patenting in India. Therefore, our results corroborate with the findings of Kanwar where he shows that foreign control has a positive and significant relationship with innovation probability of manufacturing industry in India [44]. It shows that experienced firms are patenting more as the age (AGE) of the firm positively affects the patenting activity of firms. The negative influence of export intensity (EXPI) shows that exporting firms prefer to patent in the exporting market rather than going for an Indian patent.

The results also find that variables like PBTI, SIZE, ADVI, RDI and TAR show a positive sign but do not have any significant influence on the patenting activity of firms. However, SIZE, PBTI and TAR have a positive and significant influence in other models (column 3, 5 and 6). The model does not produce any evidence of spillovers to Indian sectors, however, the variable (SPILL) shows a negative sign. The results indicate that instead of transferring knowledge to Indian market, foreign firms acquire knowledge from domestic through their interaction. Market concentration and market growth rate turn out to be insignificant in intensity of patenting but was significant in the earlier decision stage. This could be also because once a firm decides to patent these variables are not contributing factors to the number of patent they are seeking.

6. FINDINGS AND CONCLUSION

The study brings research inputs in terms of R&D expenditure and research outputs in terms of patent granted together to analyze a KPF for high-tech and medium high-tech sectors in India. Due to peculiarities of the data we applied Heckit Method in R&D equation to solve the problem of selection bias and Hurdle model in patenting equation to take care of the problem arising from large number of zeros as well as selection. The main objective of the study is to understand the relationship between the research input and research output in terms of R&D and patenting particularly in the context of improved patent protection in the country.

Table 5.Patenting Models

	1	2	3	4	5	6
AGE	1.171	0.931	-1.600	0.078	1.130	1.825
	(6.56)*	(2.89)**	(-6.22)*	(0.3)	(12.89)*	(7.84)*
FOS	1.140	0.780	0.749	0.482	0.322	1.277
	(10.29)*	(3.32)*	(8.09)*	(3.09)*	(7.9)*	(5.96)*
PBTI	0.041	0.197	0.147	0.080	0.126	0.198
	(0.72)	(1.09)	(5.01)*	(1.25)	(4.06)*	(1.75)***
SIZE	0.041	0.168	0.093	0.092	-0.260	0.175
	(0.56)	(0.35)	(1.72)***	(1.05)	(-3.66)*	(0.94)
CI	0.315		0.458	0.272	0.347	1.957
	(1.1)		(2.67)*	(0.74)	(2.14)**	(2.08)**
SPILL	-0.261		-0.386	-0.226	-0.584	-2.118
	(-1.02)		(-2.55)**	(-0.66)	(-4.02)*	(-2.31)**
HHI	-0.541	0.407	-0.467	-0.679*	-0.021	-0.528
	(-3.23)*	(1.11)	(-8.14)*	(-4.42)	(-0.34)	(-1.85)
ADVI	0.011	0.080	0.108	-0.034	0.210	0.053
	(0.15)	(0.33)	(3.15)*	(-0.48)	(6.15)*	(0.38)
EXPI	0.078	-0.320	-0.201	0.052	-0.285	0.004
	(1.43)	(-2.2)**	(-7.97)*	(0.81)	(-14.08)*	(0.04)
RDI	0.046	0.132	0.106	0.093	-0.008	0.112
	(0.61)	(0.82)	(3.43)*	(1.28)	(-0.29)	(0.91)
FRD	0.466	0.436	-0.038	-0.014	0.257	0.978
	(7.72)*	(2.88)**	(-0.84)	(-0.2)	(15.32)*	(7.57)*
PATPOL	-0.167	1.507	2.422	0.819	0.901	-0.663
	(-0.57)	(2.05)**	(16.1)*	(2.87)**	(7.46)*	(-1.05)
TAR	1.234	1.784	2.095	1.284	1.734	3.273
	(1.58)	(1.02)	(8.33)*	(1.88)	(6.59)*	(2.72)**
MGR	0.025	0.017	0.036	0.031	0.011	0.058
	(4.67)*	(1.19)	(17.48)*	(5.85)*	(5.25)*	(6.32)*
Constant	-5.461	-15.563	-0.072	-1.938	-0.338	-4.947
	(-19.04)*	(-0.01)	(-0.15)	(-4.82)*	(-2.31)**	(-12.03)*
Inflate						
PATPOL					-0.201	-78.874
					(-0.740)	(0.00)
Constant					2.887	6.187
					(23.32)*	(0.00)
ID	Yes	Yes	Yes	Yes	Yes	Yes
observation	8310	456	8310	8310	8310	8310
Model	Logit	Ztnb	Poisson	Negbin	Zip	Zinb

Z statistics are in parenthesis.*,**,*** are 1%,5% and 10% significant level respectively

