INNOVATION AND MARKET STRUCTURE: EXPLORING THE FEEDBACK EFFECT, THE ROLE OF POLICY REGIME AND TYPES OF INNOVATION

Ph.D. Thesis

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **Innovation and market structure: Exploring the feedback effect, the role of policy regime and types of innovation** in the partial fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY** and submitted in the **DISCIPLINE OF ECONOMICS, Indian Institute of Technology Indore**, is an authentic record of my own work carried out during the time period from May 2014 to June 2019 under the supervision of Dr. Ruchi Sharma, Associate Professor, Indian Institute of Technology Indore.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

Signature of the student with date
(MADAN DHANORA)

This is to certify that the above statement made by the candidate is correct to the best of my/our knowledge.

Signature of Thesis Supervisor #1 with date

(DR. RUCHI SHARMA)

Madan Dhanora has successfully given his Ph.D. Oral Examination held on **26 November 2019.**

Signature of Chairperson (OEB) Date:	Signature of External Examiner Date:	Signature(s) of Thesis Supervisor(s) Date:
Signature of PSPC Member #1 Date:	Signature of PSPC Member #2 Date:	Signature of Convener, DPGC Date:

Signature of Head of Discipline
Date:

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MADAN DHANORA

DEDICATION

Dedicated to my beloved parents

SYNOPSIS

Introduction

The relationship between innovation and market structure is complex. Competitive forces in an industry reduce future rents associated with innovation and hence discourage firms from investing in such activities (Schumpeter 1942). On the contrary, product market competition increases firms' efficiency through managerial-effectiveness which drives innovation (Arrow 1962). Aghion et al. (2005) advanced the debate by introducing the possibility of an inverted U-shaped relationship between innovation and competition. Such a nonlinear relationship occurs during a low level of competition in an industry where firms intend to escape the competition by innovating new products. Later, the pace of competition reduces and few winners emerge, thus catalyzing the Schumpeterian effect. It implies that those firms which are technological leaders dominating the industry are ultimately responsible for a negative relationship between competition and innovation.

On the other hand, scholars associated with the Chicago School of Thought on innovation and market structure which mainly emerged in 1970, argue that market dominance arises from superior efficiency which is a function of technological advancements (Shepherd 1990). Technological advancements are a source of economies of scale and efficiency which positively influence firms' market power. Thus, innovation influences firms' monopoly power and help these firms in sustaining market dominance. New products and processes provide the means for large and old firms to create high entry barriers. However, this positive impact prevails up to an optimal level only. Afterwards, monopoly shows a declining trend with further increase in innovation (Nemlioglu & Mallick 2017). Nemlioglu and Mallick (2017) show that the

Schumpeterian theory of creative destruction plays a very important role for explaining this inverted-U shaped relationship.

From the above discussion, it is evident that there exists a feedback effect between innovation and market structure. The clear majority of studies in the Indian context only analyze a one-way linear relationship between innovation and market structure by considering market structure as an exogenous variable. However, empirical evidence on Aghion et al. (2005) model is scant in the Indian context. There is no study in the Indian context which explores the feedback effect between innovation and market structure.

In the last 20 years, the Indian manufacturing sector has witnessed major patent policy changes. The agreement on Trade-Related Intellectual Property Rights (TRIPs) came into the picture in 1995 with minimum standards for patent rights for member countries of the World Trade Organization (WTO). To comply with the TRIPs agreement, India also strengthened its domestic patent policy by introducing three Amendments in the Patent Act 1972[1]. With the Patent (Amendment) Act 2004, the Indian government introduced product patent in all fields of technology. Strengthening patent policies are an important source of in-house technology creation. After the implementation of TRIPs, there has been a continuous debate on patenting and market structure. However, literature on the impact of patenting on firms' monopoly power is scant in the Indian context. The re-introduction of product patent in India also opens up the issue of types of innovation and their impact on market structure.

The focus of this doctoral dissertation is to explore the feedback effect between innovation and market structure and also to analyze the impact of

[1] These three amendments are: the Patent (Amendment) Act 1999, the Patent (Amendment) Act 2002 and the Patent (Amendment) Act 2004.

patent policy on the relationship between innovation and market structure. Further, we also theoretically and empirically verify the impact of types of technological innovations i.e. product and process innovation on market structure. Accordingly, we estimate a two-way relationship between innovation and market structure in Indian high and medium technology industries. This dissertation also attempts to provide empirical evidence on the Schumpeterian theory of creative destruction in the Indian context. For this purpose, we estimate the nonlinear impact of innovation on the firms' monopoly power. Innovation has been proxied by patent applications (PATENTAP) and grants (PATENTGR). Lerner index of monopoly power (WLI) is utilized as a measure of market structure.

On the basis of above discussions, this study addresses the following research questions:

1. Is there a feedback effect between innovation and market structure in Indian high and medium technology firms?
2. Do the changes in patent policy influence the relationship between innovation and market structure?
3. Does the type of technological innovation matter for an innovation and market structure relationship?

Literature review

Innovation and market structure

Escape-competition effect and the Schumpeterian effect generate an inverted-U shaped relationship between competition and innovation (Aghion et al. 2005). According to Aghion et al. (2005), high competition increases innovation activities in neck-and-neck firms generating a positive relationship between competition and innovation. Aghion et al. (2005) referred to this relationship as 'escape-competition effect'. At the initial level of competition, the escape-competition effect dominates the

Schumpeterian effect. On the other hand, when competition is high, firms with a higher technological gap (laggard firms) dominate the industry leading to a negative relationship between competition and innovation. Further, technological advancements help firms maintain their market dominance (Shepherd 1990). Firms try to create high entry barriers through innovation activities which result in high market concentration. Thus, there is a feedback effect between innovation and market structure. Following this discussion, a number of studies have analyzed a two-way relationship between innovation and market structure.

Patent policy and the relationship between innovation and market structure

Strong patent rights encourage firms to increase R&D investment to enhance their post-innovation profit. Utilizing innovation data from Crystal Palace Exhibition in London (1851) and the Centennial Exhibition in Philadelphia (1876); Moser (2005) suggests that patent laws are important determinants of the direction of technological change. Correa (2012) also finds an upsurge in U.S. patenting due to domestic patent policy change. Establishment of the United States Court of Appeals for the Federal Circuit (CAFC) increased the number of patent applications and grants. The establishment of CAFC increased the propensity of innovation by broadening the right of patent holder. Correa (2012) analyzed the relationship between market structure and innovation using a dataset of 311 firms listed in the London Stock Exchange (1973-1994). This study positions the establishment of CAFC in 1982 as a structural break in the dataset. This study finds that competition has a positive and significant impact on firms' innovation for the period of 1973-1982. However, this relationship becomes insignificant during 1983-1994.

Types of innovation and market structure

Innovations can be basically categorized into four types; namely, product, process, marketing and organizational innovation where the first two are technological innovations and the others are non-technological in nature. Product and process innovations influence firms' market power. Product and process innovation change the market power of a firm albeit through different channels. Product innovation increases the price margin of firms by differentiating their product from that of rivals (Belleflamme & Peitz 2015). The introduction of a new product in the market increases the sale and market share of the innovative firm that may satisfy the needs of existing customers and/or attract new customers. Process innovation is cost reducing and leads to changes in the production function allowing firms to pitch the product at a competitive price. Production performances like flexibility and cost reduction which are closely linked with process innovation have a positive impact on firms' organizational and administrative performance as well. Innovation by a firm leads to organizational learning and also fastens the speed and quality of operations that have strong linkages with organizational performance.

According to the product life cycle hypothesis, during the initial stage of product development, the innovations related to standardizing the product are extensive. However, as a firm adds more features to the same product, the advantage it may enjoy through the increment will keep reducing. Also a newer version of the product may cannibalize into the market of the earlier product. Simpson et al. (2006) also explain the negative outcomes of the excess innovation activity. For instance, a firm may introduce new innovations just for the sake of it than satisfy actual consumer needs and merely increase firms' expenditure. Further, due to market risk associated with innovation, commercialization of a new product is difficult and firms may not realize its benefits immediately. Process innovation is cost reducing but implementation of new incremental technology involves additional expenditure that may decrease the firms' market power, particularly beyond a certain level as new techniques become more complex.

Research Objectives

On the basis of the above discussion, the objectives of this dissertation are as follows:

1. To investigate the bidirectional relationship between innovation and market structure.
2. To investigate the relationship between innovation and market structure under different patent regimes.
3. To investigate the differential impact of product and process innovations on market structure.

Data and Methodology

Data

We undertake three different studies to address each of the above mentioned objectives. This study utilizes firm level panel data for Indian high and medium technology industries. We identify firms in high and medium technology industries on the basis of the OECD classification and a concordance is drawn between International Standard Industrial Classification (ISIC) 2003 Revision 3 and National Industrial Classification (NIC) 2008 via NIC 2004. The analysis is carried out at five digit NIC (2008) classification. Major source of data for this study include the Centre for Monitoring Indian Economy (CMIE) prowess database and website of Controller General of Patents, Designs and Trademarks (CGPDT, Government of India). CMIE database provides annual report data for firms that are listed in Bombay Stock Exchange (BSE). All firm level data in this study is collected from CMIE. We collected the patent data from the Indian Patent Advanced Search System (InPASS).

To investigate the bidirectional relationship between innovation and market structure, we utilize firm level data from 2000-2015. According to the current literature, the distance to the frontier is an important variable which affects the innovation and market structure relationship. To estimate the variable distance to the frontier, we need firm level information on power and fuel consumption, wages and salaries, and raw material consumption which are mostly available only after 2000 in the CMIE database. After cleaning the data, we are able to collect information on 991 firms with 322 (32.50%) firms in high technology and 669 (67.50%) in medium technology industries.

For the second objective, firm level data from 1995-2015 is collected to study three major patent policy changes introduced (1999, 2002 and 2005) during this period. However, we compromise with the variable distance to the frontier in the regression analysis as the main focus is on the patent policy change. To investigate the third objective, we require data on both product and process innovation. CGPDT published product patents granted in India for the pharmaceutical industry in 2014. We have used that list of granted patents and further CGPDT's monthly publications to capture the data for all granted process patents. Thus, we utilize firm level data of 265 pharmaceutical companies from 2006-2013 to empirically investigate the third objective.

Methodology

To investigate first and second objectives, two-stage least square estimation (2SLS) is utilized for empirical estimation. We utilize fixed effect two-stage least square (FE2SLS) for econometric specifications. To investigate the third objective, fixed and random effects models are utilized. In both innovation and market structure equations, we analyze the nonlinear impact. According to Lind and Mehlum (2010), inclusion of nonlinear term in the model is a very weak criterion to check the nonlinearity as the presence of such a term is necessary but not sufficient condition for a U-shaped or inverted U-shaped relationship. Lind and Mehlum (2010) explain that if the true relationship is convex but monotone over relevant data then nonlinear term may erroneously yield an extreme point which results in a U-shaped or inverted U-shaped relationship. For this purpose, Lind and Mehlum (2010) provide a test which fulfils both necessary and sufficient condition for such nonlinear relationships. Hence, we verify the nonlinear relationship with SLM test in each equation.

Empirical Results

We present the results of both linear and nonlinear impact of market structure (WLI) on patent applications filed (PATENTAP) and patents granted (PATENTGR) in separate columns of Table 1. In Table 1, the coefficient of WLI is insignificant in the columns. We also do not find any nonlinear relationship between market power and innovation. This result suggests that market power does not determine firms' patenting activities. This empirical finding does not fit the theory of Aghion et al. (2005). As explained earlier, distribution of technology level also influences the competition and innovation relationship. We find that the overall relationship between market power and patenting is insignificant in neck-and-neck firms as well. These results, presented in Table 2, add confidence in explaining the insignificant impact of market structure on innovation in Indian high and medium technology firms. Table 3 presents the results of market structure equation. For the full sample estimation, the coefficient of PATENTAP is positive and significant. With respect to granted patent, the coefficient of PATENTGR is positive and significant in column III. While examining the nonlinear impact of the granted patent on market power, there is a significant inverted U-shaped relationship with market power. For high technology firms, the coefficients of PATENTAP and PATENTGR are positive and significant. With respect to medium technology firms, the coefficient of PATENTAP is positive and significant. We also find that the coefficient of $PATENTAP^2$ is negative and significant. This result supports the hypothesis of an inverted U-shaped relationship between patenting and market power.

The results of the innovation equation for 1995-2005 are presented in Table 4. In columns I-IV, the impact of market structure on innovation is insignificant. Moreover, the coefficient of WLI^2 is also insignificant for these firms. Results are also similar for high technology firms. For medium technology firms, we find a positive impact of WLI on firms' patent application and grant. Overall, results based on the innovation equation suggest that there is a linear positive impact of market structure on innovation but only for medium technology firms. In Table 5, we present the results of innovation equation for post-TRIPS period i.e. 2006-2015. Results based on full sample estimation suggest that market structure has a positive and significant impact on the patent applications filed at 10% level of significance. In other columns, we do not find any positive impact of market structure on innovation. Moreover, for high and medium technology firms, the impact of market structure on innovation is insignificant. The results of market structure equation for the period of 1995-2005 are presented in Table 6. Results based on full sample estimation indicate the positive and significant impact of PATENTAP and PATENTGR on firms' market power. We also find that the coefficient of $PATENTAP^2$ is negative and significant in column II. Result based on PATENTGR shows only linear and positive impact on the market power.

In Table 7, we present the results of market structure equation for the period i.e. 2006-2015. In Table 7, we find that innovation has an insignificant impact on the monopoly power. In all the columns, coefficients of WLI and WLI^2 are insignificant.

In Columns I-IV of Table 8, we report the estimated coefficients of product innovation (PROD) and process innovation (PROC). In columns I and II, the coefficient of PROD is positive and significant. Furthermore, the coefficient of $PROD^2$ is also positive and significant in columns I and II. This result suggests that there is the existence of an inverted-U shaped relationship between product innovation and monopoly power. In Columns III and IV of Table 8, we report the estimated coefficients of process innovation (PROC) and $PROC^2$. We find that PROC has a positive and significant impact on the monopoly power. Moreover, the coefficient of $PROC^2$ is also negative and significant. Hence, the relationship between process innovation and monopoly power is also an inverted-U shaped.

Table 1: Impact of market structure on innovation

	Full sample				High technology				Medium technology			
	PATENTAP		PATENTGR		PATENTAP		PATENTGR		PATENTAP		PATENTGR	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
WLI	-14.47536 (9.81992)	24.89224 (45.52559)	-0.89884 (3.42889)	-5.60123 (19.97350)	-20.44092 (18.34478)	5.384703 (18.73091)	-4.99005 (5.38528)	-18.09142 (18.77511)	-6.39972 (7.43418)	-3.141694 (17.30579)	1.16385 (4.27942)	4.91721 (12.90663)
WLI^2		-55.70811 (59.11540)		6.65423 (27.80054)		-32.00023 (39.83411)		16.23375 (20.38088)		-5.29267 (28.79579)		-6.09734 (21.22246)
OBSERVATIONS	14887	14887	14887	14887	4849	4849	4849	4849	10038	10038	10038	10038

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models.

Table 2: Impact of market structure on innovation of neck-and-neck firms

	Full sample				High technology				Medium technology			
	PATENTAP		PATENTGR		PATENTAP		PATENTGR		PATENTAP		PATENTGR	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
WLI	-3.85547 (9.12454)	0.66301 (27.78321)	-8.71095 (8.37954)	17.57935 (28.03526)	-15.58610 (9.75048)	-26.09580 (21.38453)	-10.85040 (8.09231)	-12.25681 (18.44658)	23.21941 (15.70051)	34.68102 (33.15069)	14.30334 (11.00652)	50.53501 (34.82778)
WLI^2		-43.52685 (283.3967)		-253.25630 (273.05390)		75.37506 (143.70140)		10.08667 (127.18760)		-95.02055 (239.20070)		-300.37260 (237.4473)
OBSERVATIONS	6342	6342	6342	6342	2043	2043	2043	2043	4503	4503	4503	4503

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Square brackets contain p- value. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models.

Table 3: Impact of innovation on market structure

	Full sample				High technology				Medium technology			
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
PATENTAP	0.01043*** (0.00307)	0.01950* (0.01145)			0.01007** (0.00432)	0.00617 (0.01832)			0.00854** (0.00408)	0.03219** (0.01541)		
$PATENTAP^2$		-0.00313 (0.00352)				0.00142 (0.00592)				-0.00761* (0.00417)		
PATENTGR			0.01710*** (0.00581)	0.05112** (0.02190)			0.01471** (0.00629)	0.01069 (0.03463)			0.00757 (0.00531)	0.08594* (0.05247)
$PATENTGR^2$				-0.01625* (0.00888)				0.00210 (0.01715)				-0.02830 (0.01830)
OBSERVATIONS	14887	14887	14887	14887	4849	4849	4849	4849	10038	10038	10038	10038

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models.

Table 4: Impact of market structure on innovation (1995-2005)

	Full sample				High technology				Medium technology			
	PATENTAP		**PATENTGR**		**PATENTAP**		**PATENTGR**		**PATENTAP**		**PATENTGR**	
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
WLI	2.12560	-13.87248	1.41267	4.04764	4.35699	15.96534	2.01910	4.69842	10.43394**	-0.04053	2.25511*	1.11681
	(5.54323)	(24.13694)	(1.47862)	(4.19366)	(11.0898)	(19.34587)	(3.02015)	(5.16541)	(4.58431)	(12.05985)	(1.29547)	(2.84956)
WLI^2		372.50610		-61.35385		-143.37890		-33.0933		272.77990		29.64407
		(504.69470)		(84.36087)		(173.7163)		(50.2973)		(330.50250)		(60.48034)
OBSERVATIONS	11132	11132	11132	11132	3597	3597	3597	3597	7535	7535	7535	7535

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models.

Table 5: Impact of market structure on innovation (2006-2015)

	Full sample				High technology				Medium technology			
	PATENTAP		**PATENTGR**		**PATENTAP**		**PATENTGR**		**PATENTAP**		**PATENTGR**	
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
WLI	-3.10542	24.72147*	-0.77693	4.91056	-11.26641	22.43785	1.62552	-2.01343	1.55157	16.79968	-3.60311	0.09130
	(5.50136)	(13.91875)	(3.55478)	(7.52367)	(11.27965)	(17.71324)	(4.6642)	(5.92186)	(8.65462)	(25.47022)	(7.17285)	(14.48467)
WLI^2		-40.34227		-8.24549		-38.87584		4.19732		-41.27474		-10.0003
		(26.49663)		(10.7896)		(35.93444)		(9.14787)		(45.21724)		(24.06933)
OBSERVATIONS	10120	10120	10120	10120	3270	3270	3270	3270	6850	6850	6850	6850

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models.

Table 6: Impact of innovation on market structure (1995-2005)

	Full sample				High technology				Medium technology			
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
PATENTAP	0.018380**	0.07790**			0.01506	0.06482			0.02084**	0.15986**		
	(0.00831)	(0.03921)			(0.01091)	(0.05567)			(0.00909)	(0.07143)		
$PATENTAP^2$		-0.02269*				-0.01838				-0.05316*		
		(0.01286)				(0.01725)				(0.02777)		
PATENTGR			0.08558*	0.69659			0.03268	0.66144			0.04223	1.03343
			(0.04922)	(0.53600)			(0.02197)	(0.67743)			(0.04011)	(0.86590)
$PATENTGR^2$				-0.30754				-0.27327				-0.63018
				(0.28147)				(0.30642)				(0.61550)
OBSERVATIONS	11132	11132	11132	11132	3597	3597	3597	3597	7535	7535	7535	7535

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models.

Table 7: Impact of innovation on market structure (2006-2015)

	Full sample				High technology				Medium technology			
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
PATENTAP	0.01570 (0.01241)	0.05937 (0.04576)			0.02247 (0.02496)	0.05650 (0.04865)			0.01322 (0.01137)	0.03951 (0.02731)		
PATENTAP^2		-0.01557 (0.01418)				-0.01089 (0.01186)				-0.00892 (0.00726)		
PATENTGR			0.03965 (0.04375)	0.04233 (0.04514)			0.00636 (0.01653)	0.03669 (0.05411)			0.02562 (0.02964)	0.01086 (0.04469)
PATENTGR^2				-0.00231 (0.01036)				-0.02665 (0.03077)				0.00357 (0.00788)
OBSERVATIONS	10120	10120	10120	10120	3270	3270	3270	3270	6850	6850	6850	6850

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models.

Table 8: Product and process innovation, and firms' monopoly power

	I	**II**	**III**	**IV**
PROD	0.00057* (0.00026)	0.00164*** (0.00051)		
PROD^2		-0.00044** (0.00018)		
PROC			0.00060*** (0.00023)	0.00135*** (0.00047)
PROC^2				-0.00032* (0.00017)
OBSERVATIONS	2120	2120	2120	2120

Notes: This table presents estimations using fixed effect model. Robust standard errors are shown in parenthesis. Here ***, ** and * denote that coefficients are statistically significant at 1, 5 and 10 percent levels, respectively. Firm and time specific dummies have been incorporated in the models.

Conclusion

This research provides fresh insights into the relationship between innovation and market structure in the context of emerging economies such as India. By examining the two-way nonlinear relationship between innovation and market structure, this study tests the predictions of Aghion et al. (2005) inverted U-shaped theory and the Schumpeterian theory of creative destruction in the Indian context. Earlier studies have focused on R&D expenditure as a measure of innovation. We utilize patent applications and patent grants to measure firm-level innovation activities.

We find that the predictions of Aghion et al. (2005) do not hold in our study. Our results are consistent with studies that have used R&D as a measure of innovation. Unlike other developed economies, competitive forces are not driving innovation among the Indian manufacturing firms. Therefore, the lack of such a relationship and lesser extent of competition in the emerging market could be a significant reason for the laggardness of the developing economies in terms of technological change. This result highlights a very important factor that has been withholding innovation by firms in a country like India where a vast majority of contribution to R&D is from the government sector.

Further, this study finds a significant feedback effect of innovation on the market structure. We also confirm the existence of an inverted U-shaped relationship which is in line with the Schumpeterian theory of creative destruction. This result also holds with different types of technological innovations (product and process). Up to a certain level, patents have a positive impact on market power. However, after an optimal level, further patent protection has an adverse impact. These results have important implications for developing economies. In a strong patent regime, firms have increased their innovation activities to capture the market. Thus policy incentives stimulate innovation. However, firms need to exercise discretion while determining the optimal level of innovation to avoid diseconomies.

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1. Do foreign firms enjoy monopoly power under product patent regime? Study of Indian pharmaceutical industry. 11th Annual International Conference on Globalization of Technology and Development organized by Forum for Global Knowledge Sharing (FGKS), held at IIT Madras from December 3-5, 2016. Available at ***http://fgks.in/index.php/conference-papers/2016-conference-papers*.** [Co-authors: Ruchi Sharma]

2. Innovation and competition in Indian medium and high technology industries. 12th Annual International Conference on Changing Paradigms in Technology, Trade and Development organized by Forum for Global Knowledge Sharing (FGKS), held at Nabakrushna Choudhury Centre for Development Studies (NCDS), Bhubaneswar from November 10-12, 2017. Available at ***http://fgks.in/index.php/conference-papers/2017*.** [Co-authors: Ruchi Sharma]

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International

1. Presented paper titled "Do MNEs enjoy monopoly power under product patent regime? A study of Indian pharmaceutical industry" *9th Asia-Pacific Innovation Conference 2018,* organized by Department of Economics, Delhi School of Economics, Delhi, India during December 13-14, 2018.

2. Presented paper titled "Technology purchase, in-house R&D and patenting: A study based on Indian high and medium technology industries"*17th International Schumpeter Society (ISS 2018) Conference* on Innovation, Catch-up, and sustainable development, organized by Seoul National University, Seoul, South Korea during July 02-04, 2018.

3. Presented paper titled "Types of innovation and firms' performance: Evidence from Indian pharmaceutical industry" *16th Globelics Conference* on Innovation, Economic Growth and Sustainable Development: Strengthening Institutions for Greater Relevance, Effectiveness and Inclusivity, organized by CSIR-STEPRI at Accra, Ghana during October 24-26, 2018.

National

1. Presented paper titled "Technology purchase, in-house R&D and patenting: A study based on Indian high and medium technology industries" in *54th Annual Conference of the Indian Econometric Society (TIES)* organized by Shri Mata Vishnodevi University, Katra, Jammu during March 7-9, 2018.

2. Presented paper titled “In-house R&D expenditure and technology imports in Indian high and medium technology industries” in *5th Biennial Indian Academy of Management conference 2017 (INDAM 2017)* organized by IIM Indore during December 20, 2017.

3. Presented paper titled “Innovation and market structure in Indian high and medium technology industries” in 12th Annual International Conference on Globalization of Technology and Development organized by *Forum for Global Knowledge Sharing (FGKS)* and Nabakrushna Choudhury Centre for Development Studies (NCDS), Bhubaneswar during November 10-12, 2017.

4. Presented paper titled “Do foreign firms enjoy monopoly power under product patent regime? Study of Indian pharmaceutical industry” in 11th Annual International Conference on Globalization of Technology and Development organized by *Forum for Global Knowledge Sharing (FGKS)* and IIT Madras during December 3-5, 2016.

5. Presented paper titled “Do intellectual property rights encourage business opportunity” in 3rd International Conference on *Management of Intellectual Property and Strategy (MIPS 2016)*, organized by IIT Bombay and NITIE Mumbai during July 14 -16, 2016.

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Acronyms

2SLS	Two-Stage Least Square Estimation
CAFC	United States Court of Appeals for the Federal Circuit
CGPDT	Controller General of Patents, Designs and Trademarks
CMIE	Centre for Monitoring Indian Economy
DSIR	Department of Scientific and Industrial Research
DWH	Durbin–Wu–Hausman
FDI	Foreign Direct Investment
FE2SLS	Fixed Effect Two-Stage Least Square
GDP	Gross Domestic Product
InPASS	Indian Patent Advanced Search System
IP	Internet Protocol
IPO	Indian Patent Office
IPRI	Index of patent rights
IPRs	Intellectual Property Rights
ISIC	International Standard Industrial Classification
LPG	Liberalization, Privatization and Globalization
NIC	National Industrial Classification
OECD	Organisation for Economic Co-operation and Development
PCT	Patent Cooperation Treaty
SCP	Structural-Conduct-Performance
SEM	Simultaneous Equation Modeling
SLM	Sasabuchi–Lind–Mehlum

TRIPs	Agreement on Trade-Related Aspects of Intellectual Property Rights
UK	United Kingdom
US	United States
WTO	World Trade Organization

CHAPTER 1

INTRODUCTION

1.1. Introduction

Innovation is a primary source of economic development as technological change contributes significantly to the development of an economy. Innovation is at the centre of economic change causing creative destruction (Schumpeter 1942). He described development as a historical process of structural change substantially driven by innovation. Schumpeter defines innovation as the introduction of new goods, better methods of production, new markets, new sources of raw materials and better organization techniques.

