R&D, PATENTING AND PERFORMANCE OF INDIAN FIRMS IN MEDIUM AND HIGH TECHNOLOGY INDUSTRIES

Ph.D. Thesis

By

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DISCIPLINE OF ECONOMICS

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R&D, PATENTING AND PERFORMANCE OF INDIAN FIRMS IN MEDIUM AND HIGH TECHNOLOGY INDUSTRIES

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To

My Beloved

Uncle & Grand Mother

SYNOPSIS

R&D, Patenting and Performance of Indian Firms in Medium and High Technology Industries.

1. Introduction

The production of innovation and the link with firms' productivity is theoretically and empirically well established in advanced nations (Crepon et al. 1998; Mairesse et al. 2005; Hall and Sena 2014). The link between innovation and productivity is however inconclusive in developing nations. Data analysis of innovative activity of Indian firms during 1995-2010 using R&D expenditure and patents reveals interesting fact. R&D expenditure in India is low and stagnant (0.7-0.8% of GDP) whereas Indian Patent Office witnesses a remarkable progress in patent filing (on an average of 15% increase) during the same period. Further, the government of India made radical changes in Intellectual Property Rights (IPR) including patent policy, which is likely to boost both domestic innovation and transfer of technology to the nation. These observations, changes along with scant research on innovation in Indian context provide us the motivation to undertake the current research. The underlying questions are a) what are the determinants of the technological base of firm, measured in terms of R&D and patenting, b) what contributes to patenting? - contemporaneous or lagged R&D expenditure and c) how far the technology base of a firm can influence it's performance in terms of productivity, market value and profit. Based on the above research questions, we frame the objectives of the thesis as follows:

1) To understand the determinants of firms' innovative activities.
2) To understand the relationship between the research input and research output in terms of R&D and patenting particularly in the context of the new patent policy in the country.
3) To estimate the impact of R&D and patenting on firms' productivity and financial performance indicators.

The present doctoral work therefore assesses the determinants of innovative activities and the influence of these innovations on the performance of medium and high technology firms in India. The present study argues that under the new patent regime firms in India has lifted up their technological base, which is measured through its investment in R&D and ensuing patenting activity, which further contributes to the performance of firms.

Innovation is difficult to measure because of the broad nature and scope of such activities. The distinction of innovation into product and process is a solution. The introduction of new product or the significant improvement in the existing product is known as product innovation whereas introduction of new process for making a product is known as process innovation. Also, there are some conceptual and methodological issues while measuring innovation in terms of its novelty. Should a product or process be new to the firm, new to the domestic market or new to the World market? In the beginning, OECD countries treated investment in R&D as an input and patent counts as output of the innovation. OECD Oslo manual (1992) elaborates the concept of innovation that covers goals of the firm, criteria for identifying innovative firm, cost of innovation and the impact of the innovation. Based on the Oslo manual guideline, several countries started innovation surveys commonly known as the Community Innovation Survey (CIS). In India, the Department of Science and Technology (DST) has made an initiative to survey Indian firms through National Innovation Survey (NIS) since 2004 and aggregative results are published in various reports. The firm level data is however not available for the researchers to conduct in-depth studies. Thus the measurement of innovation in the context of India is very difficult. A separation of innovative activities into innovation inputs and outputs partially solves the difficulties (Rogers 1998). Therefore, in the current study we use investment in R&D expenditure and ensuing patent activity as the measures of innovative activities.

2. Review of Literature and Conceptual Framework

The present doctoral work builds on the framework of the knowledge production function (KPF) where patents are the output with R&D expenditure as the input (Pakes and Griliches 1984). Several factors influence firm’s investment in R&D expenditure and the ensuing patenting activity (Cohen and Levin 1989). Investment in R&D expenditure leads to the net addition of economically valuable knowledge, though unobservable can be captured through patents (Griliches 1990). These activities further contribute to the performance of a firm estimated through measures including productivity, profitability and market value (Crepon et al.1998; Griliches 1990; Halpern and Murakozy 2012). The present doctoral work focuses on different aspects of the innovative activities of medium and high-technology firms in India. As the initial data exploration reveals that Indian high-tech firms contribute on an average, 84% of total manufacturing R&D and 39% of the total patent granted during the period of 2006-2010.

The thesis includes a general introduction, three core chapters and a conclusion. The three core chapters model the innovative activities, their determinants and their impact on the performance of firms in three different research settings. First chapter analyses the determinants of R&D and patenting of firms after taking into account the industry and firm specific characteristics. Second chapter focuses on the association between R&D and patenting by incorporating the lagged influence of R&D on patenting. The third chapter estimates the impact of patenting on the performance of firms measured through three different indicators productivity, profitability and Tobin's *q*.

3. Data Sources and Variable Description

Data for the study is from the manufacturing firms in India, particularly from medium and high technology firms. The study follows The Organization of Economic Co-operation and Development (OECD) definition to identify high technology industries. The organization follows two methods to construct indicators, namely i) R&D expenditures divided by value added; and ii) R&D expenditures divided by production and the study follows second definition. The method divides the manufacturing industries into high technology, medium-high-technology, medium-low-technology and low technology sectors based on their R&D intensities. We chose high and medium technology firms as our study area because these sectors are growing rapidly, highly competitive in research and production, highly involved in significant foreign co-operations and can have multiplier impact on other sectors as well. The sectors are codified on the basis of National Industrial Classification (NIC) 2008 and International Standard Industrial Classification (ISIC) 2003. Initially, we made a concordance between ISIC and NIC. Industry and product classification in India says that NIC 2004 is based on ISIC Rev 3. Follows this information, we made a concordance between ISIC Rev 3 and NIC 2008 through

NIC 2004. Pharmaceuticals, office accounting and computing machinery, radio, TV and communication equipment, medical and optical instruments are the high tech industries. The medium- high technology sectors include industries from electrical, motor vehicles, chemicals, transport equipment and machinery equipment.

The main sources of data are the website of Controller General of Patent Design and Trade mark (CGPDT) and Centre for Monitoring Indian Economy (CMIE) Prowess for patent and firm specific variables respectively. 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. We consider patent from IPO only to test how firms in India are appropriating the new patent policy by applying for patent at IPO. R&D expenditure of the firms is also collected from DSIR that fills the missing numbers in the CMIE prowess database as well as performs a cross-check. The present study consists of exclusively those patents that were assigned in the firm’s own name. The study considers only those firms which are active and producing consistent sales data during 1995-2010. 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 which comes around 16% of total medium and high tech firms. All the variable series are adjusted for inflation using the index of industrial production and wholesale price index of respective industries based on 1993-94 prices.

4. Econometric Strategies

The particular nature of data demands special attention to the modeling in the study. In chapter 2, the study estimates the determinants of R&D and patenting. The model is estimated through recursive simultaneous equation because the dependent variable of R&D intensity in the R&D equation comes as an independent variable in patenting equation. 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 and failure to account for this sample selection problem leads to inconsistent estimation of parameters. Therefore, the determinants of R&D are estimated through Heckman’s two-step procedure, which consist of a selection equation and a primary equation. (Sasidharan and Kathuria 2011). Selection equation and primary equations are estimated through probit and Ordinary Least Square (OLS) methods respectively.

In Chapter 3 the study examines how the different lag structures of R&D expenditure affect the patenting activity of firms. Considering discrete non-negative nature of patent count data the study uses Poisson, negative binomial (NEGBIN), zero inflated Poisson model (ZIP), zero inflated negative binomial (ZINB), hurdle count data model (ZTP), quasi differencing (QD) and linear feedback model (LFM) for the analysis. The Zip model, a modification of the Poisson regression model, allows for excess zero counts in the data and permits the mechanism generating the zero observations to differ from the one for positive observations. The Hurdle model relaxes the assumption that the zeroes and the positives comes from the same data generating process. The two parts of the Hurdle model are functionally independent and the maximum likelihood estimation can be achieved through two separate estimations; one corresponding to the zeroes and the second to the positives. QD and LFM models take care of endogenity in the model.

Chapter 4 examines the impact of R&D and patenting on the performance of firms. Total Factor Productivity (TFP), profitability and Tobin's *q* are the performance indicators. To estimate the TFP of medium and high technology firms the present study considers production function approach. Production function is carried out by Levinsohn and Petrin (LP) method, which is a semi parametric method. The TFP estimation is based on an augmented Cobb-Douglas production function. The estimation includes material input as an additional explanatory variable apart from the basic labour and capital in the function. To evaluate the impact of R&D and patenting on the productivity and other performance indicators, we rely on FE method and Feasible Generalized Least Square (FGLS) estimation.

5. Results

Results of R&D and patenting determinants are given in Table 1. The negative and significant lambda value (coefficient of the mill's ratio) shows negatively biased selection problem. It implies that if we do not consider the selection problem the result would be negatively biased. Among the determinants of R&D, the probit result shows that patent policy (PATPOL), foreign ownership (FOS), experience of firm (AGE) and government incentive (GID) increase the probability of conducting R&D. Once the firm decides to invest in R&D, firms that are active in advertising (ADVI) and highly capital intensive (CI) spend more on R&D to differentiate its products from others. The negatively significant coefficient of firms concentration (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. The negative influence of firm size (SIZE) implies that small firms are the major investors in R&D. In order to survive, such firms need a continuous flow of R&D efforts.

Similar to the R&D firms, FOS and AGE enhances the probability of going for a patent. R&D by foreign firms (FRD) and market growth rate (MGR) also increase patenting by firms. The negative and significant coefficient of HHI indicates that due to the lack of competition, incumbent firms' incentive to patent would be less as they do not have any threat on their profit margin. In the level of patenting, the study observes that PATPOL is a major variable that determines firms' patenting level. The results also show that foreign owned and experienced firms do more patenting after the patent policy changes made in India.

In chapter 3, the study examines how different lag structures of R&D expenditure affect the patenting activity of firms of medium and high technology industries. The results are given in Table 2. Our results produce an evidence of the impact of present and lagged R&D on patent applications. However, the results may vary according to the econometric specification and the type of industry. The highly significant influence of changes in patent policy implies that the stronger protection for invention gives confidence to the innovators to go for patent as an option to protect their invention. The result further shows that previous patent experience (PEXP) and foreign ownership do have a favorable impact on patenting. The positive and significant coefficient of foreign firms R&D (FRD) indicates that foreign firms widely utilize patent protection in India for their invention. Results of the control variables are as per the expectation and corroborate previous results.

Table 1 Determinants of R&D and patenting.

	Determinants of R&D		Determinants of Patenting	
	1	2	3	4
AGE	0.823(16.17)*	-0.003(-0.07)	1.171(6.56)*	0.931(2.89)**
FOS	0.412(10.46)*	0.009(0.29)	1.140(10.29)*	0.780(3.32)*
PBTI	-0.006(-0.33)	-0.009(-0.56)	0.041(0.72)	0.197(1.09)
SIZE	-0.014(-0.71)	-0.087(-4.87)*	0.041(0.56)	0.168(0.35)
CI	0.133(1.52)	0.298(3.12)*	0.315(1.1)	---b
SPILL	-0.062(-0.79)	-0.085(-0.99)	-0.261(-1.02)	---c
HHI	-0.021(-0.36)	-0.084(-1.71)***	-0.541(-3.23)*	0.407(1.11)
ADVI	0.028(1.37)	0.039(1.85)***	0.011(0.15)	0.080(0.33)
EXPI	-0.009(-0.57)	0.010(0.69)	0.078(1.43)	-0.320(-2.2)**
PATPOL	1.348(1.9)***	-0.634(-1.06)	-0.167(-0.57)	1.507(2.05)**
TAR	0.070(0.14)	---a	1.234(1.58)	1.784(1.02)
MGR	0.001(0.45)	0.000(0.02)	0.025(4.67)*	0.017(1.19)
FTM	-0.008(-0.37)	0.007(0.49)	-----f	-----f
GID	1.884(34.73)*	-----a	-----f	-----f
RDI	-----d	-----e	0.046(0.61)	0.132(0.82)
FRD	-----d	-----e	0.466(7.72)*	0.436(2.88)**
LAMDA		-0.11 (-3.13)*		
Constant	-2.443(-5.85)*	0.204(0.57)	-5.461(-19.04)*	-15.563(-0.01)
TD	Yes	Yes	No	No
ID	Yes	Yes	Yes	Yes
Log likelihood	-4580.63			
Observation	8310	4216	8310	456
Model	Selection(Probit)	Outcome(OLS)	Logit	Ztnb

Note: For OLS t statistics and for rest of the models z statistics are in parenthesis s.*, **, *** are 1%, 5% and 10% level of significance respectively. TD represents time dummies and ID represents industry dummy. 'a' omitted to perform OLS regression. 'b' and 'c' omitted because of collinearity, d is not required in the present model, 'e' is not applicable as the regressand is R&D itself and 'f' is not used as it is not relevant in the model.

Chapter 4 of the thesis estimates the impact of patenting on the performance of firms using productivity, profitability and Tobin's *q* ratio as the performance indicators. The main results of the chapter are given in Table 3. Since the patent data may include process and product innovation, the choice of the different measures of performance is justified. In all the models, the study finds that stock of firms' patents has a positive and significant influence on their economic performance. The result thus clarifies that the importance of patent in firm's innovative activities is reflected through its ability to make profit from the invention. Further, the positive

Table 2 Patent, R&D and Policy

	Poisson (1)	NEGBIN(2)	QD(3)	LFM(4)
$PAT_{(t-1)}$	--	--	--	0.094(2.58)**
RDI	0.137(2.87)**	0.215(1.74)***	0.004(2)	1.07(2.33)**
RDI1	0.133(2.42)**	0.108(0.76)	0.0001(-0.31)	---
RDI2	-0.095(-1.87)***	-0.018(-0.13)	-0.002(-1.04)	---
RDI3	-0.411(-8.57)*	0.062(0.46)	-0.002(-1.14)	---
RDI4	-0.329(-6.97)*	-0.111(-0.86)	-0.001(-0.5)	---
RDI5	0.116(2.87)**	0.126(1.14)	0.002(1.17)	---
FOS	0.815(11.84)*	0.294(2.28)**	0.0001(0.07)	-5.7(-0.02)
AGE	2.250(11.89)*	0.628(3.18)*	0.001(0.2)	0.675(1.44)
TECH	-0.509(-8.39)*	-0.378(-2.12)**	0.005(1.4)	1.22(3.09)*
PBTI	-0.235(-7.75)*	-0.111(-1.18)	-0.003(-1.02)	---
HHI	-0.355(-11.63)*	-0.364(-4.45)*	-0.002(-0.94)	-0.43(-2.26)
PATPOL	5.919(48.21)*	5.089(19.81)*	0.002(0.47)	-1.02(-0.48)
ADVI	0.123(2.44)**	-0.021(-0.17)	0.003(1.37)	---
SIZE	0.0001(8.98)*	0.0001(0.76)	0.0001(0.4)	0.01(0.05)
PATEXP	1.134(16.42)*	1.932(12.51)*	0.015(4.86)*	---
ID	YES	YES	NO	NO
Con	-8.114(-23.14)*	-4.765(-11.62)*	0.823()	-3.96(-3.5)*
Observations	8310	8310	855	8310

Note: *, **, *** are 1%, 5% and 10% level of significance.

influence on Tobin's q (which measures the expectation of future profit) implies that, stock market gives high priority for the firms with large patent portfolio. Thus, we identify that both contemporaneous profit as well as expectation of future profit has been influenced by the innovative activity of a firm. The study however does not produce any evidence of R&D influence on productivity of firms whereas the variable has a significant influence on other performance indicators. The positive and significant influence of purchased technology on productivity underscores the importance of external technology for productivity improvement. The thesis finds that foreign ownership has made a positive impact on productivity, current profit as well as future profit. Firm size (SIZE) is positively and significantly associated with the performance of firms. This result indicates that large firms are more likely to enjoy economies of scale to make profit from their innovation. The effect of industry concentration (HHI) is positive and significant for productivity and Tobin's q, the coefficient is however negative in case of profitability but insignificant.

Table 3 Impact of R&D and Patenting on the Performance of Firms

	I	II	III
	TFP(LP)	PBTI(log)	Tobin's *q*(log)
PAT	0.035 (2.03)**	0.022(4.81)*	0.14(2.34)**
RDS	0.003(-0.51)	0.003(2.75)**	0.044(2.09)**
FOS	0.022(7.47)*	0.015(18.55)*	0.248(27.23)*
HHI	0.081(19.16)*	-0.001(-0.85)	0.062(4.29)*
LIC	0.004(2.07)**	-----a	-----a
SIZE	-----a	0.006(6.92)*	0.031(2.2)**
MGR	-----a	-0.001(-0.4)	-----a
EXPI	-----a	-0.001(-0.95)	-----a
ADVI	-----a	-----a	0.006(-0.39)
YEAR TREND	YES*	YES*	YES*
Industry dummy	YES*	YES*	YES*
Constant	-26.54(-31.85)*	-0.474(-2.47)**	-19.992(-6.85)*
Observations	4890	4890	4890
Model	FGLS	FGLS	FGLS

Note: *, **, *** represent 1%, 5% and 10% level of significance respectively. 'a' indicates not relevant.

Table 4 Summary of the Major Findings

Relation	Result	Remarks
Relationship between R&D and Patenting	Positive, not significant	When there is no lag effect
	Contemporaneous and lagged effect	Tendency towards 'U' shaped relationship. Tilde shape is for domestic firms.
Impact of patenting on productivity and profitability	Positive and significant	Product and process innovation
Impact of R&D on productivity	Positive, not significant	Only product innovation
Impact of R&D on profitability	Positive and significant	
Impact of R&D and patenting on Tobin's *q*	Positive and significant	Both R&D and patenting have greater implication in the stock market

6. Synthesis of the Main Findings

The study includes synthesis of all the empirical findings to draw policy implications. A common trend found among all the models is that the foreign firms are investing in R&D more, patenting extensively and are able to perform better. Though older firms are significant while deciding to invest in R&D and patenting, small firms are undertaking more R&D. Firms are deciding to go for patent in the concentrated market, however as far as the number of patents are concerned, the coefficient become positive but insignificant. There is a possibility that firms are likely to use patenting as a strategic tool.

The evidence of contemporaneous relationship between R&D and patenting signifies that more recent R&D produces more output in terms of patenting. Since foreign firms in India (that are more active in R&D) may have the access to the technological developments from their parent organizations situated abroad the current R&D is merely to adapt those developments to Indian conditions.

The nature of investment in R&D by firms in India is related to the product innovation as the relationship is significant for profitability and insignificant for productivity. The patenting habits of firm however, can be considered as both process and product innovation because the relationship is positive and significant for productivity and profitability. Findings of the thesis further clarify that both R&D and patenting by firms have greater implication while assessing the firms in the stock market. To be more specific, firms with large portfolio of patents are more likely to draw investors.

7. Policy implications and conclusion

The major conclusion from the study is that patent policy influences positively and significantly the innovative activities of firms. Further, foreign owned firms, small firms and experienced firms are highly active in conducting R&D and applying for patent at the Indian Patent Office (IPO). Patenting by firms significantly influence their productivity and performance. In the present age, the importance of innovation as the engine of growth has increased steadily. There is a need for special attention to the utilization of innovation policies at different levels with a special emphasis on the roles of the firm. Government needs to decide on providing more incentives for the innovation activity of the domestic firm. And thus, providing tax incentive for patenting firm could be the policy suggestion.However, such incentives should be limited to smaller domestic firms in competitive industries to control for any tendency to abuse patents. Further, the Indian authority has to watch out the foreign companies which may use Indian market to establish their monopoly gained through patenting. Again, special incentives need to be decided for the domestic firms that are facing high competition from foreign firms. Particularly, as we do not find any significant spillover effect of foreign companies in patenting, the need for such incentive is more prominent. Correct measurement of innovation and evaluating its impact on the economic activities of firms are likely to result in the efficient allocation of resources. In that way, the study helps investors, managers, R&D personals of business firms and policy makers.

8. Contribution of the study

The study uses granted patent of medium high technology firms, which is first in Indian context for a large number of firms. Earlier studies have focused on either pharmaceutical or semi conductor industry with patent application as an innovation indicator. The present study extends the earlier studies by incorporating medium and high technology sectors, and incorporates recent patent policy changes made in India. The study links performance of firms with innovation, and innovation by its determinants like R&D. The comprehensive study combines the data from CMIE and CGPDT.

9. Limitations of the study

All the issue associated with patent data as a measure of innovative activity is a limitation of the study as well. The difficulty involved in gathering patent information is one of the main concerns of the study. Though we attempted to verify the patent count for each firm, the margin for error remains because the Indian patent office is in the process of updating data. Several studies have concluded that there are differences in patenting activity among the sectors. However, the paucity of data reduces our scope to perform such a task. Since, we have included only firms which are producing consistent sales data so it reduces our data point from 59376 to 8864 which comes around 16% of total firms.

LIST OF PUBLICATIONS

1. Ambrammal Sunil K., Ruchi Sharma (2015), Impact of Patenting on Firm's Performance: An Empirical Investigation based on Manufacturing Firms in India. *Economics of Innovation and New Technology*, Published Online. doi=10.1080/10438599.2015.1043767.

2. Ambrammal Sunil K., Ruchi Sharma (2015). Patenting and Technical Efficiency of Manufacturing Firm in India: Evidence from Medium and High Technology Firms. *The Journal of Industrial Statistics*, [Accepted for Publication].

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4. Ambrammal Sunil K., Ruchi Sharma (2014), Innovations by Firms in High and Medium-High Technology Industries: An Indian Experience. *Journal of Chinese Economics and Business Studies: Special issue on Harnessing Internal and External Resources for Innovation in Emerging Economies* 12(2): 181-207. http://dx.doi.org/10.1080/14765284.2014.900957.

CONFERENCE PRESENTATIONS

1. "Impact of Patenting on the Performance of Firms: An Empirical Investigation," in 51st Annual conference conducted by The Indian Econometric Society during December 12-14, 2014 held at Panjabi University, Patiala.

2. 'Does Patenting Influence Firms Efficiency and Productivity?: Evidence from Indian High and Medium Tech Firms' 9th Annual conference of Forum for Global Knowledge Sharing (FGKS) held at National Institute of Advanced Studies, Bangalore, October 27-29,2014.

3. 'In-house R&D, Technology Import and Policy Environment: What does it Matters for Patenting?' 2nd International conference of Management of Intellectual Property System, 2013 held at Indian Institute of Technology, Bombay, January 30-February 02, 2014.

4. 'Innovation by Firms in High and Medium-High technology industries: An Indian experience'. 6th annual conference of the Academy of Innovation and entrepreneurship (AIE 2013) being held at Oxford, United Kingdom, 29-30 August,2013.

5. 'A firm level R&D Analysis of Indian High-Tech Manufacturing: An Empirical Investigation through Heckman's Two-step Method Using Stata' at the STATA user's conference in Mumbai (Hotel Meluha Fern) organized by SYSTECH on 01-August 2013.

6. 'Foreign Licensing by Indian Industry: The Role of Patent Policy' in 49th Annual conference conducted by The Indian Econometric Society during January 9-11, 2013 held at Patna University, Patna.

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ACRONYMS

ADVI	Advertisement Intensity
AVCA	Accounting Value of Current Asset
AVCL	Accounting Value of Current Liability
AVLTD	Accounting Value of Long Term Debt
ASI	Annual Survey of Industries
CAP	Capital
CIS	Community Innovation Survey
CGPDT	Controller General of Patent Design and Trade mark
CI	Capital Intensity
CMIE	Centre for Monitoring Indian Economy
DEA	Data Envelopment Analysis
DSIR	Department of Science and Industrial Research
DST	Department of Science and Technology
EMR	Exclusive Marketing Rights
EXPI	Export Intensity
FDI	Foreign Direct Investment
FE	Fixed Effect Model
FGLS	Feasible Generalized Least Square Method
FOS	Foreign Owned Companies
FTM	Market for Foreign Technology
GDP	Gross Domestic Product
GFA	Gross Fixed Asset
GID	Dummy for Government Incentives
GMM	Generalized Method of Moment
HHI	Hirschman- Herfindahl Index
ID	Industry Dummy
IPC	International Patent Classification
IPO	Indian Patent Office
IPR	Intellectual Property Rights
ISIC	International Standard Industrial Classification
KPF	Knowledge Production Function

LAB	Number of Labours
LFM	Linear Feedback Model
LIC	Licensing Payment
LP	Levinsohn and Petrin
MAT	Material Input
MPI	Malmquist Productivity Index
MGR	Market Growth Rate
MVS	Market value of Share
NACE	European Classification of Economic Activities
NIC	National Industrial Classification
NIS	National Innovation Survey
OEA	Office of Economic Advisor
OECD	Organization of Economic Co-operation and Development1
OLS	Ordinary Least Square
OP	Olley and Pakes
PAT	Stock of Patent
PATPOL	Patent Policy Index
PCSE	Panel Corrected Standard Errors
QD	Quasi Differencing
R&D	Research and Development Expenditure
RBI	Reserve Bank of India
RDI	R&D Intensity
RDS	Stock of R&D
SPILL	Spillover
SIZE	Sales Value Deflated with Appropriate Indexes
TA	Total Asset
TAR	Average Applied Tariff Rate
TD	Time Dummies
TECH	Technological Opportunity
TFP	Total Factor Productivity
TRIPs	Trade Related Intellectual Property Agreements
TSR	Trilateral Statistical Report
WTO	World Trade Organization
WIPO	World Intellectual Property Organization

WPI	Wholesale Price Index
ZINB	Zero Inflated Negative Binomial
ZIP	Zero Inflated Poisson
ZTP	Zero Truncated Poisson

Chapter 1

Introduction

This doctoral work focuses on different aspects of the innovative activities of medium and high technology firms in India. Firstly, we undertake the study of the nature of firm's investment in innovation through research and development (R&D) expenditure and patenting. This work builds on the framework of knowledge production function (KPF) where, patents are the output of the process and R&D expenditure is the input for the same. The inputs and outputs of the KPF are determined by factors like demand, supply side, technological, firm specific, industry specific and institutional. Secondly, we study the association between R&D and patenting after introducing various lags of R&D expenditure. Finally, this thesis estimates the impact of R&D and patenting on the performance of firms through the indicators like productivity, profitability and Tobin's *q*. The research work gains significance as in order to comply with the Trade-Related Aspects of Intellectual Property Rights (TRIPs) agreement, India made extensive changes in her Intellectual Property Right (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. The work therefore considers changes in patent policy as a major determinant of innovative activities of firms.