Table 6. Regression with patenting intensity

	1	*2*	*3*	*4*
AGE	0.192	0.185	0.131	0.131
	(4.64)*	(3.06)*	(7.88)*	(4.72)*
FOS	0.120	0.027	0.254	0.254
	(4.1)*	(0.79)	(8.43)*	(5.46)*
PBTI	0.001	-0.004	0.027	0.027
	(0.12)	(-0.65)	(4.95)*	(3.23)*
SIZE	0.009	-0.005	0.022	0.022
	(1.53)	(-0.78)	(7.49)*	(4.2)*
CI	-0.119	-0.120	-0.123	-0.123
	(-3.14)*	(-3.11)*	(-2.5)**	(-2.09)**
SPILL	0.128	0.142	0.091	0.091
	(3.55)*	(3.91)*	(1.82)***	(1.51)
HHI	-0.040	-0.033	-0.079	-0.079
	(-2.9)**	(-2.14)**	(-8.12)*	(-4.95)*
ADVI	0.002	-0.003	0.007	0.007
	(0.26)	(-0.41)	(1.43)	(1.67)***
EXPI	-0.003	0.000	-0.007	-0.007
	(-0.56)	(-0.02)	(-1.86)***	(-2.)**
RDI (Lag)	-0.006	-0.004	-0.003	-0.003
	(-0.78)	(-0.52)	(-0.39)	(-0.35)
FRD	0.015	0.000	0.053	0.053
	(1.44)	(-0.02)	(5.58)*	(3.98)*
RDS	-0.013	-0.022	-0.005	-0.005
	(-2.43)**	(-3.53)*	(-1.85)	(-1.56)
PATPOL	0.262	0.280	0.272	0.272
	(5.59)*	(5.64)*	(4.75)*	(3.57)*
TAR	0.515	0.495	0.551	0.551
	(12.35)*	(11.63)*	(10.73)*	(7.8)*
MGR	-0.001	-0.001	-0.002	-0.002
	(-1.31)	(-0.95)	(-2.73)**	(-1.79)***
Constant	-1.246	-1.105	-1.319	-1.319
	(-10.65)*	(-8.08)*	(-12.66)*	(-8.04)*
ID	YES	YES	YES	YES
BP test	8958.07			
hetroscedastic	1.80E+07			
serial corr	20.675			
cr sec corr	807.294			
observation	8864			
Model	Random effect	Fixed effect	PCSE (Het)	PCSE

Z statistics are in parenthesis.*,**,*** are 1%,5% and 10% significant level respectively

The study finds that patent policy influences significantly and positively the R&D and patenting activity of the high-tech and medium-high-tech sectors. On an average, patenting decision is not influenced by the in house-R&D of the firms. It is evident that patent policy changes are benefiting the foreign firms that have increased their R&D and patenting activity. The study suggests that firms with enough experience do more innovative activities. In the new era after liberalization and TRIPs agreement, foreign firms are relocating their R&D units into the developing countries instead of accessing technology from their parent company. Not only this, firms with foreign ownership patent significantly at the Indian patent office.

The absence of competitive pressures reduces the inclination of firms to do more research and to protect their invention from imitation through patenting. The large sized firms in the Indian context do not show much interest in innovative activities. The government incentives in case of R&D and growth rate of market in case of patenting plays a dominant role in deciding the innovative activity. The study does not find any evidence of profitability and spillover effect on the innovation. Moreover, the coefficient of spillover in most of the cases is negative.

The real nature of Indian innovation is also in question-as the Government's. Incentives for research seem to be significant whereas the R&D expenditure for patenting find to be insignificant. This can be interpreted as for benefiting from the Government sops firms are registered with DSIR. This R&D expenditure does not come out as an R&D output in the form of patenting. However, the motto of foreign firms seems to quite different where their R&D is significantly influencing the patenting activity. Thus after adapting to the Indian requirement foreign firms are taking patents.

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APPENDIX

Appendix 1. List of industries

Category	Industry	Acronym
High tech	Aircraft and spacecraft	AIR
	Pharmaceuticals	PHA
	Office, accounting and computing machinery	OAC
	Radio, TV and communications equipment	RTC
	Medical, precision and optical instruments	MPO
Medium High-tech	Electrical machinery and apparatus, n.e.c.	EL
	Motor vehicles, trailers and semi-trailers	MOTOR
	Chemicals excluding pharmaceuticals	CHE
	Railroad equipment and transport equipment, n.e.c.	RTE
	Machinery and equipment, n.e.c.	ME

Appendix 2. Hausman-Taylor Endogenity test

Variable	OLS	Htaylor	Variable	OLS	Htaylor
AGE	-0.022(-0.87)	-0.022(-0.86)	*PATPOL*	0.015(0.34)	0.016(0.35)
FOS	0.000(-0.01)	0.000(-0.02)	*TAR*	0.216(1.74)	0.217(1.75)
PBTI	***-0.010(-1.15)***		*MGR*	0.000(-0.49)	0.000(-0.51)
SIZE	***-0.049(-4.89)***		*LARGED*	-0.013(-0.79)	
CI	0.109(2.47)	0.109(2.46)	*Constant*	0.024(0.68)	0.024(.66)
SPILL	-0.037(-0.91)	-0.036(-0.91)	***TV. Endogenous***		
FTM	0.006(0.6)	0.006(0.6)	*PBTI*		***-0.010(-1.18)***
HHI	-0.043(-1.66)	-0.043(-1.66)	*SIZE*		***-0.047(-4.62)***
ADVI	0.006(0.57)	0.006(0.58)	***TI. Exogenous***		
EXPI	0.004(0.54)	0.004(0.53)	*LARGED*		-0.013(-0.8)
GID	-0.042(-2.07)	-0.042(-2.07)			
Observation	8310	8310	*Observation*	8310	8310