Innovations can be basically categorized into four types namely product, process, marketing and organizational innovation where the first two are technological innovations and others are non-technological in nature. Product innovation is defined as generation, introduction and diffusion of new products where the process remains unchanged. Process innovation includes generation, introduction and diffusion of new production process for the same product. Marketing innovations are new methods like change in product design, packaging, promotional strategies, and different pricing methods. Organizational innovation means introduction of new managerial practices that help firms to reduce transaction costs, supplier costs and improve labour productivity.

Literature on industrial organization contains a large number of studies which show the theoretical and empirical relationship between innovation and market structure (Cohen 2010). Literature which follows Schumpeter (1942) and Arrow (1962) demonstrates that market structure influences innovation. Firms with high monopoly power have both resources and incentive to conduct innovation activities. Concentrated market reduces business uncertainty and facilitates risky investments (Schumpeter 1942). On the other hand, Arrow (1962) shows that competitive environment makes firms efficient and innovative. In the presence of exclusive intellectual property rights (IPRs), firms with higher market power enjoy more pre-innovation profit; hence, incentive to innovate declines with increase in the competition.

The focus of the current doctoral dissertation is to explore the feedback effect between innovation and market structure and to analyze the influence of patent policy change on the relationship between innovation and market structure. Further, we also theoretically and empirically verify the impact of types of technological innovations i.e. product and process innovation on firms' market power.

The introduction is organized as follows: Section 1.2 discusses the context of the study. Section 1.3 explains the domestic patent policy change in India. Section 1.4 highlights the research gaps and objectives. Section 1.5 discusses various measures of innovation and market structure. Section 1.6 explains the data source and methodology. Section 1.7 presents the organization of the thesis.

1.2. The context

Competitive forces in an industry reduce future rents associated with innovation and hence discourage firms from investing in such activities (Schumpeter 1942). On the contrary, product market competition increases firms' efficiency through managerial-effectiveness which drives innovation (Arrow 1962). Aghion et al. (2005) advanced the debate by introducing the possibility of an inverted U-shaped relationship between innovation and competition. Such a nonlinear relationship occurs during a low level of competition in an industry where firms intend to escape the competition by innovating new products. Later, the pace of competition reduces and few winners emerge, thus catalyzing the Schumpeterian effect. It implies that technological leaders dominating the industry are ultimately responsible for a negative relationship between competition and innovation.

On the other hand, the scholars associated with the Chicago School of Thought on innovation and market structure which mainly emerged in 1970, argue that market dominance arises from superior efficiency which is a function of technological advancements (Shepherd 1990). Technological advancements are sources of economies of scale and efficiency which positively influence firms' market power. Thus, innovation has a positive influence on firms' market power. Innovations help firms to sustain their market dominance. New products and processes provide the means for large and old firms to create high entry barriers. However, this positive impact prevails up to an optimal level. Only afterwards does monopoly show a declining trend with further increase in innovation (Nemlioglu & Mallick 2017). Nemlioglu and Mallick (2017) show that the Schumpeterian theory of creative destruction plays a very important role for explaining this inverted-U shaped relationship. Studies also analyze a two-way relationship between innovation and market structure using simultaneous equation modeling (SEM) and the focus of such studies is to explore linear two-way relationships between innovation and market structure (Albert 1995; Koeller 1995 & 2005; Lunn 1986; Vossen 1999; Sridhar et al. 2014).

Most studies on innovation and market structure are based on developed countries. Developing countries (particularly like India) have immense demand potential and complex market structure. Such economies provide an interesting research context for undertaking a study on innovation and market structure. Indian industry has a legacy of extensive government regulation but has evolved since 1990 after the structural economic reforms. Topalova and Khandelwal (2011) find that trade liberalization and other industrial policy reforms are complementary and simultaneously encourage pro-innovation activities among Indian firms. Additionally, IPRs related reforms to conform to the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) have strengthened the incentives for firms to innovate and compete in the local and global market.

Liberalization, Privatization, Globalization policies (LPG) have positively affected the Indian economy through cutting down of tariff rates (tariff rate dropped to 43% in 1996 as compared to 87% in 1990) and removal of quantitative restrictions on imports. The objective of the liberalization policy was to enhance innovation, productivity and efficiency of Indian manufacturing firms by creating a competitive environment. A study by Goldberg et al. (2010) finds that decline in trade cost and imports of new intermediate inputs have increased innovation activities among Indian firms. By importing new inputs, firms expand their product line through differentiation of goods and services. Goldberg et al. (2010) find that after lowering tariffs, there is a 31% increase in entry of new products by domestic firms. Further, studies like Driffield and Kambhampati (2003), Chand and Sen (2002), Nataraj (2011), and Topalova and Khandelwal (2011) find that trade liberalization has a favorable impact on the productivity of Indian firms.

With the Patent (Amendment) Act 2004, the Indian government introduced product patents for all fields of technology [1]. Such a strengthening of patent policy that is exogenous to the firms is an important incentive for in-house technology creation as international evidences suggest that strengthening patent protection positively influences firms' innovation activities (Kanwar & Evenson 2003; Naghavi

[1] Next section elaborates on the patent policy changes.

& Strozzi 2015). Due to strong patent laws and other IPRs protections, developing countries are now specialising in some fields of technologyand are innovating at the frontier of such technology fields (Kumar et al. 1999; Srholec 2007; Fu & Gong 2011).

With the Patent (Amendment) Act 2004, India began granting product patent in all fields of technology. Product and process innovation are known as technological innovations which have a direct impact on the firms' market power. Product innovation increases monopoly power of a firm through a product differentiation channel as the firm now charges higher prices for differentiated products (Lunn 1986; Cohen & Klepper 1996; Vives 2008). Process innovation positively affects firms' monopoly power through cost reduction that improves productivity and output (Griliches 1980; Kamien & Schwartz 1982; Deolalikar & Roller 1989; Crépon et al. 1998; Hall 2011).

1.3. Domestic Patent Policy

In India, the history of patent policy can be traced to the British Patent law 1852. Patent administration began under Controller General of Patents with Indian Patents and Design Act 1911 which replaced all previous Acts. Before independence another amendment in 1945 provided for the filing of provisional specifications and submission of complete specifications within nine months. Post independence, the Indian Patents and Design Act 1911 was replaced by the Patent Act 1970 based on the recommendations of Justice N. Rajagopala Ayyangar Committee which was finally implemented in 1972. According to this Act, only process innovation can be patented in fields of food and medicine and for the duration of 7 years, whereas in other fields of technology the duration is for 14 years.

TRIPs came into practice in 1995. It set minimum standards for IPRs for member countries of the World Trade Organization (WTO). India also made many changes in its domestic patent policy to conform to TRIPs. The amendment provides permission to file applications for product patenting in the field of pharmaceutical, drugs and agro chemical industries (however such applications were examined only after December 31, 2004). This amendment also provides a provision for granting Exclusive Marketing Rights (EMRs). The second Amendment in Patent Act 1970 was made in 2002 with the Patent (Amendment) Act 2002. It replaced the rules of Patent Act 1970. In this Act many changes were made and the term of protection was extended up to 20 years. The source and geographical location of the biological material also had to be disclosed, licensing rights were removed, publication of applications after 18 months began and provision of pre and post grant opposition was also initiated. The third amendment to the Patent Act 1970 was made through Patent (Amendment) Act 2004 which was implemented by January 1, 2005. This Amendment provides permission for product patent in all fields of technology. It makes provision of compulsory licensing for producing and exporting of pharmaceutical products to any country having insufficient or no manufacturing policy to accommodate the Doha Round Mandate about compulsory licensing.

1.4. Research questions and objectives

In the case of developing countries like India, there is a need to understand the relationship between innovation and market structure more clearly. Firms in the developing countries are relatively protected, small in size, inefficient and have limited resources. Moreover, the market is mostly controlled by few large dominant firms. As a result, the market structure in the developing countries is different than developed countries. Moreover, in the last 30 years, the Indian economy has also undergone significant policy reforms like LPG and patent policy changes which are mostly exogenous to the firms. Such policy reforms influence the firms' competitiveness and technological capabilities; hence, the overall innovation and market structure relationship. In this dissertation, we produce empirical evidences on innovation and market structure relationship in the post-policy reform period. Such analyses will have immense significance for policy makers and researchers in formulating competition and innovation policies in developing countries.

On the empirical front, evidences on Aghion et al. (2005) inverted-U shaped relationship between innovation and market structure, and Schumpeterian theory of creative destruction are non-existent in the Indian context. Most studies analyze one-way linear relationship between innovation and market structure in the Indian manufacturing sector by considering innovation as a dependent variable (Kumar & Saqib 1996; Narayanan 1998; Kathuria 2008; Basant & Mishra 2014; Sharma et al. 2018). In this dissertation, we attempt to empirically verify the existence of Aghion et al. (2005) inverted-U shaped relationship and Schumpeterian theory of creative destruction in the context of an emerging economy India. For this purpose, we analyze a two-way nonlinear relationship between innovation and market structure in Indian high and medium technology firms by employing SEM.

The industrial structure of developing countries differs from developed countries. The markets of developing countries are mostly dominated by few large firms with small laggard followers. Aghion et al.'s (2005) model assumes that a leading firm in an unleveled industry does not innovate. Further, as the laggard firms copy the technology of the leader, an unleveled industry becomes leveled. Polder and Veldhuizen (2012) argue that the inverted U-shaped relationship may not hold in the presence of few dominant firms in an unleveled industry which compete continuously by innovating and patenting for strategic reasons. Hence, the relationship between innovation and competition may vary with the industrial structure which encourages us to empirically investigate this model in such an industrial set-up. Particularly, in a context of developing countries that have few large firms with small laggard followers.

In the academic literature, it is evident that innovation strengthens market power. The innovation types (product and process) may not affect the market power uniformly. Most importantly, the channels through which product and process innovations influence firms' performance vary. Specifically, product innovation impacts a firm by creating a differentiated good and process innovation makes the firm use existing inputs efficiently to reduce the cost of production. It still remains unexplored if product and process innovation have a non-linear impact as has been espoused in the literature for the overall innovation that combines process and product innovation together. In the Indian context studies on types of innovation are not available.

Another major gap in the existing literature of developing countries is to utilize R&D expenditure as a proxy for innovation which is an input based measure of innovation. The main issue with Indian R&D data is that many firms do not report such expenditures and all such investments are not necessarily reflected into successful innovation. However, studies have suggested methods to overcome such concerns; namely, by utilizing patenting data which is an output based proxy for innovation (Pakes & Griliches 1980; Griliches et al. 1981; Hall et al. 1986). A large number of studies utilize patent data as a robust proxy for firm level innovation activity. However, the use of patent based innovation measures for Indian studies is limited.

On the basis of the above discussion, the objectives of the study are as follows:

1. To investigate the bidirectional relationship between innovation and market structure.

2. To investigate the relationship between innovation and market structure under different patent regimes.

3. To investigate the differential impact of product and process innovations on market structure.

1.5. Measurement of innovation and market structure

1.5.1 Measures of innovation

To measure firm level innovation activities scholars use a variety of measures which they classify as inputs and outputs based measures of innovation. R&D expenditure, simple patent count, patents weighted by citations, number of researchers and scientists, new product sale, number of new products and processes and productivity are widely used measures of innovation (Hall et al. 1986; Aghion et al. 2005). Patent count is an appropriate proxy to measure firm level innovation output whereas R&D by firms is a measure of innovation input. Table 1.1, lists the different measures of innovation and the dimensions these measures capture. In this dissertation, innovation activity of firms has been proxied by patent applications and grants. It is also a broad proxy to measure firm level innovation performance. Use of patent data in the context of developing countries is limited. Patents are a direct outcome of successful R&D expenditure which has high commercial value (Griliches et al. 1981; Hall et al. 2005; Archibugi & Planta 1996; Crépon et al. 1998; Chadha 2009; Ambrammal & Sharma 2016). There are also various strategic reasons behind patenting like protection against infringement, strengthening competitive advantage, creation of entry barriers and protection from litigation. However, the use of patent data as a measure of innovation is not free from certain limitations. For example; all innovations are not patented and economic value of patents is heterogeneous due to non-commercialization. Given such limitations, researchers measure the quality of patents by using citation weighted count to resolve the heterogeneity problem (Pakes & Schankerman 1984; Schankerman & Pakes 1986; Hall et al. 2005). Indian Patent Office (IPO) does not require applicants to cite patents thus the present study relies on simple patent count.

Table 1.1: Different measures of innovation at firm and industry level

Measure	**Innovation dimensions**	**Related literature**
R&D expenditure	Input based	Pavitt (1982), Kumar and Saqib (1996), Crépon et al. (1998), Chadha (2009), Basant and Mishra (2014), Ambrammal and Sharma (2016), Sharma et al. (2018), Narayanan (1998)
Patent (application and grant)	Output based	Pavitt (1982), Archibugi and Planta (1996), Crépon et al. (1998), Chadha (2009), Hagedoorn and Wang (2012), Kang et al. (2015), Ambrammal and Sharma (2016), Altuzarra (2019)
Citation weighted patents	Output based	Pakes and Schankerman (1984), Schankerman and Pakes (1986), Hall et al. (2005), Aghion et al. (2005), Correa (2012), Hashmi (2013), Correa and Ornaghi (2014), Negassi et al. (2018)
Number of researchers and scientists	Input based	Cruz-Cázares et al. (2013)
New product sales	Output based	Blackman (1973), Hoarau and Kline (2014), Kafouros et al. (2014)
Number of new products and processes	Output based	Tohidi and Jabbari (2012), Gonzalez et al. (2013)
Productivity	Output based	Crépon et al. (1998), Lokshin (2008), Hashmi (2013), Correa and Ornaghi (2014)

Source: Authors' compilation.

1.5.2 Measures of market structure

There are various measures of market structure which researchers have utilized over a period of time; for example, concentration index (HHI, CR4, Entropy index, Howarth index), market power, firm size, price elasticity index, perceived competition, firms' entry and exit rate. Table 1.2 presents details of various measures of market structure. In this dissertation, we utilize Lerner index as a measure of market structure. The choice of this measure is due to its superiority over other measures and availability of data. Lerner index is a firm specific variable to measure market structure. Industry specific measures of market structure like HHI and CR4 are more stable even in case of high cross sectional variation and heavy competition. However, these may underestimate the actual competitive pressure in the market. The stability also leads to low variability in time series observations leading to large standard errors (Davies & Geroski 1997; Tingvall & Poldahl 2006). On the other hand, Lerner index, a firm specific measure of market structure does not suffer from such problems and gives a robust measure. Simple Lerner index, an absolute measure, does not explain the overall industrial competitiveness. For example, a small firm may have high profitability because of lower sales and costs. In reality, such firms have insignificant role in deciding the overall industrial competitiveness because of their small sales volume. On the other hand, a large firm may have low profitability because of high costs; hence, low market power. However, such firms actually enjoy more market benefits and dominate the industry. To overcome such problem, there is a need to adjust the simple Lerner index so that it can explain the relative position of a firm in an industry. Studies like Clerides et al. (2015) and Saraswathy (2018) utilize an adjusted Lerner index which is weighted by market shares. In this study too, we calculate a weighted Lerner index by considering market shares as weights.

Table 1.2: Different measures of market structure at firm and industry level

Measure	**Related literature**
Concentration index (HHI, CR4, Entropy index, Howarth index)	Scherer (1965), Mansfield (1968), Mansfield et al. (1982), Lunn (1986), Lunn and Martin (1986), Koeller (1995), Koeller (2005), Tingvall and Poldahl (2006), Basant and Mishra (2014),
Lerner index	Aghion et al. (2005), Tingvall and Poldahl (2006), Inui et al. (2012), Correa (2012), Polder and Veldhuizen (2012), Hashmi (2013), Correa and Ornaghi (2014), Negassi et al. (2018)
Weighted Lerner index	Clerides, Delis and Kokas (2015), Saraswathy (2018)
Firm size	Scherer (1965), Scott (1984), Lunn and Martin (1986), Acs and Audretsch (1987)
Market share	Williamson (1965), Robinson (1990), Banbury and Mitchell (1995), Blundell et al. (1999), Hall (1999), Roberts (1999)
Profit elasticity index	Boone (2008), Peroni and Ferreira (2012)
Perceived competition	Raymond and Plotnikova (2015)
Firms' entry and exit rate	Dasgupta and Stiglitz (1980), Geroski (1990), Klepper (1996), Agarwal and Gort (1996)

Source: Authors' compilation.

1.6. Data and empirical methodology

1.6.1 Data

We utilize firm level panel data for Indian high and medium technology firms. Indian high and medium technology firms provide a very interesting research context to explore a two-way relationship between innovation and market structure. Pavitt (1984), Nelson and Winter (1982), and Malerba and Orsenigo (1997) explain that technological opportunities and marketing conditions vary with the types of industries. According to Pavitt (1984), the patterns of innovations among different industries vary in terms of types of innovation and propensity to innovate. These aspects condition firms' innovation behaviour and technology strategies. Hence, we perform our analysis separately for both high and medium technology firms also.

We identify firms in high and medium technology industries on the basis of the OECD classification and concordance is drawn between International Standard Industrial Classification (ISIC) 2003 Revision 3 and National Industrial Classification (NIC) 2008 via NIC 2004. According to the International Standard Industrial Classification (ISIC) 2003 Revision 3; (i) Electrical machinery and apparatus (ii) Motor vehicle, trailers and semi- trailers (iii) Chemicals excluding pharmaceuticals (iv) Rail road and transport equipment (v) Machinery and equipment are considered as medium technology industries. Similarly; (i) Aircraft and space craft (ii) Pharmaceutical (iii) Office, accounting and computing machinery (iv) Radio, TV and communication equipment, and (v) Medical, Precision and optical instrument are high technology industries based on ISIC 2003 Revision 3. The analysis is carried out at five digit NIC (2008) classification. Major sources of data for this study include the Centre for Monitoring Indian Economy (CMIE) prowess database and the website of Controller General of Patents, Designs and Trademarks (CGPDT, Government of India). CMIE database provides an annual report data for firms that are listed in Bombay Stock Exchange (BSE). All firm level data in this study is collected from CMIE. We collected the patent data from Indian Patent Advanced Search System (InPASS).

The time period for each study addressing three objectives is different. To investigate the bidirectional relationship between innovation and market structure, we utilize firm level data from 2000-2015. According to the current literature, the distance to the frontier is an important variable which affect innovation and market structure relationship (Aghion et al. 2005; Acemoglu et al. 2006). We classify our sample into leveled industry (neck-and-neck firms) and unleveled industry based on distance to the frontier. To estimate the variable distance to the frontier, we calculate total factor productivity of sample firms which requires information on power and fuel consumption, wages and salaries, and raw material consumption which are mostly available only after 2000 in the CMIE database.

For the second objective, firm level data over 1995-2015 is collected. Our objective is to evaluate the impact of major patent policy changes on the relationship between innovation and market structure in Indian high and medium technology firms. We classify the dataset into two time periods, 1995-2005 and 2006-2015. The period of 1995-2005 is a transition phase during which the Indian government amended the patent Act 1970 to comply with TRIPs agreement. From 2006-2015, the real impact of TRIPs can be realized. This study helps us understand the implications of TRIPs on innovation and competition issues in the Indian manufacturing sector. However, we compromise with the variable distance to the frontier in the regression analysis as the main focus is on the patent policy change. Considering the availability of data on both product and process patents, we investigate the third objective for the Indian pharmaceutical industry. We have used the list of granted product patents issued by CGPDT and its monthly publications to get data on all granted process patents. CGPDT published the list of granted product patents in 2014.

1.6.2 Empirical methodology

The objective of this dissertation is to analyze two-way relationship between innovation and market structure. For empirical purpose, we propose to use SEM techniques. In SEM, joint dependent variables are called endogenous variables. To investigate first and second objectives, two-stage least square estimation (2SLS) is utilized for empirical estimation (Lunn 1986; Shan et al. 1994; Koeller 1995, 2005; Baltagi 2008). We utilize fixed effect two-stage least square (FE2SLS) for econometric specifications (Baltagi & Li 2009). To investigate the third objective, fixed effects model is utilized. Fixed effects model estimates the pure impact of independent variable by controlling the unobserved heterogeneity and it also tackle the endogeneity bias. Fixed effects model is consistent under both the null and alternative hypothesis of the Hausman specification test. The null hypothesis of the Hausman test is that there is no systematic difference in random effects and fixed effects coefficients (Greene 2003).

We analyze the nonlinear impact in both innovation and market structure equations. In most studies, researchers include nonlinear terms in the regression models and identify U-shaped and/or inverted-U shaped relationship between dependent and independent variables. According to Lind and Mehlum (2010), inclusion of nonlinear terms in the model is a weak criterion to check the nonlinearity as the presence of such term is a necessary but not sufficient condition for a U-shaped and/or inverted U-shaped relationship. Lind and Mehlum (2010) explain that if the true relationship is convex but monotone over relevant data than nonlinear term may erroneously yields extreme point which result in U-shaped or inverted U-shaped relationship. For this purpose, Lind and Mehlum (2010) provide a test for a nonlinear relationship which satisfies both necessary and sufficient conditions for such relationships. This test is based on the framework of the likelihood ratio test of Sasabuchi (1980) and referred to as the Sasabuchi–Lind–Mehlum (SLM) U-test. Hence, we verify the nonlinear relationship by performing SLM test in each equation.

1.7. Organization of the thesis

The thesis is divided into five further chapters. Chapter 2 provides a detailed analysis of R&D and patent statistics in India. It also discusses the R&D and patent statistics of sample firms used in this dissertation. Chapter 3 discusses the relationship between innovation and market structure in Indian high and medium technology firms. After this introduction, we review the theoretical and empirical literature which establishes the link between innovation and market structure. In the literature review section, we also specify the contribution of the chapter. In the next section, we present the description of the variables used. The following section presents the data and descriptive analysis. The next section presents the results and the discussion. The final section concludes the chapter.

Chapter 4 analyses the role of patent policy changes on the relationship between innovation and market structure. The organization of chapter three is similar to chapter 2. After a general introduction, we discuss patent policy changes in India. Following this discussion, we present the review of literature and contribution of the chapter. The next section provides a description of the variables. Following this, the next section provides information on the data sources. Lastly, we present the results and conclude the chapter.

Chapter 5 analyzes the nonlinear relation between product and process innovation and firms' monopoly power in the Indian pharmaceutical sector. After a general introduction, we define the product and process innovation. The next section presents the review of literature and theoretical model on the nonlinear relationship between product and process innovation and firms' monopoly power. Further, we test the model using firm level data of the Indian pharmaceutical industry. The next section defines the variables and mentions their sources. Finally, we estimate the results and conclude the chapter.

Chapter 6 draws out the primary conclusion and discussion of the thesis. This chapter highlights the main findings of the thesis. The next section highlights the policy recommendations and limitations of the work.

CHAPTER 2

R&D AND PATENTING IN INDIA

2.1. Introduction

The purpose of this chapter is to analyze R&D and patent statistics of India. Technological capabilities can be built and improved through in-house R&D and patenting. There is a positive impact of technological investment on the firms' performance. Through more R&D and patenting, firms can acquire updated technology and exploit new business opportunities in both local and international markets. In the recent past, industrial policy reforms like LPG and patent policy changes have expanded R&D and patenting activities in India. The key objective of these reforms was to enhance innovation, productivity and efficiency of the manufacturing firms by creating a competitive environment. This chapter provides a detailed analysis of R&D and patenting activities of India at aggregate level and of sample firms.

The rest of the chapter is organized as follows: Section 2.2 provides a brief statistic of R&D and patenting activities at macro level. Section 2.3 discusses R&D and patenting statistics of sample firms. Section 2.4 concludes the chapter.

2.2. R&D and patent statistics in India

2.2.1 Change in R&D and patent statistics in India

In this section, we will discuss R&D and patent statistics of India. In Table 2.1, the average R&D expenditure (% of GDP) between 1995-1996 to 2014-2015 is 0.73%. For the year 2014-2015, the average R&D expenditure is 0.69%. Another important finding in Table 2.1 is that this percentage is stagnant between 0.60% - 0.80% over 1995-96 to 2014-15, which is low in comparison to many developed and developing countries. When we look at patent statistics, there is a continuous increase in patent applications. The total patent applications filed in 1995-1996 is 7036, which increased to 10592 in 2001-2002 and further increased to 42736 in 2014-2015. With respect to patent grants, we find an increasing trend as well. In 1995-1996, the total number of patent grants was 1553, which increased to 5978 in 2014-2015. These statistics suggest that patenting activity has increased in India.

We observe an increasing trend for patent application between 1995-1996 to 2014-2015 whereas for patent grant, there is a sudden jump for the years 2006-2008, which further started declining after 2008. India made many changes in its domestic patent policy to confirm TRIPs. The Patent (Amendment) Act 1999 provides permission to file product patents in the fields of pharmaceutical, drugs and agrochemical. However, such applications were examined and granted only after December 31, 2004[1]. Hence, we find a sudden jump in patent grants during 2006-2008.

[1] These patent applications are commonly known as mailbox patent applications.

Table 2.1: R&D and patenting in India

Year	R&D (% of GDP)	Patent applications	Patent grants
1995-1996	0.61	7036	1533
1996-1997	0.63	8562	907
1997-1998	0.67	10155	1844
1998-1999	0.69	8954	1800
1999-2000	0.71	4824	1881
2000-2001	0.74	8503	1318
2001-2002	0.72	10592	1591
2002-2003	0.71	11466	1379
2003-2004	0.71	12613	2469
2004-2005	0.74	17466	1911
2005-2006	0.81	24505	4320
2006-2007	0.80	28940	7539
2007-2008	0.79	35218	15316
2008-2009	0.84	36812	16061
2009-2010	0.82	34287	6168
2010-2011	0.77	39400	7509
2011-2012	0.76	43197	4381
2012-2013	0.74	43674	4126
2013-2014	0.71	42951	4227
2014-2015	0.69	42763	5978

Source: Annual reports of DST and CGPDT, various issues.

2.2.2 Patent statistics of the major fields of technology

In Tables 2.2 and 2.3, we present patent statistics for the major fields of technology. These fields are namely chemical, drug, food, electrical and mechanical, which are identified by IPO based on high patent concentration. Total 2125 patents are applied in mechanical field in 1998-1999, which is the highest among all the major fields of technology. In 2014-15 also, mechanical was a leading sector in the patent filing. Moreover, there was a continuous increase in patent filing in other fields of technology. Between 1998-2003, the average patent filing is 1040 in the chemical sector, 1056 for drug, 114 for food, 999 for electrical and 1369 mechanical, respectively. In Table 2.3, we note that the patent applications are declining from 1999 till 2003. Following that there is a jump in patent filing in all the fields of technology. In comparison to 1998, there is around 209% growth in patent filing by 2015 in all major fields of technology. The highest increase was in the mechanical sector, where patent filing increased by around 372%. We also find that there was an increase in granted patents in all the fields of technology. Between 1998-2015, total patents granted to mechanical were 19307, to chemical 20129, to drug 7740, to food 1585 and to electrical sector 6597. There was around 143% growth in the patent grants between 1998-2015 in all the major fields of technology.