In this chapter we have five sections. First section explains the context of the thesis that includes a brief discussion of the study area. Second section elaborates the concepts of the measures of innovation through R&D and patent. This section also discusses the changes made in patent policy of India. The next section provides research questions and objectives of the study. The chapter further discusses about the theoretical model and empirical methodologies applied in this thesis. The last section of the chapter outlines the organization of the thesis.

1.1.The Context

Innovation according to Schumpeter (1939, p. 87) "is the setting up of a new production function" or it is the set of actions a firm execute in order to bring the new and productive technological element in the production process. Its output may either be a product with improved characteristics or a more efficient production process for an existing product. Research and development (R&D) expenditure is the main source of innovation and patent is usually the output of the process. In other words, R&D expenditure and patent count of a firm reflects on innovation activity[1]. Griliches (1990) establishes that R&D is an input into the knowledge production function that leads to output in the form of patent. Griliches (1987 & 1990) shows the relevance of the patent data vis-à-vis R&D expenditure in capturing the innovation activity. The empirical evidence shows that innovation increases the productivity and efficiency of firms (Griliches 1979; Geroski et al. 1993) which identifies that innovating firms grow faster and make higher profit than non-innovating firms. Innovation by a firm is therefore vital in gaining the advantage over other firms and sustaining it for survival in a competitive industry.

The policy makers also give considerable importance to innovation activity of firms as it fuels the economic growth of the country, creates new jobs and enhances welfare. Innovation is critical to sustain economic competitiveness and productivity. According to Baumol (2002), economic growth since 18th century has been attributed to innovation. Industrial R&D at the firm level is one of the most important sources for economic development. For firms, innovation is important for growth and survival and plays a key role in the manufacturing process. Factors like globalization push firms to improve their efficiency and effectiveness. Similarly, market competition forces both domestic and multinational

[1]Number of countries are also conducting innovation survey and use the result of the survey for statistical analysis.

enterprises to reinvent themselves in order to gain market share. Firms recognize that ‘to make the product stand out in the market’ is the key to success. Therefore, factors like financial, market, organization and competition determines the innovation.

The importance of manufacturing sector in economic growth is evident from the success of U.S.A in maintaining their world’s leadership in innovation through their strong domestic manufacturing base (Ezell and Atkinson 2011). The advanced manufacturing provides important institutional framework for learning and developing production, skills and capabilities. Globally, manufacturing sector continues to grow about 2.7 per cent annually in advanced economies and 7.4 per cent in large developing economies, where India find a position among the top 10 growing economies in 2010[2]. As an economy matures, manufacturing becomes more important to drive productivity growth, innovation and trade.

India spends 0.7-0.8% of their GDP on R&D expenditure whereas developed economy like USA and another emerging economy like China spends 2.8% and 1.8% of GDP respectively, according to the World Development Indicators (WDI 2011). R&D expenditure in India is not only low but also stagnant in the past few years whereas the patent office has been witnessing a remarkable progress in filing (on an average of 15% increase) during 2005-2011. This period is enhanced with the changes in the Indian patent policy that the country made to comply with TRIPS agreement under the World Trade Organization (WTO) commitments. Researchers have explored the reasons behind the recent surge in patenting worldwide and especially in the United States (Kortum and Lerner 1999; Hall and Ziedonis 2001). Studies put forth several

[2] Source: Information Handling Services (IHS) Global Insight; McKinsey Global Institute Analysis. The survey also finds that around 77 percent of total Research and Development expenditure of major advanced countries comes from private sector.

reasons behind the phenomenon like increase in innovation and improvement is management of R&D.

It is noteworthy that unlike USA and China, in India, R&D expenditure of the government and educational institutions constitutes 80% of the total spending leaving a meagerly amount of 20% for private businesses[3]. Considering that patent rights are likely to incentivize private sector, it is evident that such businesses may be behind the spurt in the patenting activity. Further exploration reveals that private manufacturing sector, especially high and medium high technology industries are relatively more intensive in research[4]. Data 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). These interesting trends and the relevance of innovation in the economic growth of the country motivate us to study the innovative activities of firms and its impact on the performance o firm. Further we find that 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 growth pattern of high tech R&D and patent shows that during 2000-2010 R&D expenditure progresses at an annual average rate of 18% whereas granted patent grows at 12% per annum during 1997-2007. Thus in the context of manufacturing sector we focus on different aspects of the innovative activities of medium and high technology firms in India.

1.1.1. Medium and High Technology Industry

In the manufacturing sector, high technology industries are one of the fastest growing industries in the world because of the following reasons. Firstly, these sectors are prominent as demand for their product is

[3]In USA and China, 70% of R&D spending comes from business enterprise and 30% by government, higher education and private non-profit organization taken together.
[4]High and medium-high technology industries are defined based on OECD classification (2011). Further details are given later in the chapter.

growing rapidly and usually pays above average wages. Secondly, the benefits of investment made in high technology sector spillovers to other sectors as well. This sector has extensive linkage effect with the rest of the economy through multiplier impact on the other sectors. Third, high tech sectors are highly involved in significant foreign cooperation and competition in the R&D and production activities. This in turn boosts the productivity and competitive capabilities of domestic firms as well. Fourth, this sector can improve the standard of living of the people including the rural areas. For instance, introduction of mobile phones have certainly improved the standard of living of common man. Finally, the ratio of their R&D expenditures on total sales is much higher than the average rate. All of these factors together highlight the importance of high tech industries in innovation in the entire manufacturing sector.

According to the National Science Foundation (NSF), there is no unanimously approved method for identifying high technology industries. According to the foundation, these industries have a great dependence on science and technology innovation that lead to new or improved products and processes. The basic methods for identifying high technology industries are to use either the percentage of scientific and technical employment in a particular industry compared to all industries or R&D dollars spent as a percent of total sales, which is a measure of research intensity. If an industry's proportion of R&D employment is equal to at least the average proportion of R&D employment in all industries, it can be considered as high tech. European Union (2002) has defined high technology sectors through three different approaches, namely sectoral, product and patent approaches. Sectoral approach is an aggregation of manufacturing industries according to the technological intensity (R&D expenditure/value added), based on European Classification of Economic Activities (NACE) at two or three digit level. Product approach complements the sectoral approach, based on the calculation of R&D intensity by groups of products (R&D expenditure/ total sales) and uses data on high tech trade. In patent approach groups are aggregated on the basis of International Patent Classification [(IPC), (IPC 8^{th} edition 2006)].

High tech patents are counts based on the Trilateral Statistical Report (TSR 2007). The IPC does not define high technology field. Therefore, the trilateral offices (European Patent Office, Japan Patent office and United States Patent and Trademark office) consider computer and automated business equipment, micro organism and genetic engineering, aviation, communications technology, semi-conductors and lasers as high technology field.

The Organization of Economic Co-operation and Development (OECD) follows two approaches namely sectoral approach and product approach (Hatzichronoglou 1997). The Secretariat experiments with various criteria to identify the technology content of an industry, but quantification is mainly hampered due to paucity of data. As a result, R&D intensity became the sole criterion. The organization followed two methods to construct indictors namely i) R&D expenditures divided by value added; and ii) R&D expenditures divided by production that are constructed for each of the 21 manufacturing industries in ten OECD countries. Based on these methods, OECD divides the manufacturing industries into high technology, medium-high technology; medium-low technology and low technology groups based on their R&D intensities. The division of manufacturing industries into these four groups was made after ranking the industries according to their average against aggregate OECD R&D intensities. Industries classified into higher categories have a higher average intensity for both indicators than industries in lower categories.

Among the available options, the thesis follows the OECD definition of high tech sectors and we chose high and medium technology sectors as our study area. The industries belonging to each sector are given in Table 1.1. The sectors have been codified on the basis of National Industrial Classification (NIC) 2008 and International Standard Industrial Classification (ISIC) 2003. Initially, we made a concordance between ISIC and NIC. Industry and product classification in India mentions that NIC 2004 is based on ISIC Revision 3. Using this information, we made a concordance between ISIC Revision 3 and NIC 2008 through NIC 2004.

Considering that such a classification is based on the data from developed economies one may argue that it may not be relevant for developing countries as innovation patterns may be different in such economies. Therefore, we compared the R&D intensity of these sectors with the entire manufacturing sector in India and found that R&D intensity of 20 out of 22 three digit medium and high technology sectors are higher than the rest of the manufacturing sectors. The two sectors which do not have the required R&D intensity are the manufacture of wiring and wiring devices (NIC 273) and manufacture of man-made fibers (NIC 203).

1.2. Measures of Innovation: R&D and Patenting

Innovation is difficult to measure because of the broad nature and scope of such activities. One way to define innovation is the product and process innovation. The introduction of new product or the significant improvement in the existing product is known as product innovation whereas introduction of new process for making a product is known as process innovation. Product innovation may be tangible goods (like a newly invented mobile phone) or intangible services that support the newly invented product (like software). Similarly, process innovation can arise from the use of tangible and intangible inputs. Measurement of innovation has to be dealt with the questions like: how much novelty is necessary to call a change as innovation? Should it be new to the firm, new to the domestic market or new to the world market?

There are some conceptual and methodological issues while measuring innovation (Canibano et al. 1999). Initially, OECD countries used investment in R&D as an input and patent counts as output of the innovation. Later during the 1980s, it was recognized that innovation is complex and plagued with discontinuities and feedback from the member countries lead to the development of new indicators like marketing and acquisition of new technologies. OECD Oslo manual (1992) elaborates

Table 1.1 Concordances between ISIC Revision 3 and NIC 2008

Sectors	Industries	ISIC Rev 3 code	NIC 2008 code
		3 digit / 4 digit	**3 digit/4 digit**
High tech industries	Aircraft and space craft	353	303
	Pharmaceutical	2423	210
	Office, accounting and computing machinery	300	262+332+2817
	Radio, TV and communication equipment	321+322+323	261+263+,264+322+ 3313+3314+9512+9521
	Medical, Precision and optical instrument	331+332	325+266+267+332+2651+3313+3319
Medium- high tech industries	Electrical machinery and apparatus n.e.c.	311+312+313+314+ 315+319	271+272+273+274+279+ 332+3312+3314
	Motor vehicle, trailers and semi- trailers	341+342+343	291+292+293+3311
	Chemicals excluding pharmaceuticals	241+242+243 excl 2423	201+202+203+268+1079
	Rail road and transport equipment. n.e.c	352+359	302+309+3315
	Machinery and equipment, n.e.c.	291+292+293	281+282+275+252+304+ 3311.3312.3320.2593 excluding 2817

Source: Compiled by the Author

the concept of innovation covering goals of the firm, criteria for identifying innovative firm, number of innovations, cost of innovation and the impact of innovation. Based on the Oslo manual guideline, number of countries started innovation surveys commonly known as Community Innovation Survey (CIS). At present, Eurostat has conducted 7 CIS (CIS 1992, 1996, 2001, 2004, 2006, 2008 and 2010). In India, the Department of Science and Technology (DST) has made an initiative to survey Indian firms through National Innovation Survey (NIS) since 2004 and aggregative results are published in various reports. The firm level data is however not available for the researchers to conduct in-depth studies. Therefore, the measurement of innovation in the context of India is very difficult. A separation of innovative activities into innovation inputs and outputs partially solves the difficulties (Rogers 1998). Level of R&D expenditure and the patent counts are the most extensively used measures of the innovative efforts where the former represent innovative input and the later output. Hence, the study uses R&D expenditure and patenting as a measure of innovation which represents the technological base of a firm.

1.2.1. R&D as an Investment

R&D expenditure has a number of characteristics that distinguishes it from other investments. It encompasses both basic research and applied research (Lim 2000). Basic research aims to create new understanding of a phenomenon whereas applied research focuses on the practical payoff. From the view point of firms, R&D spending consists of current and capital account. In fact, more than 50% of R&D spending is in the form of wages and salaries of high skilled employees and engineers which come under the current account. The efforts of these skilled employees enhance the firm's knowledge base and help to generate profits in future. Investment in R&D has long gestation period with high degree of uncertainty, i.e. most of the investments have a low probability of success and the returns are generated towards the end of the project. Many firms have their own R&D units with majority of them creating such laboratories to enjoy tax concession.

The importance of R&D as a measure of innovation is well understood by its definition. The OECD Frascati manual (1993) defines R&D as:
"*Creative work undertaken on a systematic basis in order to increase the stock of knowledge (or) the use of this stock of knowledge to devise new applications.*"

1.2.2. Patent as an Output Measure

In case the R&D project undertaken by a firm is successful one way to measure that success is patent among others that include profit, productivity, market capitalization, other intellectual property statistics like trade mark and designs (Rogers 1998). Patents are a very rich and potentially fruitful source of data for the study of innovation and technical change. Following are the advantages of using the patent data: (i) each patent data contain information on the innovation, technological area to which it belongs, the investor, the assignee etc. (ii) there is a very large stock of patents and each of which constitutes a highly detailed observation, (iii) patent data constitutes a principle of consistency and continuity, (iv) data contained in patents are supplied entirely on voluntary basis so these are plain and clear, (v) patent citations allow researchers to study spillovers as the data include citation to previous patents and to the scientific literature. However, usage of patent data has some limitation also as (i) all inventions are not patented, (ii) the data may not be a true representative of the wider universe of invention since there is no systematic data about non-patented inventions (iii) patent files are not entirely computerized and finally (iv) all companies may not rely on patent to appropriate their R&D (Cohen et al.2000).

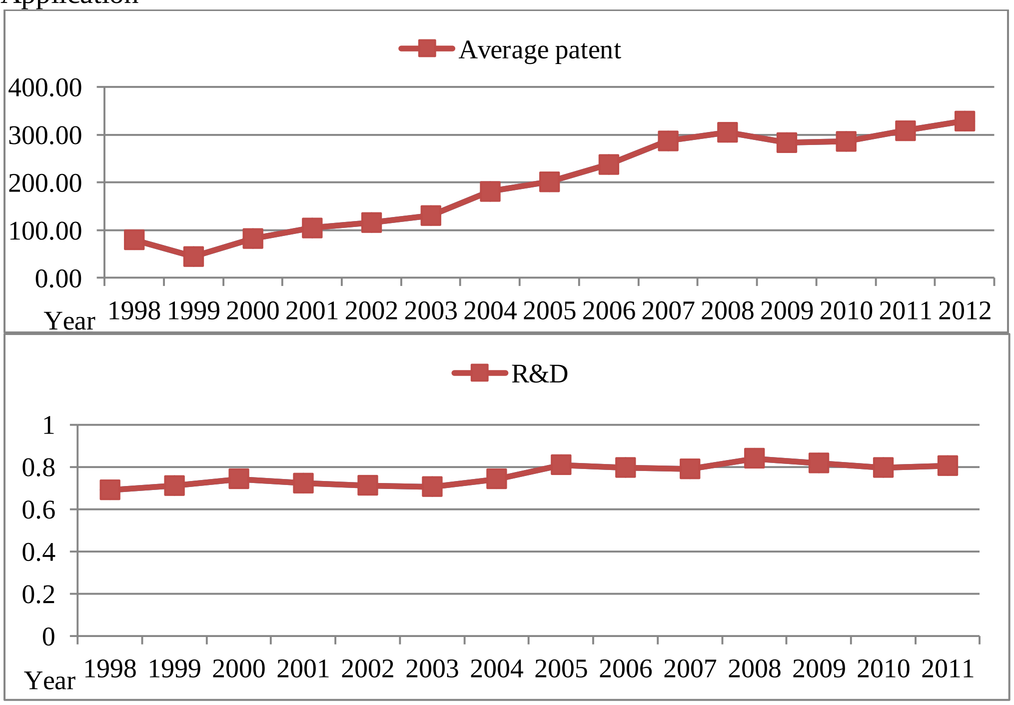
Patent statistics have been employed in several fields like as a tool for studying the relationship between technological development and economic growth (Taylor and Silberston 1973), as an assessment tool for the research and innovation process in the national and international context (Bosworth 1984) and as an indicator for assessing the level of technological development in a particular sector (Basberg 1987). Patent statistics also serve as a basis for analyzing a firm's policy with regard to research, development and estimation of the technological strength and weakness of the competitors (Narin et al. 1987). Jaffe and Trajetenberg (2002) study postulates that patents are a proxy for 'bits of knowledge' and patent citations represent a given bit of knowledge that is useful for further innovation. Griliches (1990) and Nagaoka et al. (2010) surveyed the literature that use patent as indicator of innovation and claim the usefulness of patent statistics in the empirical investigation of innovation. Therefore, the present study considers patent count as the innovation output.

1.2.3. R&D and Patent Statistics in India

Figure 1.1a plots R&D expenditure as a measure of percentage of GDP and 1.1b is average patent application which is the ratio of total patent application to researchers in R&D per million people. These two figures clearly show the difference between growth in R&D expenditure and patent application. Expenditure on R&D as percentages of GDP is stagnant with variation between 0.7-0.8 (except the high of 0.84% in 2008) whereas average patent shows a sharp increase during 1998-2008. The two figures began to fall after 2008 that can be attributed to the economic meltdown across the world; however the rise of average patent applications from 2009 onwards indicates the revival in the patenting activity.

Table 1.2 shows the breakdown of patent application into resident and nonresident. The table shows the total number of patent application filed and granted in India to the Indian nationals and foreign residents. The table also covers the number of patent by Indian residents across the world. The table shows that in 1995, total 6566 patents were filed in India and 76% of patent were filed by nationals of foreign countries. This similar trend follows throughout the years. In 2012, percentage of patent filed by foreign national is 78%. In case of patent granted, Indian patent office granted 1613 patents in 1995 while the number rises to 3606 in 2012. In the respective years, for the foreign nationals the share of patent granted to them rises from 74 per cent in 1995 to 83% in 2012. These figures show that foreign investors consider India as an attractive destination to apply their invention.

Figure 1.1a & 1.1b R&D Expenditure as Percentage of GDP and Average Patent Application



Source: WIPO and WDI

Table 1.2 Patent Statistics in India and Abroad by Indians

	Application Status			Granted Status		
	Resident	Non-Resident	Abroad	Resident	Non-Resident	Abroad
1995	1545	5021	163	415	1198	79
1996	1661	6901	294	359	661	83
1997	1926	8229	322	546	1161	80
1998	2247	6707	408	550	1223	134
1999	2206	2620	439	633	1527	157
2000	2206	6332	680	402	861	182
2001	2379	8213	1077	529	1020	288
2002	2693	8772	1471	619	921	425
2003	3425	9188	1945	615	911	621
2004	4014	13452	2714	851	1466	766
2005	4721	19661	3307	1396	2924	888
2006	5686	23242	3748	1907	5632	919
2007	6296	28922	4233	3173	12088	1125
2008	6425	30387	5121	2541	13520	1398
2009	7262	27025	4677	1725	4443	1467
2010	8853	30909	6016	1208	5930	1926
2011	8841	33450	7055	776	4392	2104
2012	9553	34402	8680	722	3606	2876

Source: World Intellectual Property Organization (WIPO) 2013.

1.2.4. Role of Patent Policy

Following the recommendations of Justice N.R. Ayyangar, Patent Act of 1970 replaced the Act of 1911. This act allowed process patent in the field of drugs and pharmaceutical for a limited period of 7 years. The act provided a protection of 14 years for the rest of the technological areas. After becoming the formal signatory to WTO/TRIPS India has made three-stage amendment process in her patent policy. Patent act 1999 makes provision for receiving the applications for the product patent in the field of pharmaceutical and agricultural chemicals during the transition phase 1995-2005[5]. Another salient feature of the 1999 act is the exclusive marketing rights (EMR), that allows the manufacture to distribute and sale their pharma product for a

[5] Patent amendment act of 1999 create a ‘mailbox’ option that permit inventors to file patent application for product invented after 1995.

period of five years from the date of obtaining marketing approval or until a product patent is granted or rejected, whichever is shorter.

The second amendment to the 1970 Act i.e. Patent (Amendment) Act, 2002 permits product patent for all items valid for 20 years. The non-patentable inventions are expanded and that include traditional knowledge, business methods, plant varieties and biological processes for production or propagation of plants and animals. 'Burden of proof' is reversed and now it is the duty of infringer to prove the dispute. Finally, this act brings some administrative changes in terms of filing and granting a patent.

The third amendment, i.e. Patents (Amendment) Act 2005 introduces some significant changes including the provision of product patent for inventions in all fields of technology. The act prohibits ever-greening of patent i.e. the mere discovery of a new form of a known substance which does not result in the enhancement of the known efficacy of that substance is not patentable. The 2005 amendment also allows compulsory licensing for producing and exporting of pharmaceutical products. Table 1.3 provides selected patent policy changes made in India during the last three amendments and their expected impact on the right holders. The '+' and '-' signs indicate positive and negative impact of patent policy changes on right holders.

Enforcement of IPR in developing country is however, subject to serious debate. Proponents of TRIPS agreement have argued that strengthening of IPR in developing country could increase the incentives of domestic firms to conduct their own R&D. Similarly, a strong IP law would increase the likelihood of technology transfer between developed and developing nations. On the contrary to this, critics have argued that a strong IP law would generate monopoly position that reduces consumer welfare. Further, the law may hurt poorer countries as they would have to involve in transfer of rent to multinational corporations based in the developed nations.

Table 1.3 Selected Domestic Patent Policy Changes

Amendment Year	Policy Changes	Impact on Right-Holder
1999	Provision for product patent in the field of pharmaceutical and agricultural chemicals.	+
	Provision for granting Exclusive Marketing Rights (EMRs).	+
2002	Term of protection extended up to 20 years.	+
	Disclosure of source and geographical origin of the biological material.	-
	Removal of "licences of right."	+
	Reversal of 'burden of proof'.	+
	Introduce publication of application after 18 months.	-
	Provision for pre and post grant opposition	-
	Introduction of the Appellate Board.	+
	Allowed application through PCT.	+
2005	Product patent in all field of technology.	+
	Compulsory licensing	-

Source: Adapted from Sharma (2012).

Empirical studies show that the impact of strong patent right on developing countries is complicated (Sharma and Saxena 2012). As the developing countries mainly depends on imitation of foreign technologies the strong patent right adversely affect such innovation. The thesis therefore includes patent policy index generated by Ginarte and Park (1997) and amended by Park (2008) as a policy variable.

1.3. Research Question and Objectives of the Study

Measuring innovation correctly and accessing their impact on the performance of firms, result in an improvement of efficiency of resource allocation. Recently, developed nations mostly rely on their innovation surveys to measure the innovative activities of firms. As stated earlier, the report of NIS is not available for researchers to conduct in-depth studies in India. So the present study employs R&D and patent statistics as indicators of innovation. The thesis mainly focuses on innovative activities of medium and high tech manufacturing firms in India in the context of new patent policy. The study begins with an analysis of the determinants of R&D and patenting behavior of these firms. The distinction of firms vis-a-vis their ownership as Indian and domestic, help us to identify the technological diversity across firms. Several studies have identified the relationship between R&D and patenting in the production of knowledge. In the next stage, we revisit the earlier research question regarding the lag structure of patent-R&D relationship. The question is important because most of the other studies that examine and verify the relationship are carried out in the context of developed nations (Hall et al.2009; Halpern and Murakozy 2012). However, in case of developing nations, the scant literature is not conclusive. Moreover, the results established under the circumstances of developed nation may not be applicable in the context of developing country. Finally, the thesis aims to measure the impact of firm’s innovation on their economic activity. The study thus addresses the question of whether there is any performance improvement in firm after innovation. In order to capture the performance we use three indicators namely productivity, profitability and Tobin’s *q*.

Briefly, the production of innovation and the link with firms’ productivity is theoretically and empirically well established in advanced nations (Crepon et al 1998; Mairesse et al. 2005; Hall and Sena 2014). The link between innovation and productivity is however inconclusive in developing nations. Data analysis of innovative activity of Indian firms during 1995-2010 using R&D expenditure and patents reveals an interesting fact. R&D expenditure in India is low and stagnant whereas Indian Patent Office witnesses a remarkable progress in patent filing during the same period. Further, the government of India made radical changes in Intellectual Property Rights (IPR) including patent policy, which is likely to boost both domestic innovation and transfer of technology to the nation. However, as developing and developed nations pursue different IPR policies, the benefits of the policy on developing nations are still blurred (Gupta 2010). These observations, changes along with scant research on innovation in Indian context provide us the motivation to undertake the current research. The underlying questions are: a) what determines the innovative activities of firm, measured in terms of R&D and patenting, b) what contributes to patenting? -contemporaneous or lagged R&D expenditure and c) how far the technology base of a firm can influence it's performance in terms of productivity, market value and profit. Based on the above research questions, we frame the objectives of the thesis as follows:

1) To understand the determinants of firms' innovative activities.
2) To understand the relationship between the research input and research output in terms of R&D and patenting particularly in the context of the new patent policy in the country.
3) To estimate the impact of R&D and patenting on firms' productivity and financial performance indicators.

1.4. Methodology

To address the objectives, we have to follow several empirical approaches based on substantial theoretical framework, appropriate econometric technique and a comprehensive data set.

Firstly, we need to analyze the R&D and patenting activities at the firm level. We estimate the KPF through a recursive simultaneous equation model where R&D is the dependent variable in the initial stage and later it is as an independent variable. Heterogeneous nature of the firms and the special facets of the dependent variables require unique consideration while formulating the model. More concretely, in case of R&D the dependent variable has the large number of zeroes and considering firms only which have positive R&D expenditure will lead to sample selection bias. Therefore, it is necessary to distinguish the zero emerging from the participation versus zero emerging from the non-participation. So we apply Heckman selection model to deal with the problem. We estimate two-stage regression with the first stage estimating the probability of conducting R&D and in the second stage focusing on the determinants of R&D under the given conditions. In case of patenting (applicable to the second chapter also), we need to provide special attention to count data as well. Moreover, the presence of many zeros in the data than predicted by count models such as Poisson and Negative binomial model requires special consideration. Hence, the study employs Hurdle count data model to solve the problem of excess zeros. The two part model relaxes the assumption that zeros and positives comes from the same data generating process. The second chapter also handles the count data issues as the dependent variable is the patent counts.