Note: TV means Time variant and TI means Time invariant

Appendix 3. Summary statistics of variables

	Granted Pat	AGE	PBTI	SIZE	CR4	HHI	FRD	MGR
Observation	8864	8864	8864	8864	8864	8864	8864	8864
Mean	0.44	29.90	6.85	3209.06	28.74	0.06	2559.85	13.02
Std. Dev.	4.41	20.53	10.54	11865.58	11.38	0.07	3306.85	9.91
Variance	19.42	421.28	111.16	1.41E+08	129.52	0.01	1.09E+07	98.24
Skewness	25.36	1.24	-0.64	11.15	2.43	6.01	2.68	-0.15
Kurtosis	1005.68	4.46	16.87	169.05	9.75	53.35	9.18	3.56
Minimum	0.00	1.00	-94.02	0.00	17.79	0.02	0.30	-35.08
Maximum	232.00	113.00	92.31	272486.70	89.63	0.82	14501.90	42.82
	RDS	RDI	ADVI	EXPI	CI	FLP	DLP	
Observation	8864	8864	8864	8864	8864	8864	8864	
Mean	1.29	0.46	0.65	12.96	42.26	0.29	0.18	
Std. Dev.	7.78	1.55	1.96	20.14	81.27	1.98	0.62	
Variance	60.56	2.42	3.86	405.79	6605.61	3.91	0.38	
Skewness	18.31	11.20	5.72	2.18	23.97	20.92	5.60	
Kurtosis	485.53	191.72	46.25	7.45	870.41	513.76	45.97	
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Maximum	277.50	40.5	33.33	100.00	3933.33	65.39	10.87	

Appendix 4.Correlation Matrix

	AGE	FOS	PBTI	SIZE	CI	SPILL	FTM	HHI	ADVI	EXPI	GI	PATPOL
AGE	1											
FOS	0.143	1										
PBTI	0.027	0.010	1									
SIZE	-0.070	0.011	0.063	1								
CI	0.010	-0.010	-0.065	0.097	1							
SPILL	0.007	-0.011	-0.064	0.086	0.918	1						
FTM	0.010	0.017	0.008	-0.006	0.005	-0.026	1					
HHI	0.025	0.016	0.028	-0.022	-0.008	-0.008	0.006	1				
ADVI	0.021	0.014	-0.006	-0.038	0.034	0.024	0.002	0.014	1			
EXPI	-0.018	-0.021	-0.007	0.055	0.054	0.049	-0.010	-0.006	0.002	1		
GI	0.184	-0.030	0.007	-0.008	0.016	0.016	0.001	0.014	0.000	0.002	1	
PATPOL	0.284	-0.008	0.047	-0.044	-0.057	-0.060	0.009	0.051	0.004	-0.010	0.182	1

Appendix 5. Determinants of R&D (R&D stock as a depended variable)@

	(1)	(2)	(3)
AGE	0.034(0.73)	0.038(0.8)	0.035(0.75)
FOS	0.030(0.97)	0.032(1.04)	0.032(1.03)
PBTI	-0.008(-0.54)	-0.009(-0.59)	-0.009(-0.59)
SIZE	-0.027(-1.58)	-0.031(-1.81)	-0.031(-1.81)
CI	-0.216(-2.34)**	-0.222(-2.4)**	-0.222(-2.4)**
SPILL	0.117(1.41)	0.122(1.47)	0.122(1.47)
FTM	-0.007(-0.47)	-0.005(-0.38)	-0.005(-0.38)
HHI	0.005(0.12)	0.019(0.39)	0.019(0.39)
ADVI	-0.010(-0.47)	-0.011(-0.53)	-0.011(-0.53)
EXPI	-0.003(-0.2)	-0.005(-0.34)	-0.005(-0.35)
PATPOL	0.064(0.86)	-0.450(-0.77)	-0.458(-0.79)
TAR	-0.075(-0.38)	------	------
MGR	0.001(0.68)	0.000(0.01)	0.000(0.02)
LAMDA	-0.144(-4.27)*	-0.136(-4)*	-0.136(-3.99)*
Constant	0.029(0.34)	0.264(0.76)	0.273(0.79)
ID	Yes	No	Yes
TD	No	Yes	Yes
Model	OLS	OLS	OLS

Note: t values are in parenthesis: *, **, *** are 1%, 5% and 10% level significant respectively.@ only producing results of OLS regression because the probit section is same as in table (3)