Table 2.2: Number of patent applications and share (% of total patent application) under major fields of technology

Year	Chemical		Drug		Food		Electrical		Mechanical	
	Patent applications	Share (% of total patent application)	Patent applications	Share (% of total patent application)	Patent applications	Share (% of total patent application)	Patent application	Share (% of total patent application)	Patent applications	Share (% of total patent application)
1998-1999	2023	22.59	1555	17.36	140	1.56	1778	19.85	2125	23.73
1999-2000	840	17.41	1000	20.72	107	2.21	877	18.17	1187	24.60
2000-2001	787	9.25	883	10.38	96	1.12	921	10.83	1106	13.00
2001-2002	778	7.34	879	8.29	110	1.03	731	6.90	1174	11.08
2002-2003	776	6.76	966	8.42	119	1.03	690	6.01	1257	10.96
2003-2004	2952	23.40	2525	20.01	123	0.97	2125	16.84	2717	21.54
2004-2005	3916	22.42	2316	13.26	190	1.08	1079	6.17	3304	18.91
2005-2006	5810	23.70	2211	9.02	101	0.41	1274	5.19	4734	19.31
2006-2007	6354	21.95	3239	11.19	1223	4.22	2371	8.19	5536	19.12
2007-2008	6375	18.10	4267	12.11	233	0.66	2210	6.27	6424	18.24
2008-2009	5884	15.98	3672	9.97	340	0.92	2319	6.29	6360	17.27
2009-2010	6014	17.54	3070	8.95	276	0.80	2376	6.92	6775	19.75
2010-2011	6911	17.54	3526	8.94	315	0.79	2719	6.90	7782	19.75
2011-2012	6698	15.50	2762	6.39	294	0.68	4160	9.63	9716	22.49
2012-2013	6812	15.59	2954	6.76	452	1.03	3568	8.16	10198	23.35
2013-2014	6769	15.75	2507	5.83	387	0.90	4371	10.17	11318	26.35
2014-2015	6454	15.09	2640	6.17	395	0.92	4031	9.42	10031	23.45

Source: Annual reports of CGPDT, various issues.

Table 2.3: Number of patent grants share (% of total patent grant) under major fields of technology

Year	Chemical		Drug		Food		Electrical		Mechanical	
	Patents granted	Share (% of total patents granted)	Patents granted	Share (% of total patents granted)	Patents granted	Share (% of total patents granted)	Patents granted	Share (% of total patents granted)	Patents granted	Share (% of total patents granted)
1998-1999	609	33.83	150	8.33	35	1.94	138	7.67	462	25.67
1999-2000	516	27.43	307	16.32	250	13.29	147	7.81	569	30.25
2000-2001	353	26.78	276	20.94	72	5.46	142	10.77	254	19.27
2001-2002	483	30.36	320	20.11	36	2.26	139	8.74	311	19.55
2002-2003	399	28.93	312	22.63	67	4.86	118	8.56	228	16.53
2003-2004	609	24.67	419	16.97	110	4.46	396	16.04	539	21.83
2004-2005	573	29.98	192	10.05	67	3.51	245	12.82	414	21.66
2005-2006	1140	26.39	457	10.58	140	3.24	451	10.44	1448	33.52
2006-2007	1989	26.38	798	10.58	244	3.24	787	10.44	2526	33.51
2007-2008	2662	17.38	905	5.91	154	1.01	1067	6.97	3503	22.87
2008-2009	2376	14.79	1207	7.52	97	0.60	1140	7.10	3242	20.19
2009-2010	1420	23.02	530	8.59	72	1.17	404	6.55	1024	16.60
2010-2011	1899	25.29	596	7.94	84	1.12	394	5.25	1458	19.42
2011-2012	1168	26.66	282	6.44	21	0.48	228	5.20	888	20.27
2012-2013	1289	31.24	344	8.34	37	0.90	188	4.56	749	18.15
2013-2014	1111	26.28	256	6.06	51	1.21	237	5.61	645	15.26
2014-2015	1533	25.64	389	6.51	48	0.80	376	6.29	1047	17.51

Source: Annual reports of CGPDT, various issues.

2.3. R&D and patent statistics of sample firms

With respect to data used in the dissertation, we provide R&D and patent statistics of sample firms in this section. We utilize firm-level information of 1012 firms based on 27 high and medium technology industries which are defined on the basis of 3-digit NIC 2008. The selection of a firm is based on the availability of its sales data between 1995-2015. The details of the industry and the number of firms in each industry are presented in Table 2.4.

Table 2.4: Details of NIC and number of firms in different NIC

NIC (2008)	Detail of NIC	No. of sample firms	High technology/medium technology industry
107	Manufacture of other food products	12	Medium technology
201	Manufacture of basic chemicals, fertilizer and nitrogen compounds, plastics and synthetic rubber in primary forms	166	Medium technology
202	Manufacture of other chemical products	117	Medium technology
203	Manufacture of man-made fibres	40	Medium technology
210	Manufacture of pharmaceuticals, medicinal chemical and botanical products	169	High technology
259	Manufacture of other fabricated metal products; metalworking service activities	9	Medium technology
261	Manufacture of electronic components	30	High technology
262	Manufacture of computers and peripheral equipment	4	High technology
263	Manufacture of communication equipment	8	High technology
264	Manufacture of consumer electronics	6	High technology
265	Manufacture of measuring, testing, navigating and control equipment; watches and clocks	18	High technology
266	Manufacture of irradiation, electromedical and electrotherapeutic equipment	5	High technology
271	Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus	30	Medium technology
272	Manufacture of batteries and accumulators	11	Medium technology
273	Manufacture of wiring and wiring devices	29	Medium technology
274	Manufacture of electric lighting equipment	4	Medium technology
275	Manufacture of domestic appliances	16	Medium technology
279	Manufacture of other electrical equipment	17	Medium technology
281	Manufacture of general purpose machinery	80	High technology
282	Manufacture of special-purpose machinery	82	Medium technology
291	Manufacture of motor vehicles	5	Medium technology
292	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	6	Medium technology
293	Manufacture of parts and accessories for motor vehicles	3	Medium technology
302	Manufacture of railway locomotives and rolling stock	8	Medium technology
303	Manufacture of air and spacecraft and related machinery	2	High technology
309	Manufacture of transport equipment n.e.c.	130	Medium technology
325	Manufacture of medical and dental instruments and supplies	5	High technology

Notes: Based on information available from CMIE-PROWESS and Central Statistical Organisation (CSO), Ministry of Statistics and Programme Implementation, Government of India.

2.3.1 R&D expenditure and patenting

In Tables 2.5 and 2.6, we analyze the average R&D and patent statistics of sample firms. In Table 2.5, we find that industries like NIC 262, 263, 265 and 210 were spending more than 1% of their sales on R&D activities during 1995-2000. However, NIC 292, 259, 107 and 302 had the lowest R&D intensity during 1995-2000. For the period 2001-2005, industries like NIC 210, 261, 291, 293 had highest R&D intensity; however, for the same period NIC 302, 292, 273, 274, 259 and 203 had R&D intensity lower than 0.10. For the period 2006-2010, NIC 210, 261, 263 and 291 had the highest R&D intensity whereas NIC 203, 273 and 292 had lowest R&D intensity. For the period 2011-2015, NIC 210, 261, 263, 264, 265 and 291 had R&D intensity greater than 1% whereas NIC 203, 262, 266 and 273 were relatively low R&D intensive industries. Industry NIC 264 was spending around 15% of its total sales on R&D during 2011-2015. We found that for certain industries like NIC 107, 202, 210, 261 and 291, there was a continuous increase in R&D intensity.

With respect to the patenting statistics in Table 2.6, we find that industries like NIC 259, 265, 210, 281, 202 and 282 had highest patent filing during 1995-2000. During 2011-2015, patent-intensive industries were NIC 303, 291, 259, 210, 281, 309, 202, and 282. For granted patents, industries like NIC 202, 274, 302, 210 and 275 had high patent grants during 1995-2000. For 2011-2015, industries like NIC 274, 291, 210, 281, and 202 had high patent grants. From Table 2.6, we note that Indian firms are becoming more patent intensive over the period of time.

Table 2.5: R&D intensity (% of sales) for Indian industries in different NIC

NIC	1995-2000	2001-2005	2006-2010	2011-2015
107	0.0861	0.1209	0.1188	0.1325
201	0.2664	0.2285	0.2039	0.1739
202	0.2776	0.3488	0.4258	0.5377
203	0.4782	0.0327	0.0077	0.0172
210	0.9059	1.7995	2.4318	2.1685
259	0.0273	0.0219	0.1231	0.1417
261	0.7494	1.0489	1.0884	1.3197
262	1.3688	0.4653	0.3060	0.0907
263	1.0765	0.5726	1.4063	2.1060
264	0.5693	0.7315	0.4944	15.600
265	1.0542	0.4969	0.8333	1.5328
266	0.1412	0.1509	0.1379	0.0279
271	0.2448	0.2238	0.2499	0.5084
272	0.7235	0.7320	0.3511	0.6098
273	0.1411	0.0295	0.0502	0.0278
274	0.1243	0.0874	0.1635	0.2463
275	0.3319	0.2636	0.2244	0.3139
279	0.2983	0.3701	0.1939	0.2266
281	0.2278	0.2766	0.2563	0.4827
282	0.3217	0.3000	0.2894	0.4146
291	0.8348	1.1231	2.1273	2.2409
292	0.0000	0.0000	0.0064	0.0000
293	0.4277	1.0782	0.9585	0.6866
302	0.0843	0.0755	0.2247	0.2036
303	0.2534	0.2576	0.5995	0.9619
309	0.4497	0.4916	0.5017	0.4507
325	0.1353	0.4825	3.0610	1.2796

Source: Calculated based on information available in CMIE PROWESS.

Table 2.6: Average patent grant and application for Indian industries at 3-digit NIC (2008) classification

Time period	1995-2000		2001-2005		2006-2010		2011-2015	
NIC	Patent Granted	Patent Application	Patent Granted	Patent Application	Patent Granted	Patent Application	Patent Granted	Patent Application
107	0.0000	0.0000	0.0000	0.0500	0.0500	0.1666	0.0333	0.1166
201	0.0040	0.0180	0.0048	0.0216	0.0265	0.1421	0.0650	0.2108
202	0.0427	0.1780	0.0905	1.5880	1.8085	2.9948	0.9726	2.5247
203	0.0000	0.0000	0.0000	0.0150	0.0250	0.1150	0.0550	0.0150
210	0.0177	0.2258	0.1964	2.2982	1.7301	5.7704	1.2142	3.1443
259	0.0000	0.6111	0.0000	1.4888	1.3333	2.9777	0.6888	3.7111
261	0.0000	0.0222	0.0000	0.1200	0.0266	0.6933	0.0200	0.2000
262	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
263	0.0000	0.0416	0.0500	0.0750	0.0250	0.2000	0.2250	0.2750
264	0.0000	0.0000	0.0000	0.1333	0.1000	0.5666	0.0333	0.4333
265	0.0000	0.3981	0.0555	0.1000	0.2111	0.3000	0.2000	0.7444
266	0.0000	0.0000	0.0000	0.0000	0.0000	0.3200	0.0000	0.5200
271	0.0000	0.0222	0.0133	0.0333	0.0866	0.1466	0.0200	0.0533
272	0.0000	0.0000	0.0000	0.1090	0.0727	0.4000	0.1090	0.2363
273	0.0000	0.0000	0.0000	0.0000	0.0000	0.0137	0.0137	0.0137
274	0.0416	0.0833	0.1500	0.3500	21.9000	0.0000	7.4500	0.0000
275	0.0104	0.1354	0.0000	1.0250	0.8875	2.0375	0.5625	1.8500
279	0.0098	0.0098	0.0000	0.0470	0.0470	0.1764	0.0000	0.2705
281	0.0020	0.2000	0.0575	0.6025	0.8325	2.1625	1.0725	2.9875
282	0.0060	0.1605	0.0268	0.2804	0.2707	1.6414	0.5292	2.4439
291	0.0000	0.0000	0.0000	0.7200	1.6000	23.240	3.9200	22.160
292	0.0000	0.0000	0.0000	0.0000	0.0000	0.0333	0.0000	0.0000
293	0.0000	0.1111	0.0666	0.4666	0.4666	1.7333	0.1333	1.2666
302	0.0208	0.0000	0.0000	0.1750	0.0000	0.2000	0.0750	0.0000
303	0.0000	0.0000	0.0000	0.5000	0.1000	0.0000	0.5000	90.200
309	0.0000	0.0243	0.0261	0.2615	0.4830	1.2738	0.5107	2.9261
325	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Authors' calculation based on information available in CMIE-PROWESS and CGPDT.

2.3.2 Share of patents in different industries

In Tables 2.7 and 2.8, we present industry wise patent share in different years for the sample firms. In Table 2.7, we note that patent filing was concentrated in only 8 industries in 1995. Out of these 8 industries, NIC 210 and 202 held around 56.9% of total patents. Between 1995-1999, the average share of patent filing for industry NIC 210 was 30.62% and for NIC 202, the share was 18.3%. In the year 2000, total of 12 industries were active in patent filings. Again, NIC 210 and 202 had the highest patent shares. Between 2004-2007, the average patent share of NIC 210 was 58.41%. Similarly, the average patent share of NIC 202 for the same period was 18.34%. After 2007, the patent share of NIC 210 started declining. In 2008, the patent share of NIC 210 was 47.35% which further decreased to 27.98% in 2011 and 27.16% in 2015. By the end of 2015, out of 27 industries, 20 industries were active in the patent filings. NIC 309, 202, 282, 291, 281, 303, 201and 259 had more than 1% of total patent share in 2015.

In Table 2.8, the share of the granted patent is presented. In the year 1995, patents were granted to only 3 industries, namely NIC 202, 201 and 279. Till 2003, patents were granted to very few industries. This number increased in 2004 where patents were granted to 7 industries. In 2004, the patent share of NIC 210 was 42.59%, and for NIC 202, it was 31.48%. In 2005, patents were granted to 11 industries where 63.13% of total patents were held by NIC 210 alone. Patent share of NIC 274 and 293 was 0.63%, which was the lowest among all industries. From 2006 onward, the patent share of NIC 210 started declining. Between 2011-2015, the average of patent grant share for NIC 210 was 34.21%. For NIC 202 this average was 18.73%. In 2015, a total of 15 industries had granted patents.

Table 2.7: Year wise share of patent filing in the different industries

NIC	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
107	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.07	0.06	0.13	0.14	0.10	0.05	0.10	0.00	0.14	0.08	0.00
201	12.07	2.99	0.85	1.80	3.31	1.02	0.37	0.26	0.95	0.30	0.53	0.65	0.84	1.58	1.33	1.34	1.60	1.07	2.23	1.47	2.09
202	20.69	16.42	18.80	30.63	4.96	20.30	37.55	34.46	32.77	23.13	19.64	15.32	15.28	17.77	16.85	21.19	16.18	19.43	12.84	9.05	14.65
203	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.71	0.27	0.00	0.20	0.05	0.05	0.00	0.05	0.00	0.05
210	36.21	32.84	24.79	17.12	42.15	44.67	33.83	45.43	47.16	54.24	59.79	65.11	54.52	47.35	36.99	30.55	27.98	26.90	25.63	21.21	27.16
259	8.62	7.46	7.69	8.11	0.83	2.03	1.49	1.04	0.95	1.72	2.47	1.71	0.89	1.04	1.69	1.44	2.37	1.17	1.07	1.55	1.99
261	0.00	0.00	0.85	0.90	0.83	0.51	0.74	2.87	0.00	0.30	0.13	0.18	1.42	1.54	0.97	0.80	0.67	0.59	0.14	0.04	0.05
262	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
263	0.00	0.00	0.85	0.00	0.83	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.05	0.31	0.05	0.10	0.05	0.14	0.08	0.16
264	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.19	0.20	0.00	0.00	0.22	0.41	0.15	0.00	0.31	0.00	0.05	0.13	0.16
265	5.17	0.00	1.71	8.11	7.44	10.15	0.00	0.26	0.38	0.20	0.27	0.18	0.22	0.50	0.36	0.05	0.57	1.22	0.23	0.50	0.75
266	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.20	0.05	0.00	0.05	0.46	0.00
271	0.00	1.49	1.71	0.00	0.83	0.00	0.00	0.78	0.19	0.00	0.07	0.30	0.58	0.09	0.05	0.05	0.15	0.10	0.05	0.04	0.05
272	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.26	0.19	0.10	0.07	0.12	0.40	0.41	0.05	0.05	0.52	0.00	0.00	0.04	0.11
273	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.04	0.05
274	0.00	0.00	0.00	0.00	0.83	0.51	1.49	0.26	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
275	3.45	2.99	3.42	2.70	0.83	0.51	4.46	0.52	1.52	2.22	2.54	2.31	1.82	1.94	1.23	0.80	2.06	1.42	1.21	1.47	0.97
279	0.00	0.00	0.00	0.00	0.00	0.51	0.37	0.26	0.00	0.00	0.13	0.30	0.09	0.05	0.15	0.20	0.26	0.39	0.23	0.17	0.05
281	10.34	26.87	18.80	15.32	14.05	8.12	8.18	3.66	7.95	6.06	6.88	5.14	6.86	8.82	10.50	11.09	14.12	13.38	12.60	11.27	5.74
282	3.45	8.96	17.95	10.81	18.18	8.12	6.69	3.66	2.84	3.43	2.27	3.78	3.90	5.65	8.81	11.14	11.70	12.65	9.58	6.54	8.27
291	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.89	0.20	0.40	0.83	5.58	5.56	8.50	7.56	5.62	5.81	4.88	4.15	6.55
292	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
293	0.00	0.00	0.00	0.90	0.83	0.00	0.00	0.26	0.38	0.20	0.13	0.30	0.31	0.18	0.20	0.30	0.21	0.15	0.19	0.13	0.27
302	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.04	0.23	0.00	0.10	0.00	0.00	0.00	0.00	0.00
303	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	9.77	24.77	5.31
309	0.00	0.00	2.56	3.60	4.13	3.55	4.09	5.22	2.65	6.87	3.81	3.02	6.60	6.42	11.53	12.99	15.40	15.58	18.93	16.81	25.55
325	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: Authors' calculation based on information available in CMIE-PROWESS and CGPDT.

Table 2.8: Year wise share of patent grants in the different industries

NIC	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
107	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.18	0.00	0.00	0.17	0.00
201	16.67	0.00	0.00	0.00	8.33	9.09	15.38	0.00	0.00	0.00	0.00	1.17	0.89	0.35	0.44	0.17	1.25	1.62	2.14	2.16	1.73
202	66.67	85.71	100.00	62.50	33.33	31.82	26.92	14.29	15.15	31.48	13.13	26.81	31.40	26.12	26.57	20.03	17.29	23.01	23.89	15.12	14.34
203	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.22	0.34	0.53	0.49	0.31	0.33	0.17
210	0.00	14.29	0.00	12.50	41.67	50.00	38.46	47.62	66.67	42.59	63.13	43.12	40.56	30.71	35.39	40.07	40.29	33.06	29.86	34.88	32.99
259	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.33	0.67	2.16	0.88	1.85	1.43	0.65	1.07	0.66	1.38
261	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.11	0.17	0.00	0.00	0.00	0.17	0.35
262	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
263	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	0.00	0.00	0.00	0.11	0.00	0.00	0.16	0.31	0.33	0.69
264	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.09	0.00	0.00	0.00	0.16	0.00	0.00	0.00
265	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85	2.50	2.10	0.89	0.17	0.00	0.00	0.71	0.65	0.77	0.33	0.52
266	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
271	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	0.23	0.45	0.43	0.11	0.34	0.36	0.00	0.15	0.00	0.00
272	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.22	0.00	0.00	0.00	0.36	0.16	0.15	0.33	0.00
273	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00
274	0.00	0.00	0.00	0.00	0.00	4.55	0.00	0.00	0.00	3.70	0.63	1.86	4.80	17.73	15.66	6.73	4.99	6.65	4.75	4.32	3.97
275	0.00	0.00	0.00	0.00	0.00	4.55	0.00	0.00	0.00	0.00	0.00	6.76	2.12	0.95	0.77	0.84	1.78	1.62	1.53	0.83	1.73
279	16.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.22	0.17	0.00	0.00	0.00	0.00	0.00
281	0.00	0.00	0.00	0.00	8.33	0.00	0.00	14.29	18.18	9.26	5.63	2.33	1.90	10.38	11.36	13.97	13.01	13.61	14.24	14.29	16.06
282	0.00	0.00	0.00	25.00	8.33	0.00	3.85	4.76	0.00	7.41	3.13	2.56	2.68	1.21	3.53	5.05	5.88	7.13	7.50	8.31	7.08
291	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	2.01	0.43	1.10	1.01	1.60	3.24	2.91	5.65	2.76
292	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
293	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.23	0.00	0.35	0.22	0.00	0.36	0.00	0.00	0.00	0.00
302	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.38	0.00	0.11	0.43	0.00	0.34	0.00	0.00	0.00	0.00	0.00
303	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.32	0.00	0.17	0.35
309	0.00	0.00	0.00	0.00	0.00	0.00	15.38	19.05	0.00	3.70	4.38	9.09	11.06	8.13	3.20	8.92	9.63	7.46	10.41	11.96	15.89
325	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: Authors' calculation based on information available in CMIE-PROWESS and CGPDT.

2.3.3 Sales, R&D expenditure and patenting

In Table 2.9, we present the sales, average R&D expenditure and patenting statistics of sample firms. From the Table 2.9, it is clear that most of the firms are small in size. Around 47% of observations have annual sales between Rs. 0.000-500 million. We also find that the market is dominated by large firms which are few in numbers. With respect to average R&D expenditure, we find that small firms have low average R&D expenditure. Firms with annual sales between Rs. 0.000-500 million have an average R&D expenditure of Rs. 0.58850 million. As, the volume of sales increase, average R&D expenditure of the firms also increases; hence, there is a positive association between sales and R&D expenditure.

In Table 2.9, we note that around 37.26% observations have an average R&D expenditure between Rs. 1-50 million whereas 4.81% observations have an average R&D expenditure between Rs. 50-100 million. Moreover, around 10% observations have an average R&D expenditure more than Rs.100 million.

With respect to patent applications and grants, we have a similar observation like R&D expenditure. Firms with small sales volume are patenting less. Average patent applications vary between 0.07-0.73 for those firms that have sales volume between Rs. 0.000-3000 million. Firms which have sales volume between Rs. 3000-5000 million, have average patent applications around 1.50. The average patent applications increase to 7.66 for those firms which have sales volume more than Rs. 10000 million. Similarly, for patent grant data, we find that firms with high sales volume have more granted patents.

Table 2.9: Sales, R&D expenditure and patenting of high and medium technology firms

Sales in million INR	Average R&D expenditure	Average patent applications	Average patent grants	No. of observations
0.000-500	0.58850	0.05697	0.00526	10074
501-1000	3.32571	0.70674	0.06935	2653
1001-1500	6.38531	0.25221	0.05752	1582
1501-2000	8.02416	0.31978	0.08130	1107
2001-2500	14.94430	0.36734	0.13469	735
2501-3000	18.09729	0.73872	0.26503	532
3001-3500	27.07758	1.48341	0.25592	422
3501-4000	29.66377	1.41389	0.25679	331
4001-4500	30.11802	1.31456	0.22185	302
4501-5000	43.55175	1.53125	0.18369	256
5001-5500	50.07805	2.43370	0.23605	233
5501-6000	57.37809	4.35897	0.99487	195
6001-6500	50.56490	2.93785	1.39548	177
6501-7000	69.44022	3.40828	1.26627	169
7001-7500	84.74262	2.61904	1.31972	147
7501-8000	101.84504	5.17857	2.60000	140
8001-8500	94.95909	3.63106	0.79611	103
8501-9000	116.13561	5.36842	1.51754	114
9001-9500	102.00272	5.20731	0.84146	83
9501-10000	101.68531	2.22471	0.41573	88
More than 10001	624.34453	7.66500	2.62078	1809

Note: Authors' calculation based on information available in CMIE-PROWESS and CGPDT.

2.3.4 Export, R&D expenditure and patenting

In Table 2.10, we analyze the statistics of export, R&D expenditure and patenting. In this Table, we note that large numbers of firms are non-exporting or exporting less. Around 83.31% of observations have annual exports between Rs 0.000-400 million. Moreover, there is a positive association between export and R&D expenditure. High exporting firms are spending more on R&D activities. Firms which have annual export between Rs 401-800 million have average R&D expenditure Rs 40.13 million. Further, with annual exports between Rs 2001-2400 million have average R&D expenditure Rs 250.98 million. Average R&D expenditure is further increased to Rs 1421.84 million for those firms which have annual exports Rs 4001 and above

With respect to patent application, we find that there is an increase in firms' average patent application with increase in the exports. For example, firms with annual exports between Rs 0.000-400 million have average patent application 0.52 which increased to 2.85 for those firms which have annual exports between Rs 2001-2400 million. Further, we find that firms with annual export between Rs 3201-3600 million have average patent application 4.62 which further increased to 15.62 for those firms which have annual exports Rs 4001 and above.

Similarly, patent grant is also increases with increase in the export. Average patent grant is 0.14 for firms which have annual exports between Rs 0.000-400 million. This average is further increased to 0.68 for those firms which have annual exports ranged between Rs. 1601-2000 million. Furthermore, firms with annual export Rs 4001 and above have an average patent grant 4.72.

Table 2.10: Exports, R&D expenditure and patenting of high and medium technology firms

Exports in million INR	Average R&D expenditure	Average patent applications	Average patent grants	No. of observations
0.000-400	6.95606	0.52408	0.14514	17707
401-800	40.31724	1.18036	0.25755	1192
801-1200	66.92044	2.12347	0.67304	575
1201-1600	124.75323	2.33062	0.55555	369
1601-2000	175.55277	2.01181	0.68897	254
2001-2400	250.98508	2.85875	0.66666	177
2401-2800	216.63796	3.08364	0.81818	121
2801-3200	198.77197	3.40000	4.60000	105
3201-3600	425.87691	4.62921	0.77528	89
3601-4000	710.13493	7.17307	0.70000	52
More than 4001	1421.84786	15.62684	4.72340	611

Note: Authors' calculation based on information available in CMIE-PROWESS and CGPDT.