In third chapter, we measure the impact of innovation activities on the performance of firms. The chapter considers stock of knowledge measured through R&D and patent as measures of innovation. Productivity, profitability and Tobin's *q* are the performance indicators. To estimate the TFP of medium and high technology firms the present study considers production function approach. Production function is carried out by Levinsohn and Petrin (LP) method, which is a semi parametric method. The TFP estimation is based on an augmented Cobb-Douglas production function. The estimation includes material input as an additional explanatory variable apart from the basic labour and capital in the function. To evaluate the impact of R&D and patenting on the productivity and other performance indicators, we rely on Fixed Effect method and Feasible Generalized Least Square (FGLS) estimation.

1.5. Organization of the Thesis

The thesis has three main chapters in addition to the general introduction and conclusion. Chapter 2 discusses the innovative activities of medium and high tech firms through R&D and patenting. The chapter begins with the review of literature and variable used in this chapter. Next subsection explains the conceptual framework that links investment in R&D and patent. Following this, the chapter briefs data sources and econometric strategy applied. Next subsection discusses the results and finally we summarize the findings.

Chapter 3 presents the lag structure of R&D on patenting activity of the firms. After the introduction, it reviews theoretical and empirical literature that analyzes influence of current and lagged R&D expenditure on the patenting by firms. Following that we discuss the econometric issues. The section also discusses about the variables used in the study and their respective data sources. Next section presents the results of the empirical model that identify the current and lagged influence of R&D expenditure on patenting. Final section offers concluding remarks.

Chapter 4 estimates the impact of R&D and patenting on the performance of firms through indicators like productivity, profitability and Tobin's *q*. After introduction, we review the literature on the impact on patenting on productivity and other financial performance indicators separately. In the next section, we discuss the research methodology used in the chapter. The methodology builds on the existing literature by identifying specific characteristics of issues that have to deal with. Next section describes about the nature, sources of data and variables in the study. Following this, we present and analyze the results of the empirical model that estimating the impact of patenting on firm's performance. In the next section, the chapter presents a synthesis of the results and offers a detailed discussion of the same. Last section offers concluding remarks to the chapter.

Chapter 5 is the concluding chapter. The chapter begins with the overall summary of the thesis. The current section includes details on variables, data sources, methodology and results. Then, we list the main findings of the study. Following this, the thesis provides synthesis of the results and policy implications of the study. In the next section, the chapter offers contributions of the study. Then, the chapter enlists limitations and future directions for research. Finally, the chapter gives concluding remark.

Chapter 2

R&D and Patenting by Firms

2.1. Introduction

There is extensive literature that studies the economic and social factors that influence innovation. However, most of these studies employ 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 chapter where we bring together R&D and patent data of firms to gauge and analyze the innovative activity of these firms. Further, due to specific growth characteristics of high and medium tech sector it provides an interesting case to be studied in detail to identify the drivers of growth in R&D expenditures and patenting in an emerging economy like India. Such a study will be relevant for policy makers to understand the reasons behind the growth in innovation in an economy and will provide toolkit for future policy changes.

The rest of the chapter is structured as follows: Section 2.2 explains the conceptual model of the study and briefly reviews empirical literature on R&D and patenting; Section 2.3 discusses about the variables used in the study based on literature review; Section 2.4 provides information on the data for the analysis including the data sources, and the empirical strategy followed in the chapter; Section 2.5 provides the results of the Heckit and count data models applied to the Indian firm's data; The concluding Section 2.6 highlights the key findings of the study.

2.2. Conceptual Framework

According to Pakes and Griliches (1984) Knowledge Production Function (KPF) is the mechanism through which past R&D expenditure along with unobservable random variables translates into invention. This KPF has two significant input and output components namely R&D, patent statistics respectively. Later, Griliches (1990) shows the importance of patent data for capturing the innovative activity of a firm. This KPF explained as a statistical descriptive model known as the simplified path analysis that represents R&D and patents as the input and output of the KPF. Patent[6] 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. Furthermore, 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.

In the context of developing country, Ray and Bhaduri (2001) estimates a research production function for India. 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 by Ray and Bhaduri (2001) covers only electronics and pharmaceutical industries. The study was conducted on the basis of 1994-95 data that does not take into account the various policy changes that have been introduced in India. These policies include liberalization, globalization and changes in the patent policy as discussed in the introduction. We build our schematic framework based on Pakes and Griliches (1984) and Ray and Bhaduri (2001). We enhance the earlier framework 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. In this study, we use more internationally comparable

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

variable for knowledge output i.e. the number of patent granted to different firms as compared to Ray and Bhaduri study. 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)[7]. We bring together R&D and patent of all high tech and medium-high technology 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[8]. 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 2.1[9], 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 influence patenting, 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.

Based on the schematic framework given in Figure 2.1 we estimate the following models.

$$R= f\,(X\beta+u) \qquad (2.1)$$

$$P= f\,(Z\,\alpha+v) \qquad (2.2)$$

[7] The official name is Controller General of Patents Design and Trademarks.
[8]For example see Kumar and Aggarwal (2005) and Ghosh (2009) etc. for R&D and innovation; Chadha (2009) and Nair (2008) etc. for patenting as a measure of innovation.
[9] Based on Pakes and Griliches (1984) and Griliches (1990) and further enhanced by authors.

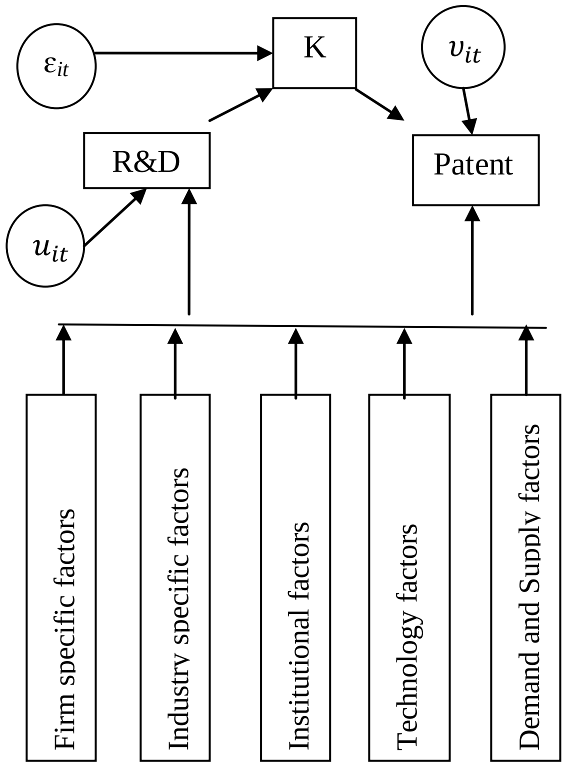


Figure 2.1. A Schematic Framework of the Knowledge Production Function

Where R is the nT × 1 vector of R&D efforts by n number of firms for time period‘t’, X is nT × k vector of explanatory variables, β is the coefficient matrix of order k × 1 and ‘u’ is the matrix of error term. In the second equation, P is the nT × 1 vector of patenting output, Z is an nT × k matrix of explanatory variables, α is the coefficient matrix of order k × 1 and ‘v’ is the matrix of error term.

2.3. Literature Review and Variables Explanation

2.3.1. R&D Expenditure: An Input Measure

It is evident from the Figure 2.1 that input of K and its output are determined by a set of factors like demand and supply side, technological, firm specific, industry specific and institutional factors. The identification of the factors for both the equations (2.1 and 2.2) is based on existing research. Further, we introduce institutional variables to take into account of policy changes in India. The details follow.

2.3.1.1. 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 (Schmookler 1954). To capture this aspect, we include market growth rate (MGR) measured as the sales growth rate in each industry as a control variable (Siddharthan 1998; Aggarwal 2000). With the increasing globalization, the demand factors are spread beyond national borders. Zimmerman (1987) finds stronger impact of the demand created by exports as compared to the domestic demand. Further, exporting companies are aware of the international technology trends and are more likely to adopt the same (Evenson and Joseph 1997).Therefore, export intensity (EXPI) measured through the percentage of export to total sales becomes an important component.

R&D expenditure involves extreme riskiness, moral hazard problem, and extensive transaction costs. Therefore, firms are likely to prefer internal sources including retained earnings or internally generated funds to finance R&D expenditure. Researchers use profit as a measure of internally generated fund (Basant and Mishra 2013; Geroski et al. 1993). These studies however, do not produce any positive statistical impact of profitability on innovation; rather they find a negative relationship. We use profitability (PBTI) measured through percentage of profit before tax to sales represents the supply side factor.

2.3.1.2. Technology Related Variables

High capital intensity (CI) encourages a firm towards in-house R&D which enhances the firm's ability to appropriate new technology (Basant and Mishra 2013). 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, do spillovers to the local firms. Feinberg and Majumdar (2001) 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.

2.3.1.3. 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. Many benefits accrue to the firm through economies of scale for firms with larger scale of operation. Several arguments have been offered to justify the positive effect of firm size on R&D activities. One of the important claims is the capital market imperfections that help firms to secure finance for risky R&D project as size correlate with availability and stability of internally generated funds (Cohen and Levinthal 1989). The returns of R&D are likely to be high due to spread of fixed cost of innovation over a large volume of sales (Basant and Mishra 2013). To capture the size aspect; we employ deflated sales (SIZE). Ray and Bhaduri (2001) find that initially R&D effort increases with size but at decreasing rate and fall after attaining an optimum firm size. Kumar and Aggarwal (2005) study the R&D activity of Indian firms in the pre and post reform period. The study finds that R&D expenditure increases with firm size. Ghosh (2009) uses a panel of 800 companies for the time period 1995-

2007 and find that large size of the firms influences R&D expenditure. Note that in many studies, number of employees represents the size of the firm, [for example see, Acs and Audretsch (1987)]. But in the present case, most of the firms in India do not report employee's data in CMIE prowess data and in accordance with the other studies based in India we use deflated sales.

Ownership, on the basis of domestic and foreign, also influences the investment decision. Foreign firms have several advantages over the domestic firms. Sasidharan and Kathuria (2011) find that Foreign Direct Investment (FDI) inflows influence R&D expenditure by the foreign-owned firms in high tech industries. 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. Based on Basant (1997) 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 on 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 (Arrow 1962). Therefore, the study includes firm's age (AGE) as a control variable, where we consider the difference between the year under consideration and incorporation year as the age of a firm.

2.3.1.4. Industry Specific Variables

According to Schumpeter (1942), the existence of large firms in a concentrated industry is conducive for technical progress. 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 Pianta (1996) find that size and concentration is positively related in Italian manufacturing sectors. Benavente (2006) confirms the Schumpeter's view in a study conducted in Chile. However, on the contrary Mukhopadhyay (1985), and Audretch and Acs (1988) report a negative relationship between concentration and investment in R&D. Researchers have combined these two possible patterns (positive and negative) and identified an inverted U shape relationship between innovation and competition which implies that neither perfect competition nor monopoly is conducive for innovation (Scherer 1967, Levin et al.1987, Braga and Willmore 1991; Baldwin et al.2000; Aghion et al.2005). In the context of India, Desai (1985) finds that market structure with a limited number of firms (2 to 6) is more conducive for innovation. Kumar and Saqib (1996) 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. Prasad (1999) in a firm level study shows the negative relationship between market concentration and investment whereas Subodh (2002) shows that market concentration has no influence on the decision to perform R&D and on R&D intensity. Basant and Mishra (2013) study the potential market concentration as a determinant of the innovative efforts by a firm. However, the study fails to produce a significant effect of market concentration on innovation. 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 competitive 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. Comanor (1967) has also applied the ADVI as a measure of product differentiation.

2.3.1.5. Institutional Factors

India is one of the countries that offer 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 (1988) also used the same set of industries in his paper. India along with other member states of WTO considered National Innovation System approach as an important tool of local institutional framework for shaping the pace of innovation (Metcalfe 1995; Cooke 1997). In order to comply with 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.

The impact of institutions such as intellectual property (IP) 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 into it. As an institutional framework the impact of IPR on innovation has two sided view. One view is that as property right become stronger, firms can appropriate their returns on investment in R&D (Cumming and Macintosh 2000; Dutta and Sharma 2008). On the contrary, monopoly power effect of IPR reduces the incentives of firms to invest or update their existing technologies (Sakakibara and Branstetter 2001). The effect of IPR on the R&D activities of developed as well as developing countries are also different. Allred and Park (2007) argue that standards of patent protection influence the R&D activity of developing firms negatively and in case of developed nations positively. Therefore, to see the impact of the protection on innovation the study uses a patent policy index[10] (PATPOL) known as Ginarte and Park index which is further updated by Park (2008). We construct an interaction variable of patent policy index with foreign licensing (FTM) payment which indicates that market for foreign technology grows under the strict property regime hence firm may prefer purchasing technology instead of indigenous development (Arora et al.2001).Tariff reduction over last two decades affects the competition in an industry from domestic as well as foreign firms. The ensuing competitive industry perhaps incentivizes the firms to conduct more R&D to sustain the market (Sharma 2012). Therefore, we use average applied tariff rate (TAR) to estimate the effect.

2.3.2. Patents: An Output Measure

In our schematic framework, patenting is considered as an imperfect measure of output of the KPF because not all inventions are patented and/or patentable. There are certain strategic motives behind patenting, for instance patent improves the reputation of the company, enhances the negotiation position while bargaining with companies and positively reflects on the performance of the company (Blind et al.2006). Among the firm specific variables, firm size plays an important role in determining the number of patents (Scherer 1965). Levin et.al (1987) and Griliches (1990) 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 firms tend to be low. Cincera (2003) 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. Later, Makinen (2007) in a study of Finland finds a U shape relationship between firm size and propensity to patent. Thus,

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

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 (Scherer 1965; Teece 1986). Cohen et al. (2000) find that firms considered patent as one of the least effective mechanism to protect their IPs. They rather go for other mechanisms like secrecy. Mansfield (1986) 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. Brouwer and Kleinknecht (1999) find a significant difference in patenting propensity among the sectors, where high technology sectors tend to have higher propensity than low technology sectors. Berg (1989) in a study of Dutch manufacturing industry finds that firms are unlikely to patent in a concentrated industry. Similarly, Arundel and Kabla (1998) also find that higher degree of competition is beneficial for higher propensity to patent.

In terms of technological factors, research efforts of a firm significantly contribute to the patenting (Crepon et al. 1998; Nicholas 2011). Some researchers argue that in-house R&D greatly influences the patenting activity (Beneito 2006), whereas some others argue that it is contracted R&D that influences the patenting propensity of a firm (Santarelli and Sterlacchini 1990; Huang et al.2010). Gurmu and Sebastian (2008) apply count data models to US firms data from 1982-1992. The analysis intends to identify the lag between R&D and patenting but instead finds a strong contemporaneous relationship between them. To analyze the influence of R&D on patenting activity we have three variables of R&D i.e. R&D intensity (RDI), Foreign R&D (FRD) and R&D stock (RDS). RDI measures the percentage of R&D

expenditure to sales. FRD is an interaction variable of foreign dummy and RDS which analyses foreign firms R&D impact on innovation of the firms. RDS is used as an important variable as it represents expenditure incurred over a period of time to innovate new products and processes.

R&D stock is calculated using perpetual inventory method using depreciation rate of 15% based on Hall (1996) and Basant and Fikkert (1996). Specifically, we calculate R&D stock based on $R_t = I_t + (1-\delta)R_{t-1}$ where, Rt = stock of R&D, I_t = R&D investment made at time t and δ is the depreciation rate. 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. The starting year of the R&D series is 1990-91. Thus, for computing R&D stock for the base year of the study (2000), the real investment in R&D for the last 5 years has been used (Goldar 2004).

Studies provide mixed result in terms of the influence of institutional factors on the patenting activity of firms. Hall and Ziedonis (2001) 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 suggests that strengthening of patent right in 1980 has led to a remarkable hike in patent filing among the firms in U.S. The probable reason is that improvements in patent rights provide confidence among the firms and they are able to recoup their investment on innovation. Studies of Branstetter et al. (2004) and Chan (2005) do not provide any evidence of a significant impact of patent protection on firm's propensity to patent. 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 gains in terms of total factor productivity. Chadha (2009) and Nair (2008) show that after complying with TRIPs, the tendency of patenting among pharmaceutical firm has increased considerably.

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 the developing country's perspective. Secondly, there is no study that brings together the R&D and patenting behavior of firms together in the Indian context. One such exception is Ray and Bhaduri (2001) study, but their data covers 1992-1994 only. Thereafter, Indian economy has introduced considerable changes in the industrial policy. Finally, after complying with TRIPs there is no study on the larger set of industries. The studies of Chadha (2009) and Nair (2008) considered only pharmaceutical industry. 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.

It is clear from the above literature review that the following variables are likely to influence the innovative activities of high and medium tech firms. From the above discussion and conceptual model 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) (2.3)

PT = f(AGE,FOS,PBTI,SIZE,CI,SPILL,HHI,ADVI,EXPI,RDI,FRD,
PATPOL,TAR, MGR,) (2.4)

2.4. Data Sources and Econometric Strategy

2.4.1. Data Sources

The main sources of data for the study are the website of Controller General of Patent Design and Trade mark (CGPDT) and Centre for Monitoring Indian Economy (CMIE) Prowess for patent and firms specific variables respectively. The prowess data base 27183 companies from 1990 onwards. R&D expenditure and patent granted to the Indian high technology and medium-high technology industries at IPO during the 1995-2010 are considered as two measures of innovation. We chose only patenting at IPO to maintain certain level of consistency, reliability and comparability (Ahuja and Katila 2001). R&D expenditure of the firms is also collected from DSIR to fill the missing numbers in the CMIE prowess database as well as perform a 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[11]. 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 in this chapter is given in Table 2.1.

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

2.4.2. Econometric Strategy

The model as given by equation 2.1 and 2.2 in section 2.2 and further extended in equation 2.3 and 2.4 can be estimated by recursive simultaneous equation because the dependent variable of RDI (equation 2.1) comes as an independent variable in patenting equation (equation 2.2).

$$R_{it} = X_{it}\beta + C_{it}, \text{ i=1,…., N and t=1,…, T,} \qquad (2.5)$$

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

$$P_{it} = Z_{it}\alpha + \upsilon_{it}, \text{ i=1,…., N and t=1,…, T,} \qquad (2.6)$$

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

Each of these models has its own specificities that have to be dealt carefully. In case of equation (2.1), a firm's decision to invest in R&D depends on several factors including demand, supply and technology related aspects. 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 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

Table 2.1 Summary and Definition of Variables

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

inferences drawn based on the sample for the population. To correct problems of self-selection bias and heterogeneity researchers applies Heckman's two-step procedure (Sasidharan and Kathuria 2011). This model is applied on a panel data and its details follow.

2.4.2.1. Heckman's Procedure

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

$$S_{it} = X_{1it}Y_{it} + C_{i1} + \upsilon_{it1}, \text{ i=1…, N and } t\text{=1… T,} \qquad (2.7)$$

$$S_{it} = \begin{Bmatrix} 1 = if \ \ y_{it} > 1 \\ 0, \ \ otherwise \end{Bmatrix} \qquad (2.7.1)$$

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 by C_i and C_{i1} in equation 2.5 and 2.7 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 (Dustmann 2007). Thus, one of the focuses in modeling is the potential correlation between dependent variable and unobserved individual firm's characteristics: - C_{i1}. Hausman and Taylor (1981) suggest transformation of the data into deviations from individual means to remove the individual effects. 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 (Htaylor) test for endogenity. The result is given in Appendix A1 which 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 (2003), Green (2005) and Sasidharan and Kathuria (2011) we can estimate a model consisting of two equations through Heckman's two step procedure (popularly known as Heckit method). We have two equations; a selection equation (2.7) and an equation of interest (2.5), known as primary equation.

Kyriazidou (1997) suggests first differencing of the observable variable to remove the individual effects. Hence, the selection equation parameter Υ_i in equation (2.7) can be estimated using the probit model[12]. The estimation gives inverse Mill's ratio 'λ' from the selection equation.

$$\lambda_{it} = \frac{\theta(\mathrm{z}_{\mathrm{it}} Y_i)}{\phi(\mathrm{z}_{\mathrm{it}} Y_i)} \qquad (2.8)$$

Where $\theta(.)$ 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 (2.6) is that the dependent variable is count data. Considering discrete non-negative nature of patent

[12]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.

counts we use Hurdle two part model. This model relaxes the assumption that the zeros and the positives values comes from the same data generating process (Cameron and Trivedi 2010). 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 2.6). The second step estimate the parameters through zero truncated negative binomial model, where the equation estimates only if there is a positive patent application.

2.5. Results and Discussion

Table 2.2 provides 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 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 and medium -high technology 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. Further, to know the aspects of multicollinearity we perform a correlation test and the results are given in Appendix A2. 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.

Table 2.2 Summary Statistics of Variables

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

As a preliminary evaluation, the relationship between market concentration and R&D expenditure is given in Table 2.3. 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 (1984) taxonomy where only pharmaceutical sectors considered patent as an effective mechanism to protect their innovation. 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 industry is highly concentrated. On the other hand, even though the industry is highly concentrated, firms in OAC and MPO do not significantly invest in R&D. Finally, RTE and ME firms are the poor performers of R&D even if market is highly competitive.

Table 2.3 R&D Intensity and Market Concentration Matrix

<table>
<tr><th colspan="4">HHI</th></tr>
<tr><td rowspan="3">RDI</td><td></td><td>Low</td><td>High</td></tr>
<tr><td>High</td><td>Pharmaceuticals(PHA)</td><td>Radio, T.V and communication equipment (RTC); Motor vehicles, trailers and semi-trailers (MOTOR)</td></tr>
<tr><td>Low</td><td>Rail road equipment and transport equipment(RTE); Machinery and equipment (ME)</td><td>Office, accounting and computing machinery (OAC); Medical precision and optical instruments (MPO); Electrical (EL)</td></tr>
</table>

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 results of R&D and patenting equations are discussed in subsections 2.5.1 and 2.5.2 respectively. Table 2.4 & 2.5 provide results based on R&D intensity while Appendix A3 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 2.5.

2.5.1 R&D as an Innovation Input

Initially R&D activity of firms is estimated through Tobit regression that gives random-effect estimates. The results of which given in Table 2.4.

As of now, there does not have a sufficient statistics allowing the fixed effects in Tobit regression. Honore (1992) 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. Therefore, R&D activity of the firms is estimated through Heckit method, which comprises of two parts, the probit model and the OLS.

Table 2.4 R&D Analysis through Tobit Model

	(1)	(2)	(3)
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
Observations	8310	8310	8310

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

The probit model explains the probability of R&D decision whereas the OLS method explains the level of the investment based on the firms that have already decided to invest in R&D. The results of which are given in Table 2.5

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 (Ray and Bhaduri 2001). Therefore, as an alternative measure, we produce results of the R&D activity with R&D stock as a dependent variable in Appendix A3. Among these Tables, we concentrate on the column 5 and 6 of the Table 2.5 for discussion.

Firstly, the lambda value (coefficient of the mill's ratio) is negative and significant which 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 2.5) 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 (2001) however, find inter-industry differences of ownership effect on R&D. Kumar and Aggarwal (2005) 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 at the home. However, contrary to these results we find stronger evidence that foreign firms R&D activity is highly significant and corroborate with Dunning and Narula (1995). 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 is one of the most influential variables in the R&D decision process. Kanwar (2013) also finds a positive influence of patent policy on innovative activity of Indian firms; however the study does not take into account the effect of liberalized regime. 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 etal. (1987) and Basant and Mishra (2013) have already established that industry concentration has no effect on the innovation. Further, Aghion et al. (2005) also show that it is only for new firms that the market competition is a matter of concern for innovation. All the remaining variables in case of R&D decision are insignificant.

In terms of level of R&D investment, results are given in column (6) of Table 2.5. The results show 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 to differentiate it products from other firms. Our result corroborate with findings of Basant and Mishra (2013) where they find that industries with higher capital intensity invest more on innovation. R&D stock model also confirms the influence of CI on R&D. However, in case of advertising, the study by Basant and Mishra (2013) finds a negative relationship whereas in case of present study we find that advertising firms are investing more on innovation. This clarifies the product differentiation aspect where the competitive nature of the market necessitates firms to invest more on innovation. As every new invention gives a temporary monopoly power to firms and they are 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 (1996) 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 authors capture the aspect of R&D activity in early 1990s where the changes made in Indian economy after the liberalization and TRIPs agreement are not fully covered. The size of the firm (SIZE) negatively influences the R&D intensity. It implies that investment in R&D decrease with size. In order to survive, small 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.