2.3.5 Profitability, R&D expenditure and patenting

In Table 2.11, we analyze the relationship between profit, R&D expenditure and patenting. This analysis suggests that profitable firms are innovation intensive as such firms conduct more R&D and patenting activities. Firms with an annual profit between Rs. 0.00-50 million have an average R&D expenditure of 2.63, an average patent application of 0.14 and an average patent grant of 0.016. Further, firms with annual profit between Rs.50-250 million have an average R&D expenditure of Rs. 6.01 million, an average patent application of 0.38 and an average patent grant of 0.08. Moreover, firms with the annual profit between Rs. 300-700 million have an average R&D expenditure of Rs. 23.85 million, an average patent application of 0.85 and an average patent grant of 0.16. Firms which have annual profit of more than Rs. 750 million have an average R&D expenditure of Rs. 116.62 million, average patent applications of 2.56 and an average patent grant of 0.83. We also note that large numbers of firms are less profitable and such firms are spending less on innovation activities; hence less patenting is done by Indian high and medium technology industries.

Table 2.11: Profitability, R&D expenditure and patenting of high and medium technology firms

Profits	Average R&D expenditure	Average patent applications	Average patent grants	No. of observations
0.000-50	2.63092	0.14560	0.01619	10247
51-100	2.73717	0.14075	0.01208	2316
101-150	5.18437	0.33710	0.03619	1326
151-200	6.49141	0.28274	0.07068	962
201-250	9.63932	0.76807	0.20481	664
251-300	12.60907	0.62109	0.12695	512
301-350	15.19057	0.47692	0.11648	455
351-400	16.67252	0.45110	0.10410	317
401-450	17.19381	0.57731	0.16151	291
451-500	22.01275	0.77500	0.10000	240
501-550	27.40470	1.00507	0.15228	197
551-600	28.61894	1.28140	0.24120	199
601-650	35.16511	1.33701	0.23204	181
651-700	39.82727	1.19760	0.26347	167
701-750	39.10609	0.88125	0.30625	160
751-800	56.30194	1.07407	0.28148	135
801-850	44.96785	0.84848	0.61363	132
851-900	56.99948	1.57758	0.45689	116
901-950	79.06189	4.34000	1.18000	100
951-1000	51.09306	1.55445	0.50495	101
More than 1001	488.85443	7.68364	2.51150	2434

Note: Authors' calculation based on information available in CMIE-PROWESS and CGPDT.

2.4. Key findings

In this chapter, we analyzed the R&D and patent statistics of India. Analysis of aggregate R&D expenditure suggests that India's spending on R&D is less than 1% of GDP. We also note that for a long period of time, R&D expenditure has been stagnant between 0.60-0.80% of GDP. With respect to the aggregate patenting activities, we find that there is an increase in both patent applications filed and grants. However, patenting activity is concentrated to some major fields of technology.

In this chapter, we also analyzed the R&D and patent statistics of sample firms. The firm-level analysis is based on 1012 firms which belong to 27 high and medium technology industries. Such analysis suggests that R&D expenditure and patenting is increasing over the period of time. We also note that R&D expenditure and patenting activities are concentrated to few industries. Large, export-oriented and high profitable firms are indulging in more R&D and patenting.

CHAPTER 3

TWO-WAY RELATIONSHIP BETWEEN INNOVATION AND MARKET STRUCTURE: EVIDENCE FROM INDIAN HIGH AND MEDIUM TECHNOLOGY FIRMS

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3.1. Introduction

In this chapter, we analyze a two-way relationship between innovation and market structure in Indian high and medium technology firms during 2000-2015. This study employs SEM to estimate the two-way relationship with two equations namely innovation and market structure equation. This study follows from the research of Schumpeter (1942), Arrow (1962) and Aghion et al. (2005) who revealed that market structure influences innovation. The Structural-Conduct-Performance (SCP) paradigm is an essential tool of industrial organization theory which shows the linkages between market structure, conduct and performance (Bain 1968). SCP paradigm shows the relationship between market structure, conduct and performance with no feedback effect with effective competition as a major source of efficiency and innovation. Research further suggests that in setting public policy, market structure is more important than conduct (Mason 1939; Baldwin 1969; Shepherd 1990). On the other hand, scholars associated with the Chicago School of Thought established that market dominance arises from the superior efficiency of firms determined by their technological advancements (Baldwin 1969; Shepherd 1990; Scherer & Ross 1990). According to this school, causality runs from performance to the structure, which means superior innovations increase firms' profitability, which further results in higher market dominance.

Through the innovation equation in SEM, we test the predictions of Aghion et al. (2005) inverted U-shaped relationship between innovation and market structure in the Indian context. Further, Aghion et al. (2005) predict the positive relationship between innovation and competition is stronger for neck-and-neck firms than laggards. We test this prediction by analyzing the relationship for neck-and-neck firms. The second equation of SEM is a market structure equation, where we analyze the feedback effect of innovation on market structure. We also analyze the nonlinear impact of patenting on firms' market power. As Schumpeterian theory of creative destruction predicts an excessive innovation activity is only fruitful up to an optimal level after which a firm may incur losses due to higher coordination and monitoring costs.

The rest of the chapter is organized as follows: Section 3.2 provides a brief review of the literature on the relationship between innovation and market structure. Section 3.3 presents description of the variables. Section 3.4 discusses the data and descriptive statistics. Section 3.5 explains the results of model estimations. Section 3.6 outlines the key findings.

3.2. Literature review

The relationship between innovation and market structure is inconclusive. Studies find both negative and positive impact of competition on firms' innovation activities. Schumpeter (1942) established a negative relationship between competition and innovation. In a competitive industry, the benefits of a company decline with an increase in the competition (Schumpeter 1942; Scherer 1967; König & Zimmermann 1986; Gottschalk & Janz 2001). Also, future rent associated with innovation activities declines with an increase in the competition (Schumpeter 1942; Arrow 1962; Reinganum 1983). On the other hand, studies like Arrow (1962), Nickell (1996), Blundell et al. (1999) and, Raymond and Plotnikova (2015) explore positive the relationship between competition and innovation. Product market competition increases firms' efficiency through managerial-effectiveness, which drives innovation. Levin (1978), Kamien and Schwartz (1982), Geroski (1990), Einav and Levin (2010) explain that market structure influences firms' innovation activities via anticipated market power. Geroski (1990) develops a theoretical model to explore the relationship between competition and innovation and put it in an empirical test. According to this model, firms' monopoly power affects innovation both directly and indirectly. According to Levin (1978), innovation may lead to excess profit and create barriers to entry in such a way that monopoly can be preserved by more innovation activities. Raymond and Plotnikova (2015) also show that firms which are characterized by rapidly changing technologies invest more to upgrade its' products and processes in response to increasing competition in the market. Studies like Scherer (1965), Levin and Reiss (1984), Scott (1984) and Levin et al. (1985), find no correlation between innovation and market structure. Comanor (1967) explains that market structure does not influence firm-level innovation activities in the presence of high entry barriers. Furthermore, Boldrin et al. (2011) explain that firms with higher market power do not necessarily increase their innovation activities as such investments are risky and not always beneficial in short run.

In Indian context also, a large number of studies focus on linear relationship between competition and innovation. Studies like Kumar (1987), Ambrammal and Sharma (2014), Sharma et al. (2018) and Khachoo et al. (2018) reported the negative impact of concentration on innovation in Indian manufacturing sector. Kumar (1987) argues that in the case of high entry barriers concentration does not encourage firms' innovation activities. Studies also find insignificant impact of concentration on innovation (Kumar & Saqib 1996; Subodh 2002; Mishra 2007; Basant & Mishra 2014; Jagadeesh & Sasidharan 2014; Saraswathy 2018). However, some studies also reported positive impact of concentration on innovation (Sasidharan & Kathuria 2011).

Aghion et al. (2005) advanced the debate by introducing the possibility of an inverted U-shaped relationship between innovation and competition. Such a nonlinear relationship occurs during a low level of competition in an industry where firms intend to escape the competition by innovating new products. Later, the pace of competition reduces and few winners emerge, thus catalyzing the Schumpeterian effect. It implies that those firms which are technological leaders dominating the industry are ultimately responsible for a negative relationship between competition and innovation. Many empirical studies have produced favorable results to support an inverted U-shaped relationship (Tingvall & Poldahl 2006; Polder & Veldhuizen 2012; Inui et al. 2012; Negassi et al. 2019). Inui et al. (2012) find a nonlinear relationship between competition and innovation in Japanese manufacturing firms. Tingvall and Poldahl (2006) estimated nonlinear relationship between competition and innovation in the Swedish manufacturing sector. This study finds that the inverted-U shaped relationship is supported by the HHI index but not by the Lerner index. Tingvall and Poldahl (2006) also show that the inverted-U shaped relationship is more sharpened in the case of neck-and-neck firms.

Researchers have also found contradictory results to Aghion et al. (2005). Correa (2012) replicates the theoretical model by utilizing a similar dataset to Aghion et al. (2005). This study referred to the establishment of the United States Court of Appeals for the Federal Circuit (CAFC) in 1982 as a structural break in the dataset. It found that while competition has a positive and significant impact on innovation for the period 1973-1982, this relationship becomes insignificant from 1983-1994. Correa and Ornaghi (2014) note a positive relationship between innovation and competition for U.S. firms. Their study shows that in a well defined IPRs regime, firms innovate more when they face high competition. A study by Beneito et al.

(2017) on Spanish manufacturing sector also suggests that an inefficient firm innovates in the face of an exit threat, leading to a positive relationship between innovation and competition. On the other hand, a study like Hashmi (2013) in the context of US manufacturing firms finds a negative relationship between innovation and competition. This study explains that the average technology gap in the US is higher than the UK, which is responsible for this negative relationship.

Innovations help firms to sustain their market dominance. New products and processes provide the means for large and old firms to create high entry barriers. As Utterback and Suarez (1993) argue, dominant designs developed by a firm deter the entry of new firms and increase merger activities, which then result in high market power. These factors generate the feedback effect of innovation on market structure (Dasgupta & Stiglitz 1980). Literature from evolutionary economics reveals that the relationship between innovation and market structure cannot be isolated from the technological regime and sectoral-specific characteristics (Malerba & Orsenigo 1996; Breschi et al. 2000). The technological regime of a country influences creative destruction and creative accumulation patterns of innovation, which further influence market structure. Creative destruction pattern is the innovations that did not exist before. These innovations are also known as Schumpeter Mark I pattern. On the other side, creative accumulation pattern means those innovations which were introduced earlier also. These innovations are called as Schumpeter Mark II pattern. Creative destruction pattern only temporarily increases the firm's market power as competitors quickly challenge these innovations. On the other hand, accumulation pattern is highly tacit and more specific to a firm which is not easily challenged by competitors; hence, the market becomes more concentrated due to the dominance of few firms.

Many studies analyze a two-way relationship between innovation and market structure by utilizing SEM. For example, a study by Albert (1995) analyzes the relationship between production, product differentiation and innovation and suggests that there is a positive influence of innovation on product differentiation (though the feedback effect does not exist). Firm specific characteristics including the size and technology level; condition the two-way relationship between innovation and market structure. Koeller (1995) finds that concentration negatively affects the innovation output of small firms whereas large firms' innovation output has a significant positive influence on concentration. Also, concentration has a significant negative influence on the innovation output of technologically progressive industries whereas innovation output has a significant positive impact on the concentration of technologically unprogressive industries (Koeller 2005). A study by Lunn (1986) analyzes the interdependence between innovation and market structure by considering product and process patents as measures of innovation. This study concludes that process patents positively encourage concentration that further positively influences process patenting by low technology firms. In Indian context, two-way relationship between innovation and market structure is unexplored. Recent studies also investigate the nonlinear impact of innovation on market structure arguing that a positive impact of innovation exists up to an optimal level. Afterwards market power declines due to an increase in coordination and monitoring costs associated with higher levels of innovation (Berchicci 2013; Hagedoorn & Wang 2012; Nemlioglu & Mallick 2017). Following the Schumpeterian theory of creative destruction, Scherer (1979), and Chandy and Tellis (1998) also argue that a differentiated product may destroy the market of its earlier version, a market cannibalization effect.

Based on above discussion, we analyze the two-way nonlinear relationship between innovation and market structure in this chapter. According to Aghion et al. (2005) model, the positive relationship between innovation and market structure exists for neck-and-neck firms. Aghion et al. (2005) and Acemoglu et al. (2006) explain that the distribution of technology levels among the firms (neck-and-neck v/s laggardness) play an important role while estimating an inverted-U shaped between innovation and competition. Hence, we also conduct a separate analysis for neck-and-neck firms while analyzing the impact of market structure on innovation. Through market structure equation, this chapter provides empirical evidence on the Schumpeterian theory of creative destruction by estimating the nonlinear impact of innovation on market structure.

3.3. Description of variables

To empirically investigate the two-way relationship, two-stage least square estimation (2SLS) is utilized (Lunn 1986; Shan et al. 1994; Koeller 1995, 2005; Baltagi 2008). In the first equation, the innovation activity of firms has been proxied by patent applications (PATENTAP) as these are the direct outcome of a successful R&D investment. Patent data are closely associated with new technology, new product sales, product and process innovation and citation data (Hall et al. 2005; Hagedoorn & Wang 2012). We validate the results obtained using the patent application by employing grant data (PATENTGR).

In the second equation, dependent variable is Lerner index (LI), which is a widely used measure of market power. According to Scherer and Ross (1990) and Connor and Peterson (1992), price-cost margin is a reasonable approximation of the Lerner Index. Following Koetter et al. (2012), we define Lerner Index as: $LI_{it} = [(\prod_{it} + TC_{it} - MC_{it}\ Q_{it})/(\prod_{it} + TC_{it})]$, where $\prod_{it}$ is profit, TC_{it} is the total cost, MC_{it} is marginal cost, and Q_{it} is the output. Data on MC_{it} is not usually available; hence, we proxy marginal cost by average cost (AC_{it}). When we assume $MC_{it} = AC_{it}$, then Lerner index can be defined as: $[(\prod_{it} / P_{it}Q_{it})]$. Studies like Aghion et al. (2005), Tingvall and Poldahl (2006), and Correa and Ornaghi (2014) also defined the Lerner index in a similar way. According to Correa and Ornaghi (2014), the Lerner index defined by firms' profitability is the best approximation to measure market structure as it reflects on the accurate competition intensity in the market. Following Clerides et al. (2015) and Saraswathy (2018), we calculate weighted the Lerner Index (WLI) where weights are market shares (MS).

3.3.1. Innovation equation

Through the innovation equation, we analyze the impact of market structure on firms' patenting activity. Following Aghion et al. (2005), we utilize both linear and quadratic terms of market structure (WLI and WLI^2) in the innovation equation. We further enhance this relationship by introducing certain control variables in the innovation equation. The detailed reasons for introducing these variables are given below along with the construction of the variables and their expected impact.

Technology Gap (TGAP): Tingvall and Poldahl (2006) utilize TGAP as a determinant of innovation that represents firm-level technology differences. A lower value of TGAP means that a firm is technologically closer to the frontier, whereas the high value of TGAP for any firm is an indicator of the laggardness. Measurement of TGAP is based on the Levinsohn and Petrin method (Levinsohn & Petrin 2003) of productivity estimation (TFP). In the presence of a potential correlation between inputs levels and unobserved productivity shock, ordinary least square (OLS) estimation of production estimation yields biased results (Levinsohn & Petrin 2003). Levinsohn and Petrin (2003) attempt to solve this problem by utilizing intermediate input like materials, electricity, power and fuels as proxy variables. Following Tukey (1977), we correct firm-level productivity outliers. We consider an observation as an outlier if it lies below Q_L - 1.5 (Q_U - Q_L) and/or above Q_U + 1.5 (Q_U - Q_L) where Q_U and Q_L are upper and lower quartile, respectively. Using previous studies (Tingvall & Poldahl 2006), we define TGAP as: TGAP= [($TFP_{maxj,t}$ – TFP_{ijt})/ $TFP_{maxj,t}$], where $TFP_{maxj,t}$ is the total factor productivity (TFP) of the firm with maximum TFP in industry j in time period t, whereas TFP_{ijt} is the TFP of firm i in time period t.

Size of the firm (SIZE): According to the Schumpeterian hypothesis, SIZE is an important determinant of innovation. Due to the availability of financial resources, economies of scale and stability of internally generated funds, large firms are more innovative and productive (Cohen & Levinthal 1989; Sasidharan & Kathuria 2011). R&D investment is also more productive for large firms. However, Katrak (1990) explains that insulation of large firms from market competition due to their domination coupled with diseconomies in terms of coordination and mismanagement can lead to fewer innovations. Hence, we include a square term of size ($SIZE^2$) to estimate a nonlinear relationship. SIZE is defined as Natural logarithm of gross fixed assets.

Research & Development intensity (RD): We utilize R&D intensity (RD) in the innovation equation as the knowledge production function shows a positive relationship between R&D and patenting (Pakes & Griliches 1980). There is a positive impact of RD on the firm performance like patenting activities, new product sale, and the number of new products and processes. Due to the rapid increase in the technological environment, it is difficult for a firm to survive in the market without exploring new technology. In-house R&D improves firms' technological and manufacturing capabilities. R&D intensive firms also learn and absorb the knowledge available in the local market (Mowery & Oxley 1995; Bell & Pavit 1997; Zahra & George 2002). Further, Czarnitzki et al. (2009), and Hagedoorn and Wang (2012) explain that R&D expenditure includes two types of expenditure; expenditure on research (R) which is closely associated with patent production activities and expenditure on development (D) which is highly correlated with new products and processes development. RD is calculated as R&D expenditure by a firm divided by sales.

Export intensity (EXPI): Export intensity (EXPI) affects innovation, as export-oriented firms are aware of recent technological advancements (Evenson & Joseph 1999). Such firms also face intense competition in the international market. To gain a competitive advantage in the international market, such firms have a greater engagement in R&D and patenting activities (Braga & Willmore 1991; Sasidharan & Kathuria 2011). Usually, exporting firms are large, productive and skill intensive. EXPI is defined as Export of goods and services divided by sales.

Embodied (EMBD) and disembodied (DISEMBD) technology import intensity: Technology imports either embodied (EMBD) in capital imports or disembodied (DISEMBD) as licenses influence innovation by firms (though the literature provides mixed evidence on the nature of this relationship). Transaction cost theory suggests a substitute relationship between in-house innovation and technology imports (Pisano 1990), whereas absorption capacity building hypothesis states a complementary relationship between these two (Cohen & Levinthal 1989). Only R&D is not sufficient for new knowledge production. According to Hagedoorn (1993) and Berchicci (2013), knowledge acquired through licensing and other sources like technology agreements also plays an important role in the creation of new knowledge. According to Tiwana and Keil (2007), external technology acquisition helps firms to concentrate their resources and capabilities for core technological competencies. Similarly, Dosi (1982), and Mowery and Rosenberg (1989) suggest that firms with external technology acquisition can acquire updated technology and extend new business opportunities in both local and international markets.

Advertisement intensity (ADI): Advertisement intensity (ADI) is a proxy for product differentiation. Firms with high product differentiation are innovative. However, the opposite argument is that advertisement expenditure may be an alternative strategy for R&D to deter the entry of new firms which make existing firms less innovative (Basant & Mishra 2014). ADI is calculated as advertisement expenditure divided by sales.

The age of a firm (AGE): The age of a firm (AGE) is an approximation of learning by doing as older firms get higher returns on innovation (Arrow

1962). However, Thornhill (2006) finds a negative relationship between age and innovation, implying that younger firms are innovative. Such alternating evidence generates the possibility of a nonlinear relationship between AGE and innovation. AGE is calculated as the difference between the present year and the year of incorporation of a company.

Patent policy changes (TRIPS): With the implementation of TRIPs, R&D and patenting activities in the developing countries has been increased. Firms have become competitive in the new patent regime (Bhattacharjea & Sindhwani, 2014). A study by Sharma et al. (2018) suggests that TRIPs brings positive changes in innovation performance of Indian firms through increase in the protection duration, enforcement mechanism, and membership into the international convention. Other studies like Chadha (2009), Haley and Haley (2012), Jagadeesh and Sasidharan (2014) also find that TRIPs have a positive influence of R&D expenditure of Indian firms and industries. In this study, to analyze the impact of the patent policy environment, we utilize patent policy dummy in the empirical analysis. With the Patent (Amendment) Act 2004, Indian fully complied with TRIPs. To analyze the impact of these amendments, we create dummy variable: TRIPS2005=1 if > 2005 and 0 otherwise.

3.3.2. Market structure equation

Following earlier works on the determinants of market structure (Gupta 1983; Lunn 1986, 1989; Yoon 2004; Koeller 1995, 2005), we analyze the impact of innovation on market structure. Recent literature also highlights the nonlinear impact of innovation on market structure (Nemlioglu & Mallick 2017). Hence, we incorporate both linear and quadratic term of innovation (PATENTAP and $PATENTAP^2$) in the model. Furthermore, we add control variables in the market structure equation. The rationale for introducing these variables along with definitions is highlighted below.

Export intensity (EXPI): EXPI and firm performance are positively related. According to Resende (2007) and Yoon (2004), export intensity (EXPI) underscores the dynamic characteristics of a firm and accordingly is a determinant of its market power. According to Vu et al. (2014), exports have a positive impact on profitability for high-profit growth firms. According to Sharma (2012), export intensive firms are more productive and efficient; hence, they dominate the market. Bernard and Jensen (2004) suggest that export intensive firms reallocate their resource from inefficient to efficient plants, which further enhance their market performance.

Advertisement intensity (ADI): Advertisement expenditure (ADI), a proxy for product differentiation, by creating entry barriers is positively associated with concentration (Comanor & Wilson 1967; Yoon 2004; Resende 2007). Through higher advertisement expenditure, firm enhances its brand value. In the Indian context, Tyagi and Nauriyal (2017) find a positive and significant impact of ADI on firms' profitability in the pharmaceutical industry. Ambrammal and Sharma (2016) also analyze the relationship between ADI and firm performance in Indian high and medium technology industry but report insignificant relationship.

Market growth rate (MGR): Market growth rate (MGR) captures the opportunities presented by the industry that negatively influences the market power of firms (Gupta 1983; Lunn 1986, 1989; Koeller 1995). MGR is an industry-specific variable. Gupta (1983) explains that the growth rate of small firms is usually faster than large firms; hence, MGR is negatively associated with market power. However, Ambrammal and Sharma (2016) find an insignificant impact of MGR on firms' profitability in Indian high and medium technology firms. MGR is calculated as the current year value of sales minus previous year value of sales divided by the previous year value of sales.

Import intensity (IMPI): Kambhampati and Parikh (2003) explain that import intensity (IMPI) has a positive influence on the market power as imports enhance the quality of products and make firms efficient. According to Yoon (2004), IMPI is positively associated with firm performance. It promotes the competition in the domestic market through the openness of the market. High imports improve firm performance by efficient resource distribution, which results in higher profitability and productivity. IMPI is defined as the import of finished goods and raw materials divided by sales.

Total factor productivity (TFP): Productive firms enjoy more market power due to cost-effectiveness and efficient utilization of resources; hence, TFP is also an important determinant of market power (Demsetz 1973; Yazdanfar 2013). Productive firms have a high potential for risky investments, which results in high profitability. The productivity of a firm is proxied by total factor productivity, which is calculated based on based on LP method.

The age of a firm (AGE): Narayanan (1998) considers AGE as a proxy for learning by doing and technology accumulation that gives a firm competitive edge and high market power. Accumulation of technology over a long period of time gives a competitive edge over new entrants. Arrow (1962) explains that experience helps firms perform in better ways.

Capital intensity (CAPITAL): According to Miller and Cardinal (1994), the performance of capital intensive firms is better than labor-intensive firms. Thus, capital intensity (CAPITAL) positively influences firms' market power (Hart & Ahuja 1996; Kambhampati & Parikh 2003). Capital intensity is calculated as gross fixed assets divided by sales.

From the above discussions, we use the following SEM for analyzing the innovation and market structure relationship:

PATENTAP = f (WLI, WLI^2, TGAP, SIZE, SIZE ^{2}, RD, EXPI, EBMD, DISEMBD, ADI, AGE, AGE ^{2}, TRIPS) (1)

WLI = f (PATENTAP, PATENTAP^2, EXPI, ADI, MGR, IMPI, AGE, TFP, CAPITAL) (2)

3.4. Data and descriptive statistics

This chapter utilizes firm-level panel data for Indian high and medium technology firms during 2000-2015. We have also dropped all those firms that are reporting zero sales. After cleaning the data, we are able to collect information on 991 firms with 322 (32.50%) firms in high technology and 669 (67.50%) in medium technology industries. Table 3.1 presents the definition of variables and their data sources. Table 3.2 presents the descriptive statistics of the full sample, high and medium technology firms. In Table 3.2, we find that the average patent application in high technology firm is 2.31, which are higher than medium technology firms. Similarly, the average patent grant in high technology firm is 0.63, which is also higher than medium technology firm. High technology firms are more patent-intensive. These firms conduct more in-house R&D expenditure in comparison to other low and medium technology firms. We also note that high technology industries are more concentrated because the value of both HHI and WLI are higher for these industries. Moreover, we also note that medium technology firms are larger and more productive in comparison to high technology firms.

Table 3.1: Definitions of variables and their data source

Variables	Definition	Source of Data
Patent application (PATENTAP)	Number of total patent applications by a firm.	CGPDT
Patent grant (PATENTGR)	Number of total patents granted to a firm.	CGPDT
Profitability (PBT)	Operational profit divided by sales.	CMIE (Prowess)
Market share (MS)	Sales of a firm divided by total sale of industry.	CMIE (Prowess)
Hirschman–Herfindahl index (HHI)	Sum of the square of the sales' share of each firm in a year.	CMIE (Prowess)
R&D expenditure (RD)	R&D expenditure by a firm divided by sales.	CMIE (Prowess)
Export intensity (EXPI)	Export of goods and services divided by sales.	CMIE (Prowess)
Age (AGE)	Age is the difference between present year and the year of incorporation.	CMIE (Prowess)
Size of firm (SIZE)	Natural logarithm of gross fixed assets.	CMIE (Prowess)
Advertisement intensity (ADI)	Advertisement expenditure divided by sales.	CMIE (Prowess)
Capital intensity (CAPITAL)	Gross fixed assets divided by sales.	CMIE (Prowess)
Disembodied technology import intensity (DISEMBD)	Royalties and technological fees divided by sales.	CMIE (Prowess)
Embodied technology import intensity (EMBD)	Imports of capital (machinery and equipment) goods divided by sales.	CMIE (Prowess)
Market growth rate (MGR)	Current year value of sales minus previous year value of sales divided by previous year value of sales.	CMIE (Prowess)
Import intensity (IMPI)	Imports of finished goods and raw materials divided by sales.	CMIE (Prowess)
Total factor productivity (TFP)	Calculated based on LP method.	CMIE (Prowess)
Technology gap (TGAP)	TGAP = $\frac{TFP_{maxj,t} - TFP_{ijt}}{TFP_{maxj,t}}$, where $TFP_{maxj,t}$ is the total factor productivity (TFP) of the firm with maximum TFP in industry j in time period t, whereas TFP_{ijt} is the TFP of firm i in time period t.	CMIE (Prowess)

Table 3.2: Descriptive statistics of full sample, high and medium technology industries

Variables	Full sample	High technology industries	Medium technology industries
	Mean (Standard Deviation)	Mean (Standard Deviation)	Mean (Standard Deviation)
PATENTAP	1.50433 (10.7288)	2.31119 (14.53637)	1.11456 (8.25753)
PATENTGR	0.45771 (4.46072)	0.63538 (4.71662)	0.371886 (4.32933)
HHI	0.12794 (0.12921)	0.14876 (0.15772)	0.11788 (0.11151)
WLI	0.00393 (0.02744)	0.00500 (0.03753)	0.00342 (0.02088)
EXPI	0.14532 (0.45666)	0.19420 (0.68682)	0.12171 (0.28236)
DISEMBD	0.00189 (0.00795)	0.00176 (0.00952)	0.00195 (0.00707)
EBMD	0.00997 (0.09312)	0.01323 (0.15129)	0.00839 (0.04240)
RD	0.00707 (0.05730)	0.01515 (0.09912)	0.00317 (0.00876)
ADI	0.00545 (0.02774)	0.00600 (0.02293)	0.00518 (0.02978)
SIZE	5.93008 (1.81886)	5.76873 (1.79342)	6.00802 (1.82602)
AGE	3.39655 (0.53034)	3.33331 (0.53813)	3.42710 (0.52384)
IMPI	0.15910 (4.29182)	0.25347 (7.34351)	0.11351 (1.12456)
MGR	11.63947 (11.63227)	12.22731 (9.67555)	11.35551 (12.45849)
TFP	2.67366 (1.3406)	2.60041 (1.32769)	2.70904 (1.34542)
TGAP	0.58277 (0.20830)	0.59248 (0.20948)	0.57807 (0.20757)
CAPITAL	4.51857 (85.27614)	5.14042 (106.06100)	4.21817 (73.15442)
OBSERVATIONS	14887	4849	10038

Notes: Authors' calculations on the basis of information available in CMIE PROWESS and CGPDT. Standard deviations are shown in parenthesis.

3.5. Empirical result

To analyze the SEM discussed in Section 3.3, we propose to use two-stage least square model (Gupta 1983; Lunn 1986; Shan et al. 1994; Albert 1995; Koeller 1995, 2005; Vossen 1999; Baltagi 2008). In Section 1.6.2 of this dissertation, we have provided detail explanation on empirical methodology used in this chapter. We have estimated the results based on FE2SLS estimation technique. First, we present the results of the innovation equation for the full panel and then segregate the panel into medium and high technology industries and report their results. Similarly, we discuss the results of the market structure equation.

3.5.1 Results of the innovation equation

We present the results of both linear and nonlinear impact of market power on patent applications filed and patents granted in separate columns of Table 3.3. Columns I-IV provides the results for the full sample, columns V-VIII for high technology and IX-XII for medium technology firms. In Table 3.3, we find that the coefficient of WLI is insignificant in all the columns. We also do not find any nonlinear relationship between market power and innovation as the coefficient of WLI^2 is insignificant in all the columns. This result suggests that market power does not determine firms' patenting activities. This empirical finding does not fit into the theory of Aghion et al. (2005). These results are in line with other studies which utilize R&D as a measure of innovation in the Indian context (Kumar & Saqib 1996; Subodh 2002; Mishra 2007; Basant and Mishra 2014; Jagadeesh & Sasidharan 2014; Shukla 2018; Saraswathy 2018).

The coefficient of TGAP is negative and significant at 10% level in column IX. In the rest of the columns, this coefficient is insignificant. A negative and significant coefficient of TGAP in column IX suggests that neck-and-neck firms in the medium technology industry are innovation intensive and file more patent applications. However, this result is not strong and is inconsistent for high technology firms and patent grant data.

The coefficients of SIZE and SIZE^2 suggest a U-shaped relationship with patenting. This U-shaped relationship implies that patenting goes down initially with an increase in the size of the firm, but goes up once a threshold level is crossed. However, Lind and Mehlum (2010) explain that the addition of a nonlinear term in the regression is necessary but not sufficient condition to explain U-shaped or inverted U-shaped relationship. If the true relationship is convex but monotone over relevant data, nonlinear terms may erroneously yield extreme point which results in significant U-shaped or inverted U-shaped relationship. Therefore, we conduct a SLM test to check the true relationship as suggested by Lind and Mehlum (2010). SLM test fulfils both necessary and sufficient condition to explain the U-shaped or inverted U-shaped relationship. The SLM test statistics confirm the U-shaped relationship between size and patenting. We have used STATA version 14.2 for estimation. When SLM test statistics is insignificant, U-test in STATA does not reject null the hypothesis (H0= Monotone or inverse U shape). However, it also does not show the value of test statistics. Hence, we have not reported the value of SLM test statistics when it produces insignificant relationships. This result agrees with the findings of Siddharthan (1988), Kumar and Aggarwal (2005), and Khachoo and Sharma (2017).

In columns III-IV and XI-XII of Table 3.3, we find that the coefficient of AGE and AGE^2 generate an inverted U-shaped relationship with the patent grant. This result only holds for medium technology firms. Other studies like Ghosh (2009), and Khachoo and Sharma (2017) also find that the nonlinear relationship between the age of the firms and R&D. However, the SLM test does not support this inverted U-shaped relationship between AGE and patenting. Hence, we erroneously observe an inverted U-shaped relationship between AGE and patenting in some columns.

The coefficient of RD is also positive and significant for the full sample and high technology firms. For medium technology firms, RD is producing a significant impact on PATENTAP. In the Indian context, Chadha (2009), Ambrammal and Sharma (2014), Kanwar and Singh (2018) also find a positive relationship between R&D and patenting. With respect to patent policy changes, the impact of TRIPS is positive and significant in columns I-IV and IX-XII. This result suggests that TRIPS has increased patenting activities in medium technology firms. Other control variables like EXPI, DISEMBD, EBMD and ADI have an insignificant impact on patenting.

As explained earlier, the distribution of technology level also influences the competition and innovation relationship. Neck-and-neck firms are equally efficient and adopt similar technologies; hence, post innovation profits will be higher for these firms. Accordingly, a positive relationship is expected between innovation and competition for neck-and-neck firms. We classify neck-and-neck firms using TGAP as the firms that are below the mean value of TGAP. Mean value of TGAP for the full sample is 0.58, for the high technology firms it is 0.59 and for the medium technology firms, the mean value is 0.58. In the full sample, around 42.60% observations lie below the mean value of TGAP. Similarly, for the high technology sample 42.13% and the medium technology firm 44.85% observations lies below the mean value of TGAP. In Table 3.4, we find that the overall relationship between market power and patenting is insignificant in neck-neck-firms as well. These results, presented in Table 3.4, add confidence in explaining the insignificant impact of market structure on innovation in Indian high and medium technology firms. Results of other control variables are similar to Table 3.3.

Table 3.3: Impact of market structure on innovation (market structure measure- WLI)

	Full sample				High technology				Medium technology			
	PATENTAP		PATENTGR		PATENTAP		PATENTGR		PATENTAP		PATENTGR	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
WLI	-14.47536 (9.81992)	24.89224 (45.52559)	-0.89884 (3.42889)	-5.60123 (19.97350)	-20.44092 (18.34478)	5.384703 (18.73091)	-4.99005 (5.38528)	-18.09142 (18.77511)	-6.39972 (7.43418)	-3.141694 (17.30579)	1.16385 (4.27942)	4.91721 (12.90663)
WLI^2		-55.70811 (59.11540)		6.65423 (27.80054)		-32.00023 (39.83411)		16.23375 (20.38088)		-5.29267 (28.79579)		-6.09734 (21.22246)
RD	0.69866** (0.33474)	0.83146** (0.38414)	0.39752** (0.19821)	0.38165* (0.20826)	0.60856** (0.29331)	0.69161** (0.29364)	0.39565** (0.17024)	0.35352** (0.17758)	2.16266 (1.41440)	2.19946* (1.392229)	1.01019 (0.83967)	1.052584 (0.81622)
EXPI	0.05570 (0.05371)	0.01311 (0.06337)	0.01108 (0.03053)	0.01617 (0.03506)	0.07031 (0.10113)	0.01475 (0.08284)	-0.02561 (0.04758)	0.00256 (0.06623)	0.05600 (0.05117)	0.05517 (0.05093)	0.00295 (0.03138)	0.00199 (0.03171)
EBMD	-0.00108 (0.12137)	-0.12391 (0.20469)	0.05490 (0.06207)	0.06957 (0.08742)	-0.21330 (0.34521)	-0.43980 (0.29368)	0.12858 (0.17429)	0.24348 (0.23189)	0.10715 (0.11582)	0.10543 (0.11705)	0.04504 (0.07924)	0.04305 (0.08084)
DISEMBD	1.01868 (1.43075)	0.71646 (1.37675)	1.58864 (1.06427)	1.62474 (1.11363)	0.93445 (1.41043)	0.32643 (1.04434)	0.35483 (0.75361)	0.66327 (1.05156)	1.50149 (2.76219)	1.52487 (2.71307)	3.06639* (1.83407)	3.09332* (1.8222)
ADI	0.33965 (0.39934)	0.44899 (0.43084)	0.12360 (0.22883)	0.11054 (0.23256)	1.46199 (1.56292)	2.07723* (1.219142)	-0.03850 (0.62693)	-0.35061 (0.78446)	-0.02967 (0.23826)	-0.03076 (0.23504)	0.03309 (0.21135)	0.03182 (0.21099)
AGE	0.28131 (0.60944)	0.15217 (0.61476)	0.87071* (0.50461)	0.88613* (0.51726)	-0.54957 (0.94574)	-0.81089 (0.97966)	-0.04274 (0.87328)	0.08982 (0.93529)	0.56416 (0.77104)	0.57539 (0.77297)	1.28710** (0.62090)	1.30002** (0.61466)
AGE^2	-0.13056 (0.14522)	-0.12318 (0.14467)	-0.28349** (0.12297)	-0.28437** (0.12376)	0.06293 (0.22252)	0.08825 (0.22171)	-0.09790 (0.20843)	-0.11074 (0.21625)	-0.19294 (0.18508)	-0.19606 (0.18527)	-0.36765** (0.15242)	-0.37124** (0.15043)
SIZE	-0.30832*** (0.06268)	-0.24593** (0.09866)	-0.17433*** (0.04321)	-0.18178*** (0.05297)	-0.33003*** (0.09465)	-0.26596*** (0.07611)	-0.30269*** (0.06586)	-0.33519*** (0.07670)	-0.30637*** (0.09028)	-0.30306*** (0.09211)	-0.08193 (0.05286)	-0.07811 (0.05705)
SIZE^2	0.03714*** (0.00659)	0.02893** (0.01211)	0.01957*** (0.00447)	0.02055*** (0.00605)	0.04365*** (0.01095)	0.03541*** (0.00894)	0.03549*** (0.00697)	0.03967*** (0.00874)	0.03347*** (0.00873)	0.03302*** (0.00909)	0.00856* (0.00519)	0.00803 (0.00581)
TRIPS	0.38438** (0.19151)	0.47690** (0.22562)	0.60532*** (0.16269)	0.59427*** (0.16543)	0.11270 (0.32715)	0.22496 (0.28991)	0.48423* (0.27764)	0.42728 (0.28554)	0.47143** (0.23963)	0.47916** (0.24003)	0.65996*** (0.20124)	0.66887*** (0.19680)
TGAP	-0.10888 (0.06905)	0.12152 (0.23633)	-0.05777 (0.04448)	-0.08530 (0.13003)	-0.22235 (0.21637)	0.00779 (0.20247)	-0.17901 (0.11264)	-0.29576 (0.20728)	-0.09142* (0.05635)	-0.07465 (0.10678)	-0.01661 (0.03862)	0.00271 (0.07911)
CONSTANT	1.02940** (0.50790)	1.06982** (0.50546)	0.46694 (0.37856)	0.46211 (0.38250)	1.71908** (0.86543)	1.99441** (0.89707)	1.67174** (0.77813)	1.53206* (0.85445)	0.84635 (0.61708)	0.82353 (0.63915)	-0.11485 (0.40763)	-0.14114 (0.41291)
SLM (WLI)	–	–	–	–	–	–	–	–	–	–	–	–
SLM (AGE)	–	–	–	–	–	–	–	–	–	–	–	–
SLM (SIZE)	4.91*** [4.62e-07]	2.31** [0.01040]	4.03*** [0.00002]	3.33*** [0.00043]	3.45*** [0.00028]	3.45*** [0.00027]	4.56*** [2.68e-06]	4.35*** [7.01e-06]	3.39*** [0.00035]	3.29*** [0.00051]	1.55* [0.06080]	1.37* [0.08550]
OBSERVATIONS	14887	14887	14887	14887	4849	4849	4849	4849	10038	10038	10038	10038

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Square brackets contain p- value. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models. SLM test is Sasabuchi–Lind–Mehlum test to validate U-shaped or inverted U-shaped relationship. In all the columns SLM test statistics is positive and significant which suggest a significant U-shaped relationship between size and patenting.

Table 3.4: Impact of market structure on innovation of neck-and-neck firms (market structure measure- WLI)

	Full sample				High technology				Medium technology			
	PATENTAP		PATENTGR		PATENTAP		PATENTGR		PATENTAP		PATENTGR	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
WLI	-3.85547 (9.12454)	0.66301 (27.78321)	-8.71095 (8.37954)	17.57935 (28.03526)	-15.58610 (9.75048)	-26.09580 (21.38453)	-10.85040 (8.09231)	-12.25681 (18.44658)	23.21941 (15.70051)	34.68102 (33.15069)	14.30334 (11.00652)	50.53501 (34.82778)
WLI^2		-43.52685 (283.39670)		-253.25630 (273.05390)		75.37506 (143.70140)		10.08667 (127.18760)		-95.02055 (239.20070)		-300.37260 (237.4473)
RD	4.57984*** (1.32619)	4.59603*** (1.33959)	2.53071*** (0.94481)	2.62493** (1.06582)	3.76036** (1.52844)	3.63959** (1.58372)	1.55402 (1.19107)	1.53786 (1.19472)	6.57172** (2.96838)	6.63724** (3.05040)	3.18105* (2.03605)	3.38819 (2.28956)
EXPI	0.11401 (0.09865)	0.08987 (0.20308)	0.05284 (0.07346)	-0.08762 (0.16682)	0.23086 (0.17734)	0.32058 (0.23733)	0.03107 (0.12730)	0.04308 (0.18690)	-0.01744 (0.12122)	-0.02939 (0.12590)	-0.04392 (0.08053)	-0.08169 (0.09859)
EBMD	0.07026 (0.23650)	-0.09096 (1.09190)	-0.06786 (0.18993)	-1.00597 (1.43595)	-0.27829 (1.19445)	0.43639 (1.57132)	0.04354 (0.70177)	0.13918 (1.23316)	-0.06357 (0.25961)	-0.16168 (0.38102)	-0.21113 (0.14589)	-0.52128 (0.40131)
DISEMBD	1.52011 (2.00440)	1.51649 (2.01489)	1.92457 (1.71444)	1.90349 (2.01528)	0.48833 (0.96798)	0.44838 (0.84849)	-0.22626 (0.55088)	-0.23161 (0.54946)	4.67627 (4.89074)	4.24601 (5.30919)	7.46285** (3.65769)	6.10272* (3.78556)
ADI	1.07285 (1.80509)	0.31599 (5.77171)	0.05762 (1.67677)	-4.34607 (6.43248)	0.43551 (2.54698)	2.50861 (4.72011)	-1.60015 (1.86363)	-1.32273 (3.63378)	0.19446 (2.25947)	0.42365 (2.41678)	1.32649 (2.45764)	2.05097 (2.73895)
AGE	-0.50349 (1.12740)	-0.56540 (1.20686)	2.24028** (1.05208)	1.88006* (1.14189)	-1.95961 (1.52990)	-1.58665 (1.74083)	1.41820 (1.54295)	1.46811 (1.71358)	0.22593 (1.40773)	0.18899 (1.41800)	2.59527** (1.30397)	2.478491* (1.36940)
AGE^2	0.04754 (0.26746)	0.06745 (0.30198)	-0.63629** (0.25973)	-0.52048* (0.28572)	0.40271 (0.34680)	0.31003 (0.39798)	-0.47432 (0.38724)	-0.48672 (0.42781)	-0.10843 (0.33319)	-0.09754 (0.33584)	-0.70065** (0.31937)	-0.66623** (0.33178)
SIZE	-0.53836*** (0.146423)	-0.55395*** (0.20031)	-0.32255*** (0.10222)	-0.41324** (0.16915)	-0.41559*** (0.13156)	-0.37201** (0.14893)	-0.47991*** (0.14872)	-0.47407*** (0.17328)	-0.69421*** (0.21417)	-0.68973*** (0.21559)	-0.19745 (0.14943)	-0.18330 (0.16671)
$SIZE^2$	0.05298*** (0.01279)	0.05371*** (0.01483)	0.02842*** (0.00932)	0.03269** (0.01308)	0.04678*** (0.01158)	0.04487*** (0.01170)	0.04392*** (0.01310)	0.04367*** (0.01402)	0.05936*** (0.01855)	0.05792*** (0.01892)	0.01318 (0.01336)	0.00862 (0.01595)
TRIPS	0.23245 (0.35712)	0.20911 (0.39625)	1.17142*** (0.36755)	1.03564*** (0.38697)	-0.22493 (0.43422)	-0.15588 (0.45644)	1.17903** (0.56595)	1.18827** (0.58716)	0.43012 (0.43515)	0.43037 (0.43788)	1.18817*** (0.43518)	1.18897*** (0.43794)
TGAP	-0.02994 (0.09360)	-0.00594 (0.17006)	-0.02816 (0.08314)	0.11147 (0.18181)	-0.11826 (0.17212)	-0.18211 (0.22448)	-0.06199 (0.15602)	-0.07054 (0.20887)	0.12187 (0.12662)	0.178787 (0.18777)	0.11389 (0.09514)	0.29379 (0.20424)
CONSTANT	2.37546** (1.03080)	2.42334** (1.10609)	0.20246 (0.75336)	0.48107 (0.91538)	3.08610 (1.56162)	2.68919 (1.81453)	1.49685 (1.27178)	1.44374 (1.49721)	2.13985* (1.24138)	2.12092* (1.24122)	-0.55760 (0.87951)	-0.61742 (0.94478)
SLM (WLI)	–	–	–	–	–	–	–	–	–	–	–	–
SLM (AGE)	–	–	–	–	–	–	–	–	–	–	–	–
SLM (SIZE)	3.65*** [0.00013]	2.72*** [0.00327]	2.89*** [0.00196]	2.25** [0.01230]	3.10*** [0.00099]	2.42*** [0.00782]	3.21*** [0.00066]	2.71*** [0.00339]	3.10*** [0.00097]	2.82*** [0.00240]	0.69 [0.24600]	0.11 [0.45600]
OBSERVATIONS	6342	6342	6342	6342	2043	2043	2043	2043	4503	4503	4503	4503

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Square brackets contain p- value. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models. SLM test is Sasabuchi–Lind–Mehlum test to validate U-shaped or inverted U-shaped relationship. In all the columns SLM test statistics is positive and significant which suggest a significant U-shaped relationship between size and patenting.

We have checked the sensitivity of results by utilizing an alternative measure of market structure, the Hirschman–Herfindahl index (HHI). We report the results of the innovation equation based on HHI in Table 3.6 of Appendix I and find that the coefficient of HHI is significant in column V; otherwise, it is insignificant in all the columns. A nonlinear term of HHI (HHI^2) is also insignificant in all the columns. In Table 3.7 of Appendix I, we estimate the results for neck-and-neck firms. In this table also, the coefficients of HHI and HHI^2 are insignificant. These results corroborate results based on market power.

3.5.2. Results of market structure equation

Table 3.5 presents the results of market structure equation. Columns I-IV presents the result based on the full sample, columns V-VIII for high technology firms and results based on medium technology firms are presented in columns IX-XII. For the full sample estimation, we find that the coefficient of PATENTAP is positive and significant. We do not find any nonlinear impact of the patent application on firms' market power as the coefficient of $PATENTAP^2$ is insignificant in column II. With respect to the granted patent, the coefficient of PATENTGR is positive and significant in column III. While examining the nonlinear impact of the granted patent on market power, there is a significant inverted U-shaped relationship with market power as the coefficient of $PATENTGR^2$ is negative and significant in column IV. SLM test also confirms an inverted U-shaped relationship. This result is also depicted in Figure 3.1. This positive influence of patenting on firms' market power also holds when we segregate the analysis for high and medium technology firms. For high technology firm, we find that the coefficient of PATENTAP is positive and significant in column V; similarly, in column VII, the coefficient of PATENTGR is positive and significant. Another finding for high technology firms is that we do not find any nonlinear impact of the patent application and grant on the market power as the coefficients of $PATENTAP^2$ and $PATENTGR^2$ are insignificant in columns VI and VIII, respectively. With respect to medium technology firms, the coefficient of PATENTAP is positive and significant in column IX. While examining the nonlinear influence of patent application in column X, we find that the coefficient of $PATENTAP^2$ is negative and significant. This result is also confirmed by the SLM test. We plot the estimated market powers from the regression in column X in Figure 3.2. This result supports the hypothesis of an inverted U-shaped relationship between patenting and market power. However, this relationship holds only for patent applications, not for granted patents. This result shows that technological innovations are capable of altering the competitive pressure in the Indian markets. With respect to other control variables, we find that the coefficient of AGE is positive and significant for the full sample and high technology firms. This result suggests that experienced and older firms have better market performance. The coefficient of MGR is positive and significant for the full sample; however, this impact becomes insignificant once the analysis is segregated for high and medium technology firms. The coefficient of TFP is positive and significant for high technology firms. Due to cost-effectiveness and efficient resource utilization, productive firms have an edge in the competitive market. The impact of IMPI, EXPI, ADV and CAPITAL is insignificant on market power.

We also check the robustness of the results by utilizing HHI as a dependent variable in the market structure equation. To estimate the model, firm-level data is aggregated for 27 industries at three-digit NIC (2008) level. Out of 27 industries, 10 (37%) belong to high technology, and 17 (63%) are from medium technology. In Table 3.8 of Appendix I, we report the results of HHI. The coefficients of PATENTAP, PATENTGR and their nonlinear terms are insignificant in all the columns. We find that our results do not corroborate with the market power. There are certain

Table 3.5: Impact of innovation on market structure (market structure measure- WLI)

WLI	Full sample				High technology				Medium technology			
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
PATENTAP	0.01043*** (0.00307)	0.01950* (0.01145)			0.01007** (0.00432)	0.00617 (0.01832)			0.00854** (0.00408)	0.03219** (0.01541)		
PATENTAP^2		-0.00313 (0.00352)				0.00142 (0.00592)				-0.00761* (0.00417)		
PATENTGR			0.01710*** (0.00581)	0.05112** (0.02190)			0.01471** (0.00629)	0.01069 (0.03463)			0.00757 (0.00531)	0.08594* (0.05247)
PATENTGR^2				-0.01625* (0.00888)				0.00210 (0.01715)				-0.02830 (0.01830)
IMPI	0.00033 (0.00103)	0.00037 (0.00101)	0.00042 (0.00106)	0.00040 (0.00125)	0.00259 (0.00262)	0.00256 (0.00260)	0.00261 (0.00263)	0.00252 (0.00240)	-0.00172 (0.00116)	-0.00213 (0.00146)	-0.00149 (0.00091)	-0.00445* (0.00263)
EXPI	0.00044 (0.00080)	0.00034 (0.00080)	0.00067 (0.00089)	0.00004 (0.00108)	0.00175 (0.00149)	0.00186 (0.00143)	0.00230 (0.00169)	0.00237 (0.00158)	-0.00071 (0.00082)	-0.00062 (0.00101)	-0.00027 (0.00078)	-0.00056 (0.00153)
ADI	-0.01303 (0.01227)	-0.01299 (0.01222)	-0.01094 (0.01216)	-0.01438 (0.01305)	-0.04998 (0.03936)	-0.05042 (0.04089)	-0.03873 (0.03906)	-0.03795 (0.03452)	-5.48e-06 (0.00378)	0.00031 (0.00479)	-0.00022 (0.00424)	-0.00508 (0.01080)
AGE	0.00548*** (0.00210)	0.00446* (0.00252)	0.00885*** (0.00279)	0.00558** (0.00276)	0.01140*** (0.00424)	0.01238* (0.00686)	0.01488*** (0.00511)	0.01555* (0.00855)	0.00184 (0.00203)	0.00109 (0.00229)	0.00224 (0.00223)	0.00388 (0.00442)
CAPITAL	0.00002 (0.00059)	0.00005 (0.00060)	-0.00004 (0.00060)	0.00009 (0.00061)	0.00113* (0.00063)	0.00105 (0.00072)	0.00085 (0.00060)	0.00080 (0.00070)	-0.00071 (0.00088)	-0.00075 (0.00089)	-0.00071 (0.00088)	-0.00057 (0.00094)
MGR	0.00007** (0.00003)	0.00007* (0.00003)	0.00006* (0.00003)	0.00005 (0.00003)	0.00019 (0.00013)	0.00019 (0.00013)	0.00016 (0.00013)	0.00017 (0.00015)	0.00004 (0.00002)	0.00004 (0.00003)	0.00004 (0.00003)	0.00003 (0.00003)
TFP	0.00090 (0.00152)	0.00090 (0.00152)	0.00080 (0.00154)	0.00131 (0.00153)	0.00545*** (0.00176)	0.00534*** (0.00181)	0.00479*** (0.00163)	0.00456** (0.00220)	-0.00138 (0.00224)	-0.00165 (0.00233)	-0.00125 (0.00220)	-0.00137 (0.00234)
CONSTANT	-0.01643** (0.00766)	-0.01358 (0.00902)	-0.02610*** (0.00937)	-0.01657* (0.00961)	-0.04175*** (0.01576)	-0.04435** (0.02145)	-0.05008*** (0.01788)	-0.05181** (0.02611)	-0.00124 (0.00756)	0.00094 (0.00851)	-0.00229 (0.00798)	-0.00724 (0.01416)
SLM(PATENTAP)	–	–	–	–	–	–	–	–	–	1.64** [0.05000]	–	–
SLM(PATENTGR)	–	–	–	1.66** [0.04870]	–	–	–	–	–	–	–	–
OBSERVATIONS	14887	14887	14887	14887	4849	4849	4849	4849	10038	10038	10038	10038

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Square brackets contain p- value. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models. SLM test is Sasabuchi–Lind–Mehlum test to validate U-shaped or inverted U-shaped relationship. In Columns IV and X, the SLM test statistics is positive and significant which suggest a significant inverted U-shaped relationship between market power and patenting.