2.5.2. Patenting as an Innovation Output

We use hurdle count data model that comprises of two parts to know the patenting activity of firms in India. In the first part, we do regression with logit model (column 1) which tells us about the probability of patenting while the second part (column 2) of zero truncated negative binomial model (ztnb) shows the level of patenting activity after taking care of the selection problem. Although we concentrate on the hurdle count data model to interpret our results (column 1 and 2), estimates of other regression (Poisson. Negative binomial, Zip and Zinb) are also given in Table 2.6. As a robustness

Table 2.5 Decision and Determinants of R&D

	1	2	3	4	5	6
AGE	0.793(15.89)*	-0.016(-0.33)	0.812(16.05)*	-0.002(-0.03)	0.823(16.17)*	-0.003(-0.07)
FOS	0.407(10.37)*	0.009(0.29)	0.413(10.51)*	0.011(0.34)	0.412(10.46)*	0.009(0.29)
PBTI	-0.005(-0.31)	-0.009(-0.56)	0.001(0.07)	-0.003(-0.2)	-0.006(-0.33)	-0.009(-0.56)
SIZE	-0.013(-0.66)	-0.085(-4.81)*	-0.010(-0.5)	-0.078(-4.4)*	-0.014(-0.71)	-0.087(-4.87)*
CI	0.134(1.54)	0.301(3.15)*	0.131(1.51)	0.305(3.2)*	0.133(1.52)	0.298(3.12)*
SPILL	-0.064(-0.81)	-0.087(-1.02)	-0.061(-0.78)	-0.092(-1.08)	-0.062(-0.79)	-0.085(-0.99)
FTM	-0.007(-0.36)	0.007(0.49)	-0.002(-0.11)	0.005(0.34)	-0.008(-0.37)	0.007(0.49)
HHI	-0.025(-0.44)	-0.084(-1.7)***	-0.055(-1.06)	-0.094(-2.11)**	-0.021(-0.36)	-0.084(-1.71)***
ADVI	0.028(1.38)	0.040(1.86)***	0.026(1.28)	0.043(2.0)***	0.028(1.37)	0.039(1.85)***
EXPI	-0.009(-0.59)	0.010(0.69)	-0.005(-0.34)	0.012(0.82)	-0.009(-0.57)	0.010(0.69)
GID	1.894(34.99)*	---a	1.815(33.99)*	---a	1.884(34.73)*	---a
PATPOL	1.243(1.75)***	-0.677(-1.13)	-0.381(-4.24)*	-0.056(-0.73)	1.348(1.9)***	-0.634(-1.06)
TAR	0.068(0.14)	---a	0.607(2.42)**	0.435(2.11)**	0.070(0.14)	---a
MGR	0.001(0.66)	0.002(0.11)	-0.001(-0.75)	0.001(0.45)	0.001(0.45)	0.000(0.02)
LAMDA	-----	-0.114(-3.29)*	----	-0.103(-2.98)*	----	-0.11 (-3.13)*
Constant	-2.315(-5.58)*	0.258(0.73)	-1.274(-17.4)*	-0.037(-0.42)	-2.443(-5.85)*	0.204(0.57)
TD	Yes	Yes	No	No	Yes	Yes
ID	No	No	Yes	Yes	Yes	Yes
Log likelihood	-4585.48		-4614.21		-4580.63	
Observations	8310	4216	8310	4216	8310	4216
Model	Selection Probit	Outcome OLS	Selection Probit	Outcome OLS	Selection Probit	Outcome OLS

Z statistics are in parenthesis.*, **,*** are 1%,5% and 10% level of significance respectively. TD represents time dummies and ID represents industry dummy in the entire model. ‘a’ omitted to perform OLS regression.

check, we perform an experiment with logarithm of patent intensity as a dependent variable, the result of which is given in Table 2.7.

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 Table 2.6). 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 extensively 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 (HHI) negatively affects the patenting behavior of firms. Since the industry that lacks competition, the incumbent firm does not have any threat on their profit margin and no motivation to patent.

In case of the level of patenting, (column 2 of Table 2.6) 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 rights in India. Column numbers 1-4 of Table 2.7 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 level of patenting 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 (2013) where the author shows that foreign control has a positive and significant relationship with innovation probability of manufacturing industry in India. 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 probably 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 (column 2). 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 as the variable (SPILL) shows a negative sign. It implies that there is hardly any horizontal linkage among the manufacturing firms in India. The firms are doing their invention either by purchasing the technology from abroad or accommodating those technologies with indigenous technological capability. The results also indicate that instead of transferring knowledge to Indian market, foreign firms acquire knowledge from domestic firms through their interaction, for instance, information about the local requirements, domestic market and the distribution channels. Foreign firms may thus gaining information from the domestic firms. Market concentration and market growth rate turn out to be insignificant in level 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.

2.6. 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 KPF for high and medium- high tech sectors in India. Due to data peculiarities, we applied Heckit Method in R&D equation, to solve the problem of selection bias and Hurdle count data model in patenting equation, to take care of the problem arising from large number of zeroes. 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 data.

The changes brought in Indian patent policy have significant and positive influence on R&D and patenting activity of the high and medium-high technology sectors but, not through the in- house R&D of the firms. Foreign firms R&D have a significant influence on their patenting. It is evident from the study that foreign firms are really benefitted from the new reforms in patent policy in terms of their R&D expenditure as well as patenting. The study suggests that firms with enough experience do more innovative

Table 2.6 Patenting Models

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

Z statistics are in parenthesis.*, **, *** are 1%,5% and 10% level of significance respectively. ‘a’ and ‘b’ omitted because of co linearity. ZIP and ZINB are inflated through the variable PATPOL.

Table 2.7 Regression with Patenting Intensity

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

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

activities. The absence of competitive pressures reduces the inclination of firms to do more research and to protect their invention from imitation through patenting. Hence, their patenting and R&D shows a declining trend under concentration.

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 is significant whereas the R&D expenditure for patenting is 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 aim of foreign firms is quite different where their R&D is significantly influencing the patenting activity. Thus, after adapting to the Indian requirement foreign firms are taking patents.

Chapter 3

Patents, R&D Expenditure and the Lag Effects

3.1. Introduction

The recent statistics show that there is a surge in patenting activity across the world but R&D expenditure remains constant. WIPO (2011) data shows that growth rate in patent application have accelerated from 2.8 per cent in 1985-1986 to 7.2 per cent in 2009-2010. The data on R&D expenditure as a percentage of GDP shows that it has only increased from 1.9 % in 1996 to 2 % in 2010[13]. The expenditure is low and stagnant. Similarly, worldwide patent application growth rate of India increased from 0.6 per cent in 1985 to 15 per cent in 2010. In case of India also, R&D expenditure as a percentage of GDP remains as low as 0.6% and 0.8% during 1996 to 2010. The sharp increase in patenting which is not accompanied with R&D expenditure invites the attention of the researchers and the phenomenon can be seen as an acceleration of innovative efforts of the firms, and/or as their response to changes in patent policy (Kortum and Lerner 1999; Hall and Ziedonis 2001)[14]. To answer these questions, researchers explore the impact of contemporaneous and lagged R&D expenditure and patent policy changes on patenting activity by firms.

In the previous chapter, in case of Indian medium and high tech industries we did not find any significant relationship between current R&D and patenting. It is possible that patenting captures the R&D conducted by firm in past few years. Thus in this chapter we examine how the different lag structures of R&D expenditure affect the patenting activity of firms of medium and high technology industries. As the econometric techniques involved in understanding the lag effect of R&D on patenting are different from the methods employed earlier we have a special chapter on this issue.

[13] World Development Indicators (2014).

[14] Firms also patent for strategic reasons (Hall and Ziedonis 2001) that aspect in the Indian context remains unexplored.

The reminder of this chapter is organized as follows: Section 3.2 reviews the literature in two sections. First subsection reviews the theoretical background on the expected current and lag effect of R&D on patenting. Second subsection provides a brief review on the available methodologies. Section 3.3 describes the data, variables and methodology used in the study. We report the empirical results in Section 3.4. Section 3.5 concludes the chapter while highlighting the key findings.

3.2. Review of Literature

3.2.1. Theoretical and Empirical Evidence on the Relationship between R&D and Patenting

Firms' expenditure on R&D is treated as investment as it adds to the stock of knowledge (Hall et al. 1986) and existing studies consider patents as the indicator of the additional knowledge created in firms (Hausman et al.1984). Studies estimate the relationship between R&D and patenting through the KPF, which assumes that the production of new knowledge depends on current and its past investment in new knowledge (Griliches 1979; Griliches and Pakes 1980; Griliches 1984; Crepon et al. 1998). In the present scenario, the debate is whether the current or the past R&D significantly contributes to the knowledge creation in the form of patent.

In respect of patent- R&D relationship more recent investment in R&D is expected to have a significant impact on firms' patenting (Hall et al. 1986). The probable reason is that, as time elapses, knowledge stock usually depreciates and no longer matches the present innovation situation (Helfat and Raubitschek 2000). As the knowledge stock depreciates, the current R&D expenditure impacts the patent instead of the lagged R&D (Scotchmer 1991). Therefore, recently created knowledge becomes more valuable than the older knowledge. Several theoretical arguments support the use of more recent R&D on the creation of knowledge. These are organization-environment fit, competence building in emerging area and cheap search cost (Katila 2002). Organization-environment fit argues that in changing environment, the core technologies of firms become out of date as the firms' age. Though, these firms (organizations) are performing better according to the evaluation their adaptability to the changing environment is far from the reality. Hence, competencies that build on the recent knowledge enable firms to remain competitive. In case of competency building, firms that build on the recent knowledge are able to predict the nature of future technological advances (Cohen and Levinthal 1989). Further, results shows that recently created knowledge preserve time and capability as it is easily available.

In support of this view, empirical researchers find a contemporaneous relationship between R&D and patenting in the developed nations (Hausman et al. 1984; Hall et al.1986). Studies conclude that there is a significant relationship between R&D input and patent counts where elasticity of patenting with respect to R&D is unity, and this estimated elasticity varies across industries and model specifications (Scherer 1965; Bound et al 1984). Bound et al. (1984) have arrived at two interesting conclusions from their large panel data set of U.S firms during 1972-78. The study finds that the small firms which do R&D tend to patent more than larger firms. Further, the study also shows that firms with R&D expenditure in between $1-$2 billion produce a constant ratio of patenting to R&D. Scherer (1984) has estimated a link between R&D input and innovation output where the estimated elasticity varies in between 74%-104%. The data for the study was collected from 443 large U.S companies. Blundell et al. (2002) find that only contemporaneous relationship is strong. The authors use a derived data set that have been used by Hausman et al.(1984). A study by Gurmu and Sebastian (2008) examine the relationship using a series of estimators for the U.S. manufacturing and arrive at a conclusion that the relationship between R&D and patent is contemporaneous in nature.

The process of innovation has a cumulative nature as the innovations builds upon pre –existing knowledge requires multiple stages or increments (Dutfield and Suthersanen 2004). This forms the theoretical rationale that there is a lag or long run effect of R&D on the innovative activity of firms which further produce knowledge in the form of patent. Researchers suggest that current R&D may not always be considered as a significant contributor of knowledge because the past knowledge also significantly contributes in the process of innovation (Abrahamson 1996). Presence of lag effect implies that R&D undertaken in the past can still play a crucial role in the innovation process. The probable reason is that the older knowledge that has been around for longer time is more legitimate and reliable (March 1991). Since it is better tested and understood by firms, the occurrence of costly errors will be less (Katila 2002). On the other hand, the modern technologies are in fact a fusion of complicated technologies, the chances of errors will be high and the rate of successful innovation will be low (Fleming 2001). Further, the past knowledge has its own advantage than the recent one as it reduces the threat of retaliation (Smith et al.1991). Therefore, there are chances that R&D may have a long run impact on the innovative activity of firms as the knowledge derived from the past R&D investment might have a great potential value in the future when condition favors to reuse it (Nerkar 2003). In respect of this view, Montalvo (1997) uses 461 Japanese firms during 1977 to 1981 to understand the relationship between R&D and patenting and find that first lag of R&D is positive and significant. In the context of India, Chadha (2009) conduct a study based on 131 pharmaceutical firms that engage in exporting activity during the period of 1989-2004. The study finds a two year gestation lag between R&D and patent application in the pharmaceutical sector.

The above discussion shows that firms' investment in R&D gives rise to short run and long run impact on the patenting activity of firms. The short run impact implies that more recent R&D produces more patenting whereas in the case of long run, not only the current R&D but the previous R&D also influences the creation of knowledge output. This argument is extended and researchers in developed nation arrive at a conclusion that there is a likelihood of 'U' shape relationship between R&D and patenting. Pakes and Griliches (1984), in a sample of 127 American manufacturing firms found that the coefficients in the first and last years are significantly positive with a little effect of the interim R&D on patent applications[15]. Cincera (1997) on the other hand, based on 181 firm level data conclude that there is a high sensitivity of econometric specification on the relationship between R&D and patenting. The returns to R&D are characterized by a U shape relationship in the context of conditional fixed effect and Poisson models. However, the relationship disappears in the GMM estimation. In a very recent study, Wang and Hagedoorn (2014) test the relationship in pharmaceutical industry and find that first and fifth lag of R&D positively influences patenting activity of firms.

Invariably, these studies focus on R&D and patenting behavior of the firms located in developed economies. In the Indian context, we do not have adequate studies that evaluate the R&D-patent relationship with an exception of Chadha (2009). From the literature survey, it is evident that the relation between patent and R&D varies according to the model and there is no unanimity among the researchers about the effect of R&D on patenting. The above discussion produces complex relationship between R&D and patenting as there is contemporaneous, lagged and U shape influence of R&D on the innovative output. The ambiguity in results however attributes to several factors like the econometric tools applied, and the socio-economic conditions of the country where the study was conducted. Therefore, there is a need to understand the patent-R&D relationship in the context of emerging economies for wider extent of industries to draw conclusive inferences about the patent-R&D relationship. The present study, therefore, assesses the impact of various lag structure of R&D on the patenting behavior of firms. The research also requires a brief examination of various estimation tools available to test the relationship.

3.2.2. Review based on Econometric Specification on Count Data Models

The above literature review shows that the degree of association and the lag effect vary according to the study depending on the econometric specification applied in each study. Researchers also depict the sensitivity of

[15] The author's have admitted that this is a preliminary sample and neither complete nor representative of full firms.

econometric specification while analyzing this relationship (Cincera 1997). This also demands a discussion on the various econometric specifications available to estimate the relationship. Owing to the nature of non- negative discrete panel data that generate non- linearities, studies have employed count data model to estimate the relationship (Hausman et al. 1984; Hall et al.1986; Duguet and Kabala 1998). Understanding the fact that not all R&D making firms are applying for patent, Hausman et al. (1984) applied Poisson count data models to estimate the relationship. Poisson is the basic count data model with a restraining property of equality between mean and median (Hausman et al.1984). In practice, the patent counts show an over dispersion where variance will be greater than mean. In such a situation, the estimates are consistent but not efficient (Gourieroux et al. 1984). Along with this, the heterogeneity among the firms is also taken care of in the negative binomial model (Cameron and Trivedi 1998). In our case however, we have confronted with another problem: which is large number of zeroes (about 96% in our sample). Zero inflated models, allows the presence of excess zeroes in the model, (Gurmu and Trivedi 1996) and the model assumes that zeros and positive counts are generated through different processes. Later, researchers applied a modified version of count data model, i.e. Hurdle model (Chadha 2009) which assumes that the processes that generate positive and zero counts are different.

All the models explained above require strict exogeneity of the explanatory variables. Endogenity may arise either due to unobservable fixed effect or the reverse causality (Blundell et al.2002). For example, the decision on whether or not to report R&D depend on firms and therefore analyzing the activity based only on the available R&D data leads to endogenity from unobservable. Further, in the R&D patent relationship patent may themselves make future R&D expenditure that causes a feedback from patent to R&D. Therefore, in case of violation of this exogeneity assumption, researchers have employed first difference transformation of original specification as it leads to finding a valid instrument (Anderson and Hsiao 1981).

In count data models, the standard generalized method of moment (GMM) estimator is not applicable as it produces non- linearity due to the non negative discrete nature of the data. Later, Montalvo (1997) proposes a new estimation technique called (GMM) estimator with fixed effect. The model is applicable in the case of endogenous as well as pre- determined regressors. A regressor is pre-determined when it is correlated with lagged values of dependent variable but uncorrelated with present and future shocks. In case of panel count data models, the process under consideration is intrinsically dynamic in nature because its history becomes a vital determinant of the present. To tackle this problem, Blundell et al. (2002) proposes quasi-differenced GMM estimators.[16] The inclusion of lagged dependent variable as an explanatory variable in the exponential function however can lead to a problem with transforming zero values. Therefore, Blundell et al. (2002) proposes an alternative specification called linear feedback model (LFM). In the LFM, the conditional mean of the dependent variable enters linearly in the model.

3.3. Data, Variables and Methodology

3.3.1. Data

Originally our sample data consists of 3711 high tech and medium- high tech manufacturing firms registered in India. Based on the OECD (2011) classification, we grouped our firms as high tech and medium- high tech. We exclude all the firms which do not report their sales data more than four years. Therefore, our final sample consists of 554 firms. The firm level data is collected from Prowess CMIE data base for the period 1995-2010. Website of Controller General of Patent Design and Trademark (CGPDT) is the main source of patent data. The patent search for all firms is completed through the options of "Applicant Name" and "Name of Grantee" respectively for patent application and granted patent. We cross check each patent document to confirm the ownership. For example, in case of granted patent, Phillips Electronics India Ltd has 627 granted patents during the study period. We have gone through all the patent document displayed

[16] Windmeijer (2008) gives an account of recent literature on panel count data estimation.

against the name of Phillips Electronics India Ltd and selected only those patents granted to original grantee. We haven't considered any patent granted either to their subsidiaries or to their joint ventures. We repeated the experiment at regular intervals of time and confirm no patent data are missing during the collection. The study also uses data on R&D from various publications of Department of Science and Industrial Research (DSIR). All the variables are measured in terms of ratio to deflated sales (adjusted to inflation)[17] and then taken in logarithmic form.

3.3.2. Variables

3.3.2.1. Dependent Variable

The number of published patent application by each firm is taken as a dependent variable.

3.3.2.2. Independent Variables

We use values of R&D up to five lags (RDI, RDI lag1, RDI lag2, RDI lag3, RDI lag4 and RDI lag5) in the present study to test the U shape relationship. RDI is calculated as the percentage of R&D expenditure to sales. We also employ patent policy index generated by Ginarte and Park (1997) and further developed by Park (2008) as a measure of patent policy changes made in India (PATPOL). The index shows that most of the nations have increased their protection through stipulated changes in their patent policy (India's index value increase from 2.27 to 3.76 during 1985 to 2005).

We also introduce firm specific as well as industry specific variables in the model as controls. Many studies consider age of the firm (AGE) as one of the significant variable that influences patenting (Balasubramanian and Lee 2008). Age is the logarithmic difference between year under consideration and incorporation year of a firm. To measure the experience of firm in patenting we construct stock of patent (PATEXP) as a patent experience variable (Schneider 2007). Ownership of the firm also matters in case of innovation as the foreign firms have greater access of advanced technologies and these firms are more vibrant in innovation than domestic firm (Love et

[17]Sales are adjusted for inflation by deflating all the sectors to their respective whole sale price (WPI) index of base year 2004-05.

al.1996; Love and Ashcroft 1999). Hence, we consider a dummy of foreign ownership (FOS) where all firms having foreign equity of more than 10 per cent is considered as foreign. The size of the enterprise influence innovative activities and we incorporate deflated sales to control for firm's size (SIZE)[18] (Acs and Audretsch 1987). Acs and Audretsch (1987) have identified that large firms are intensive in innovation if the markets are concentrated. In order to capture concentration and product differentiation aspects we employ Herfindahl-Hirschman index (HHI) and advertisement intensity (ADVI) respectively. Technological opportunities are defined as the external benefit that a firm derives from the industry where it belongs. Therefore, we include technological opportunity variable (TECH) measured as the average R&D expenditure per industry (Van Den 1989). Finally, in order to check the relative importance of internally developed fund in innovation we include profit calculated before tax (PBTI) as a control variable in our study.

3.3.3 Descriptive Statistics and Correlation Matrix

Table 3.1 presents descriptive statistics for variables used in the study. We find that around 93-94 percent of patent application and grants are zero. This is a very high number of zeros that necessitates the use of appropriate model discussed later in the text. The correlation matrix is given in Appendix B1.

[18] Sales variable is deflated using the respective industries whole sale price index.

Table 3.1 Descriptive Statistics of Main Variables

	Observations	Mean	Std. Dev.	Variance
Patent Application	8864	1.23	10.2	104.06
Granted Patent	8864	0.44	4.41	19.42
RDI (logarithm)	8864	-0.27	0.55	0.3
AGE	8864	29.9	20.53	421.28
PBTI (logarithm)	8864	0.68	0.5	0.25
HHI (logarithm)	8864	-3.1	0.67	0.44
ADVI (logarithm)	8864	-0.29	0.63	0.4
SIZE (logarithm)	8864	2.77	0.84	0.7
	Minimum	**Maximum**	**Fraction with zero**	
Patent Application	0	292	0.9328	
Granted Patent	0	232	0.9471	
RDI (logarithm)	-3.42	3	0.479	
AGE	1	113		
PBTI (logarithm)	-2.26	1.97		
HHI (logarithm)	-4.12	-0.2		
ADVI (logarithm)	-3.01	1.52		
SIZE (logarithm)	-0.84	5.44		

3.3.4. Empirical Strategy

3.3.4.1. Poisson and Negative Binomial Models

Since our dependent variables are count measures, we begin with a Poisson regression model that provides a standard framework for the analysis of count data (Green 2005). However, not all count data meets the assumptions of the Poisson distribution. Since, over dispersion is common for most of the count data (variance exceeds the mean), the basic Poisson models are not applicable in most of the cases. The negative binomial model (NEGBIN) is more general in such cases as the model accommodates over dispersion.

$$\Pr[Y = y_{it}] = \exp(-\lambda_{it})\lambda_i^Y / y \quad ; \; y = 0,1,2....and \quad \lambda > 0 \qquad (3.1)$$

Where y_{it} is the number of patent granted to firm i at time t, where i=1…N indexes firms and t=1….T indexes time periods. The λ_{it} is the deterministic function that takes the form of $\log \lambda_{it} = x_{it}{}'\beta$, where x_{it} is a vector of *m* regressors for firm *i* at time *t*.

3.3.4.2. Zero Inflated and Hurdle Model

Since we have only few numbers of positive counts (6.72) per cent in patent applications) we need to take account of these large zeroes. Large degree of skewness in patent distribution with the presence of observed and unobserved heterogeneity requires special modeling strategy for the data. The problem of excess zeroes necessitates the use of zero inflated models like zero inflated poison and negative binomial [(ZIP) and (ZINB), (Cameron and Trivedi 2010)]. These models, a modification of the Poisson and negative binomial models, allow for excess zero counts in the data and permits the mechanism generating the zero observations to differ from the one for positive observations. It is quite natural that patent data can be characterized by a larger frequency of extra zeroes and the outcome is driven by different factors than the mean of the positive outcome. Econometricians have expressed these model as a mixture of Poisson distribution (with probability p) and degenerate distribution with point mass one at zero (with probability (1- p)). The response variable Y_i (y_1, y_2,…y_n) has the following form;

$$Y_i \approx \begin{cases} 0 & \textit{with probability} \quad 1-p_i \\ Poisson(\lambda_i), & \textit{with probability} \quad p_i \end{cases} \qquad (3.2)$$

The probability mass function for Zip model is given by

$$p(Y=0) = p + (1-p)\Pr(K=0) \qquad (3.3)$$
$$P(Y=y) = (1-p)\Pr(K=y),$$

$$y = 1,2,3..... \qquad \textit{where}$$

$$\Pr(K=y) = \frac{e^{-\lambda}\lambda^{y}}{y} \qquad (3.4)$$

ZIP model suggests that the excess zeroes are generated by a separate process from the count values and that the excess zeroes can be modeled independently. Thus, the two part of zip model (poisson count and logit) are able to predict the excess zeroes. Zip model assumes that population contain two types of firms: one that always gives zero count with probability 1 and the second gives a Poisson count including zero with 1-p probability.

Further, the hurdle model relaxes the assumption that the zeroes and the positives comes from the same data generating process. The two parts of the model are functionally independent and the maximum likelihood estimation can be achieved through two separate estimations; one corresponding to the zeroes and the second to the positives. As the sample consists of both innovators and non-innovators, one part of the model determines whether a firm takes patent or not and the second model determines the extent of patenting activity given that the firm has positive patent.

3.3.4.3. Linear Feedback and Quasi Differenced Estimators

All the models discussed above assume that explanatory variables are strictly exogenous. However, it is likely that patenting in period *t* influence the decision of firm to increase R&D in next (*t+1*) period. Thus, the relationship cannot be considered as strictly exogenous as patents depend on additional R&D expenditure for their full development or improvement. Therefore, it is common that there is a feedback from the patent to R&D and that may be a pre-determined variable in the model (Windmeijer 2008)[19]. To surmount this problem, we apply quasi-differencing transformation as suggested by Wooldridge (1991). The transformation removes the fixed effect and generates orthogonality condition. This condition ensures consistent estimation in the count data models. The Wooldridge transformation is as follows:

$$q_{it} = \frac{y_{it}}{\mu_{it}} - \frac{y_{it-1}}{\mu_{it-1}} \qquad (3.5)$$

Where q_{it} is the transformed variable for firm *i* in the tth period and μ_{it} is the expected value of the i^{th} observation and we have to estimate the equation through two stages GMM. In the multiplicative distributive lag model, collinearity between current and other R&D terms are possible. To tackle this, Blundell et al. (2002) introduce dynamic linear feedback model where the lag of the dependent variable linearly enters the model as an additional explanatory variable. The author’s proposition can be expressed as follows:

[19] A regressor is said to be predetermined when it is correlated with past shocks. The variable however is not correlated with current and future shocks.

$$y_{it} = \gamma y_{it-1} + \exp(x_{it}^{'}\beta + \eta_i) + u_{it} \qquad (3.6)$$

Where $1-\gamma$ is the depreciation factor, β is the long run elasticity and $(1-\gamma)\beta$ is the short run elasticity. In the present section, the study estimates models through GMM estimators[20]. Based on the above discussion, we can formulate the research equations as follows:

$$\begin{aligned} P_{it} = f(&PATPOL, RDI_{it}, RDI_{it-1}, RDI_{it-2}, \\ &RDI_{it-3}, RDI_{it-4}, RDI_{it-5}, X_{it},) + \varepsilon_{it} \end{aligned} \qquad (3.7)$$

Equation 3.7 states that patent count will be a function of two determining factors like patent right index (PATPOL), own research and development expenditure (R&D) and a vector of other firm specific as well as industry specific factors (X_i). Firm's unobserved heterogeneity is measured through ε_i. First differencing of observable variable removes the individual specific effect (Kyriazidou 1997). In order to capture the sectoral aspect, we introduce an industry dummy of value =1 if the firm belongs to high tech industries, otherwise zero.

3.4. Empirical Analysis

3.4.1. Distribution of Patent according to Sector and Ownership: A Descriptive Statistics

Table 3.2 gives sector wise and year wise distribution of published patent applications. For counting the number of patent applications we considered only those firms which have at least one granted patent during the study period. The statistics shows that pharmaceutical sector leads the list with 8356 patent application (from 92 firms). Chemical sector on the other hand, shows that they are able to convert half of their patent applications into grant (2302 and 1130 number of patents respectively). These two figures validate survey observations that 60 percentages of innovations in the pharmaceutical sector and 40 percent in chemical sector develop with patent protection

[20] For dynamic linear feedback model, we consider the GMM estimator as suggested by Cameron and Trivedi (2005).