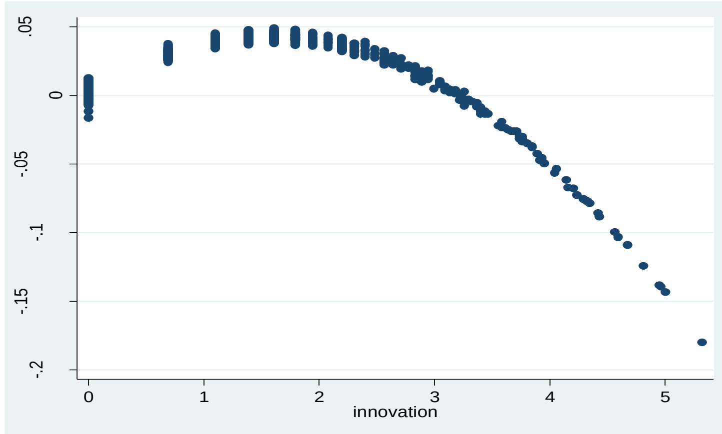

Figure 3.1: Estimated relationship between market power and innovation (proxied by granted patents). The figure is derived from the regression specified in column IV of Table 3.6. Sasabuchi–Lind–Mehlum test also confirms this inverted U-shaped relationship.

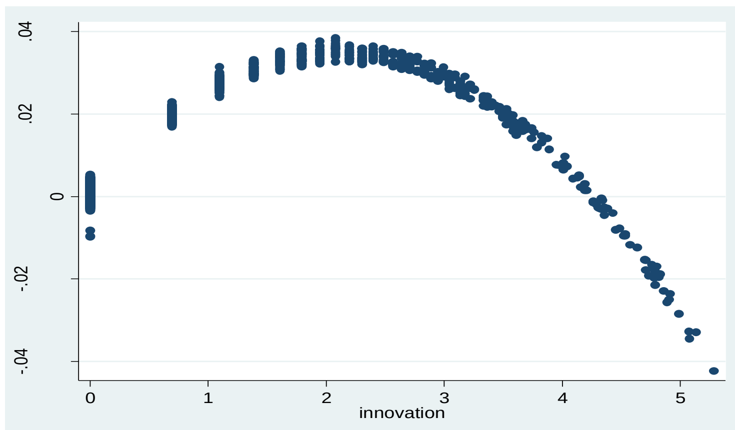

Figure 3.2: Estimated relationship between market power and innovation (proxied by patent applications). The figure is derived from the regression specified in column X of Table 3.6. Sasabuchi–Lind–Mehlum test also confirms this inverted U-shaped relationship.

reasons for differences in the results of market power and HHI. Tingvall and Poldahl (2006) explain these differences in terms of quantification of market power and HHI. They explain that market power, which is closely associated with price-cost margin, is influenced by domestic producers, the degree of competition in the foreign market and foreign producers. However, while calculating HHI, the extent of competition in the foreign market and foreign producers are absent.

3.6. Key findings

In this chapter, we find that the predictions of Aghion et al. (2005) do not hold in our study as the market structure has an insignificant impact on innovation. Our results are consistent with studies that have used R&D as a measure of innovation. The results are similar even after using an output-based proxy of innovation. Earlier studies do not consider the technology gap among the firms while understanding the relationship between innovation and market structure. After controlling for this effect also, we do not find sufficient support for the linear and nonlinear impact of market structure on innovation. Further, this study finds a significant feedback effect of innovation on the market structure. We also confirm the existence of an inverted U-shaped relationship which is in line with the Schumpeterian theory of creative destruction. Up to a certain level, patents have a positive impact on market power. However, after an optimal level further patent protection has an adverse impact.

This chapter is an attempt to analyze the two-way relationship between innovation and market structure. We have also analyzed the impact of patent policy changes on the patenting activity of Indian manufacturing firms. For this purpose, we have utilized time dummy based on the Patent (Amendment) Act 2004. Our results highlight that patenting activity has increased after patent policy changes. Furthermore, it is also possible that patent policy changes influence the overall innovation and market structure relationship. Studies like Kortum and Lerner (1998), Moser (2005) and Correa (2012) highlight that patent policy changes influence the innovation and market structure relationship. However, mere utilization of patent policy dummy does not capture the changing relationship between innovation and market structure. Hence, in the next chapter, we empirically verify the impact of patent policy changes on the relationship between innovation and market structure in detail.

APPENDIX I

Table 3.6: Impact of market structure on innovation (market structure measure- HHI)

	Full sample				High technology				Medium technology			
	PATENTAP		PATENTGR		PATENTAP		PATENTGR		PATENTAP		PATENTGR	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
HHI	-3.25918* (1.67625)	-6.81334** (3.28302)	-0.36436 (1.16810)	0.55462 (2.21739)	-5.09739** (2.39414)	31.05285 (23.27084)	-2.37592 (1.56158)	-6.12156 (12.57454)	-0.88868 (1.28490)	-3.58698 (2.78368)	0.42851 (1.01269)	-0.23930 (1.78509)
HHI^2		8.34719 (8.27249)		-2.15832 (5.34995)		-47.15179 (29.03702)		4.88554 (15.99761)		11.22601 (9.79196)		2.77843 (6.26799)
CONSTANT	1.54518** (0.63541)	1.80896*** (0.64651)	-0.16993 (0.42780)	0.46151 (0.43733)	2.66703** (1.14065)	0.18169 (2.06128)	2.12803** (0.92565)	2.38555* (1.26392)	0.90444 (0.65870)	1.28198* (0.71431)	-0.16993 (0.42780)	-0.07649 (0.45982)
OBSERVATIONS	14887	14887	14887	14887	4849	4849	4849	4849	10038	10038	10038	10038

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. RD, EXPI, EBMD, DISEMBD, ADI, SIZE, SIZE^2, TRIPS and TGAP are used as control variables in the regression analysis. Time dummies have been incorporated in the models.

Table 3.7: Impact of market structure on innovation of neck-and-neck firms (market structure measure-HHI)

	Full sample				High technology				Medium technology			
	PATENTAP		PATENTGR		PATENTAP		PATENTGR		PATENTAP		PATENTGR	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
HHI	-2.34578 (2.90610)	-5.05518 (12.93098)	-1.37032 (2.38914)	12.59092 (10.6775)	-3.86985 (4.16890)	12.05148 (14.13936)	-1.74342 (3.20037)	-6.55663 (7.57130)	-1.36205 (2.34609)	-5.41452 (6.43607)	3.78161 (2.44160)	4.85088 (4.16349)
HHI^2		4.99337 (24.30438)		-25.73031 (20.66498)		-24.10187 (19.02768)		7.28629 (10.58992)		9.05297 (14.11350)		-2.38868 (8.31241)
CONSTANT	2.80152** (1.29883)	2.987706* (1.59011)	0.44488 (0.84897)	-0.51446 (1.20477)	3.81521** (1.73157)	3.08696* (1.79439)	1.78850 (1.49134)	2.00866 (1.61748)	2.42488* (1.36955)	2.91536* (1.52887)	-0.88023 (0.99380)	-1.00964 (1.14905)
OBSERVATIONS	6342	6342	6342	6342	2043	2043	2043	2043	4503	4503	4503	4503

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. RD, EXPI, EBMD, DISEMBD, ADI, SIZE, SIZE^2, TRIPS and TGAP are used as control variables in the regression analysis. Time dummies have been incorporated in the models.

Table 3.8: Impact of innovation on market structure (market structure measure- HHI)

	Full sample				High technology				Medium technology			
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
PATENTAP	0.00344 (0.01508)	-0.09076 (0.08704)			0.02029 (0.03295)	0.01657 (0.12626)			0.00573 (0.01075)	-0.04364 (0.07937)		
PATENTAP^2		0.01216 (0.01165)				0.00043 (0.01344)				0.00700 (0.01050)		
PATENTGR			0.00310 (0.01298)	-0.12642 (0.10598)			0.01176 (0.01464)	-0.00062 (0.09108)			0.00069 (0.01414)	0.01162 (0.05466)
PATENTGR^2				0.02345 (0.02169)				0.00180 (0.01348)				-0.00239 (0.01302)
CONSTANT	0.40343*** (0.05489)	0.50759*** (0.11664)	0.40880*** (0.05067)	0.43209*** (0.078623)	0.63989*** (0.12351)	0.64372*** (0.18224)	0.66833*** (0.13434)	0.66042*** (0.14934)	0.29201*** (0.06163)	0.37040** (0.17097)	0.30550*** (0.05923)	0.29718*** (0.06972)
OBSERVATIONS	432	432	432	432	160	160	160	160	272	272	272	272

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Square brackets contain p-value. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. IMPI, EXPI, ADI, CAPITAL, MGR and TFP are used as control variables in the regression analysis. Time dummies have been incorporated in the models.

CHAPTER 4

PATENT POLICY AND THE RELATIONSHIP BETWEEN INNOVATION AND MARKET STRUCTURE: EVIDENCE FROM INDIAN HIGH AND MEDIUM TECHNOLOGY INDUSTRIES

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4.1. Introduction

In the previous chapter, we have analyzed a two-way relationship between innovation and market structure through SEM. As mentioned earlier, patent policy changes may influence the innovation and market structure relationship. Hence, in this chapter, we analyze the impact of patent policy change on the relationship between innovation and market structure.

Patent policy is an important component of the technological regime that defines the appropriability conditions. Technological regime influences the innovation activity of firms. Hence, it remains unanswered if the relationship between innovation and market structure that we investigated in Chapter 3 vary with policy change. We introduced a patent policy dummy based on the Patent (Amendment) Act 2004 in Chapter 3, however, the patent policy change was initiated in 1995 and were completed in 2005. Thus, we define 1995-2005 as a pre-TRIPs period and 2006-2015 as post-TRIPs period and accordingly focus on the relationship between innovation and market structure in the two different time periods.

The rest of the chapter is organized as follows: Section 4.2 discusses strengthening of patent rights in India and its' impact on patent right holders. Section 4.3 provides brief review of the literature on the relationship between innovation and market structure. Section 3 conditions a description of the variables and methodology. Section 4 discusses the results. Section 5 outlines the key findings.

4.2. Strengthening of patent rights in India

In Chapter 1 of the dissertation, we have provided details of the patent policy changes in India. In this section, we discuss the impact of patent policy changes on the patent right holders. In the Patent (Amendment) Act 1999, there is a provision for receiving the application for product patents in the field of pharmaceutical and agricultural chemicals and also granting Exclusive Marketing Rights (EMRs). Both of these provisions have a positive impact on the patent right holder. And, through EMRs, firms have wider coverage of patent protection as they have exclusive right to sell or distribute the product covered under patent protection in a particular country.

In the Patent (Amendment) Act 2002, the term of protection of product and process has increased to 20 years which was earlier 14 years. Under the new patent regime, firms can enjoy state granted monopoly for 20 years over the patented products and processes. This Amendment also requires the complete description of biological material if patent is related to such materials. A patent can be revoked if there is wrong information about the source and geographical origin of the biological material. Such provision has a negative impact on the patent right holder. Another provision in this act requires an infringer to prove non-infringement of patent right in case of any dispute. This provision is beneficial for patent right holders as they may not have much knowledge about the infringers' processes. Another provision in this act is the removal of "license of right". On the ground of non-working of the patent and unaffordable prices, Controller General can grant compulsory license to other producers after 3 years of patent grant without the consent of the patent holder. Such provision negatively influences the patent right holders as they cannot enjoy the monopoly over sleeping patents. Further, this amendment also requires the publication of patent application in the patent gazettes after 18 months. Moreover, it also makes provisions for both pre and post-grant opposition to the patent. If a patent is filed or granted on unfair ground, one can challenge its validity in the Appellate Board. Last provision is about filing patent application through Patent Cooperation Treaty (PCT). Through PCT a patent can be filed in multiple countries (known as international patent application). International patent application can be filed through national patent office or directly through WIPO.

With third amendment to the Patent Act 1970 made through Patent (Amendment) Act 2004 product patents were allowed in all fields of technology, following which India fully complies with TRIPs. This is the most debatable provision under TRIPs regime. The basic argument which is made by the opponents of TRIPs in the developing countries context is that such changes will result in monopoly power of right owners which lead to high drug prices. Hence, there is a probability of consumer welfare loss to developing economies. Another important provision in this amendment is to provide compulsory license for producing and exporting of pharmaceutical products to those countries which have low or no manufacturing capacity to produce such products. This is in order to accommodate the Doha Round Mandate on compulsory licensing.

IPRs are formal institutions which incentivize firm level innovations by reducing the transaction costs and uncertainty in decision making process (North 2012). Patents, a type of IPRs, are a state granted monopoly to innovator. And patent policy changes that increase the innovators' rights affect the innovation activities of a firm and concomitantly market structure of the industry. IPRs related reforms positively influence innovation performance mainly through two channels; promotional channel and technology transfer channel (Maskus 2004). Through promotional channel, strong IPRs protection is expected to trigger the domestic innovations by stimulating in-house R&D expenditure (Rivera & Romer 1991; Grossman & Helpman 1991); whereas, technology transfer channel encourages innovations through exports, foreign direct investment (FDI), licensing, capital imports and patent data analysis.

Based on the extent of coverage (allowing patent in various fields), membership in the international patent agreements, enforcement mechanisms and duration of protection, Ginarte and Park (1997) and Park (2008) highlight that IPRs protection in India has strengthened after TRIPs related changes. In Table 4.1, index of patent rights for India is discussed between 1996-2005. In 1960, the value of the index was 1.85 which decreased to 1.42 in 1970. Between 1970-2000, we find that there is a continuous decrease in the value of index. This is due to the introduction of the Patent Act 1970. According to the Patent Act 1970 only process innovations can be patented in the fields of food and medicine for the duration of 7 years, whereas in other fields of technology the duration was 14 years. In 2000, the value of index was 2.27 which was 84.55% higher than 1995. This value further increased to 3.76 in 2005.

Due to strong patent laws and other IPRs protections, developing countries are now specialising in some fields of technology and are innovating at the frontier of such technology fields. A study by Sharma et al. (2018) also highlights that duration of protection, enforcement mechanism and membership in international agreement has significantly improved technological capabilities of India. Other evidences also show that TRIPs have significantly increased R&D and patenting in India (Chadha 2009; Haley & Haley 2012; Jagadeesh & Sasidharan 2014).

Table 4.1: Index of patent rights in India

Year	Index of patent rights
1960	1.85
1965	1.85
1970	1.42
1995	1.62
1980	1.62
1985	1.62
1990	1.48
1995	1.23
2000	2.27
2005	3.76

Source: Adopted from Ginarte and Park (1997) and Park (2008).

Many studies focus on the impact of patent policy changes on Indian manufacturing sector predominantly following the signing of the TRIPs agreement. According to Goldar (2013), in domestic drug market, dominance of foreign firms decreased after Patent Act 1970 because of provision for only process patenting but after TRIPs foreign firms are regaining monopoly power. The study by Ramani and Maria (2005) questions the relevance of TRIPs for low- and middle-income countries like China, Brazil and India. The supporters of TRIPs argue that it will encourage low and middle income countries to be innovators. However, a study by Ramani and Maria (2005) suggests that TRIPs will encourage the racing of first or lowest cost production of off-patented brands only. This finding is also at par with Correa (1997) who explains that developing countries are not much benefited by TRIPs agreement. Average firm size of developing countries is small and they do not have financing capacity to develop new chemical entities which require huge R&D expenditure (Correa 1997). Hence, the empirical evidence on the impact of developing countries is ambiguous (Sharma and Saxena 2012).

Table 4.2: Three amendments to the Patent Act 1970

Amendment year	Policy Changes	Impact on Right-Holder
1999	1. Provision for receiving the application for product patent in the field of pharmaceutical and agricultural chemicals.	+
	2. Provision for granting Exclusive Marketing Rights (EMRs).	+
2002	1. Term of protection extended up to 20 years.	+
	2. Source and geographical origin of the biological material has to be disclosed.	–
	3. Removal of "licences of right."	+
	4. In case of dispute infringer should prove non-infringement (reversal of 'burden of proof').	+
	5. Introduce publication of application after 18 months.	–
	6. Provision for pre and post grant opposition	–
	7. Introduction of the Appellate Board.	+
	8. Allowed application through PCT (India joined in PCT in 1998.).	+
2005	1. Product patent in all field of technology	+
	2. To accommodate Doha round mandate allows exportation of goods produced under compulsory license subject to certain condition at host country.	–

Source: Adopted from Sharma and Ambrammal (2015).

4.3. Literature review

According to Grossman and Helpman (1991), strong IPRs encourage entrepreneurs to increase their R&D investment which further increase their post-innovation profits and reduce the cost of future innovations. Strengthening IPRs positively influence technological progress of a country (Kanwar & Evenson 2003; Hausmann et al. 2014; Naghavi & Strozzi 2015; Boring 2015; Zhang & Yang 2016). Successful innovators commercialize new technology on their own and/or they sell or license to others. In a weak IPRs regime, innovators do not reap full benefits by using and/or selling new technologies due to high chances of imitation (Autio & Acs 2010). Strong IPRs also increase technology transfer to developing countries which contribute to the innovation activity of firms of such countries (Maskus 2004; Sasidharan & Kathuria 2011; Khachoo et al. 2018). In literature various channels of technology transfer are discussed like; trade of goods and services, FDI, licensing, joint ventures, departure of employees, temporary migration and patent application data (Maskus 2004). Strong IPRs protection increases competition in the market by incentivizing entry of new firms (Djankov et al. 2002; Klapper et al. 2006) that also depends on the quality of opportunity available in the market (Davidsson 1991). Kahneman and Tversky (1979) also explain that the impact of strong IPRs will be large for new business formation rather than established ones. However, Gilbert and Newbary (1982) explain that in strong IPRs protection cost of imitation is very high which increases the monopolistic behavior in the market (Gilbert & Newbary 1982).

Utilizing innovation data from Crystal Palace Exhibition in London (1851) and the Centennial Exhibition in Philadelphia (1876), Moser (2005) suggests that patent laws are important determinant of direction of technological change. Kortum and Lerner (1998) and Correa (2012) also find upsurge in the U.S. patenting due to domestic patent policy change. Establishment of the United States Court of Appeals for the Federal Circuit (CAFC) increased number of patent applications and grants. The establishment of CAFC increased the propensity of innovation by broadening the right of patent holder. Kortum and Lerner (1998) named it as friendly-court hypothesis. Correa (2012) analyzes the relationship between market structure and innovation using dataset of 311 firms listed in London Stock Exchange over 1973-1994. This study utilizes the establishment of CAFC in 1982 as a structural break in the dataset. This study finds that competition has positive and significant impact on firms' innovation for the period of 1973-1982; however, this relationship become insignificant over 1983-1994. The findings of this study suggest that patent policy change plays a very important role in explaining the innovation-market structure relationship. Estimating the relationship without considering structural breaks may mislead the researchers and policy makers.

In the Indian context, a study by Sharma et al. (2018) finds positive impact of patent policy change on the R&D of Indian industries. This study incorporated different components of patent policy index developed by Ginarte and Park (1997). The findings of this study suggest that duration of protection, enforcement mechanism and membership in international agreement have positive and significant influence on the innovation capacity of Indian industries. Utilizing firm level data Jagadeesh and Sasidharan (2014) analyze the R&D behavior of Indian pharmaceutical firms before and after TRIPs. This study also finds that policy changes have significantly increased R&D of the pharmaceutical firms. According to Haley and Haley (2012), Indian pharmaceutical firms were globally competitive in the production of generics from 1972-2004 due to process patent regime. This study suggests that the Indian pharmaceutical firms positively responded to changes in patent policy by decreasing the filing of process patents. Study by Chadha (2009) analyzed the impact of TRIPs on patenting activities of the Indian pharmaceutical firms. This study finds that patenting activities have increased in post-TRIPs era.

Table 4.3: Impact of TRIPs on Indian industries: Some major empirical studies

Author	Innovation measure	Time period	Findings
Chadha (2009)	Patent	1991-2004	1. The Patent (Amendment) Act 1999 has positive and significant impact on process patents of Indian pharmaceutical firms.
Haley and Haley (2012)	Patent and R&D expenditure	2005-2008	1. Indian pharmaceutical companies have positively responded to change in patent laws. 2. Number of process patents filed by major pharmaceutical companies has been declined under product patent regime. 3. Firms are filing more product patents.
Jagadeesh and Sasidharan (2014)	R&D expenditure	1994-2010	1. There is positive impact of the Patent (Amendment) Act 2005 on firms' R&D expenditure. 2. The Patent (Amendment) Act 1999 has insignificant impact on firms' R&D expenditure.
Sharma et al. (2018)	R&D expenditure	1990-2010	1. The Patent (Amendment) Act 1999 has significant impact on the R&D expenditure of Indian industries. 2. Patent policy index (Ginarte and Park 1997; Park 2008) has significant impact on R&D of Indian industries. 3. The positive impact of Patent policy index on R&D is mostly driven through increase in the protection duration, enforcement mechanism, and membership into international convention.

Source: Authors' compilation.

It is evident that both innovation and market structure are interdependent. Literature also suggests that patent policy changes influence the relationship between innovation and market structure. Considering the literature and patent policy changes in India, in this chapter we empirically verify the impact of TRIPs on the two-way relationship between patenting and monopoly power in the Indian high and medium technology firms. To explore the interdependence between patenting and monopoly power, we utilize system of two equations; patenting equation and monopoly power equation. To analyze the impact of TRIPs, we classify our database into two time periods; 1995-2005 and 2006-2015, as India fully complied with TRIPs agreement in 2005 by allowing product patent in all the fields of technology. We also separately perform the analysis for both high and medium technology firms as the sectoral patterns of innovation literature suggest that types of innovation and propensity to innovate vary among industries.

4.4. Data and description of variables

This study includes all high and medium technology firms which are reporting their sales between 1995-2015. Like chapter 2, WLI and, PATENTAP and PATENTGR are utilized as dependent variables for market structure and innovation equations respectively for empirical purpose. After proper cleaning of data, we are able to collect the information for 1012 firms. Out of these 1012 firms, 327 (32.31%) firms are high technology and 685 (67.68%) are medium technology firms. Definitions of all the variables are similar to Table 3.1 discussed in Chapter 3. Table 4.4 presents the descriptive statistics of full sample, high and medium technology firms.

During 1995-2005, the average patent application filed was 0.38 for full sample, 0.73 for high technology firms and 0.23 for medium technology firms. We observed a drastic increase in the average patent application after the implementation of TRIPs. Evidently, the average patent applications during 2006-2015 were 2.03 (the average is increased by 434.22% in comparison to 1995-2005) for the full sample, 3.26 for the high technology firms (346.58% increase) and 1.45 for the medium technology firms (530.44% increase).

Table 4.4: Descriptive statistics of full sample, high and medium technology industries

Variables		1995-2005			2006-2015	
	Full sample	High technology industries	Medium technology industries	Full sample	High technology industries	Medium technology industries
	Mean (Standard Deviation)	*Mean (Standard Deviation)*	*Mean (Standard Deviation)*	*Mean (Standard Deviation)*	*Mean (Standard Deviation)*	*Mean (Standard Deviation)*
PATENTAP	0.38968 (4.13850)	0.72310 (6.31091)	0.23052 (2.49322)	2.02668 (13.34173)	3.25137 (18.74019)	1.44204 (9.71109)
PATENTGR	0.031171 (0.81360)	0.05977 (1.37514)	0.01751 (0.27353)	0.69051 (5.48795)	1.01345 (5.97761)	0.53635 (5.23152)
HHI	0.13014 (0.14038)	0.15964 (0.17844)	0.11606 (0.11535)	0.12734 (0.12675)	0.14532 (0.15361)	0.11875 (0.11066)
WLI	0.00362 (0.01385)	0.00444 (0.01678)	0.00323 (0.01218)	0.00442 (0.03261)	0.00633 (0.04578)	0.00352 (0.02383)
EXPI	0.11232 (0.27787)	0.13526 (0.23810)	0.10137 (0.29435)	0.15070 (0.49788)	0.20831 (0.81838)	0.12320 (0.21031)
DISEMBD	0.00184 (0.00790)	0.00141 (0.00515)	0.00204 (0.00891)	0.00183 (0.00831)	0.00191 (0.01089)	0.00179 (0.00673)
EBMD	0.04613 (1.85582)	0.01838 (0.41399)	0.05937 (2.23743)	0.01042 (0.10722)	0.01405 (0.18016)	0.00869 (0.03851)
RD	0.00506 (0.04430)	0.00917 (0.07578)	0.00310 (0.01209)	0.00765 (0.05491)	0.01687 (0.09497)	0.00326 (0.00944)
ADI	0.00519 (0.01630)	0.00627 (0.01781)	0.00468 (0.01550)	0.00572 (0.03204)	0.00639 (0.02617)	0.00540 (0.03449)
SIZE	5.56878 (1.74332)	5.30126 (1.69695)	5.69649 (1.75078)	5.98464 (1.86706)	5.89865 (1.83401)	6.02569 (1.88137)
AGE	3.04357 (0.70638)	2.96884 (0.72418)	3.07925 (0.69495)	3.50445 (0.45329)	3.45884 (0.45830)	3.52622 (0.44929)
IMPI	0.13335 (1.93260)	0.11945 (0.47767)	0.13999 (2.32574)	0.19190 (5.19210)	0.32558 (8.94120)	0.12808 (1.28788)
MGR	12.64436 (10.86705)	13.72860 (10.52327)	12.12677 (10.99041)	12.5096 (12.4148)	12.70213 (10.11631)	12.4177 (13.37316)
CAPITAL	3.164834 (63.30892)	1.63858 (8.97638)	3.89342 (76.69087)	7.75734 (155.2038)	10.66515 (224.1265)	6.36923 (107.7364)
OBSERVATIONS	11132	3597	7535	10120	3270	6850

Notes: Authors' calculations on the basis of information available in CMIE PROWESS and CGPDT. Standard deviations are shown in parenthesis.

Patent statistics based on granted patent also show an increasing trend. For the period of 1995-2005, the average patent granted for full sample was 0.032, for high technology firms 0.059 and for medium technology firms 0.01. In post-TRIPs era, the average patent granted for full sample was 0.69, for high technology firms 1.01 and for medium technology firms this average was 0.53. Similarly, we find that R&D intensity of Indian manufacturing firm has also increased after TRIPs. For full sample R&D intensity increased from 0.5% to 0.7% between 1995-2005 to 2006-2015. For high technology firms, R&D intensity increased from 0.9% to 1.6%. However, we do not find a significant increase in R&D intensity (5.16% increases) of medium technology firms.

Based on previous chapter, we use the following SEM for analyzing the innovation and market structure relationship under different technology regime:

PATENTAP = f (WLI, WLI^2, SIZE, SIZE ^{2}, RD, EXPI, EBMD, DISEMBD, ADI, AGE, AGE ^{2})   (1)

WLI = f (PATENTAP, PATENTAP^2, EXPI, ADI, MGR, IMPI, AGE, CAPITAL)   (2)

4.5. Empirical result

For empirical specification, we employ FE2SLS estimation technique to estimate the model discussed in the previous section. Section 1.6.2 of Chapter 1 and Section 3.5 of Chapter 3 discuss FE2SLS into more details. First, we estimate the results for innovation equation for the full panel which include both high and medium technology industries and then segregate the panel into high and medium technology firms. We perform the analysis differently for 1995-2005 and 2006-2015. Similarly, we estimate the results of market structure equation.

4.5.1 Results of the innovation equation

4.5.1.1 Estimation for 1995-2005

The results of innovation equation are presented in Table 4.5. Columns I - IV present the result of full sample, columns V-VIII for high technology, and columns IX and XII for medium technology firms. In columns I-IV, impact of market structure on innovation is insignificant as the coefficient of WLI is insignificant. Moreover, the coefficient of WLI^2 is also insignificant for these firms. Results are also similar for high technology firms as the coefficients WLI and WLI^2 are insignificant in columns V-VIII. For medium technology firms, we find positive impact of WLI on firms' patent application and grant. However, we do not find any nonlinear impact of market structure on innovation activities as the coefficient of WLI^2 is insignificant in all the columns. Overall, results based on innovation equation suggest that there is a linear positive impact of market structure on innovation but only for medium technology firms.

The coefficient of RD is positive and significant in columns I, II, V and VI which suggest that RD has positive and significant impact on patent application for full sample and high technology firms. The coefficient of ADI is positive and significant in Columns I, II, V and IX which suggest that more product differentiation leads to more patenting. The coefficient of AGE is positive and AGE^2 is negative and both are significant which indicates a significant inverted U-shaped relationship between age and patenting activities. This U-shaped relationship is also supported by SLM test. In columns I, V and VI, the coefficient of SIZE is negative and $SIZE^2$ is positive and both are significant suggesting a U-shaped relationship between size and innovation. SLM test in these columns also support such U-shaped relationship. The coefficients of EMBD, DISEMBD and EXPI are insignificant in all columns. These results also corroborate with results of previous chapter.

4.5.1.2 Estimation for 2006-2015

In Table 4.6, we estimate the results of innovation equation for post-TRIPS period i.e. 2006-2015. The basic setup of Table 4.6 is similar to Table 4.5. Results based on full sample estimation suggest that market structure has positive and significant impact on patent application in column II; however, the level of significance is low (significant at 10% level only). In other columns, we do not find any positive impact of market structure on innovation. Moreover, for high and medium technology firms, the impact of market structure on innovation is insignificant. We do not find any linear and/or nonlinear impact of market structure on innovation for the period of 2006-2015. These results also similar to previous chapter where we find insignificant impact of market structure on firms' patenting activity.

With respect to control variables, the coefficient of EXPI is negative and significant in columns IV, VII and VIII. This result indicates that export intensity has negative impact on patent grants in high technology firms. The relationship between size and patenting is reported as U-shaped in columns I, IX and X. With respect to other control variable like RD, EBMD, DISEMBD, ADI and AGE, the results are insignificant in post-TRIPS era.

Table 4.5: Impact of market structure on innovation- 1995-2005 (market structure measure- WLI)

	Full sample				High technology				Medium technology			
	PATENTAP		PATENTGR		PATENTAP		PATENTGR		PATENTAP		PATENTGR	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
WLI	2.12560 (5.54323)	-13.87248 (24.13694)	1.41267 (1.47862)	4.04764 (4.19366)	4.35699 (11.0898)	15.96534 (19.34587)	2.01910 (3.02015)	4.69842 (5.16541)	10.43394** (4.58431)	-0.04053 (12.05985)	2.25511* (1.29547)	1.11681 (2.84956)
WLI^2		372.50610 (504.69470)		-61.35385 (84.36087)		-143.37890 (173.7163)		-33.0933 (50.2973)		272.77990 (330.50250)		29.64407 (60.48034)
RD	0.82281*** (0.25728)	0.81881*** (0.28968)	0.09005 (0.07506)	0.09071 (0.07182)	0.82458*** (0.27148)	0.83022*** (0.24595)	0.09772 (0.08499)	0.09902 (0.08054)	0.15940 (0.26470)	0.21162 (0.27165)	-0.04722 (0.05571)	-0.04154 (0.05714)
EXPI	0.06229* (0.03781)	0.11243 (0.07664)	0.00670 (0.00563)	-0.00155 (0.01206)	0.12192 (0.07811)	0.06339 (0.10000)	0.01787 (0.01176)	0.00436 (0.02272)	-0.00554 (0.03269)	0.01769 (0.04177)	-0.00200 (0.00543)	0.00052 (0.00747)
EBMD	0.02545* (0.01506)	-0.00890 (0.05065)	0.00244 (0.00325)	0.00810 (0.00802)	-0.01608 (0.06735)	0.00300 (0.07586)	0.00630 (0.01006)	0.01070 (0.01299)	0.01235 (0.00946)	0.00614 (0.01298)	0.00002 (0.00130)	-0.00064 (0.00208)
DISEMBD	-0.81084 (0.66708)	-3.83330 (4.64411)	-0.28567 (0.39322)	0.21214 (0.74420)	-5.3532 (5.05896)	-1.10512 (5.57088)	-3.14434 (2.56687)	-2.16383 (2.16189)	-0.42300 (0.40626)	-0.89380 (0.87304)	0.14711 (0.15950)	0.09595 (0.17912)
ADI	2.41019** (1.01466)	2.12946* (1.19473)	0.17571 (0.21358)	0.22195 (0.24704)	2.26054* (1.36094)	2.21379 (1.36381)	0.196913 (0.26799)	0.18612 (0.25735)	2.94277** (1.39519)	1.96424 (1.65193)	0.19683 (0.35042)	0.09049 (0.34156)
AGE	0.52840*** (0.15636)	0.45482** (0.18783)	0.13325*** (0.05059)	0.145373*** (0.05353)	0.86648*** (0.32000)	0.95534*** (0.34441)	0.24748** (0.12926)	0.26799* (0.14253)	0.38990** (0.16122)	0.42713* (0.18226)	0.07701** (0.03420)	0.08106** (0.03874)
AGE^2	-0.21759*** (0.05747)	-0.19161*** (0.06754)	-0.05114*** (0.01773)	-0.05541*** (0.01928)	-0.37428*** (0.12037)	-0.41215*** (0.13259)	-0.09081** (0.04646)	-0.09955* (0.05377)	-0.16632*** (0.05801)	-0.18137*** (0.06544)	-0.03380*** (0.01282)	-0.03544** (0.01445)
SIZE	-0.15596*** (0.04807)	-0.02471 (0.18650)	-0.01702 (0.01237)	-0.03864 (0.02988)	-0.26391** (0.10767)	-0.35253*** (0.13004)	-0.03549 (0.03300)	-0.05595 (0.04388)	-0.06883* (0.03897)	-0.05451 (0.04140)	-0.00322 (0.00427)	-0.00167 (0.00517)
SIZE^2	0.02094*** (0.00634)	0.00435 (0.02392)	0.00187 (0.00158)	0.00460 (0.00378)	0.03936*** (0.01511)	0.05036*** (0.01715)	0.00433 (0.00435)	0.00687 (0.00568)	0.00736 (0.00472)	0.00527 (0.00545)	0.00009 (0.00058)	-0.00012 (0.00074)
CONSTANT	0.52270*** (.11196)	0.33767 (0.25455)	0.08492** (0.03905)	0.11540** (0.05956)	0.84071*** (0.23057)	1.01531*** (0.30938)	0.09921 (0.08219)	0.13951 (0.12003)	0.42716*** (0.11694)	0.44683*** (0.14483)	0.08163*** (0.02229)	0.08377*** (0.02538)
SLM (WLI)	-	-	-	-	-	-	-	-	-	-	-	-
SLM (AGE)	2.77*** [0.00278]	1.86** [0.0313]	2.15** [0.016]	2.30** [0.0108]	2.13** [0.0168]	2.25** [0 .0124]	1.69** [0.0453]	1.73** [0.0415]	1.85** [0.0321]	1.78** [0.0372]	1.76** [0.0392]	1.64* [0.051]
SLM (SIZE)	3.24*** [0.00059]	0.13 [0.447]	1.07 [0.143]	1.17 [0.121]	2.44*** [0.0073]	2.70*** [0.00348]	0.95 [0.171]	1.17 [0.121]	1.42* [0.0782]	0.77 [0.221]	-	-
OBSERVATIONS	11132	11132	11132	11132	3597	3597	3597	3597	7535	7535	7535	7535

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Square brackets contain p- value. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models. SLM test is Sasabuchi–Lind–Mehlum test to validate U-shaped or inverted U-shaped relationship. In all the columns SLM test statistics is positive and significant which suggest a significant U-shaped relationship between size and patenting.

4.5.2 Market structure equation

4.5.2.1 Estimation for 1995-2005

The results of market structure equation for the period of 1995-2005 are presented in Table 4.7. Results based on full sample estimation suggest positive and significant impact of PATENTAP and PATENTGR on firms' market power. Studies like; Gupta (1983), Lunn (1986), Koeller (1995), Delorme et al. (2002) and Yoon (2004) also find positive impact of innovation on firms' monopoly power. Patenting activity is a positive source of monopoly power by increasing pricing structure through product differentiation and also by minimizing the cost of production (Dhanora et al. 2018). We also find that the coefficient of $PATENTAP^2$ is negative and significant in column II. This result indicates the existence of inverted-U shaped relationship between PATENTAP and monopoly power. This result is also supported by SLM-test. However, result based on PATENTGR shows only linear positive impact on the market power. Studies like Lokshin (2008), Berchicci (2013), Nemlioglu and Mallick (2017), and Dhanora et al. (2018) also find nonlinear impact of innovation on firms' performance related activities.

For high technology firms, we find insignificant impact of PATENTAP and PATENTGR on firms' monopoly power. Results based on medium technology firms also suggest that PATENTAP has positive and significant impact on the market power. Moreover, the coefficient of $PATENTAP^2$ is negative and significant in columns X. Overall, we find that there is an inverted-U shaped relationship between PATENTAP and market power in medium technology firms. This result is also supported by SLM test. Results based on PATENTGR and $PATENTGR^2$ have insignificant impact on the monopoly power of medium technology firms.

With respect to control variables, we find that the coefficient of AGE is positive and significant for full sample and medium technology firms. The impact of capital intensity is negative and significant. We do not find any significant impact of IMPI, EXPI, ADI and MGR on the monopoly power.

4.5.2.2 Estimation for 2006-2015

In Tables 4.8, we estimate the results of market structure equation for post-TRIPS period i.e. 2006-2015. In Table 4.8, we find that innovation has insignificant impact on the monopoly power. In all the columns, coefficients of WLI and WLI^2 are insignificant. The coefficient of EXP is positive and significant in columns I, III, IV and VII; however, the level of significance is low (10% level). This result indicates that export oriented firms are enjoying more monopoly power in post-TRIPs era. The coefficient of AGE is positive and significant in column VII. The coefficient of CAPITAL is negative and significant in columns VII and VIII.

Table 4.6: Impact of market structure on innovation- 2006-2015 (market structure measure - WLI)

	Full sample				High technology				Medium technology			
	PATENTAP		PATENTGR		PATENTAP		PATENTGR		PATENTAP		PATENTGR	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
WLI	-3.10542 (5.50136)	24.72147* (13.91875)	-0.77693 (3.55478)	4.91056 (7.52367)	-11.26641 (11.27965)	22.43785 (17.71324)	1.62552 (4.6642)	-2.01343 (5.92186)	1.55157 (8.65462)	16.79968 (25.47022)	-3.60311 (7.17285)	0.09130 (14.48467)
WLI^2		-40.34227 (26.49663)		-8.24549 (10.7896)		-38.87584 (35.93444)		4.19732 (9.14787)		-41.27474 (45.21724)		-10.0003 (24.06933)
RD	0.15025 (0.29310)	.032380 (0.34104)	0.01550 (0.10170)	0.05097 (0.11941)	0.00751 (0.32565)	0.18308 (0.35072)	0.04900 (0.09393)	0.03004 (0.08798)	0.95894 (0.75817)	1.27382 (1.00237)	0.30409 (0.51393)	0.38038 (0.61999)
EXPI	-0.00183 (0.04311)	-0.03404 (0.04317)	-0.03181 (0.01978)	-0.038394* (0.02155)	0.07289 (0.07658)	0.01080 (0.06391)	-0.07575** (0.03764)	-0.06905** (0.03440)	0.00551 (0.05390)	-0.00517 (0.05595)	-0.00614 (0.02088)	-0.00873 (0.02290)
EBMD	0.00413 (0.07685)	-0.07856 (0.09248)	-0.01359 (0.04145)	-0.03050 (0.04850)	0.22015 (0.32083)	-0.01491 (0.30941)	-0.10662 (0.17876)	-0.08124 (0.18324)	-0.04940 (0.09502)	-0.04146 (0.10520)	-0.07035 (0.05994)	-0.06842 (0.06181)
DISEMBD	-0.43220 (1.3063)	0.30067 (1.39220)	-0.00216 (0.45835)	0.14762 (0.47837)	0.05838 (0.57999)	0.89557 (0.75267)	0.26748 (0.42267)	0.17709 (0.43983)	-1.42590 (4.70499)	-1.25704 (4.74509)	-1.1156 (1.61304)	-1.07469 (1.63044)
ADI	-0.04331 (0.26876)	0.00356 (0.28021)	-0.02575 (0.18388)	-0.01617 (0.18407)	-0.73507 (1.45725)	-0.23843 (1.4549)	0.60445 (0.87194)	0.55083 (0.88215)	0.04367 (0.11132)	0.06177 (0.12612)	-0.18736 (0.15321)	-0.18297 (0.15243)
AGE	-0.48293 (1.57116)	-0.71398 (1.6252)	-0.40045 (1.0224)	-0.44768 (1.02964)	2.41480 (3.35845)	0.88889 (3.25433)	-1.3520 (2.2579)	-1.1872 (2.2090)	-1.18869 (1.75727)	-1.3585 (1.8002)	-0.25380 (1.157)	-0.29494 (1.15386)
AGE^2	0.14721 (0.33763)	0.19974 (0.34714)	0.06469 (0.22082)	0.07543 (0.22248)	-0.34794 (0.71698)	-0.03856 (0.70325)	0.20039 (0.47401)	0.16699 (0.46822)	0.27084 (0.37350)	0.30426 (0.38059)	0.05334 (0.25051)	0.06144 (0.24988)
SIZE	-0.12284** (0.05612)	-0.09089 (0.06426)	-0.05700 (0.04127)	-0.05047 (0.04338)	0.00559 (0.09498)	0.07533 (0.08110)	-0.09188 (0.07965)	-0.09941 (0.08221)	-0.20794*** (0.07318)	-0.23806*** (0.08340)	-0.03854 (0.04204)	-0.04584 (0.04800)
$SIZE^2$	0.01509** (0.00604)	0.01134 (0.00717)	0.00630 (0.00442)	0.00554 (0.00468)	0.00174 (0.01130)	-0.00664 (0.00959)	0.011407 (0.00906)	0.01231 (0.00931)	0.02361*** (0.00755)	0.02697*** (0.00930)	0.00352 (0.00448)	0.00434 (0.00528)
CONSTANT	0.31188 (1.490329)	0.33659 (1.57368)	0.79255 (0.94329)	0.79760 (0.95069)	-3.79235 (3.34477)	-2.46043 (3.19584)	2.46232 (2.33593)	2.31851 (2.25365)	1.33784 (1.70363)	1.52605 (1.78339)	0.41995 (1.02439)	0.46555 (1.02894)
SLM (WLI)	-	-	-	-	-	-	-	-	-	-	-	-
SLM (AGE)	-	-	0.20 [0.419]	0.25 [0.4]	0.25 [0.402]	-	0.24 [0.406]	0.17 [0.432]	-	-	-	-
SLM (SIZE)	2.18** [0.0145]	1.41* [0.079]	1.38* [0.0838]	1.16 [0.122]	-	0.54 [0.296]	1.13 [0.129]	1.19 [0.118]	2.84*** [0.00228]	2.85*** [0.0021]	0.69 [0.244]	0.73 [0.233]
OBSERVATIONS	10120	10120	10120	10120	3270	3270	3270	3270	6850	6850	6850	6850

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Square brackets contain p- value. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models. SLM test is Sasabuchi–Lind–Mehlum test to validate U-shaped or inverted U-shaped relationship. In all the columns SLM test statistics is positive and significant which suggest a significant U-shaped relationship between size and patenting.

Table 4.7: Impact of innovation on market structure- 1995-2005 (market structure measure- WLI)

WLI	Full sample				High technology				Medium technology			
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
PATENTAP	0.018380** (0.00831)	0.07790** (0.03921)			0.01506 (0.01091)	0.06482 (0.05567)			0.02084** (0.00909)	0.15986** (0.07143)		
PATENTAP^2		-0.02269* (0.01286)				-0.01838 (0.01725)				-0.05316* (0.02777)		
PATENTGR			0.08558* (0.04922)	0.69659 (0.53600)			0.03268 (0.02197)	0.66144 (0.67743)			0.04223 (0.04011)	1.03343 (0.86590)
PATENTGR^2				-0.30754 (0.28147)				-0.27327 (0.30642)				-0.63018 (0.61550)
IMPI	0.00056 (0.00045)	0.00033 (0.00059)	0.00025 (0.00039)	-0.00050 (0.00106)	0.00131 (0.00208)	0.00109 (0.00262)	0.00043 (0.00145)	-0.00177 (0.00276)	0.00031 (0.00041)	-0.00011 (0.00082)	0.00055 (0.00038)	-0.00029 (0.00099)
EXPI	-0.00114 (0.00115)	-0.00101 (0.00134)	-0.00020 (0.00081)	-0.00225 (0.00257)	-0.00198 (0.00305)	-0.00316 (0.00416)	0.00067 (0.00117)	-0.00753 (0.00899)	0.00002 (0.00086)	0.00155 (0.00154)	-0.00010 (0.00068)	0.00037 (0.00288)
ADI	-0.04224 (0.02922)	0.02901 (0.04111)	-0.01304 (0.02090)	-0.01377 (0.08444)	-0.03806 (0.03465)	0.03040 (0.06122)	-0.01319 (0.0168)	0.05123 (0.10784)	-0.04868 (0.03723)	0.07054 (0.09345)	0.00843 (0.02324)	-0.13724 (0.20817)
AGE	0.00462*** (0.00173)	0.00275* (0.00143)	0.00394* (0.00212)	0.00472 (0.00332)	0.00358 (0.00324)	-0.00001 (0.00205)	0.00065 (0.00173)	0.00030 (0.00632)	0.00525*** (0.00196)	0.00478** (0.00229)	0.00391** (0.00181)	0.00408 (0.00288)
CAPITAL	-0.00064*** (0.00022)	-0.00084*** (0.00025)	-0.00057** (0.00025)	-0.00076** (0.00034)	-0.00083** (0.00037)	-0.00132** (0.00057)	-0.00062* (0.00037)	-0.00161* (0.00089)	-0.00050* (0.00027)	-0.00049 (0.00033)	-0.00065** (0.00028)	-0.00054 (0.00047)
MGR	0.00003 (0.00002)	3.74e-06 (0.00003)	0.00001 (0.00002)	-0.00004 (0.00006)	0.00003 (0.00004)	0.00003 (0.00005)	0.00002 (0.00004)	-0.00003 (0.00010)	0.00002 (0.00002)	-0.00006 (0.00004)	9.90e-06 (0.00002)	-0.00008 (0.00007)
CONSTANT	-0.00976** (0.00494)	-0.00500 (0.00411)	-0.00767 (0.00596)	-0.00913 (0.00907)	-0.00617 (0.00854)	0.00227 (0.00526)	0.00185 (0.00459)	0.00492 (0.01683)	-0.01176** (0.00584)	-0.01041 (0.00682)	-0.00778 (0.00550)	-0.00747 (0.00806)
SLM(PATENTAP)	-	1.67** [0.0477]	-	-	-	-	-	-	-	1.74** [0.0413]	-	-
SLM(PATENTGR)	-	-	-	-	-	-	-	-	-	-	-	-
OBSERVATIONS	11132	11132	11132	11132	3597	3597	3597	3597	7535	7535	7535	7535

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Square brackets contain p- value. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models. SLM test is Sasabuchi–Lind–Mehlum test to validate U-shaped or inverted U-shaped relationship. In all the columns SLM test statistics is positive and significant which suggest a significant U-shaped relationship between size and patenting.

Table 4.8: Impact of innovation on market structure- 2006-2015 (market structure measure- WLI)

WLI	Full sample				High technology				Medium technology			
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
PATENTAP	0.01570	0.05937			0.02247	0.05650			0.01322	0.03951		
	(0.01241)	(0.04576)			(0.02496)	(0.04865)			(0.01137)	(0.02731)		
PATENTAP^2		-0.01557				-0.01089				-0.00892		
		(0.01418)				(0.01186)				(0.00726)		
PATENTGR			0.03965	0.04233			0.00636	0.03669			0.02562	0.01086
			(0.04375)	(0.04514)			(0.01653)	(0.05411)			(0.02964)	(0.04469)
PATENTGR^2				-0.00231				-0.02665				0.00357
				(0.01036)				(0.03077)				(0.00788)
IMPI	0.00153	0.00100	0.00136	0.00135	0.00435	0.00411	0.00423	0.00451	-0.00041	-0.00106	-0.00159	-0.00095
	(0.00131)	(0.00152)	(0.00178)	(0.00177)	(0.00315)	(0.00315)	(0.00302)	(0.00363)	(0.00085)	(0.00132)	(0.00184)	(0.00236)
EXPI	0.00183*	0.00171	0.00318*	0.00317*	0.00162	0.00071	0.00317*	0.00296	0.00056	0.00108	0.00116	0.00086
	(0.00110)	(0.00132)	(0.00177)	(0.00171)	(0.00211)	(0.00269)	(0.00197)	(0.00293)	(0.00100)	(0.00142)	(0.00114)	(0.00122)
ADI	-0.00634	-0.00383	-0.00516	-0.00649	-0.02421	-0.01901	-0.02590	-0.02792	-0.00279	-0.00162	0.00225	0.00284
	(0.00800)	(0.00905)	(0.00921)	(0.01093)	(0.03269)	(0.03862)	(0.02340)	(0.03125)	(0.00451)	(0.00419)	(0.00569)	(0.00551)
AGE	0.00218	0.00640	0.00934	0.00965	0.00204	0.01258	0.01957**	0.01838	-0.00236	-0.00340	-0.00047	-0.00142
	(0.00670)	(0.00783)	(0.00681)	(0.00655)	(0.02028)	(0.02405)	(0.00828)	(0.02119)	(0.00415)	(0.00500)	(0.00457)	(0.00434)
CAPITAL	-0.00055	-0.00018	-0.00070	-0.00069	-0.00136	-0.00084	-0.00195**	-0.00210**	-0.00019	-0.00005	-0.00029	-0.00030
	(0.00075)	(0.00089)	(0.00068)	(0.00068)	(0.00094)	(0.00119)	(0.00085)	(0.00095)	(0.00099)	(0.00103)	(0.00093)	(0.00093)
MGR	0.00005	0.00006*	0.00005	0.00004	0.00021	0.00021	0.00011	0.00001	0.00003	0.00003	0.00003	0.00003
	(0.00003)	(0.00004)	(0.00003)	(0.00003)	(0.00020)	(0.00022)	(0.00015)	(0.00021)	(0.00003)	(0.00003)	(0.00003)	(0.00003)
CONSTANT	-0.00767	-0.02317	-0.03175	-0.03255	-0.01323	-0.04893	-0.06199**	-0.05287	0.00890	0.01105	0.00268	0.00643
	(0.02128)	(0.02541)	(0.02495)	(0.02405)	(0.06059)	(0.07138)	(0.02865)	(0.07387)	(0.01324)	(0.01591)	(0.01539)	(0.01517)
SLM(PATENTAP)	-	-	-	-	-	-	-	-	-	-	-	-
SLM(PATENTGR)	-	-	-	-	-	-	-	-	-	-	-	-
OBSERVATIONS	10120	10120	10120	10120	3270	3270	3270	3270	6850	6850	6850	6850

Notes: This table presents estimations using fixed effect two-stage least square estimation (FE2SLS) technique. Robust standard errors are shown in parenthesis. Square brackets contain p- value. Here ***, ** and * denote that coefficients are statistically significant at 1%, 5% and 10%, respectively. Time and firm specific dummies have been incorporated in the models. SLM test is Sasabuchi–Lind–Mehlum test to validate U-shaped or inverted U-shaped relationship. In all the columns SLM test statistics is positive and significant which suggest a significant U-shaped relationship between size and patenting.

4.6. Key findings

The results of innovation equation for the period of 1995-2005 suggest that there is a linear positive impact of market structure on innovation but only for medium technology firms. We do not find any significant impact of monopoly power on firms' patenting activity for high technology industry. Results based on innovation equation for post-TRIPS period i.e. 2006-2015 suggest that market structure has a positive and significant impact on patent applications for full sample. However, this significant impact of market power disappears when we segregate the sample into high and medium technology firms. These results corroborate with the findings of Chapter 3. The results based on market structure equation for the period of 1995-2005 suggest that patent applications and grants have a positive and significant impact on market power. With respect to full sample, we find an inverted-U shaped relationship between market power and patent applications. This inverted-U shaped relationship also exists for medium technology firms. However, for the period of 2006-2015, we find insignificant impact of patenting on firms' market power.

In Chapter 3 and Chapter 4, we have analyzed the two-way relationship between innovation and market structure. In most of the cases, our finding reveals that innovation has a positive and significant impact on firms' market power. However, literature also discussed that impact of innovation on market power and other firm performance related variables varies with types of innovation namely technological (product and process) and non-technological (marketing and organizational) innovation. Hence, in the next Chapter, we will analyze the impact of different types of innovation of firms' market power.

CHAPTER 5

NON-LINEAR IMPACT OF PRODUCT AND PROCESS INNOVATIONS ON MARKET POWER: A THEORETICAL AND EMPIRICAL INVESTIGATION

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5.1. Introduction

In the previous chapters, we have analyzed a two-way relationship between innovation and market structure in Indian high and medium technology firms. While examining the first objective of the thesis in Chapter 3, we employ firm level data on high and medium technology firms over 2000-2015. In order to fulfill the second objective in Chapter 4, we analyze the impact of patent policy change on the relationship between innovation and market structure in Indian high and medium technology firms. While analyzing the first and second objective of this dissertation, we have considered aggregate patenting activity at firm level. Patenting activity is a proxy for firms' technological innovations which can be further classified as product and process innovation. Such technological innovations influence the current market structure of an industry. Moreover, the influence of technological innovation on market power varies in case of product and process innovations. Hence, there is a need to clearly define product and process innovations to highlight the possible channels through which the types of technological innovations influence market power of a firm. In previous chapters, we find insignificant impact of market structure on firms' patenting activity. Thus, we restrict to second equation i.e. market structure equation in this chapter.