(Mansfield 1987; Levin et al. 1987). Electrical machinery has 2850 rail road equipment sector has 2745 number of patent applications.

Further, we distinguish these patents on the basis of ownership into domestic and foreign firms. Table 3.3 gives patent applications by domestic and foreign firms in various years. It is evident from the table that there is a lion's share of domestic firms and it ranges between 81 to 83 percent during 1995-2010. However, these firms' patenting habits are very less: only 2 to 10 percent of domestic firms apply for a patent. The case of foreign firms is different as it constitutes only 19 percent in the sample but their patenting percentage ranges in between 8 to 20. It shows that foreign firms are extensively patenting at the IPO than the domestic firms. Further, a diagrammatic representation of average patenting by foreign and domestic firms is given in figure 3.1 (unweighted averages to number of firms). Clearly, foreign firms are patenting more in India as compared to domestic firms. The statistics further show that average patenting application significantly rises up to 2007 and 2005 respectively. However, since then it shows dramatic decrease[21].

[21] This feature is attributed to the long gap between patent application and granting date. Firms who applied for patent after 2005 may not be granted till 2010. This could be a main reason behind sharp decline in patent after 2005. Similar is the case of patent application as the sharp increase can be seen up to year 2007.

Table 3.2 Distribution of Patent Application across Sectors and Years

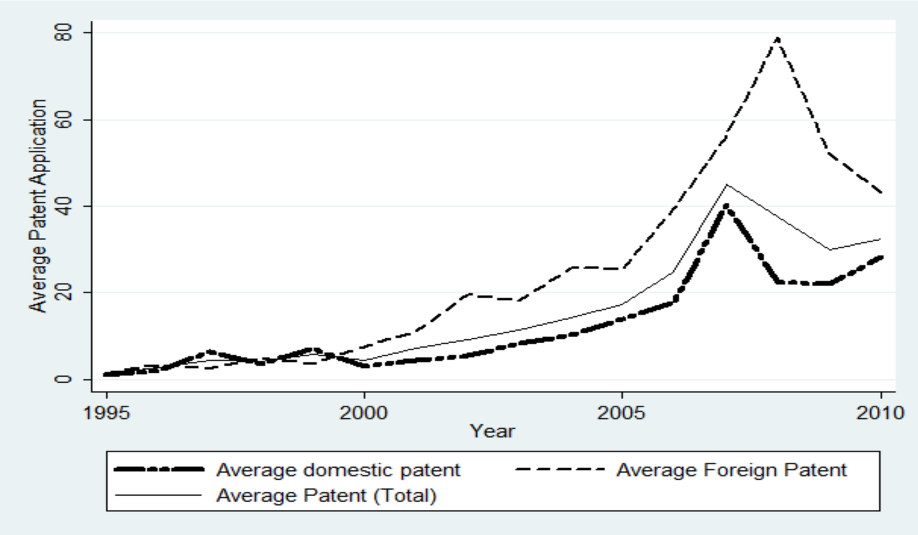
Sectors	Pharma	OAC	RTC	Medical	Electrical	Motor	Chemical	Rail	Machinery
1995	22	0	1	1	1	0	3	6	13
1996	58	0	1	2	4	0	11	11	23
1997	65	0	7	0	11	1	11	7	34
1998	47	2	1	0	14	1	17	19	38
1999	46	0	8	0	27	3	7	8	41
2000	94	0	9	1	52	12	43	45	36
2001	160	1	2	0	86	16	76	85	48
2002	261	2	2	0	75	10	103	114	37
2003	391	0	1	2	26	12	158	172	49
2004	487	0	1	0	49	31	163	184	77
2005	875	0	4	2	241	27	217	253	107
2006	1292	0	12	11	90	58	188	242	140
2007	1572	1	52	14	853	58	255	362	214
2008	1500	2	23	5	187	184	388	442	289
2009	948	1	11	5	446	149	321	394	249
2010	538	0	14	1	688	164	341	401	245
Companies	92	2	6	5	8	5	54	35	41

Table.3.3 Difference in Patenting: Foreign Versus Domestic Firms

	Year	1995	2000	2005	2010
Firms	Foreign	103(18.6)	105(18.9)	106(19.1)	93(16.8)
	Domestic	451(81.4)	449(81.1)	448(80.9)	461(83.2)
Patenting Firms	Foreign	8(8)	13(12.4)	21(19.8)	16(17)
	Domestic	8(2)	28(6.2)	48(10.7)	36(7.8)
Patent Applications	Foreign	15	140	528	643
	Domestic	14	85	825	449
Average Patenting	Foreign	1.88	10.77	25.14	40.19
	Domestic	1.75	3.04	17.19	12.47

Note: Figures in bracket indicate their proportion in total.

Figure 3.1.Comaprative analysis of Patenting by Foreign and Domestic Firms



3.4.2. Results of Econometric analysis

The results of this chapter is arranged into four sections: i) full sample analysis ii) a separate analysis for high and medium-high technology sectors iii) an analysis for foreign and domestic firms individually and iv) a sector specific analysis.

3.4.2.1 Full Sample: Influence of R&D and Patent Policy

The main findings of the model for the full sample are presented in Table 3.4. Results of Poisson, NEGBIN, ZIP, ZINB, zero truncated Poisson models (ZTP), quasi differencing (QD) and linear feedback model (LFM) are given in columns 1 to 7. The coefficient of contemporaneous R&D is positive and significant in the basic count data models (columns 1& 2). The results confirm with earlier studies (Hausman et al.1984; Hall et al.1986; Gurmu and Sebastian 2008). However, when we consider the large number of zeroes, the contemporaneous R&D become negative (columns 3, 4 &7) and significant as well (columns 3 & 7). Although, this not expected, similar cases have also reported in previous studies (Gurmun and Sebastain 2008). Their study finds a lag influence for the Poisson model but no evidence has been found in the case of negative binomial model.

Except in case of Poisson model, we do not have any significant evidence of first lag of R&D on patenting. In the GMM estimation, (column 6), the contemporaneous and first lag of R&Ds becomes positive but not significant. Finally, the dynamic LFM is estimated using GMM reports in column 7. The estimated coefficients of the lagged dependent variable and R&D are equal to 0.09 (γ) and 1.06 (β) respectively. This implies that contribution of R&D investment depreciate exponentially at the rate of (1-γ)= 91%, the short run elasticity with respect to R&D is (1-γ)β = 0.96 and the long run elasticity is about β = 1.06. These results give a hint of lag effect of R&D expenditure on patenting.

The common feature throughout the models is that, the fifth lag of R&D is positive in all the models and significant in some cases as well (column 1, 3, and 7). Therefore, we cannot negate the possibility of a U shape relationship between R&D and patenting. However, the same relationship cannot be established in most of the models. For example, in the hurdle model as we go from the contemporaneous to fifth lag of R&D, the coefficients increases up to second lag, then decreases up to fourth lag and finally we see an increase in the fifth lag of R&D. Therefore, there is an evidence of 'tilde shape (~)' which is not established earlier in the literature. The significant coefficient for the last of lag of R&D is usually observed as correlated fixed effects, i.e. the permanent patenting propensity of firms and their investment in R&D. To control this, we include a patenting experience variable (PATEXP) through firm pervious patenting stock. PATEXP has a positive and significant impact on patenting activity. The result indicates that previous knowledge on patenting activity significantly boosts up the patenting behavior of a firm.

In all the models, foreign ownership (FOS) significantly influences innovation. As expected, foreign firms widely utilize Indian patent protection for their invention particularly, after 1995. One reason is that externally owned firms devote more resources to R&D (most likely in the home countries) and therefore, innovate more than their domestic counterparts.

From these two results, we can confirm the year to year relationship between R&D and patenting as an influence of foreign firms activity in India. Since foreign firms in India (that are more active in R&D) may have the access to the technological developments from their parent organization situated abroad, the current R&D is merely to adapt those developments to Indian conditions.

Results shows that the positive changes in patent policy (PATPOL) in the favor of property holders, made significant influence on patenting at the Indian Patent Office. This implies that the stronger protection for invention gives confidence to the innovators about the appropriation of their invention. Hence, they go for patent as an option to protect their invention. This result provides a good explanation to the debate of stronger versus weak property protection in developing country scenario.

The negative and significant result of technological opportunity (TECH) shows that external industrial knowledge does not contribute to firm’s innovation. The present results therefore contradict with earlier study (Malerba 1999). The negative and significant coefficients of HHI imply that firms in India prefer to patent less in a concentrated market.

Table 3.4 Results of Full Sample: R&D, Patent Policy and Patenting

	Poisson (1)	NEGBIN(2)	ZIP(3)	ZINB(4)	ZTP(5)[@]	QD(6)	LFM(7)
$PAT_{(t-1)}$	--	--	--	--	--	--	0.094(2.58)**
RDI	0.137(2.87)**	0.215(1.74)***	-0.256(-6.81)*	-0.301(-1.48)	-0.254(-6.78)*	0.004(2)	1.07(2.33)**
RDI1	0.133(2.42)**	0.108(0.76)	-0.003(-0.07)	0.140(0.54)	-0.005(-0.11)	0.0001(-0.31)	---
RDI2	-0.095(-1.87)***	-0.018(-0.13)	-0.078(-1.65)	0.044(0.16)	-0.077(-1.64)	-0.002(-1.04)	---
RDI3	-0.411(-8.57)*	0.062(0.46)	-0.113(-2.51)**	-0.039(-0.15)	-0.111(-2.48)*	-0.002(-1.14)	---
RDI4	-0.329(-6.97)*	-0.111(-0.86)	-0.183(-4.47)*	0.224(0.82)	-0.181(-4.44)	-0.001(-0.5)	---
RDI5	0.116(2.87)**	0.126(1.14)	0.385(11.95)*	0.232(0.96)	0.383(11.89)*	0.002(1.17)	---
FOS	0.815(11.84)*	0.294(2.28)**	0.952(42.53)*	0.530(3.33)*	0.951(42.57)*	0.0001(0.07)	-5.7(-0.02)
AGE	2.250(11.89)*	0.628(3.18)*	0.290(6.89)*	2.154(9.06)*	0.287(6.84)*	0.001(0.2)	0.675(1.44)
TECH	-0.509(-8.39)*	-0.378(-2.12)**	-0.277(-8.75)*	-0.200(-0.68)	-0.485(-9.52)*	0.005(1.4)	1.22(3.09)*
PBTI	-0.235(-7.75)*	-0.111(-1.18)	-0.487(-9.52)*	-0.357(-2.56)**	-0.278(-8.8)*	-0.003(-1.02)	---
HHI	-0.355(-11.63)*	-0.364(-4.45)*	-0.192(-10.61)*	-0.234(-2.4)**	-0.188(-10.48)*	-0.002(-0.94)	-0.43(-2.26)
PATPOL	5.919(48.21)*	5.089(19.81)*	4.049(39.45)*	9.566(20.97)*	3.975(39.48)*	0.002(0.47)	-1.02(-0.48)
ADVI	0.123(2.44)**	-0.021(-0.17)	0.087(1.95)***	0.256(1.34)	0.087(1.96)***	0.003(1.37)	---
SIZE	0.0001(8.98)*	0.0001(0.76)	0.0001(58.77)*	0.0001(8.48)*	0.0001(58.74)*	0.0001(0.4)	0.01(0.05)
PATEXP	1.134(16.42)*	1.932(12.51)*	0.176(2.64)**	14.711(13.84)*	0.130(1.95)***	0.015(4.86)*	---
ID	YES	YES	YES	YES	YES	NO	NO
Con	-8.114(-23.14)*	-4.765(-11.62)*	-1.440(-13.74)*	-9.686(-19.05)*	-1.373(-13.29)*	0.823()	-3.96(-3.5)*
Observations	8310	8310	8310	8310	722	855	8310
$Waldchi^2$	4917.83	564.73	--	--	--	--	--
vuong	--		12.28*	9.36*	--	--	--

Note: *, **,*** are 1%,5% and 10% level of significance.[@] The model considers only positive value and hence the number of observations are different from QD.

3.4.2.2. Impact of R&D and Patent Policy on Medium and High Technology Firms

The present section aims to distinguish between medium and high technology firms in the case of R&D impact on patenting. The separation of firm into high and medium- high tech helps us to understand the special nature of investment in R&D in these sectors and the influence of the same on the patenting behavior. We made the separation from the fact that 60% of patent application belong to high tech sector (7520 patent application out of 12444) and 40% having by medium-high tech sector. The findings of these two sectors are given in Table 3.5 and 3.6 respectively for the high tech and medium-high sectors. As the main motive of the chapter is to identify the contemporaneous and lagged influence of R&D on patenting, the section only interprets the coefficients of R&D and PATPOL only. However, the tables provide the results of other control variables also.

In case of high tech firms i.e. Table 3.5, the coefficients of contemporaneous R&D in Poisson and NEGBIN models are positive and significant, whereas it is positive in QD. All the other models that account for excess zeroes provide negative (columns 4&5) and significant (column 3) with respect to current R&D. Similar to full sample model, the fifth lag of R&D in all the models (column 1-6) are either positive and significant or positive. Therefore, we can affirm that high tech sectors are nested with full sample model as we get similar results in both cases. When we consider the relationship in the medium-high tech sector (Table 3.6), we find a contemporaneous significant relationship only in the case of QD model (column 6). The coefficient of current R&D is positive in column 2 &7. In the rest of the models, the relationship is either negative or negative and significant. In contrast to previous two models, overall and high tech sector, we could not find any positive influence of fifth R&D lag on the patenting behavior. The coefficient of PATPOL is positive and significant through columns 1-5. Since the coefficient of lagged dependent variable and current R&D is not significant in both medium and high tech sectors, it is not relevant to estimate the short run and long run elasticities.

To give a short summary of all the three tables (3.4, 3.5 and 3.6), based on various models present above, the overall model and high tech models are significant for contemporaneous R&D and in most of the cases fifth lag of R&D as well. In the case of medium-high tech firms, however, neither current nor fifth lag is significant. In all the three models, various lags of R&D become negative and significant. As our descriptive analysis shows distinct behavior of foreign and domestic firms in case of patenting, we undertake a separate analysis for these firms.

Table 3.5 Results of High Tech Firms: Impact of R&D and Patent Policy on Patenting

	Poisson(1)	NEGBIN(2)	ZIP(3)	ZINB(4)	ZTP(5) [@]	QD(6)	LFM(7)
$PAT_{(t-1)}$	---	---	---	---	---	---	0.05(0.57)
RDI	0.29(4.42)*	0.34(2.05)**	-0.35(-6.79)*	-0.47(-1.54)	-0.35(-6.61)	0.004(1.15)	1.23(0.238)
RDI1	0.02(0.21)	0.33(1.68)***	-0.03(-0.42)	0.52(1.36)	-0.03(-0.43)	0.002(0.59)	---
RDI2	-0.10(-1.52)	-0.02(-0.11)	0.04(0.6)	0.61(1.67)	0.04(0.68)	-0.004(-1.48)	---
RDI3	-0.59(-10.51)*	0.15(0.77)	-0.33(-6.02)*	0.14(0.41)	-0.34(-6.09)*	-0.003(-0.72)	---
RDI4	-0.54(-10.22)*	-0.22(-1.27)	-0.35(-6.6)*	-0.27(-0.79)	-0.35(-6.66)*	-0.002(-0.43)	---
RDI5	0.13(2.71)*	0.10(0.67)	0.61(14.08)*	0.28(0.92)	0.61(14.11)*	0.008(1.62)	---
FOS	0.62(4.37)*	0.36(2)**	1.02(31.94)*	1.27(4.59)*	1.02(32.2)*	-0.001(-0.26)	-0.55(-0.08)
AGE	3.11(10.98)*	1.01(3.91)*	-0.29(-5.43)*	1.72(5.99)*	-0.30(-5.48)*	0.002(0.54)	1.1(4.95)*
TECH	-2.42(-18.1)*	-1.24(-4.2)*	-2.02(-17.7)*	-1.66(-4.15)*	-1.91(-16.74)*	0.008(2.21)*	0.34(0.23)
PBTI	-0.21(-6.13)*	-0.11(-1.05)	-0.20(-5.59)*	-0.23(-1.18)	-0.20(-5.51)*	0.0001(0.1)	---
HHI	-1.46(-18.83)*	-0.72(-3.9)*	-1.55(-23.01)*	-1.56(-10.75)*	-1.45(-21.71)*	-0.002(-1.33)	-0.48(-1.51)
PATPOL	6.19(36.01)*	4.91(13.79)*	5.12(33.47)*	7.19(12.71)*	5.05(33.36)*	0.0001(0.04)	-0.66(-0.12)
ADVI	-0.05(-0.88)	-0.06(-0.36)	-0.24(-4.09)*	0.18(0.72)	-0.24(-4.14)*	0.0001(0.09)	---
SIZE	0.001(-2.3)**	0.001(-0.21)	0.001(20.74)*	0.001(-0.48)	0.001(20.34)*	0.0001(-0.6)	-0.13(-0.52)
PATEXP	1.20(9.86)*	1.93(8.12)*	-0.42(-3.63)*	5.63(6.24)*	-0.48(-4.16)*	0.015(3.65)*	---
Observations	1860	1860	1860	1860	370	413	1860
$Waldchi^2$	3594.73	335.03	--	--	--	--	--
Vuong	--	--	9.67*	9.03*	--	--	--

Note: *,**,*** are 1%,5% and 10% level of significance. [@] The model considers only positive value and hence the number of observations are different from QD.

Table 3.6 Results of Medium-High Tech Firms: Impact of R&D and Patent Policy on Patenting

	Poisson(1)	NEGBIN(2)	ZIP(3)	ZINB(4)	ZTP(5)[@]	QD(6)	LFM(7)
$PAT_{(t-1)}$	---	---	---	---	---	---	-0.04(-0.4)
RDI	-0.10(-1.2)	0.11(0.59)	-0.26(-4.25)*	-0.07(-0.27)	-0.26(-4.23)*	0.004(1.69)***	0.06(0.74)
RDI1	0.13(1.41)	-0.12(-0.59)	-0.04(-0.5)	0.13(0.4)	-0.04(-0.52)	-0.003(-1.67)	---
RDI2	-0.17(-1.85)***	-0.04(-0.22)	-0.37(-4.81)*	-0.25(-0.7)	-0.37(-4.84)*	0.001(0.55)	---
RDI3	0.14(1.51)	-0.07(-0.37)	0.38(5.16)*	-0.24(-0.65)	0.39(5.19)*	0.001(-0.2)	---
RDI4	0.49(5.3)*	-0.02(-0.13)	0.18(2.71)**	0.71(1.76)***	0.18(2.76)**	0.001(0.25)	---
RDI5	-0.33(-4.01)*	0.15(0.92)	-0.15(-2.62)**	0.24(0.69)	-0.15(-2.64)**	-0.001(-0.58)	---
FOS	0.84(9.67)*	0.29(1.48)	0.71(19.63)*	0.73(3.05)*	0.70(19.45)*	0.003(1.04)	0.62(2.59)**
AGE	2.11(7.11)*	0.01(0.03)	1.24(12.75)*	2.11(5.42)*	1.28(12.73)*	-0.002(-0.54)	2.04(2.81)**
TECH	0.31(3.84)*	0.39(1.52)	0.001(-0.04)	0.44(0.98)	0.001(-0.06)	0.001(0.07)	0.28(0.97)
PBTI	-0.11(-1.63)	-0.09(-0.53)	-0.51(-6.92)*	-0.29(-1.41)	-0.51(-6.93)*	-0.007(-1.49)	---
HHI	-0.26(-6.92)*	-0.44(-4.45)*	-0.10(-4.75)*	0.03(0.23)	-0.10(-4.81)*	-0.002(-0.7)	0.06(0.42)
PATPOL	5.34(28.63)*	4.91(12.19)*	2.13(14.22)*	10.73(14.35)*	2.10(14.16)*	0.004(1.49)	2.28(3.15)*
ADVI	0.92(9.88)*	0.15(0.76)	0.88(15.78)*	0.49(1.76)*	0.90(15.98)*	0.006(1.37)	---
SIZE	0.001(9.15)*	0.001(0.9)	0.001(45.94)*	0.001(6.26)*	0.001(45.8)*	0.001(0.26)	-0.02(-0.15)
PATEXP	1.08(12.34)*	2.03(9.72)*	0.20(2.36)**	19.52(9.64)*	0.18(2.14)*	0.014(3.71)*	---
Con	-7.41(-15.87)*	-4.06(-7.64)*	-1.62(-8.86)*	-9.51(-12.19)*	-1.67(-8.95)*	0.83(166.6)*	-5.76(-6.66)*
Observations	6450	6450	6450	6450	352	442	6450
$Waldchi^2$	1945.83	273.99	--	--	--	--	--
vuong	--	--	8.67*	5.6*	--	--	--

Note: *,**,*** are 1%,5% and 10% level of significance. [@] The model considers only positive value and hence the number of observations are different from QD.

3.4.2.3. Impact of R&D and Patent Policy on Foreign and Domestic Firms

The findings of foreign and domestic firms are given in Tables 3.7 and 3.8 respectively. Table 3.7 shows that the coefficient of fifth lag of R&D is positive and significant in most of the cases. In NEGBIN and ZINB models (columns 2 & 4) first and fifth lag of R&D are positive but not significant. In all the models, second and third lags are negative and significant in columns 1, 3 and 5. The negative significant coefficient is explained on the ground that foreign firms have the access of technological development from their parent institution. Considering that the expenditure incurred by the foreign firms is used for the developmental activities instead of research activities, the results are justified. Table 3.8 shows the results of the similar analysis in the case domestic firms. It shows that in Poisson, ZIP, ZINB and ZTP models, the coefficients of first, second and fifth lags of R&D is positive and significant. These results indicate that there is a 'tilde' shape relationship between R&D and patenting. This result indicates that on an average it took five years to convert an investment in R&D into patent. Further, second, third and fourth lags of R&D do not contribute to the patenting of firms. The results further highlight the importance of present year and first lag of R&D for a successful completion of patent. The difference in the results of foreign and domestic firms shows the distinct behavior of these firms as expected.

In case of foreign firms due to the insignificant coefficient of both R&D and lagged dependent variable, the elasticities are not estimated in LFM. However, as the estimated relationship is significant in domestic firms the elasticities are calculated. The contribution of R&D to patenting is depreciating at the rate of 91%. Further, there is an indication of lag effect as the long run elasticity (0.53) is higher than short run (0.48) elasticity.

Table 3.7 Foreign Firms: Impact of Various R&D Lags on Patenting

	Poisson(1)	NEGBIN(2)	ZIP(3)	ZINB(4)	ZTP(5)	QD@	LFM
$PAT_{(t-1)}$	---	---	---	---	---	---	0.03(0.46)
RDI	-0.023(-0.32)	0.35(1.64)	-0.85(-15.39)*	0.11(0.21)	-0.63(-11.31)*	0.004(0.84)	0.48(0.33)
RDI1	0.129(1.63)	-0.27(-1.15)	0.001(-0.04)	-0.12(-0.17)	-0.05(-0.66)	0.003(.59)	---
RDI2	-0.099(-1.39)	0.04(0.15)	0.03(0.43)	0.47(0.73)	0.04(0.65)	-0.005(-0.85)	---
RDI3	-0.776(-11.81)*	-0.40(-1.69)***	-0.07(-1.17)	-0.38(-0.64)	-0.22(-3.56)*	-0.008(-1.12)	---
RDI4	-0.254(-4.07)*	0.09(0.44)	-0.16(-3.34)*	0.01(0.01)	-0.21(-4.08)*	0.003(0.46)	---
RDI5	0.336(6.06)*	0.06(0.31)	0.72(18.13)*	0.27(0.62)	0.60(14.38)*	0.008(1.11)	---
AGE	7.581(10.98)*	2.04(2.84)**	-0.65(-8.67)*	4.61(7.16)*	-0.05(-0.65)	0.008(0.59)	2.82(3.06)*
TECH	0.030(0.35)	-0.01(-0.03)	-1.17(-16.36)*	-2.60(-3.36)*	-1.16(-15.35)*	0.02(1.83)***	1.07(0.73)
PBTI	0.234(3.45)*	0.07(0.3)	0.28(5.02)	0.06(0.14)	0.40(7.26)*	0.005(1.01)	---
HHI	-0.326(-7.78)*	-0.26(-2.12)**	-0.56(-21.59)*	-1.98(-9.29)*	-0.37(-13.15)*	-0.003(-2.43)**	-0.13(-0.22)
PATPOL	5.006(24.65)*	5.20(11.57)*	4.58(33.47)*	12.44(12.53)*	4.44(32.53)*	0.005(0.5)	-0.43(-0.13)
ADVI	-0.512(-4.3)*	-0.85(-2.36)*	-0.92(-8.59)*	-0.71(-1.11)	-1.24(-11.34)*	-0.002(-0.59)	---
SIZE	0.0001(-1.66)	0.001(0.12)	0.001(19.26)*	0.001(0.5)	0.001(30.73)*	0.0001(1.33)	0.3(0.53)
PATTEXP	0.562(5.41)*	0.77(3.12)*	-0.31(-3.38)*	17.84(8.23)*	-0.07(-0.8)	0.02(3.15)*	---
Constant	-14.271(-13.06)*	-6.18(-4.88)*	0.05(0.29)	-18.81(-13.73)*	-0.99(-5.7)*	0.8(36.76)*	-5.95(-4.74)
Observations	1548	1548	1548	1548	227	248	1548
Waldchi2	2903.290	197.14	---	---	---	---	---
vuong	---	---	9.35*	8.54*	---	---	---

Note: *,**,*** are 1%,5% and 10% level of significance. @ The model considers only positive value and hence the number of observations are different from QD.

Table 3.8 Domestic Firms: Impact of Various R&D Lags on Patenting

	Poisson	NEGB	ZIP	ZINB	ZTP@	QD	LFM
$PAT_{(t-1)}$	---	---	---	---	---	---	0.09(4.59)*
RDI	0.55(6.59)*	0.17(1.12)	0.27(4.36)*	-0.39(-1.86)***	0.24(3.9)*	0.003(2.34)**	0.53(3.37)*
RDI1	0.56(6.06)*	0.19(1.12)	0.31(4.22)*	0.79(2.92)**	0.27(3.73)*	-0.001(-1.06)	---
RDI2	0.07(0.88)	0.11(0.68)	-0.04(-0.65)	-0.13(-0.4)	-0.06(-0.87)	-0.0001(-0.09)	---
RDI3	0.14(1.89)**	0.20(1.29)	0.07(1.09)	0.26(0.86)	0.04(0.56)	0.0001(0.09)	---
RDI4	-0.18(-2.4)	-0.22(-1.49)	0.02(0.29)	0.37(1.18)	-0.02(-0.35)	-0.003(-1.93)	---
RDI5	0.14(2.28)**	0.28(2.18)*	0.09(1.66)***	0.54(1.94)**	0.09(1.73)*	0.009(0.67)	---
AGE	2.20(9.98)*	0.64(3.07)*	0.51(10.56)*	1.76(7.14)*	0.52(10.72)*	-0.001(-0.3)	0.45(1.71)***
TECH	-0.12(-1.12)	-0.54(-2.45)**	0.37(4.63)*	0.57(1.67)*	0.34(4.36)*	0.001(0.33)	0.89(3.49)*
PBTI	-0.33(-9.93)*	-0.15(-1.48)	-0.48(-12.22)*	-0.31(-2.04)**	-0.48(-12.39)*	-0.004(-1.36)	---
HHI	-0.43(-7.85)*	-0.46(-4.64)*	0.12(4.66)*	-0.15(-1.21)	0.15(6.03)*	-0.001(-0.54)	-0.68(-2.84)
PATPOL	4.93(27.72)*	4.79(14.54)8	3.16(20.34)*	8.65(16.29)**	3.19(20.73)*	0.0002(0.08)	0.9(2.07)
ADVI	0.38(6.57)*	0.11(0.79)	0.27(5.92)*	0.06(0.27)	0.26(5.65)*	0.004(1.64)	---
SIZE	0.001(9.92)*	0.001(0.45)	0.001(25.21)*	0.001(5.14)*	0.001(26.2)*	0.00001(0.12)	-0.06(-0.3)
PATEXP	2.15(20.86)*	2.80(14.67)*	0.38(4.02)*	13.12(10.02)*	0.42(4.38)*	0.01(3.93)*	---
Constant	-7.17(-17.83)8	-4.88(-10.41)*	0.14(1)	-7.29(-11.8)*	0.07(0.5)	0.83(162.5)*	-5.28(-7.26)*
Observations	6762	6762	6762	6762	495	607	6762
Waldchi2	2344.91	419.18	---	---	---	---	---
vuong	---	---	9.7*	8.18*	---	---	---

Note: *,**,*** are 1%,5% and 10% level of significance.@ The model considers only positive value and hence the number of observations are different from QD.

3.4.2.4. The Sector Specificity of R&D Lags on Patenting

Recognizing the sector specificity in R&D and patenting behavior, the present section makes a separate analysis of each industry to understand the relationship between them. We consider three sectors that include pharmaceutical, chemical and machinery industries. Selection of these sectors is further justified from the patent application status. These three sectors together contribute 88 per cent of total patent application by medium and high tech industries (59% by pharmaceutical, 18% by chemical and 11% by machinery sector). Rest of the 12% is distributed among the 7 sectors and an analysis based on these numbers does not provide convergent results of the count data models.

Industry specific results are given through Table 3.9-3.11 respectively for pharmaceutical, chemical and machinery industries. The aim of the section is to see whether there is any significant difference than what we established before. One of the main finding is that machinery sector provides a year to year relationship between R&D and patenting in all the models except LFM. Unlike pharmaceutical sector, the machinery sector does not require long clinical trials which necessitate continues investment in R&D spanning over a period of time. Therefore, recent R&D is more significant in this sector. In most of the cases, pharmaceutical sector shows an evidence of first and fifth lag of R&D becoming positive and significant for patenting. In case of chemical sector, however, we cannot reach any specific conclusion. The ZTP model provides comparatively better results as the third, fourth and fifth lags of R&D is positive and significant on patenting. The above discussion shows that the relationship between lagged R&D and patenting varies across the different industries as expected. Each sector has their own specificity and the results of the sectors vary accordingly. Further, we don’t calculate the elasticities as there is no significant relationship in lagged dependent variable.

Table 3.9 Results of Pharmaceutical Sector

	Poisson	NEGBIN	ZIP	ZINB	ZTP[@]	QD	LFM
$PAT_{(t-1)}$	---	---	---	---	---	---	0.02(0.48)
RDI	0.35(5.29)*	0.38(2.15)**	-0.30(-5.47)*	0.11(0.37)	-0.30(-5.44)*	0.003(0.86)	0.95(2.19)*
RDI1	-0.06(-0.84)	0.24(1.20)	-0.13(-1.82)***	0.07(0.20)	-0.13(-1.85)***	0.0001(0.15)	---
RDI2	-0.14(-2.17)**	-0.08(-0.39)	0.01(0.10)	0.36(1.21)	0.01(0.13)	-0.003(-1.00)	---
RDI3	-0.61(-10.78)*	0.06(0.29)	-0.32(-5.80)*	-0.11(-0.39)	-0.33(-5.85)*	-0.002(-0.60)	---
RDI4	-0.57(-10.86)*	-0.26(-1.52)	-0.37(-6.90)*	-0.79(-2.66)**	-0.36(-6.84)*	-0.001(-0.30)	---
RDI5	0.11(2.20)**	0.06(0.40)	0.63(14.47)*	0.42(1.63)	0.63(14.44)*	0.01(2.12)**	---
FOS	0.42(2.88)**	0.31(1.68)***	1.01(31.07)*	1.78(8.14)*	1.01(31.11)*	0.0001(0.04)	0.58(0.61)
AGE	3.30(11.11)*	0.93(3.57)*	-0.38(-6.85)*	0.24(0.97)	-0.39(-7.07)*	0.003(0.84)	0.88(4.08)*
TECH	-2.96(-20.05)*	-1.90(-4.62)*	-2.57(-18.15)*	-2.79(-4.28)*	-2.56(-18.04)*	0.001(0.10)	0.68(0.43)
PBTI	-0.22(-6.34)*	-0.13(-1.26)	-0.21(-5.76)*	-0.21(-1.17)	-0.21(-5.79)*	0.0001(-0.04)	---
HHI	-1.87(-21.11)*	-1.06(-4.51)*	-1.94(-24.17)*	-1.56(-3.82)*	-1.94(-24.12)*	-0.02(-3.20)*	-0.04(-0.17)
PATPOL	6.14(34.83)*	5.06(13.69)*	5.20(31.91)*	7.28(14.33)*	5.17(31.83)*	0.005(0.75)	0.67(0.36)
ADVI	-0.16(-2.56)**	-0.08(-0.51)	-0.28(-4.77)*	0.07(0.30)	-0.28(-4.84)*	0.001(-0.31)	---
SIZE	0.001(2.10)**	0.001(1.89)***	0.001(21.11)*	0.001(5.75)*	0.001(21.15)*	-0.0001(-1.02)	-0.19(-1.19)
PATEXP	1.31(10.64)*	1.99(8.30)*	-0.35(-2.95)**	4.64(6.44)*	-0.42(-3.44)*	0.014(3.85)*	---
Con	-11.94(-19.51)*	-7.26(-8.13)*	-6.23(-20.30)**	-8.05(-5.65)*	-6.19(-20.20)*	0.77(42.10)*	-2.56(-2.54)**
Observations	1335	1335	1335	1335	352	389	1335
Waldchi2	3640.63	357.78	--	--	--	--	--
vuong	--	--	10.61*	9.47*	--	--	--

Note: *,**,*** are 1%,5% and 10% level of significance. [@] The model considers only positive value and hence the number of observations are different from QD.

Table 3.10 Results of Chemical Sector

	Poisson	NEGBIN	ZIP	ZINB	ZTP@	QD	LFM
$PAT_{(t-1)}$	---	---	---	---	---	---	0.004(0.02)
RDI	-0.02(-0.19)	0.15(0.68)	-0.06(-0.50)	1.71(3.94)*	-0.06(-0.50)	0.001(0.5)	0.08(0.34)
RDI1	-0.39(-3.19)*	-0.36(-1.42)	-0.32(-2.50)**	-0.14(-0.32)	-0.33(-2.54)**	-0.001(-0.45)	---
RDI2	-0.23(-2.04)**	-0.17(-0.71)	0.02(0.18)	-0.13(-0.31)	0.02(0.14)	0.001(0.49)	---
RDI3	0.11(0.93)	0.02(0.07)	0.56(5.40)*	-0.38(-0.94)	0.57(5.51)*	0.0001(0.05)	---
RDI4	0.16(1.24)	0.03(0.11)	0.33(3.70)*	-0.12(-0.27)	0.33(3.69)*	0.0004(0.3)	---
RDI5	-0.08(-0.73)	0.08(0.38)	0.16(2.03)**	0.09(0.22)	0.16(2.05)*	-0.001(-1.03)	---
FOS	0.68(3.01)*	0.54(1.17)	2.16(22.65)*	2.84(7.72)*	2.17(22.52)*	0.002(1.18)	---
AGE	8.60(6.15)*	1.97(2.00)*	-0.39(-2.09)**	4.80(7.09)*	-0.39(-2.12)**	-0.0004(-0.37)	1.65(2.06)*
TECH	0.46(4.20)*	0.55(1.71)*	0.30(2.77)**	0.83(1.48)	0.30(2.75)**	0.009(2.13)**	-0.06(-0.1)
PBTI	-0.04(-0.23)	-0.08(-0.28)	0.26(1.45)	0.37(0.82)	0.26(1.42)	0.0008(0.52)	---
HHI	-0.12(-2.20)**	-0.26(-2.03)**	-0.25(-5.46)*	-0.79(-2.72)**	-0.25(-5.45)*	-0.0001(-0.06)	0.21(0.87)
PATPOL	4.50(13.03)*	5.95(8.10)*	4.27(16.72)*	7.57(5.88)*	4.25(16.63)*	0.0016(0.36)	3.63(3.25)*
ADVI	0.34(1.35)	0.65(1.47)	0.96(5.03)*	0.03(0.05)	0.96(4.97)*	-0.0007(-0.35)	---
SIZE	0.001(0.09)	0.001(-1.37)	0.001(24.35)*	0.001(2.12)**	0.001(24.39)*	0.0001(0.55)	-0.28(-0.87)
PATEXP	0.95(7.61)*	1.74(4.78)*	0.09(0.71)	23.20(8.01)*	0.07(0.57)	0.012(1.88)***	---
Con	-17.26(-9.05)*	-6.86(-4.75)*	-1.08(-3.29)*	-16.45(-10.90)*	-1.06(-3.23)*	0.83(191.8)*	-5.74(-3.4)*
Observations	2805	2805	2805	2805	120	150	2805
Waldchi2	836.58	126.51	---	---	---	---	----
vuong	---	---	6.19*	7.92*	---	----	---

Note: *,**,*** are 1%,5% and 10% level of significance. @ The model considers only positive value and hence the number of observations are different from QD.

Table 3.11 Results of Machinery Sector

	Poisson	NEGBIN	ZIP	ZINB	ZTP@	QD	LFM
$PAT_{(t-1)}$	---	---	---	---	---	---	0.02(0.21)
RDI	0.80(6.24)*	0.37(1.84)***	0.53(4.89)*	0.59(1.28)	0.52(4.87)*	0.004(2.04)**	-0.26(-1.15)
RDI1	0.15(0.82)	-0.37(-1.37)	0.16(1.00)	0.36(0.54)	0.18(1.10)	-0.002(-1.02)	---
RDI2	-0.41(-1.72)***	0.08(0.23)	-0.70(-4.01)*	-0.99(-1.24)	-0.71(-4.06)*	-0.002(-1)	---
RDI3	-0.81(-3.10)*	-0.62(-1.68)***	-0.60(-3.52)*	-0.37(-0.44)	-0.59(-3.51)*	-0.002(-0.78)	---
RDI4	0.54(2.04)**	0.01(0.03)	0.82(5.83)*	1.34(1.61)	0.82(5.77)*	0.003(1.54)	---
RDI5	-0.11(-0.42)	-0.33(-1.16)	0.13(1.00)	1.07(1.40)	0.13(0.97)	0.001(0.39)	---
FOS	-0.43(-1.51)	-0.02(-0.05)	-0.65(-7.56)*	-1.95(-4.31)*	-0.65(-7.61)*	-0.002(-1.62)	0.51(1.59)
AGE	2.52(0.47)	2.82(1.86)***	-0.71(-2.48)**	8.79(5.70)*	-0.69(-2.47)**	-0.002(-0.58)	1.69(6.14)
TECH	2.27(4.97)*	1.88(3.92)*	1.51(6.34)*	0.59(0.47)	1.51(6.36)*	0.014(2.03)**	-0.42(-0.62)
PBTI	-0.04(-0.50)	-0.07(-0.26)	-0.49(-5.28)*	-0.32(-0.97)	-0.49(-5.29)*	-0.002(-0.64)	---
HHI	2.26(3.68)*	1.34(3.46)*	1.26(8.53)*	2.99(3.73)*	1.25(8.47)*	-0.001(-0.17)	-0.71(-0.64)
PATPOL	4.71(3.22)*	3.20(4.96)*	2.42(7.96)*	7.16(4.23)*	2.37(7.90)*	0.005(0.94)	1.47(1.5)
ADVI	0.37(2.60)**	-0.08(-0.33)	0.22(3.82)*	0.10(0.23)	0.23(3.86)*	0.001(0.54)	---
SIZE	0.001(-5.53)*	0.001(-1.97)***	0.001(15.41)*	0.001(1.92)***	0.001(15.45)*	0.0001(-1.46)	-0.26(-0.15)
PATEXP	3.24(11.25)*	2.83(7.10)*	0.47(2.01)**	18.23(4.81)*	0.41(1.77)***	0.008(2.37)**	---
Con	8.71	-1.90(-0.67)	5.81(9.07)*	-8.08(-2.22)**	5.79(9.10)*	0.833(42.9)*	-7.12(-2.04)**
Observations	1440	1440	1440	1440	113	133	1440
Waldchi2	802.98	169.01	--	--	--	--	--
vuong	--	--	4.72*	3.33*	--	--	--

Note: *,**,*** are 1%,5% and 10% level of significance. @ The model considers only positive value and hence the number of observations are different from QD.

3.5. Conclusion

This chapter attempts to learn about the gestation lags in knowledge production of investment activities by high and medium- high tech firms in India. We study the relationship of current and different lags of R&D and patent policy changes with respect to patenting. We find that the results vary according to the econometric specification and the nature of the industry. The study finds that ownership vis-à-vis foreign and domestic, matters for the innovative activities. Further, the industry specificity of the innovative activity has an influence on the relationship between lagged R&D and patenting. Machinery sector has a year to year relationship between R&D and patenting, whereas pharma and chemical sectors do not provide such relationship.

Chapter 4

Impact of R&D and Patenting on the Performance of Firm

4.1. Introduction

In the previous chapters, we studied the determinants of innovative activity of the firms. Firstly, we considered the factors that influence the R&D expenditure of firms and concomitantly it's patenting activity. Secondly, we studied the relationship between lagged R&D and patenting in detail by employing different econometric techniques. Innovation is the key factor for firms' success, survival and sustainable competitive advantage (Wolfe 1994; Bartel and Garud 2009). Firm's innovation plays a major role in enhancing its performance (Mokyr 2010). The production of innovation and the link with firms' performance is theoretically and empirically well established in economic literature (Crepon et al.1998; Hall and Sena 2014). Therefore, in this chapter we study the impact of innovative activities undertaken by firms in its performance.

The rest of the chapter is organized into 5 sections. Section 4.2 briefly explains the theory and literature related to innovation and performance. Section 4.3 provides an overview of the research methodology applied in the study. Subsections 4.3.1-4.3.3 provide a brief description of various TFP estimation and econometric technologies applied in this study. Section 4.4 focuses on description of data and variables used in the study. Section 4.5 presents the results and analysis and in section 4.6 the chapter offers a brief synthesis of the results. Finally, section 4.7 offers concluding remarks highlighting the key findings.

4.2. Literature Review

An explanation of the relationship between firm level innovation and performance is initiated from the seminal work of Schumpeter (1942). He argues that firm that introduces innovative product in the market faces limited competition and enjoys relatively high profits. However, over time this profit can wear away due to imitation and competition, but firms that engage in continuous innovation can retain the profit for a sustained period (Varis and Littunen 2010). Measurement of innovation and firm performance are multidimensional concepts. Existing studies have used wide measures of innovation that are related to product, process, organization and marketing (Gunday et al.2011). Similarly, the indicators of firm performance can be production, finance, marketing or profits (Sohn et al.2007; Wolff and Pett 2006). In this study, we use patent granted to medium and high tech firms in India along with stock of R&D as a measure of innovation to test the impact on different performance variables.

4.2.1. Review based on Performance Indicators

To assess the performance of firms, we employ three indicators namely, productivity, profitability and Tobin's *q*, with each representing different aspects of performance that are discussed below (Jaffe 1986; Bosworth and Rogers 2002; Griffith et al.2005; Stierwald A 2010). The choice of the different measures of performance is justified considering that patent data may include both process and product innovation (Geroski et al.1993; Gunday et al.2011)[22]. Introduction of a new product or significant improvement in the existing one represents product innovation that is likely to increase the profitability whereas process innovation entails cost cutting and productivity improvement (Fagerberg et al.2004; OECD Oslo Manual 2005). Therefore, productivity is one way to measure the process

[22]Oslo manual define innovations in four ways; product, process, marketing and organizational innovation. We restrict to product and process innovation.

innovation of firms and profitability for product innovation. The existing literature on firm level productivity establishes either a direct link between R&D and productivity (Mansfield 1984; Griliches and Mairesse 1984; Raut 1995; Sharma 2010 & 2011) or an indirect link between R&D and productivity through patenting (Deolalikar and Roller 1989; Eaton and Kortum 1996; Crepon et al. 1998).

Product innovation by introducing new product/s aims to maintain a temporary monopoly in the market and makes profit in the current period as well as raises the margins of expected profit in the future (Sagerstrom 1991). Profitability is the most accepted measure of performance as it evaluates appropriability condition of a firm's investment (Hansen and Wernerfelt 1989). Though the accounting measure of performance is debatable, it is still commonly used (Benston 1985; Jacobson 1987). The current profit at all the time may not be a pure indicator of firm performance since the investments made lowers the current profit. Therefore, the present study also employs Tobin's *q* (a proxy for expected profit) as a performance indicator (Bharadwaj et al. 1999; Dybvig and Warachka 2012).

4.2.2. R&D, Patenting, Productivity and Financial Performance

Theories on technological innovation at the firm level consider that both research input in the form of R&D investment and output (intermediate) in the form of patent contribute to the higher productivity (Kamien and Schwartz 1982; Griliches 1987; Crepon et al. 1998). Many studies provide evidence of the structural relationship between R&D investment and patenting where R&D leads to innovation output in the form of patenting and the patents further contribute to the productivity (Deolalikar and Roller 1989; Crepon et al. 1998; Griffith et al. 2006; Santarelli and Lotti 2008). However, studies like Black and Lynch (1996); Ballot et al (2001) and Benavente (2006) find that innovation measures in terms of R&D or patenting is either negatively related to productivity or does not provide a strong link between them.

Patenting is a profit maximizing strategy either leading to sales revenue maximization or cost reduction (Van-Triest and Vis 2007). In developed economies, the relationship between firm's financial performance and patenting is empirically established and is positive and significant (Scherer 1965a; Jaffe 1986; Narin et al. 1987; Geroski et al. 1993; Harhoff et al.1999) but a few studies find that the relationship is either negative (Hall, Jaffe and Trajtenberg 2005) or non-existing (Griffith et al.2005; Loof and Heshmati 2006). Jaffe (1986) finds that the patent has negative spillover effect on profitability of innovating firms if the neighboring firms are more research intensive. Some studies that measure the impact of patenting on Tobin's *q* confirms a positive and significant relationship (Bosworth and Rogers 2002; Bloom and Van Reenen 2002; Hall et al. 2007) however, Neuhausler et al. (2011) and Sandner and Block (2011) could not find any significant influence of patenting on the Tobin's *q*.

The existing empirical evidence for developing nations is also not as conclusive. For example, though studies conducted in Brazil and Mexico (Raffo et al.2008) and in six Latin American countries find a significant impact of innovation on the productivity of firms (Crespi and Zuniga 2012) the studies based in Argentina (Raffo et al.2008) and Brazil (Goedhuys 2007) fail to establish the relationship. Further, there remains a scarcity of literature that considers the effect of granted patents on the performance of firms in the developing countries, especially in Indian context. Therefore, the present study evaluates the impact of innovation on the performance of firms through a developing country's perspective.

In Indian context, the present study is important because increasing R&D expenditure and patent application brings constructional and technological changes in firms and industry, which further leads to the development of economy. Therefore, it is necessary to study the relationship between R&D expenditure, patent counts and economic performance of firms to see the innovation influence on the development of the economy in general and firms in particular. Moreover, in the context of India, there are studies that evaluate the influence of innovation on the performance of firms (Goldar 1986b; Raut 1995; Sharma 2010& 2011). However, all of them concentrate on R&D expenditure as a proxy for innovation leaving the impact of patenting on firms' performance unexplored (Deolalikar and Roller 1989 is an exception but their study is based on 1974-79 data). Further, according to WIPO (2011), annual average growth rate of patenting in India has accelerated from 2.8% in 1985-1986 to 7.2% in 2009-2010 implying that firms in India (domestic and foreign) are increasingly using patents as an appropriation mechanism.

4.3. Research Methodology

To estimate the TFP of medium and high technology firms, the present study considers a production function approach. Production function is carried out by Levinsohn and Petrin (LP) method, which is a semi parametric method. It is non-frontier approach that considers technological progress as a measure of productivity. Frontier approach is other way to measure the productivity of firms. This approach identifies the maximum attainable position given the input or the prices by a firm. Then it compares the existing firms' vis-à-vis the benchmarked firms. Further, the frontier approach helps to elucidate the role of technical efficiency in the overall performance of firms. Since the objective of the study is to estimate the impact of technological factors on TFP, we chose the non-frontier approach (Kathuria et al. 2013). To estimate the impact of patenting on TFP we follow a two-stage approach in which the first stage involves the specification and estimation of TFP and the second stage employs appropriate econometric models to determine the calculated TFP (Fethi et al. 2000).

4.3.1. Levinsohn and Petrin (LP) Method

The TFP estimation in the current study is based on an augmented Cobb-Douglas production function. The estimation includes material input as an additional explanatory variable apart from the basic labour and capital in the function. Production function estimation with Ordinary Least Squares (OLS) gives inconsistent and biased estimators as there is likely to be a correlation between inputs and unobserved firm specific productivity. Any productivity estimation without considering these unobserved inputs is therefore biased and leads to endogenity (Kim 2007). To address the issue of endogenity researchers have relied on several methodologies like Instrumental Variable (IV) method, Fixed Effect (FE) Model, Generalized method of Moment (GMM) estimator and semi parametric estimators developed by Olley and Pakes [(1996) (OP)] and Levinsohn and Petrin [(2003) (LP)] methods.

OP method estimates the parameters of the production function with two inputs namely labour and capital and these parameters are used to analyze the firms' performance. The consistent estimates of a production function depend on how the issues related to the selection and simultaneity problems have been resolved. Selection problem arises from the interrelationship between unobserved productivity and the firms' shutdown decision. Simultaneity on the other hand, depends on the relationship between productivity and input decision. By introducing investment as a proxy variable in the production function, OP method addresses both the above issues. The proxy controls the errors associated with inputs. However, the monotonicity condition of OP method insists that investment is strictly increasing in productivity. In case a firm reports zero investment for a significant number of cases it can lead to the doubt about the efficiency and validity of the monotonicity condition. LP (Levinsohn and Petrin 2003) method on the other hand, is an extension of OP method where labour is the free variable and capital is the quasi fixed variable. Instead of investment as proxy variable, LP method employs material as a proxy to control for unobservable. The advantage is that firms usually report materials and therefore it is easy to retain most of the observations. Further, GMM and IV approach is normally used in the case of dynamic panel data models. Thus, we use LP method for current research.

We can express the production function in log based on Levinsohn and Petrin (2003) method as follows:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \eta_{it} \qquad (4.1)$$

Where, y is output, l is labour, k is capital and m is material. The error term has two parts, the productivity component ω_{it} and η_i, an error term that is not correlated with input choices. We assumes that material, the proxy variable, is the function of productivity (ω) and the state variable (k). Therefore, the material demand function is given by

$$m_{it} = s_{it}(\omega_t, k_{it}) \qquad (4.1.1)$$

The demand function ensures monotonicity i.e m is strictly increasing in ω and one can revert the material demand function as

$$\omega_{it} = s_{it}(m_{it}, k_{it}) \qquad (4.1.2)$$

The unobserved productivity term is now expressed as a function of two observed inputs. Using this expression (4.1.2), equation (4.1) can be rewritten as

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + s_{it}(m_{it}, k_{it}) + \eta_{it} \qquad (4.2)$$

By re ordering equation (4.2) we obtain

$$y_{it} = \beta_l l_{it} + \phi_{it}(m_{it}, k_{it}) + \eta_{it} \qquad (4.2.1)$$

Where

$$\phi_{it}(m_{it}, k_{it}) = \beta_0 +_k \beta_k k_{it} + s_t(m_{it}, k_{it}) \qquad (4.2.2)$$

In LP method the above equation is usually estimated through two stages. In the first stage, the estimators linear in l_{it} and non parametric in ϕ_{it} is used to obtain a consistent estimate of β_l. In the second stage, by obtaining the estimated values for ϕ_{it}, the coefficients of β_k and β_m are calculated. Finally, the authors estimate productivity in levels ($\hat{\omega}_{it}$) using

$$\hat{\omega}_{it} = \exp(y_{it} - \hat{\beta}_l l_{it} - \hat{\beta}_k k_{it} - \hat{\beta}_m m_{it}) \qquad (4.3)$$

4.3.2. Impact of R&D and Patenting on TFP

The scores of TFP obtained through LP method is further regressed with appropriate models. To evaluate the impact of R&D and patenting on the productivity of firms we rely on FE method and Feasible generalized least square (FGLS) estimation. While applying fixed effect model, we can control the problem of endogenity from unobservable (Chudnovsky et al. 2006). First differencing of observable variable eliminates individual fixed effects (Kyriazidou 1997). In order to control for time varying unobservable, we introduce time trend in the model (Chudnovsky et al. 2006). Finally, we introduce industry dummy to control the sectoral aspects. In the model, however, there exists a problem of heteroskedasticity. To solve this issue, we follow FGLS model that fits for panel data linear regression in the presence of autocorrelation, cross sectional correlation and heteroskedasticity (Carter et al. 2008). The estimated model is given below;

$$\log(TFP_{it}) = \log PAT_{it} + \log RDS_{it} + X_{it} + \varepsilon_{it} + \upsilon_{it} \qquad (4.4)$$

Where, TFP is the total factor productivity estimated by LP method. PAT and RDS are the stock of patent and R&D, X_{it} is the vector of firm specific as well as industry specific variables, ε_{it} is the industry effect and υ_{it} is the unobservable random shocks, i represent firms and t is time. In order to check the likely occurrence of multicollinearity between RDS and PAT, we introduce these variables separately in the model.

4.3.3. Impact of R&D and Patenting on Financial Variables

To estimate the impact of patenting on financial performance of firms, we rely on two measures; profitability (ratio of profit before tax to sales) and Tobin's *q* ratio (the ratio of the market value of a company to its physical value (Wolfe and Sauaia 2003)). Profitability measures the year to year patent performance whereas Tobin's *q* access the relationship between patent and the firm's future performance potential (Lang and Litzenberger 1989). For a firm, the long- run equilibrium market value must be equal to the replacement value of its assets which gives the value of *q* close to unity. Any deviation from unity (greater than 1) signifies the influence of intangible assets such as R&D, patent, advertising and brand equity enjoyed by the firm (Megna and Klock 1993, Hall 1993). Chung and Pruitt (1994) also underline the usefulness of Tobin's *q* to explain a number of corporate phenomena that includes the firm value as well.

Tobin's *q* is the ratio of market value of a firm to its replacement cost. The initial calculation of Tobin's *q* put forth by Lindenberg and Ross (1981) has some computational difficulties (Chung and Pruitt 1994). These difficulties are in the form of data obligation and computational effort. Therefore, we adopt the modified version of the Tobin's *q*, that is a close approximate of the original formulation[23] (Chung and Pruitt 1994; Wolfe and Sauaia 2003). Therefore,

$$q = (MVS + D)/TA \qquad (4.5)$$

Where, MVS is the market value of all outstanding shares, which is the product of a firm's stock price and outstanding shares, TA is the firm's total assets which include cash, receivable, inventory and book value and D is the debt which is defined as

$$D = (AVCL - AVCA) + AVLTD \qquad (4.5.1)$$

Where, AVCL, AVCA and AVLTD respectively represents accounting values of firm's current liabilities, current assets and long term debts. Therefore, we have two separate equations (4.6 & 4.7) of financial performance where *q* represents Tobin's *q* ratio and pbti represents profitability of firms. Both of these methods use FGLS regression techniques as explained in the previous section.

$$\log(q_{it}) = \log PAT_{it} + \log RDS_{it} + X_{it} + \varepsilon_{it} + \upsilon_{it} \qquad (4.6)$$

$$\log(pbti_{it}) = \log PAT_{it} + \log RDS_{it} + X_{it} + \varepsilon_{it} + \upsilon_{it} \qquad (4.7)$$

4.4 Data and Variable Description

The research setting of the study is the firms from medium and high technology industries in India that are research intensive. Particularly, we focus on firms which are producing consistent data on input and output variables. The main source of data for our study is the website of Controller General of Design, Trademark and Patent (CGDTP). All patent data used in this study are based on patent granted to each firm at the Indian Patent office (IPO). We arrange all the patents based on the application date on the assumption that there is no time lag between patent

[23]Chung and Pruit (1994) compare their approximate Tobin *q* value with that of Linderberg and Ross (1981).

application and completed invention. We use Center for Monitoring Indian Economy (CMIE) prowess data base to collect all firm level information and deflate all variables with appropriate deflators. Sales data is deflated by industry specific Whole Sale Price (WPI) index. The index is obtained from the website of Office of Economic Advisor (OEA), which comes under the Ministry of Commerce and Industry. The capital data is deflated by the capital deflator and raw material data is deflated by index number of intermediate goods. The index number of industrial production is obtained from Handbook of Statistics on Indian Economy (RBI 2012).

4.4.1. Input and Output Variables

In order to calculate productivity, similar to Mahadevan (2003), we apply one output (deflated net sales) and two inputs (labour and capital) in the model[24]. In addition to this, we introduce stock of input material (MAT) as a proxy variable in the production function. For capital, we consider Gross Fixed Asset (GFA) that comprises of tangible assets, land and buildings, plant and machinery, transport and communications, furniture and other fixed assets (Sharma 2011). GFA as a capital is given in the stock format and allowed for normal depreciation[25]. Since we do not have direct information on labour, we construct it by obtaining average wage rate (wages for the workers/number of workers) of each industry from the Annual Survey of Industries (ASI) database and further each firm's salaries and wages divided by the average wage rate. This provides the number of labour employed by firm (Sharma 2010).

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[24] Sales net of indirect taxes overcome the problem of indirect taxes that does not reflect in the production capacity.

[25] The depreciation rate applied to the assets when creating the accounts at the end of each financial year depends on the discretion of the company but it should comply with the prescriptive rates given in the Companies Act (1956). Further, companies need to comply with Income Tax Act (1961) while depreciating their assets. Since NFA comprises of many components, the depreciation rates are different for each of these components.

4.4.2. Determinants of Productivity, Profitability and Tobin's *q*

Measures of performance like productivity, profitability and Tobin's *q* are determined by the relevant set of explanatory variables. Based on the extensive literature survey we identify variables that impact the performance of medium and high tech firms. Similar to Deolalikar and Roller (1989) and Crepon et al. (1998), we consider patenting by firms as the major determinant of firms' differences in productivity. We use firm level knowledge stock (PAT) based on stock of patent as a means to explain productivity (Chang et al. 2013). Firms invest in R&D activities expecting product, process or organizational innovation, all of which together contribute to productivity. Hence, we consider R&D stock (RDS) as one of the explanatory variables that determines the level of productivity of firms[26]. Not only firm's own R&D but technology purchased from others also enhances productivity of firms (Basant and Fikkert 1996). Therefore, we introduce licensing payment (LIC) made by a firm as an additional explanatory variable. Many researchers consider the impact of foreign ownership (FOS) on the level of productivity. Aitken and Harrison (1999) and Arnold and Javorick (2005) have found that foreign ownership leads to a significant improvement in productivity. In case of market concentration, there is no unanimous opinion among the researchers. Several studies attempt to clarify the relationship between concentration and innovation and found positive (Scherer 1967; Angelmar 1985), negative (Connolly and Hirschey 1984) and moderate (Scherer 1965a; Levin et al.1985) relationship. Therefore, the present study uses Herfindahl Hirschman Index (HHI) as a concentration variable. The HHI is calculated by squaring the market share of each firm in the market in terms of sales and then summing up the results.

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[26] R&D stock has been constructed through perpetual inventory method. The starting year of the R&D series is 1990-91. Thus, for computing R&D stock for the base year of the study (2000), the real investment in R&D for the last 10 years has been used (Goldar 2004).

In addition to the above variables, we consider size (SIZE) and experience of a firm (AGE) to determine the financial performance. Mengistae (1995) finds that age positively influences performance of a firm[27]. Contrary to the finding, Ahmed and Ahmed (2013) argue that big size and old age is a source of inefficiency of firms. Further, we use market growth rate (MGR), export intensity (EXPI) and advertising intensity (ADVI) as control variables because these variables reflect on market condition in each industry. The control variables for each dependent variable (TFP, Profitability and Tobin's *q*) are given in Appendix C1.

4.5. Results

The descriptive statistics of variables are reported in Table 4.1. The average patent stock is 3.17 and the stock of R&D is 1.76. The table shows that firms' have a good stock of capital and material as the average is 3.09 and 2.76 respectively. The average value of Tobin's *q* is negative which indicates that the ratio of market value of firms' asset to its replacement cost is negative for most of the firms. The average number of labours is 135 (2.13 in log) in Indian firms. The simple correlation among the variables reported in Appendix C3 and which does not show any high correlation among the variables. In panel data models, the issue of heteroskedasticity emerges and in case of our data set the likelihood ratio test confirms the same for which the results are given in Appendix C4. By applying bootstrap standard errors we deal with the problem. We consider the possibility of bias arising in results from the potential endogenity between patent and productivity. We tackle the problem by introducing material proxy variable in the production function. A detailed explanation of the same has been given in section 4.3.1.

[27] We measure experience of a firm in terms of the age that is equivalent to using year trend to capture time-specific effects. Evidently, both cannot be included simultaneously in any model. Therefore, we omit age.

Table 4.1 Descriptive Statistics of Variables

Variable	Obse:	Mean	S.D	Min	Max
Patent Stock(PAT)	5379	3.17	20.24	0	427.32
R&D Stock (RDS)	5379	1.76	9.61	0	277.49
Capital stock(GFA)	5379	3.09	0.76	0.0001	5.23
Material Stock(MAT)	5379	2.76	1.06	0.0001	5.53
Tobin's *q* ratio (q)*	5137	-0.07	0.22	-0.657	2.39
Netsale(log)	5379	2.86	0.77	0.508	5.42
labour (log)	5379	2.13	0.75	0	4.569
Deflated Sale (SIZE)	5379	3922.4	14188.2	0	272486.7
Profitability (PBTI)	5379	107.47	10.29	14.901	188.06
Export Intensity(EXPI)	5379	14.34	20.62	0	99.867
HHI	5379	0.06	0.05	0.016	0.398
Licensing Intensity (LIC)	5379	7.88	59.84	0.00012	1715.503
Market Growth Rate(MGR)	5379	12.58	10.20	-20.5633	35.212

* Note that since values of certain variables are not available for some firms the observation is different from 5379. Further, in the calculation of Tobin's *q* through $q = (MVS + D)/TA$ method, most of the firm's debt is negative and it higher than MVS. Therefore, the mean value of Tobin's *q* is negative.

4.5.1. TFP Estimation through LP

Table 4.2 gives the parameter estimates from LP method. Coefficient of labour (LAB) is found to be highly statistically significant whereas capital (CAP) even though it is positive is not significant. The result shows that output share of labour is higher and significant than capital. We then estimate TFP scores as specified in equations 4.3. A summary statistics of overall TFP based on LP are given in Table 4.3. The average TFP level estimates show an improvement during the period. It has increased from 2.53 in 2001 to 3.47 in 2010. These figures indicate the efficiency of a firm to convert their inputs into output. Therefore, it is observed that the average firm's efficiency to transform their inputs into output has increased by 0.94 times (difference between 3.47 and 2.53) during the period.

Table 4.2 Estimation of TFP using LP method

	Coe	Boot.std.error	z value
Labour(LAB)	0.869*	0.02	43.37
Capital (CAP)	0.005	0.332	0.01
Material (MAT)	0.006	0.141	0.04

Note: * indicate statistically significant at 1% level.

Table 4.3 Summary Statistics of Overall Total Factor Productivity (TFP)

Year	Number of firms	Mean	Std. Dev.	Minimum	Maximum
2000	489	2.591	0.980	0.838	8.274
2001	489	2.529	0.980	0.875	8.275
2002	489	2.529	0.960	0.858	8.619
2003	489	2.619	0.977	0.872	7.557
2004	489	2.680	1.025	0.852	8.501
2005	489	2.729	1.017	0.842	8.203
2006	489	2.778	1.059	0.838	8.665
2007	489	2.806	1.112	0.982	9.323
2008	489	3.222	1.199	1.150	10.809
2009	489	3.283	1.224	1.183	11.370
2010	489	3.465	1.278	1.147	12.089

The study further investigates the TFP differential of the foreign and domestic firms and the report is given in Table 4.4. The report shows clear differences in productivity among the foreign and domestic firms where foreign firms outperform domestic firms.

Table 4.4 TFP Summary: Foreign and Domestic Firms

	Foreign firms			Domestic firms		
Year	Mean	SD	Firms	Mean	SD	Firms
2000	2.66	0.97	92	2.57	0.96	397
2001	2.58	0.99	97	2.52	0.98	392
2002	2.68	1.07	99	2.49	0.93	390
2003	2.75	1	93	2.59	0.97	396
2004	2.84	1.06	91	2.64	1.01	398
2005	2.87	1.03	94	2.69	1.01	395
2006	2.91	1.11	89	2.75	1.05	400
2007	2.93	1.15	92	2.78	1.1	397
2008	3.19	0.96	90	3.23	1.25	399
2009	3.34	1.09	89	3.27	1.25	400
2010	3.45	1.09	83	3.47	1.31	406
Average	2.92	1.08	92	2.82	1.13	398

4.5.2. Impact of R&D and Patenting on TFP

We employ fixed effect and generalized least square estimators to assess the impact of R&D and patenting on TFP. The results are given in Table 4.5. Initially we consider both PAT and RDS variables together (columns 1 & 2). However, there are likely occurrence of collinearity between RDS and PAT. Therefore, we consider these variables separately through columns 3-6. The results indicate a significant impact of patenting on productivity among the firms. The result therefore corroborates with earlier findings like Deolalikar and Roller (1989) and Crepon et al (1998) but there is no evidence of R&D impact on productivity. In all the models, technology purchase (LIC) indicates a positive and significant impact on TFP. Our result therefore corroborates with findings of Basant and Fikkert (1996) and Branstetter and Chen (2005). Both the studies examine the impact of R&D and technology purchase on productivity. It is also important to note that foreign ownership (FOS) also has an impact on the productivity of medium and high tech firms in India.

Table 4.5 Impact of R&D and Patenting on TFP (LP)

	1	2	3	4	5	6
PAT	0.039	0.035	0.038	0.035	----b	----b
	(2.83)**	(2.03)**	(2.81)**	(2.05)**		
RDS	-0.003	0.003	----a	----a	-0.003	0.003
	(-0.78)	(0.51)			(-0.69)	(0.54)
LIC	0.003	0.004	0.003	0.004	0.003	0.004
	(2)**	(2.07)**	(2)**	(2.07)**	(1.91)***	(2.06)**
FOS	0.005	0.022	0.005	0.022	0.005	0.022
	(0.9)	(7.47)*	(0.91)	(7.47)*	(0.88)	(7.51)*
HHI	-0.110	0.081	-0.110	0.081	-0.110	0.081
	(-21.4)*	(19.2)*	(-21.4)*	(19.1)*	(-21.6)*	(19.1)*
YEAR TREND	YES*	YES*	YES*	YES*	YES*	YES*
Industry dummy	NO	YES*	NO	YES*	No	YES*
Constant	-31.785	-26.54	-31.78	-25.47	-31.486	-25.23
	(-52.9)	(-31.9)	(-52.96)	(-31.32)	(-53.25)	(-31.49)
Observations	4890	4890	4890	4890	4890	4890
Model	**FEM**	**FGLS**	**FEM**	**FGLS**	**FEM**	**FGLS**

Note: *,**,*** represent 1%,5% and 10% significant level respectively. ‘a’ and ‘b’ as we removed RDS and PAT variables to avoid multicollinearity.

4.5.3. Impact of Patenting on Financial Performance: FGLS Estimation Result

Table 4.6 reports regressions estimating the impact of patenting on profitability (PBT) and Tobin’s *q*. The regression employs logarithmic value of PBT and Tobin’s *q* as dependent variables. There are two reasons because of which the dependent variables (PBTI and Tobin’s *q*) may fluctuate over time. Firstly, in response to changes in tax rate, tax credit and depreciation allowance. Secondly, the numerator of Tobin’s *q* is likely to change as current expectation of future profitability gets affected by business cycles. One preferable method to get rid of the problem is to include time trend (Shane and Klock 1997). Further, in order to control the industry features, we include a dummy variable equal to 1 for high tech sectors and 0 for the medium-high tech sectors. The coefficients of PAT indicate positive and significant influence of patenting on the two performances measures. The influence of patent on Tobin's *q* indicates that patent would act as a signal for investors. The present result therefore corroborates earlier findings of Baum and Silverman (2004) and Audretsch et al.(2012) that firms with larger portfolio of patents are more likely to draw outstanding investors. Similar to Harhoff et al. (1999), results also assert that a large patent stock increases the chance of high profitability in the high tech sectors. This indicates that firms which focus on innovation strategies concerning technology leadership are able to grasp above average profit margins. In all the regressions of Table 4.6, the coefficients for RDS are significant and positive. This supports the importance of investment in R&D on the performance of firms. We find that performance of foreign ownership is highly significant supplementing the earlier findings for the similar set of firms as they find that such firms are highly active in R&D and patenting. The result reports greater influence of firm's size in the determination of their performance because in all the models these variables are positively significant. The results also show that industry concentration (HHI) has a positive effect on company value whereas it does not have an influence on profitability.

4.6. Synthesis of the Results and Discussion

Results of all the regressions are summarized in Table 4.7. The results clearly indicate that both investment in R&D and patenting by firms have a positive influence on all the performance indicators. However, there are differences in significance levels. We have clear indication that firm's patent stock has a significant influence on all the firm performance indicators whereas investment in R&D significantly influences firms' profitability and Tobin's *q* ratio. Therefore, based on the results we can argue that in India, investment in R&D is oriented towards product innovation whereas patenting is primarily related to product as well as

Table 4.6 Impact of Patenting on Profitability and Tobin *q*

	PBTI(log)			Tobin's *q*(log)		
	1	2	3	4	5	6
PAT	0.022	0.022	NA	0.140	0.148	NA
	(4.81)*	(4.87)*		(2.34)**	(2.47)**	
RDS	0.003	NA	0.003	0.044	NA	0.051
	(2.75)**		(2.84)**	(2.09)**		(2.48)**
SIZE	0.006	0.006	0.006	0.031	0.031	0.031
	(6.92)*	(6.85)*	(6.93)*	(2.2)**	(2.24)**	(2.21)**
HHI	-0.001	-0.001	-0.001	0.062	0.061	0.062
	(-0.85)	(-0.8)	(-0.72)	(4.29)*	(4.27)*	(4.33)*
FOS	0.015	0.015	0.015	0.248	0.248	0.250
	(18.55)*	(18.53)*	(18.12)*	(27.23)*	(27.21)*	(28.1)*
MGR	-0.001	-0.001	-0.001	NA	NA	NA
	(-0.4)	(-0.24)	(-0.25)			
EXPI	-0.001	-0.001	-0.001	NA	NA	NA
	(-0.95)	(-0.97)	(-0.81)			
ADVI	NA	NA	NA	0.006	0.006	0.007
				(0.39)	(0.41)	(0.53)
ID	YES*	YES*	YES*	YES*	YES*	YES*
Year Trend	YES*	YES*	YES*	YES*	YES*	YES*
Constant	-0.474	-0.504	-0.323	-19.992	-20.162	-18.046
	(-2.47)**	(-2.62)**	(-1.69)***	(-6.85)*	(-6.91)*	(-6.39)*
Obser:	4890	4890	4890	4890	4890	4890
Model	FGLS	FGLS	FGLS	FGLS	FGLS	FGLS

Note: Heteroskedastic consistent Z values are in parenthesis and *, ** and *** indicate 1%, 5% and 10% significant level. NA implies not applied.

process innovation. Further, the influence of patent stock on Tobin's *q* implies that the intangible asset measured through patent is highly valued by stock market. The results thus confirm the commercial value of patent as already established by Bosworth and Rogers (2001), Bloom and Van Reenen (2002) and Hall et al. (2007). Another notable feature of the result is the positive and significant influence of foreign ownership on the performance of firms. Foreign firms are superior in terms of their physical assets, managerial capability and external linkages. These firms can easily assess modern technology from their parent company, which are operating in the developed nation, and can grow easily. Finally, the influence of concentration is positive and significant on productivity and Tobin's *q*. Though the coefficient is negative in case of profitability it is insignificant. These results indicate that in the concentrated market firms are targeting more on the development of the new product and enhancement of new process. This strategy will help the firms to maintain their monopoly at least in the short period. So, we conclude that firms in concentrated markets are more productive and have better future investment potential as well.

Table 4.7 Summary of the results

Measures of performance	Results		
	RDS	PAT	FOS
Productivity (LP)	Positive not significant	Positive and Significant	Positive and Significant
Profitability	Positive and Significant	Positive and Significant	Positive and Significant
Tobin's *q*	Positive and Significant	Positive and Significant	Positive and Significant

4.7. Conclusion

In this study, we aim to determine the impact of innovation on firm level performance. We find that the stock patent has significantly contributed to the performance in terms of their productivity and profitability. Stock of R&D though not significantly associated with productivity, has a significant impact on the profitability. Further, RDS and PAT have a significant implication while attracting the investors.

Chapter 5

Conclusion

This doctoral work focuses on R&D, patenting and the productivity of firms in the context of medium and high technology sectors in India during 1995-2000. The underlying questions are a) what are the determinants of the innovative activities of firms, measured in terms of R&D and patenting, b) what contribute to patenting-contemporaneous or lagged R&D expenditure and c) how far the technology base of a firm, measured through R&D and patenting activity, can influence its performance in terms of productivity, market value and profit. The thesis includes general introduction, three core chapters and conclusion. The three core chapters model the innovative activities, their determinants, their relationship and impact on the performance of firms in three different research settings. First chapter analyses the determinants of R&D and patenting by firms after taking into account the industry and firm specific characteristics. The chapter builds on the framework of knowledge production function (KPF) where R&D expenditure is the input and patent are the output of the process. Second chapter focuses on the association between R&D and patenting by incorporating the lagged influence of R&D on patenting. The third chapter estimates the impact of R&D and patenting on the performance of firms measured through three different indicators productivity, profitability and Tobin's *q*.

In this chapter, we conclude the dissertation and outline the same in different sections as follows. Section 5.1 gives the summary of chapters 2, 3 and 4 and highlights the main findings of the study. This section is arranged into three subsections. First subsection sum up the determinants of investment activity of the firms and second examines the major findings of relationship between current and lagged R&D and patenting. The third subsection concludes the empirical results of the influence of technological base of the companies on their economic performance. Section 5.2 provides a brief summary of the major findings of the study. Section 5.3 gives the synthesis of the results and policy implications of the study. We delineate the contributions of the study in the section 5.4 following it comes the section 5.5 which gives the limitations and future outline for research. Lastly, section 5.6 concludes the thesis and highlights the major findings.

5.1. Summary of the Thesis

The thesis focuses on R&D and patenting behavior of medium and high tech manufacturing firms in India in the context of changes/amendments made in the domestic patent policy from 1999 to 2005. The study begins with an analysis of the determinants of R&D and patenting behavior of these firms. The distinction of firms vis-à-vis their ownership as Indian and foreign, help us to identify the technological diversity across firms. Firms having foreign equity greater than 10% of their total equity are classified as foreign firms. To see the gestation lags in knowledge production of R&D by firms, the thesis further examines the relationship between R&D and patenting. The question is important because most of the other studies which examine the relationship in the context of developed nations have established either a year to year relationship between R&D and patenting (Hall et al.2009; Halpern and Murakozy 2012) or a ‘U’ shaped relationship (Wang and Hagedoorn 2014). However, in the case of developing nation, the literature on this issue is scant. Moreover, the result established under the circumstances of developed nation may not be applicable in the context of developing country. In case of India, Chadha (2009) has identified two year gestation lag between R&D spending and patent application. However, the study by Chadha (2009) focuses only on the pharmaceutical firms and therefore a broad applicability of the result is limited. Finally, the present thesis aims to measure the impact of firm's innovation on their economic activity. The study thus addresses the question of whether there is any performance improvement in firm after innovation with performance indicators productivity, profitability and Tobin's *q*.

5.1.1. Data Sources and Variable Description

Data for the study comes from the manufacturing firms in India, particularly from medium and high technology firms. The study follows Organization of Economic Co-operation and Development (OECD) definition to identify high technology industries. The organization follows two methods to construct indicators, namely i) R&D expenditures divided by value added; and ii) R&D expenditures divided by production. Out of the two the study follows second definition. The method divides the manufacturing industries into high technology, medium-high technology, medium-low technology and low technology sectors based on their R&D intensities. We chose high and medium technology firms as our study area because these sectors are growing rapidly, highly competitive in research and production, highly involved in significant foreign co-operations and can have multiplier impact on other sectors as well. The sectors are codified on the basis of National Industrial Classification (NIC) 2008 and International Standard Industrial Classification (ISIC) 2003. Initially, we made a concordance between ISIC and NIC. Industry and product classification in India says that NIC 2004 is based on ISIC Revision 3. Following this information, we made a concordance between ISIC Revision 3 and NIC 2008 through NIC 2004.

The main sources of data for the study are the website of Controller General of Patent Design and Trade mark (CGPDT) and Centre for Monitoring Indian Economy (CMIE) Prowess respectively for patent and firms specific variables. 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. R&D expenditure of the firms is also collected from DSIR that fills the missing numbers in the CMIE prowess database as well as performs a cross-check. The present study consists of exclusively those patents that were assigned in the firm's own name. The study considers only those firms which are active and producing consistent sales data during 1995-2010. 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, which comes around 16% of total firms. All the variable series are adjusted for inflation using the index of industrial production and wholesale price index of respective industries based on 1993-94 prices. R&D stock is calculated using perpetual inventory method using depreciation rate of 15% (Hall 1996); Basant and Fikkert 1996). 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.

5.1.2. Determinants of R&D and Patenting

The studies on innovative activities of manufacturing firms based in the developed nation are abundant but are scarce in case of developing nations. Theories originated in developed nations such as USA and UK have limited applicability in developing nations as these nations maintain different institutional, political and economic conditions. The present study, therefore initially looks at the determinants of the innovative activities of firms in India as an emerging economy. Innovative activity is measured in terms of firm's investment in R&D and their patenting behavior through the framework of Knowledge Production Function (KPF). The KPF is estimated through a recursive simultaneous equation model where R&D is the regressand in the initial stage and later it is included as a regressor. Due to the special features of dependent variables, we select the appropriate econometric strategy. More specifically, due to the presence of zeroes in case of R&D expenditure data, it is necessary to distinguish the zero emerging from the participation versus zero emerging from the non-participation of firms in innovative activity. So we apply Heckman selection model to deal with the problem. We estimate two-stage regression with the first stage estimating the probability of conducting R&D and in the second stage focusing the determinants of R&D under the given conditions. In case of patenting equation, the characteristics of count data as well as the presence of many zeros than predicted by count models such as Poisson and Negative binomial model requires special attention. Hence, the study employ Hurdle count data model to solve the problem of excess zeros. The two part model relaxes the assumption that zeros and positive values comes from the same data generating process.

The study finds that some factors have similar influence on both R&D and patenting. For example, we have a clear evidence of positive and significant influence of patent policy changes made in India on innovative activities (both R&D and patenting) of medium and high tech firms. Thus, the result indicates that the changes made in patent regime stimulate R&D and patenting activities. Nationality of ownership is a matter of discussion in the literature as India has a mixture of both Indian and foreign owned firms. The positive and significant influence of FOS on R&D and patenting indicates that the foreign firms in India are active in R&D and patenting. The study therefore asserts that foreign investors are much confident about the success of their investment in India. The increased patent protection in India is another factor that leads to the higher level of investment by foreign firms.

Firm's experience, proxied by their age, as a point of analysis to estimate the impact of firm's age upon innovation has started very recently (Sorensen and Stuart 2000). The present study acknowledges that the level of innovative activities has improved over time as they build up experience. This result follows the principle of 'learning by doing' that has been associated with diminishing marginal cost of production as firms gain more experience. Several studies previously established the positive association between size of the firm and the level of expenditure on R&D (Dosi 1988; Acs and Audretsch 1988). The present study, however, finds that smaller firms are engaged in R&D activities as the relationship between size and R&D is negative. It thus corroborates the findings that large numbers of small firms that belong to high tech sectors are highly active in R&D (Kleinknecht and Verspagen 1989; Acs and Audretsch 1993).

Earlier studies on the effect of concentration aspect on innovation, based on developed nations argue that the 'monopoly profit' that provides an incentive for companies to engage in more innovative activities (Schumpeter 1942; Smith et al 2002; Subodh 2002). However, we got a clear evidence of negative influence of concentration on R&D similar to the findings of researchers in India (Subrahmanian 1971; Kumar 1987). The result indicates that competitive firms are more encouraged to be innovative to gain 'anticipated possession' of market power. Thus, the study proves that competition among firms encourage innovation. However, though we got a similar result in case of firms' decision to go for patent, the level of patenting activity is found positive but not significant. Therefore, there are chances that firms in concentrated industry are patenting extensively.

Government policies that intend to promote R&D are found to be significant in all the cases. However, tariff reduction which intends to enhance competition among the domestic as well as foreign firms, found to be significant only when we introduce the industry dummy. Therefore, we can argue that the effect of policy variable on R&D is industry specific.

5.1.3. Relationship between R&D and Patenting

The purpose of the chapter is to examine the relationship between R&D spending and its output in terms of patenting. Firm's commitment to fund R&D enables them to create the internal knowledge needed for product and process innovations. It also helps them to evaluate and use knowledge created outside the firm. Internal research capability generated in terms of spending more on R&D enables firms to transform this knowledge into invention and further leads to marketable product. The study therefore assesses the relationship between R&D spending and patenting activity of firms.

We employ the framework of knowledge production function to estimate the relationship. We estimate the relationship in two ways. Firstly, based on the earlier conclusion that there exist a year to year relationship between R&D and patenting (Hall 1986 & 2011) the present study uses only contemporaneous R&D to estimate the relationship. Secondly, we adopt a specification along the lines of Pakes and Griliches (1984) as these authors consider patents are a function of contemporary as well as lagged flow of the firm's investment in R&D. The large degree of skewness in the distribution of patent data as well as the large proportion of zeroes in the data necessitates special modeling strategies. The present study therefore applies Hurdle count data model. Depending upon the methodology adopted, previous studies produce contemporaneous and lag effects of R&D on patenting (Hausman et al.1984; Montalvo 1997; Guo and Trivedi 2002; Wang and Hagedoorn 2014.). Initially, the present study fails to produce any contemporaneous relationship between R&D and patenting even though we control for the permanent differences among the firms and sectors. However, as an indication to increased foreign investment activities in India, foreign firm's R&D shows positive and significant contemporaneous influence on patenting. The study further checks the gestation lags in knowledge production of R&D by firms by introducing R&D lags up to three years in the model. Interestingly, we could not find any lagged influence instead we got the year to year relationship between them. The coefficient of first and second lags of R&D shows a diminishing trend and the coefficient of third lag becomes negative as well. Therefore, the result indicates that more recent R&D produces more output in terms of patenting. This is because in the era of globalization, the increased level of competition along with reduced product life cycle requires continuous stream of innovations.

5.1.4. Impact of R&D and Patenting on Firms' Performance Indicators

This section concludes the result from the analysis of the impact of R&D and patenting on the economic performance of firms which is measured through different indicators namely productivity, profitability and Tobin's *q*. To estimate the Total Factor Productivity (TFP) of firms the present study considers production function approach. Production function is carried out by Levinsohn and Petrin (LP) method, which is a semi-parametric method. The TFP estimation is based on an augmented Cobb-Douglas production function. The estimation includes material input as an additional explanatory variable apart from the basic labour and capital in the function.

The choice of the different measures of performance is further justified considering that patent data may include both process and product innovation. Introduction of a new product or significant improvement in the existing one represents product innovation that is likely to increase the profitability whereas process innovation entails cost cutting and productivity improvement. The current profit at all the time may not represent the pure indicator of firm performance since the investment made by firm lowers their current profit. Therefore, the present study also employs Tobin's *q*. Tobin's *q* asses the relationship between patent and the firm's future performance potential. For a firm, the long run equilibrium market value must be equal to the replacement value of its assets which gives the value of *q* close to unity. Any deviation from unity (greater than 1) signifies the influence of intangible assets such as R&D, patent, advertising and brand equity enjoyed by the firm.

The TFP estimation based on LP estimator shows that the output share of labour is statistically highly significant. However, though the share of capital is positive it is not significant. It is also important to note that TFP have been increasing during the study period. As mentioned earlier, the thesis uses indicators like productivity, profitability and Tobin's *q* to estimate the impact of R&D and patenting by firms on their economic performance. The study employs several methods to perform the multiple regressions. FE method is used to consider endogenity from unobservable (Chudnovsky et al. 2008). We used FGLS method to take care of autocorrelation and heteroskedasticity (Carter et al.2008). In all the models the study explains that stock of firms patenting has a positive and significant influence on firm's economic performance. The result thus clarifies that by patenting firms have increased their productivity. Similarly, patenting enable firms to make profit from their invention. Further, the positive influence of patenting by firms on Tobin's *q* (which measures the expectation of future profit) implies that, stock market has given higher priority to the firms that have a better patent portfolio. Thus, we find that both contemporaneous profit as well as expectation of future profit has been influenced by the innovative activities of a firm. The study, however, does not produce any evidence of R&D influence on productivity of firms, whereas the variable R&D has a significant influence on other performance indicators. The positive and significant influence of purchased technology on productivity emphasizes the importance of external technology for productivity improvement.

The thesis finds that foreign ownership has a positive impact on current as well as future profit of firms. The study finds a positive and significant impact of FOS on the productivity, profitability and the market value of firms. Firm size (SIZE) is positive and significantly associated with the performance of firms. This result indicates that larger firms are more likely to enjoy economies of scale and make profit from their innovation. The effect of market concentration (HHI) is positive and significant on productivity and Tobin's *q* with no influence on profitability of firms.

5.2. Main Findings of the Study

The key findings of the study are as follows

1. Older firms and foreign firms decide to undertake more R&D.
2. Once firm decide to undertake R&D, highly capital intensive firm invests more in R&D.
3. Firms which are investing more in advertising, to differentiate their product, and firms with small size are also investing more in R&D.
4. Government incentives positively influence firms to undertake R&D.
5. New patent policy significantly influences the decision to undertake R&D and the level of patenting.
6. Concentrated market takes lower R&D and lower patent.
7. Older firms and foreign firms decide to go for a patent. Similarly, these two categories of firms also positively influence the level of patenting.
8. Exporting firms are less likely to apply for a patent in Indian Patent Office.

9. R&D of foreign firms in India has a significant influence on the behavior of firms patenting.
10. After controlling the R&D lags up to five years, contemporaneous and fifth lag of R&D positively influence patenting behavior of firms.
11. Firms experience in patenting has significant influence on the level of patenting.
12. The stock of patent has a positive and significant influence on firm's productivity and profitability.
13. The stock of patent has a great implication while deciding about the stock market investment.
14. R&D influences profitability and stock market value of a firm.
15. Foreign firms are highly productive, making huge profit and attracting investors.

5.3. Synthesis and Policy Implication of the Study

5.3.1 Synthesis

The present section synthesizes the empirical findings discussed in chapters 2, 3 and 4. The key findings of the study are summarized in Tables 5.1 and 5.2. The study finds that though the older firms decide to undertake R&D, it is smaller firms who have invested in R&D more. These results distinguish the approaches of firms during the decision and the level of investment activity. The result can be interpreted that small firms are more innovative than large firms. Further, Acs and Audretsch (1990) show that the innovative activities are higher in industries where large firms are predominant however in such industries smaller firms are active in innovation. The study also finds that government incentives on R&D have a greater implication on firms' decision to conduct R&D. The changes made in Indian patent policy have a significant impact on firm's innovative ability in terms of the R&D decision and level of patenting.

It is also noteworthy that ownership plays a significant role in the determination of innovative activities as foreign companies are relatively more active in R&D and patenting. Not only the foreign ownership but also the R&D spending by foreign firms is also positively associated with patenting. This implies that foreign firms which are operating in R&D in India have also been applying for patent at the Indian Patent Office. However, the study finds that there is no lagged influence of R&D on patenting. These results clearly indicate that foreign firms produce their technology abroad and apply it to the Indian condition. The result is also attributed to the new patent policy in India. Similarly, foreign owned firms' make productive investment in India as the ownership factor is significant in TFP, profitability and Tobin's *q*. These results emphasize the importance of technology produced abroad, patented in India, that further influence the performance of such firms.

The study shows that, as concentration increases the level of expenditure in R&D declines which is due to the fact that firms in concentrated industry are less likely to go for constant innovation as long as they do not face any threat from their rivals. Firms in concentrated market receive more patent probably considering patenting as a strategic tool for entry deterrence. Further, the study has looked into the importance of firm's experience while determining the innovativeness. The present study has proved that firms' experience measured through previous patent stock has a significant influence on firm's innovative activities.

Table 5.1 Summary of Major Findings 1

Findings	**Remarks**
Foreign ownership boost the innovative activities	The role of foreign technology.
Experienced firms have significant innovative ability	The role of experience.
Patent policy has a significant role	Investors enjoy greater appropriation of their investment.
R&D by foreign firms increases	Highlight the role of purchased

patenting	technology.
In concentrated industry level of R&D declines whereas patenting increase	Patenting may be considered as a strategic tool.

Table 5.2 indicates that contemporaneous and lag effect of R&D on patenting is persisting. The present result therefore signifies the earlier findings that more recent R&D produces more output in terms of patenting. This is because, firms in the era of globalization, the increased level of competition along with reduced product life cycle require continuous stream of innovations. Further, the result should be read in the context of foreign firms' accessibility of their parent firms R&D laboratory located abroad. Research and innovation is devised at the headquarters of a foreign multinational company. The role of the subsidiary is to introduce the innovation in Indian market and apply for the patent. The significant relationship between foreign firms' R&D and patenting further signifies the argument. Industry specificity of the relationship between lagged R&D and patenting show that innovation activity varies across industries.

With respect to the influence of innovative activity on the performance of firm, the major finding is that patenting by firms significantly contributes to the improvement of their performance in terms of profitability, Tobin's *q* and productivity. This result is associated with the amendment made in Indian patent laws that may benefit firms in India to improve their performance. The nature of investment in R&D by firms in India is related to the product innovation as the relationship is significant for profitability and insignificant for productivity. The present result also confirms the importance of purchased technology on the productivity improvement of firms.

The patenting habits of firms however, can be considered as both process and product innovation. This is because the influence of patenting is positive and significant for productivity and profitability. The results signify the patent policy changes made in India after 2005. Further, results of the thesis clarify that both R&D and patenting by firms have greater implication while assessing the firms in the stock market. To be more specific, firms with larger portfolio of patents are more likely to draw investors.

Table 5.2 Summary of Major Findings 2

Relation	Result	Remarks
Relationship between R&D and Patenting	Positive, not significant	When there is no lag effect.
	Positive and significant	Current and fifth lag of R&D influences.
Impact of Patenting on Productivity and Profitability	Positive and significant	Product and process innovation.
Impact of R&D on Productivity	Positive, not significant	Only product innovation.
Impact of R&D on Profitability	Positive and significant	
Impact of R&D and Patenting on Tobin's *q*	Positive and significant	Both R&D and patenting have impact on the stock market evaluation.

5.3.2. Policy Implications

In the present age, the importance of innovation as the engine of growth has increased steadily. There is a need for special attention to the formulation of innovation policies at different levels with a special emphasis on the roles of the firm. Government needs to decide on providing more incentives for the innovation activity of firms. And thus, providing tax incentive for patenting firms could be the policy suggestion. Such incentives should be limited to smaller firms in the competitive industries.

The Indian authority, says Competition Commission, has to carefully watch the activities of foreign companies which may use Indian market for their monopoly, gained through patenting. Again, special incentives need to be decided for the domestic firms that are facing high competition from foreign firms for conducting R&D and patenting. Particularly, as we do not find any significant spillover effect of foreign companies in patenting, the need for such incentive is more prominent. Exact measurement of innovation and assessing its impact on the economic activities of firms are likely to result in the efficiency of the allocation of resources. In that way the study helps investors, managers and R&D personals of business firms.

On the one hand, we fail to produce any direct evidence of R&D to patenting in the initial stages of estimation and on the other the same linkages have been established between R&D of foreign firms and their patenting habits. Theory argues that contact and presence of foreign firm certainly transfer specific amount of technology to the host country firms which further improves the investment activity of domestic firms. Therefore, there is an urgent need to observe the scope, nature and impacts of foreign investment in the way that could benefit domestic firms.

The importance of purchased technology (LIC) on productivity improvement of firms raises the validity of firms own R&D laboratories. If firms have a cheaper access to advance technology developed abroad, then spending huge amount on their own R&D laboratories becomes a question. However, as Cohen and Levinthal (1990) argue that R&D involves innovation and learning which enhances firm’s absorptive capacity that further boosts the technology transfer from abroad. Therefore, a mere import or purchase of external technology may not enhance the innovation capacity of a recipient firm. In-house R&D centers are therefore crucial for firms not only to innovate and generate new knowledge but also to assimilate absorptive capacity. The result therefore helps the policy makers to decide an optimal mix of domestic and purchased technology as economy develops. Moreover, foreign purchase of technology should be facilitated by the government as it leads to higher productivity of firms.

The thesis shows that the enhancement of patent policy has improved the investment nature of firms in India in terms of R&D investment and patenting by foreign firms. The result must be considered in the context of existing debate over 'monopoly power effect' versus 'incentive to innovation effect' regarding the patent policy. Protection of innovation through enhanced IP laws leads to a temporary monopoly and it harms consumers because they have to pay higher prices for the product. Further, the law hinders improvement in subsequent innovation if the patent holder prohibits that. Under a strong patent regime, the incentive to invest in research increases because the inventor aims the monopoly profit they would earn from the invention as the law provides legal protection to appropriate the return from innovation. As it is evident that foreign firms are making use of the policy changes extensively by patenting, there is a need to watch out for monopolistic tendencies in future by these firms. As mentioned earlier, competition authority has to play a pivotal role to confront for any abuse of patent that may occur in future.

5.4. Contribution of the Study

The study contributes to the existing literature by analyzing the determinants of innovative activity of firms in Indian high and manufacturing technologies concomitantly with the effect of such activities on the performance of these firms.

The present research includes both R&D expenditure and patenting by firms to capture the innovative activity of firm. The existing literature has not looked into the patenting aspect yet which is gaining popularity to appropriate investment made in R&D across the globe for research-intensive industries. The significance of the analysis grows in view of the important patent policy changes made in domestic legislation of India to comply with TRIPS agreement.

In terms of methodological issues, the study uses the most appropriate techniques depending upon the specific requirement of the data. Lastly, the linkage of the innovative activity of firm with its performance helps us in understanding the importance of such activities to gain competitiveness in market.

The results of study in different chapters bring forth the country specificity of the analysis. As the research context is a developing country, the distinction between foreign and domestic firms in terms of innovation is evident. Some of the results found in the context of developed economies particularly related to relationship between lagged R&D and patenting do not hold for developing country like India. It highlights the role played by foreign firms in developing countries which is mostly restricted to making use of market for selling their newer products.

5.5. Limitation and Future Direction for Research

All the issues associated with patent data as a measure of innovative activity is a limitation of the study as well. The difficulty involved in gathering patent information is one of the main concerns of the study. Though we attempted to verify the patent count for each firm, the margin for error remains because the Indian patent office is in the process of updating data.

Several studies have concluded that there are differences in patenting activity among the sectors. However, the paucity of data reduces our scope to perform such a task. Since, we have included only firms which are producing consistent sales data so it reduces our data point from 59376 to

8864, which comes around 16% of total firms. Another limitation of the study is that it is restricted to only high tech and medium- high tech sectors. To comprehend the real investment nature and their influence on firms we need a separate analysis for each sector, by including non- high tech sectors.

For productivity calculation, information on labour is derived from two sources, ASI and prowess. However, the series in ASI are available only after 2000. Therefore, our calculation is primarily based on the data point after 2000. This can be seen as an additional limitation of the study.

In future, we can extend the study by incorporating investment in Information and Communication Technology (ICT) to analyze the role of technological spillovers in gaining the TFP. The fact is that ICT enables firms to be better connected to access superior technology produced outside the firm.

The research can be extended further by segregating R&D expenditure into research expenditure and development expenditure. This is because the proportion of expenditure of research in R&D expenditure is the main contributor to patents. The study also paves the way for future research as we can estimate the transfer of technology to Indian firms using patent citation data under strengthened patent regime. As we found some hints on patenting by firms being used as a strategic tool, individual industry level analysis will reveal more about these tendencies of firms. Thus, we propose that such a study can be undertaken in the future.

Finally, in the present study we do not consider reversed causality from performance of firms to innovation. Therefore, it is highly encouraged to test how the performance of firms affects the innovative activities.

5.6 Conclusion

In conclusion, patent policy changes in India have given a boost to innovation in the economy as firms are investing in R&D and are patenting. The trend is not limited to large firms as small firms are investing in R&D. However, maximum advantage seems to be limited to foreign firms till now. The policy makers have to ensure that the gains should trickle down to domestic firms as well to boost innovativeness and competitiveness of Indian firms.

APPENDIX

Appendix A

Table A1 Hausman-Taylor Endogenity Test

Variable	OLS	Htaylor	Variable	OLS	Htaylor
AGE	-0.02(-.87)	-0.02(-0.86)	PATPOL	0.015(0.34)	0.016(0.35)
FOS	0.01(-0.01)	0.01(-0.02)	TAR	0.216(1.74)	0.217(1.75)
PBTI	-0.01(-.15)		MGR	0.001(-0.5)	0.001(-0.51)
SIZE	-0.05(-.89)		LARGED	-0.013(-.8)	
CI	0.11(2.47)	0.109(2.46)	Constant	0.024(0.68)	0.024(.66)
SPILL	-0.04(-0.91)	-0.036(-0.91)	**TV. Endogenous**		
FTM	0.01(0.6)	0.006(0.6)	PBTI		-0.010(-1.18)
HHI	-0.04(-1.66)	-0.043(-1.66)	SIZE		-0.047(-4.62)
ADVI	0.01(0.57)	0.006(0.58)	**TI. Exogenous**		
EXPI	0.01(0.54)	0.004(0.53)	LARGED		-0.013(-0.8)
GID	-0.04(-2.07)	-0.042(-2.07)			
Obser:	8310	8310	Obser:	8310	8310

Note: TV Means Time Variant and TI Means Time Invariant.

Table A2 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

Table A3 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 (2.3)

Appendix B

Table B1 Correlation Matrix (Chapter 3)

	Pat.Appln	RDI	RDI lag1	RDI lag2	RDI lag3	FOS	AGE	TECH	PBTI	HHI	PRI	ADVI	SIZE	PATEXP
Pat. Appln	1													
RDI	-0.03	1												
RDI lag1	0	0.44	1											
RDI lag2	0	0.38	0.83	1										
RDI lag3	0	0.33	0.73	0.82	1									
FOS	0.12	-0.07	-0.09	-0.08	-0.08	1								
AGE	0.09	-0.13	-0.2	-0.2	-0.2	0.14	1							
TECH	0.07	-0.02	-0.03	-0.02	-0.04	0	0.09	1						
PBTI	0.03	0.01	0.02	0.02	0.01	0.02	0.04	0.02	1					
HHI	-0.03	0	0.01	0.01	0.01	0.06	-0.01	-0.28	-0.03	1				
PRI	0.1	-0.08	-0.13	-0.16	-0.19	-0.01	0.31	0.25	0.06	0.05	1			
ADVI	0.02	0.01	0	-0.01	-0.01	0.05	0.01	-0.04	0.02	0	-0.06	1		
SIZE	0.08	-0.03	-0.1	-0.1	-0.11	0.08	0.11	0.15	0.05	0.06	0.23	0	1	
PATEXP	0.62	-0.06	0.05	0.05	0.04	0.13	0.13	0.09	0.05	-0.05	0.14	0.01	0.16	1

Appendix C

Table C1 Summary of Explanatory Variables (Chapter4)

Dependent Variables	Independent Variables
TFP	PAT,RDS,LIC,FOS,HHI
Profitability	PAT,RDS,SIZE,HHI,FOS,MGR,EXPI
Tobin's *q*	PAT,RDS,SIZE,HHI,FOS,ADVI

Table C2 Descriptive Statistics of Variables (Chapter 4)

Variable	Obse:	Mean	S.D	Min	Max
Patent Stock(PAT)	5379	3.17	20.24	0	427.32
R&D Stock (RDS)	5379	1.76	9.61	0	277.49
Capital stock(GFA)	5379	3.09	0.76	0.0001	5.23
Material Stock(MAT)	5379	2.76	1.06	0.0001	5.53
Tobin's *q* ratio*	5137	-0.07	0.22	-0.657	2.39
Netsale(log)	5379	2.86	0.77	0.508	5.42
labour (log)	5379	2.13	0.75	0.0001	4.569
Deflated Sale (SIZE)	5379	3922.4	14188.2	0	272486.7
Profitability (PBTI)	5379	107.47	10.29	14.901	188.06
Export Intensity(EXPI)	5379	14.34	20.62	0	99.867
HHI	5379	0.06	0.05	0.016	0.398
Licensing Intensity (LIC)	5379	7.88	59.84	0.00012	1715.503
Market Growth Rate(MGR)	5379	12.58	10.20	-20.5633	35.212

* Note that since values of certain variables are not available for some firms the observation is different from 5379. Further, in the calculation of Tobin's *q* through $q=(MVS+D)/TA$ method, most of the firm's debt is negative and it higher than MVS. Therefore, the mean value of Tobin's *q* is negative. The calculation is carried out after taking the first difference.

Table C3 Correlation Matrix

	TFP	PBTI	Tobin's *q*	RDS	PAT	LIC	HHI	FOS	AGE	MGR	EXPI	SIZE
TFP	1											
PBTI	-0.02	1										
Tobin's *q*	0.03	-0.05	1									
RDS	0.03	0.09	0.08	1								
PAT	-0.08	0.27	0.07	0.32	1							
LIC	-0.08	0.04	-0.03	0.07	-0.01	1						
HHI	0.31	-0.03	-0.06	0.06	-0.12	0.06	1					
FOS	0.04	0.16	0.02	0.01	0.13	-0.03	0.07	1				
AGE	-0.03	0.07	-0.04	0.16	0.17	-0.11	0.00	0.13	1			
MGR	0.05	0.08	-0.02	0.02	0.02	-0.04	0.03	0.02	0.004	1		
EXPI	-0.11	0.08	-0.16	0.15	0.03	0.26	-0.06	-0.07	-0.09	0.02	1	
SIZE	0.35	0.05	0.17	0.35	0.27	0.05	0.22	0.01	0.11	0.03	-0.05	1

Table C4 Test for Heterogeneity

Dependent variable	Productivity		Tobin's *q* ratio		Ratio of profit before tax to sales	
	1	2	1	2	1	2
PAT	0.002(0.17)	-0.08(-2.45)**	0.23(25)	0.21 (11.3)	0.002(0.49)	0.22(2.22)**
RDS	0.002(0.39)	-0.001(-0.12)	0.0019(3.73)	0.0018(2.05)	0.003(2.81)**	0.004(1.18)
LIC	0.001(0.84)	0.001(0.41)	----	----	---	---
SIZE		---	0.0000(4.45)	0.0001(4.15)	0.003(3.89)*	0.008(4.33)*
HHI	0.14(33.39)*	0.12(16.06)*	0.0395(3.15)	0.0091(0.39)	0.0001(0.93)	-0.004(-1.6)
FOS	0.022(7.55)*	0.014(2.59)**	0.1618(19.86)	0.2099(12.28)	0.008(11.74)*	0.014(8.37)*
MGR	---	---	0.0016(5.64)	0.004(6.23)	-2.7E-05(-1.53)	2.77E-06(0.05)
EXPI	---	---	-0.0009(-4.64)	0.0003(0.87)	-0.0006(-1.08)	-0.001(-0.65)
Constant	0.61(104.9)*	0.589(56.05)*			2.02(1822.9)*	2.022(633.8)*
LR Test(9)	2770.95*		2505.08*		5541.05*	

Note: LR Test Indicate Likelihood Ratio Test.

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