The rest of the chapter is organized as follows: Section 5.2 presents the literature review. Section 5.3 derives the theoretical model on the relationship between product and process innovation, and firms' monopoly power. Section 5.4 gives description of variables and data sources. Section 5.5 discusses the results. Section 5.6 presents the key findings.

5.2. Literature review

5.2.1. Product and process innovation

According to Pavitt (1984), product innovations are used outside the sector of production and process innovations are employed within. OECD (2005) defines product innovations as “the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.” Prajogo (2006) measures product innovation as novelty of new products, the use of latest technologies, speed of product development, number of new products and early market entrants and Raymond et al. (2010) add significantly improved products to the list. Examples of product innovations (OECD, 2005) are: cameras in mobile telephones, fastening systems in clothing, replacing inputs with materials with improved characteristics (breathable textiles, light but strong composites, environmentally friendly plastics, etc.), global positioning systems (GPS) in transport equipment, household appliances, anti-fraud software, inbuilt wireless networking in laptops, food products with new functional characteristics, products with significantly reduced energy consumption, significant changes in products to meet environmental standards, programmable radiators or thermostats, IP (internet protocol) telephones and new medicine with significantly improved effects. Process innovation as defined by OECD (2005) refers to the “the implementation of a new or significantly improved production or delivery method.” Process innovation includes new methods, techniques, software and equipment in ancillary support activities. Examples of process innovations (OECD 2005) are: installation of new or improved manufacturing technology, such as automation equipment or real-time sensors that can adjust processes, new equipment required for new or improved products, laser cutting tools, automated packaging, computer-assisted product development, digitization of printing processes, computerized equipment for quality control of production, improved testing equipment for monitoring production, portable scanners/computers for registering goods and inventory, introduction of bar coding or passive radio frequency identification (RFID) chips to track materials through the supply chain, introduction of software to identify optimal delivery routes, new or improved software or routines for purchasing, accounting or maintenance systems, introduction of electronic clearing systems, introduction of automated voice-response system, introduction of electronic ticketing system, new software tools designed to improve supply flows, new or significantly improved computer networks.

5.2.2. Product and process innovation, and market power

Innovation at the center of economic change leads to creative destruction of existing structures[1] including the monopoly power of the incumbent firms (Schumpeter 1942; Minniti 2010; Matsumura et al. 2013). Gaining of market power by newer firms, either through new products or processes reduces the market value of the current technology, and thereby making monopoly a temporary phenomenon (Gilbert 2006). Thus, technological innovations influence the current competition in an industry.

Product and process innovations change the market power of a firm (Schumpeter 1942; Mueller & Tilton 1969; Gilbert & Newbery 1982;

[1] Shifting of print media (newspaper and magazine) into digital media (blog commentary and news information available on internet), transformation of medical practices from population based approach to individualized medicine through digital technologies, destruction of film based business market of Kodak by invention of digital photography are some examples of creative destruction.

Segerstrom 1991; Utterback & Suárez 1993), albeit through different channels. Product innovation increases the price margin of firms by differentiating their product from that of rivals (Markides 2006; Belleflamme & Peitz 2015). The introduction of new product in the market increases the sale and market share of innovative firm that may satisfy the needs of existing customers and/or attract new customers (Pelham 1997; Wang & Wei 2005). According to Lunn (1986), process innovation is cost reducing and leads to change in the production function allowing firm to place the product at a competitive price (Kamien & Schwartz 1982; Griliches 1998; Deolalikar & Roller 1989; Peters 2008). Production performances like flexibility and cost reduction which are closely linked with process innovation have positive impact on firms' organizational and administrative performance as well (Quadros et al. 2001). Innovation by a firm leads to organizational learning and also fastens the speed and quality of operations that have strong linkages with organizational performance (Koufteros & Marcoulides 2006). There are few studies that explore the non-linear relationship between different types of innovation and firm specific performance indicator. For example, a study by Nemlioglu and Mallick (2017) tested the non-linear impact of managerial practices, intangibles and R&D intensity on firms' performance. This study suggests that with respect to managerial practices and intangibles there exists inverted U-shaped relationship, however, R&D intensity does not have such impact.

The evidence on the impact of product and process innovation on market power is scant. In this context, the present chapter contributes to the existing literature as it attempts to explore both theoretically and empirically the impact of both types of technological innovations (product and process) on the market power, separately. Creative destruction with respect to firms' own product innovation may lead to reduction in market power after an optimal point of product development and extensive cost of implementing new processes may lessen market power of the firm beyond a certain level.

Since the innovation types (product and process) may not influence the market power uniformly, it becomes pertinent to analyze them individually. Thus, we address the non-linearity issue between product and process innovation, and market power in the current chapter. The empirical verification of the hypotheses is based on firm level data from Indian pharmaceutical sector from 2006-2013.

5.3. The model

Theoretical literature suggests that price (P) is a function of number of firms (n) and product substitution (σ) (Vives, 2008). As product innovation (ψ) affects product differentiation and process innovation (ϕ) influences cost of production, we assume that $\mathrm{P} = \mathrm{P}\big(\mathrm{n}, \sigma(\psi)\big)$ and $\mathrm{c} = \mathrm{c}(\phi)$, and rewrite the Lerner index (L) as follows:

$$\mathrm{L} = \frac{\mathrm{P}(\mathrm{n},\sigma(\psi)) - \mathrm{c}(\phi)}{\mathrm{P}(\mathrm{n},\sigma(\psi))} \qquad (1)$$

First, we study the impact of product innovation (ψ) on market power (L). Product innovation increases the product differentiation which enhances firms' market power by providing opportunity to raise the price of the good. For this purpose, we differentiate L w.r.t. Ψ and get the following:

$$\frac{\partial \mathrm{L}}{\partial \psi} = \frac{\mathrm{P}\big(\mathrm{n},\sigma(\psi)\big)\frac{\partial}{\partial \psi}\Big(\mathrm{P}\big(\mathrm{n},\sigma(\psi)\big) - \mathrm{c}(\phi)\Big) - \Big(\mathrm{P}\big(\mathrm{n},\sigma(\psi)\big) - \mathrm{c}(\phi)\Big)\frac{\partial}{\partial \psi}\mathrm{P}(\mathrm{n},\sigma(\psi))}{\mathrm{P}^2(\mathrm{n},\sigma(\psi))}$$

$$\frac{\partial \mathrm{L}}{\partial \psi} = \frac{\mathrm{P}\big(\mathrm{n},\sigma(\psi)\big)\frac{\partial \mathrm{P}}{\partial \sigma}\frac{\partial \sigma}{\partial \psi} - \mathrm{P}\big(\mathrm{n},\sigma(\psi)\big)\frac{\partial \mathrm{P}}{\partial \sigma}\frac{\partial \sigma}{\partial \psi} + \mathrm{c}(\phi)\frac{\partial \mathrm{P}}{\partial \sigma}\frac{\partial \sigma}{\partial \psi}}{\mathrm{P}^2(\mathrm{n},\sigma(\psi))}$$

$$\frac{\partial \mathrm{L}}{\partial \psi} = \frac{\mathrm{c}(\phi)\frac{\partial \mathrm{P}}{\partial \sigma}\frac{\partial \sigma}{\partial \psi}}{\mathrm{P}^2(\mathrm{n},\sigma(\psi))} = \frac{\mathrm{c}(\phi)}{\mathrm{P}^2(\mathrm{n},\sigma(\psi))}\frac{\partial \mathrm{P}}{\partial \sigma}\frac{\partial \sigma}{\partial \psi} \qquad (2)$$

According to Lunn (1986) and Belleflamme and Peitz (2015), product innovation (ψ) increases the prices (P) via product differentiation or decreases product substitution (σ) which means $\frac{\partial P}{\partial \sigma} \leq 0$ and $\frac{\partial \sigma}{\partial \psi} \leq 0$. On the basis of these relationships, we can conclude as follows:

$$\frac{\partial L}{\partial \psi} = \frac{c(\phi)}{P^2(n,\sigma(\psi))} \frac{\partial P}{\partial \sigma} \frac{\partial \sigma}{\partial \psi} \geq 0 \qquad (3)$$

Equation (3) implies that product innovation has positive influence on firm market power.

Hypothesis A1: Product innovation (ψ) has a positive impact on firms' market power.

Further, we perform second order derivatives between product innovation (ψ) and market power (L).

$$\frac{\partial L}{\partial \psi} = \frac{c(\phi)}{P^2(n,\sigma(\psi))} \frac{\partial P}{\partial \sigma} \frac{\partial \sigma}{\partial \psi} \geq 0 \qquad (3)$$

$$\frac{\partial^2 L}{\partial \psi^2} = c(\phi) \ \frac{\partial}{\partial \psi} [\frac{1}{P^2(n,\sigma(\psi))} \frac{\partial P}{\partial \sigma} \frac{\partial \sigma}{\partial \psi}]$$

$$\frac{\partial^2 L}{\partial \psi^2} = \frac{c(\phi)}{P^2} \ [(\frac{\partial^2 P}{\partial \sigma^2} (\frac{\partial \sigma}{\partial \psi})^2 + \frac{\partial P}{\partial \sigma} \frac{\partial^2 \sigma}{\partial \psi^2}) - \frac{1}{(P(n,\sigma(\psi)))} (\frac{\partial P}{\partial \sigma} \frac{\partial \sigma}{\partial \psi})^2 - \frac{1}{(P(n,\sigma(\psi))} (\frac{\partial P}{\partial \sigma} \frac{\partial \sigma}{\partial \psi})^2]$$

After some simplification, we can rewrite the last equation as follows:

$$\frac{\partial^2 L}{\partial \psi^2} = \frac{c(\phi)}{P^2}[(\frac{\partial \sigma}{\partial \psi})^2(\frac{\partial^2 P}{\partial \sigma^2} - \frac{1}{P} (\frac{\partial P}{\partial \sigma})^2) + \frac{\partial P}{\partial \sigma} (\frac{\partial^2 \sigma}{\partial \psi^2} - \frac{1}{P} \frac{\partial P}{\partial \sigma} (\frac{\partial \sigma}{\partial \psi})^2)] \qquad (4)$$

For simplicity, we assume that:

$A = (\frac{\partial \sigma}{\partial \psi})^2(\frac{\partial^2 P}{\partial \sigma^2} - \frac{1}{P} (\frac{\partial P}{\partial \sigma})^2)$ and $B = \frac{\partial P}{\partial \sigma} (\frac{\partial^2 \sigma}{\partial \psi^2} - \frac{1}{P} \frac{\partial P}{\partial \sigma} (\frac{\partial \sigma}{\partial \psi})^2)$ and write equation (4) as follows:

$$\frac{\partial^2 L}{\partial \psi^2} = \frac{c(\phi)}{P^2} [A + B] \qquad (5)$$

As $\frac{\partial P}{\partial \sigma} \leq 0$, we assume that P α $\frac{1}{\sigma}$ or $P = \frac{z'}{\sigma}$ where z' is a positive constant number. Similarly, we define the relationship between σ and ψ by assuming σ α $\frac{1}{\psi}$ or $\sigma = \frac{d'}{\psi}$ where d' is a positive constant number. Further as $P = \frac{z'}{\sigma}$ it can be inferred that $\frac{\partial P}{\partial \sigma} = -\frac{z'}{\sigma^2}$ and $\frac{\partial^2 P}{\partial \sigma^2} = \frac{2z'}{\sigma^3} \geq 0$. Using $\sigma = \frac{d'}{\psi}$, $\frac{\partial \sigma}{\partial \psi} = -\frac{d'}{\psi^2}$ and $\frac{\partial^2 \sigma}{\partial \psi^2} = \frac{2d'}{\psi^3} \geq 0$, we solve the equation (5) in the following manner:

First, we solve for A and then for B:

$$A= (\frac{\partial \sigma}{\partial \psi})^2(\frac{\partial^2 P}{\partial \sigma^2} - \frac{1}{P}(\frac{\partial P}{\partial \sigma})^2) = (-\frac{d'}{\psi^2})^2 (\frac{2z'}{\sigma^3} - \frac{1}{(z'/\sigma)}(-\frac{z'}{\sigma^2})^2$$

$$A = (-\frac{d'}{\psi^2})^2 (\frac{2z'}{\sigma^3} - \frac{z'}{\sigma^3}) = \frac{d'^2 z'}{\psi^4 \sigma^3}$$ [We know that $\sigma = \frac{d'}{\psi}$ where d' = σψ]

$$A = \frac{d'^2 z'}{\psi^4 \sigma^3} = \frac{z'}{\sigma\psi^2} \qquad (6)$$

$$B = \frac{\partial P}{\partial \sigma} (\frac{\partial^2 \sigma}{\partial \psi^2} - \frac{1}{P}\frac{\partial P}{\partial \sigma}(\frac{\partial \sigma}{\partial \psi})^2) = [(-\frac{z'}{\sigma^2}) (\frac{2d'}{\psi^3} - \frac{1}{(z'/\sigma)}(-\frac{z'}{\sigma^2}) (-\frac{d'}{\psi^2})^2]$$

$$B = (-\frac{z'}{\sigma^2}) (\frac{2\sigma^3}{d'^2} - \frac{\sigma}{z'}(-\frac{z'}{\sigma^2}) (\frac{\sigma^4}{d'}) = (-\frac{z'}{\sigma^2}) (\frac{2\sigma^3}{d'^2} + \frac{\sigma^3}{d'^2}) = - (\frac{3\sigma z'}{d'^2}) \qquad (7)$$

On the basis of equations (6) and (7), we can rewrite equation (5) as follows:

$$\frac{\partial^2 L}{\partial \psi^2} = \frac{c(\phi)}{P^2} [\frac{z'}{\sigma\psi^2} + (-\frac{3\sigma z'}{d'^2})]$$

$$\frac{\partial^2 L}{\partial \psi^2} = \frac{c(\phi)}{P^2} z' [\frac{1}{\sigma\psi^2} - \frac{3\sigma}{d'^2}]$$ [We know that $\sigma = \frac{d'}{\psi}$ where d' = σψ]

$$\frac{\partial^2 L}{\partial \psi^2} = \frac{c(\phi)}{P^2} z' [\frac{1}{\sigma\psi^2} - \frac{3\sigma}{(\sigma\psi)^2}] = \frac{c(\phi)}{P^2} z' [-\frac{2}{\sigma\psi^2}] \leq 0 \qquad (8)$$

Equation (8) suggests that $\frac{\partial^2 L}{\partial \psi^2} \leq 0$ implying that the relationship between product innovation (ψ) and market power (L) is increasing concave leading to decline in the monopoly power of a firm beyond a point with increase in product innovation.

Hypothesis A2: The relationship between product innovation (ψ) and market power is increasing concave.

Now, we focus on the impact of process innovation (ϕ) on market power (L). For this purpose, we differentiate equation (1) w.r.t ϕ.

$$L = \frac{P(n,\sigma(\psi)) - c(\phi)}{P(n,\sigma(\psi))} \qquad (1)$$

$$\frac{\partial L}{\partial \phi} = \frac{P(n,\sigma(\psi))\frac{\partial}{\partial \phi}\left(P(n,\sigma(\psi)) - c(\phi)\right) - \left(P(n,\sigma(\psi)) - c(\phi)\right)\frac{\partial}{\partial \phi}P(n,\sigma(\psi))}{P^2(n,\sigma(\psi))}$$

$$\frac{\partial L}{\partial \phi} = \frac{P(n,\sigma(\psi))\frac{\partial}{\partial \phi}\left(P(n,\sigma(\psi)) - c(\phi)\right)}{P^2(n,\sigma(\psi))} = \frac{P(n,\sigma(\psi))}{P^2(n,\sigma(\psi))}\frac{-\partial c(\phi)}{\partial \phi} \qquad (9)$$

Lunn (1986), Klepper (1996), Cohen and Klepper (1996), Vives (2008) and Belleflamme and Peitz (2015) explain that process innovation (ϕ) is cost reducing; hence, $\frac{\partial c(\phi)}{\partial \phi} \leq 0$ and we can rewrite equation (9) as follows:

$$\frac{\partial L}{\partial \phi} = \frac{P(n,\sigma(\psi))}{P^2(n,\sigma(\psi))}\frac{-\partial c(\phi)}{\partial \phi} \geq 0 \qquad (10)$$

Equation (10) shows the positive relationship between process innovations (ϕ) and market power (L).

Hypothesis B1: Process innovation (ϕ) has a positive impact on firms' market power.

Now, we perform second order derivation between process innovation (ϕ) and market power (L).

$$\frac{\partial^2 L}{\partial \phi^2} = -\frac{P(n,\sigma(\psi))}{P^2(n,\sigma(\psi))}\left(\frac{\partial^2 C(\phi)}{\partial \phi^2}\right) \qquad (11)$$

As $\frac{\partial c(\phi)}{\partial \phi} \leq 0$, we assume that $c \propto \frac{1}{\phi}$ or $c = \frac{t'}{\phi}$ where t' is a positive constant number. Accordingly, we can write $\frac{\partial c}{\partial \phi} = -\frac{t'}{\phi^2}$ and $\frac{\partial^2 c}{\partial \phi^2} = \frac{2t'}{\phi^3} \geq 0$. On the basis of these conditions, equation (11) becomes as follows:

$$\frac{\partial^2 L}{\partial \phi^2} = -\frac{P(n,\sigma(\psi))}{P^2(n,\sigma(\psi))}\left(\frac{2t'}{\phi^3}\right) \leq 0 \qquad (12)$$

Equation (12) suggests that $\frac{\partial^2 L}{\partial \phi^2} \leq 0$, which means the relationship between process innovation (ϕ) and market power (L) is also increasing concave.

Hypothesis B2: The relationship between process innovation (ϕ) and market power is increasing concave.

In our theoretical model, we find that product and process innovation have an inverted U-shaped relationship with market power. According to product life cycle hypothesis, during the initial stage of product development, the innovations related to standardizing the product are extensive (Scherer 1979; Chandy & Tellis 1998). However, as a firm adds more features to the same product, the advantage it may enjoy through the increment will keep on reducing. Also, a newer version of the product may cannibalize into the market of earlier product.[2] This is very similar to creative destruction where new firms enter into the market with differentiated products and accumulate the market power by displacing the existing firms. Simpson et al. (2006) also explain the negative outcomes of the excess innovation activity. For instance, a firm may do innovation just for the sake of it that may not satisfy

[2] Apples' product cannibalization is a good example of creative destruction where iPhone and MacBook negatively affected the business of iPad, and later the introduction of PadBook negatively influenced the business of both iPad and MacBook.

actual consumer needs and merely increase firms' expenditure. Further, due to market risk associated with innovation, commercialization of a new product is difficult and firm may not realize its benefits immediately.

Process innovation is cost reducing but implementation of new incremental technology involves additional expenditure that may decrease the firms' market power, particularly beyond a certain level as new techniques become more complex. For instance, introduction of new techniques requires skilled workers with high wages (Bartel & Lichtenberg 1987). According to Edmondson et al. (2001), successful implementation of new technology is a result of collective learning, authority structures (team leaders), psychological safety, team stability and other organizational factors like availability of resources, size of organization and management support. Evidently, implementation and/or change in existing technology is time consuming and a costly process, which require change in existing organizational structure (Bartel & Lichtenberg 1987; Pisano 1997; Edmondson et al. 2001).

5.4. Data and descriptive statistics

5.4.1 Testing with data

In the previous section, we have theoretically established the relationship between technological innovation and firms' market power. In this section, we will test our proposed model empirically. Considering the nature of patent sensitivity and availability of data on both product and process patents, we will check the inverted U-shaped relationship between innovation and monopoly power for Indian pharmaceutical firms. The third amendment to the Patent Act (1970), made through Patent (Amendment) Act 2004 and implemented on January 1, 2005 introduces product patent in all fields of technology. In the context of Indian pharmaceutical industry, literature explores the nature of R&D, pricing structure of drugs and its impact on consumer welfare, and performance of pharmaceutical firms (Chaudhuri et al. 2006; Kale & Little 2007; Duggan et al. 2016). However, the impact of product and process innovations on firms' market power is unexplored.

We utilize weighted Lerner index (WLI) as a measure of market structure. The innovation activity of firms is proxied by number of product (PROD) and process (PROC) patents to a firm. From above discussions and literature cited in previous two chapters, we use the following models to analyze the relationship between product and process innovation, and firms' market power:

$$\mathbf{WLI = f\ (PROD,\ PROD^2,\ EXPI,\ ADI,\ IMPI,\ AGE,\ CAPITAL)} \quad \mathbf{(1)}$$

$$\mathbf{WLI = f\ (PROC,\ PROC^2,\ EXPI,\ ADI,\ IMPI,\ AGE,\ CAPITAL)} \quad \mathbf{(2)}$$

5.4.2 Data source and descriptive statistics

This study utilizes firm level data of 265 pharmaceutical companies. Major sources of data for this study include CMIE prowess database and website CGPDT. We have utilized the list of granted product patents issued by CGPDT and its monthly publications to get data on all granted process patents. In the context of India, CGPDT published product patent data for pharmaceutical industry. However, we have also visited the abstract and claims of all the patents (both product and process) which are granted to pharmaceutical firms in India during 2006-2013 by CGPDT. Following OECD (2005) and taking help of Professors and research scholars of School of Engineering and Sciences at IIT Indore, we have classified patent data as product and process to further cross-check the information. In Table 5.1, descriptive statistics and correlation matrix have been constructed in Table 5.2.

Table 5.1: Descriptive statistics

VARIABLES	MEAN
PROD	0.43915 (2.78082)
PROC	0.73490 (2.87320)
IMPI	0.07761 (0.10858)
EXPI	0.17059 (0.20471)
ADI	0.01233 (0.04111)
AGE	3.18381 (0.55252)
CAPITAL	0.54669 (0.40761)
OBSERVATIONs	2120

Notes: Authors' calculations on the basis of information available in CMIE PROWESS and CGPDT.

Table 5.2: Correlation matrix

	PROD	PROC	IMPI	EXPI	ADI	AGE	CAPITAL
PROD	1.0000						
PROC	0.6943	1.0000					
IMPI	0.0688	0.1089	1.0000				
EXPI	-0.0317	0.0810	0.4130	1.0000			
ADI	0.0704	0.1195	0.0551	-0.1091	1.0000		
AGE	0.1447	0.1769	0.0031	-0.0355	0.0587	1.0000	
CAPITAL	-0.1059	-0.0915	-0.0844	0.0281	0.0954	-0.1572	1.0000

Notes: Authors' calculations on the basis of information available in CMIE PROWESS and CGPDT.

5.5. Empirical results

5.5.1. Endogeneity check

In the previous chapters, we did not find significant impact of market structure on innovation in high and medium technology firms. However, there may be a possibility of feedback effect between innovation and market power in a particular industry. Market structure may also influence firms' innovation decision via anticipated monopoly power (Levin 1978; Kamien & Schwartz 1982; Geroski 1990).[3] Thus, it is important for us to test the endogeneity of independent variables in an innovation and monopoly power relationship. For this purpose, we conduct the Durbin–Wu–Hausman (DWH) test for endogeneity that follows a Chi-square distribution. The null hypothesis is that endogenous regressors can be treated as exogenous. The instrumental variables used for the test are one-year lagged differences of independent variables (Schultz et al. 2010; Nguyen et al. 2014). The year dummies as well as the age of the firm (AGE) are included in the test specification and treated as exogenous variables. The results of the DWH test statistics in Table 5.3 show that null hypothesis cannot be rejected at any conventional level of significance. This indicates that our specified model does not suffer from the endogeneity problem. In Indian context, other studies have also reported insignificant impact of market structure and economic profit on firms' innovation activities (Kumar & Saqib 1996; Subodh 2002; Mishra 2007; Basant & Mishra 2014; Jagadeesh & Sasidharan 2014; Saraswathy 2018). Moreover, in previous chapters also we find similar results.

[3] According to Geroski (1990), firms' anticipated monopoly power is not directly observable. However, under the assumption of adaptive expectation or error learning behaviour, anticipated monopoly power can be proxied by actual monopoly power (Geroski, 1990; Love & Roper, 1999; Basant & Mishra, 2014).

Table 5.3: Durbin–Wu–Hausman (DWH) test

VARIABLES	DWH test
PROD (Ho: PROD is exogenous)	$\chi^2 = 3.76505$ (p = 0.5837)
PROC (Ho: PROC is exogenous)	$\chi^2 = 3.32812$ (p = 0.6495)
OBSERVATION	2120

Note: The DHW test does not reject the null hypothesis that PROD and PROC are exogenous variables at any conventional significance levels.

5.5.2. Technological innovation and market power

We use appropriate panel data econometric techniques to estimate the models discussed in Section 3. We prefer fixed effect and random effect estimation techniques as these give efficient estimates. Further, the decision between fixed effect and random effect is based on the Hausman test (given in each table). The null hypothesis of the Hausman test is that that there is no systematic difference in random effects and fixed effects coefficients (Greene 2003). However, we report both fixed effect and random effect results.

In Columns I-IV of Table 5.4, we report the estimated coefficients of PROD and PROD^2. First, we analyze the linear impact of PROD on firms' monopoly power (columns I and II). Further, we include quadratic term in the model (columns III and IV). In columns I and II, the coefficient of PROD is positive and significant. Furthermore, the coefficient of PROD^2 is also positive and significant in columns III and IV. This result suggests that there is existence of inverted-U shaped relationship between product innovation and monopoly power. This result is also depicted in Figure 5.1.

Table 5.4: Product and firms' market power

	I	II	III	IV
PROD	0.00057* (0.00026)	0.00104*** (0.00021)	0.00164*** (0.00051)	0.00306*** (0.00047)
PROD^2			-0.00044** (0.00018)	-0.00082*** (0.00017)
IMPI	0.00084 (0.00133)	0.00072 (0.00102)	0.00081 (0.00133)	0.00063 (0.00099)
EXPI	0.00217** (0.00097)	0.00327*** (0.00061)	0.00217** (0.00097)	0.00319*** (0.00058)
ADI	0.00108 (0.00267)	0.00263 (0.00224)	0.00099 (0.00267)	0.00257 (0.00220)
AGE	-0.00032 (0.00106)	0.00083*** (0.00025)	-0.00027 (0.00106)	0.00080*** (0.00023)
CAPITAL	0.00004 (0.00033)	-0.00012 (0.00025)	0.00005 (0.00033)	-0.00014 (0.00024)
CONSTANT	0.00127 (0.00324)	-0.00233*** (0.00082)	0.00108 (0.00324)	-0.00227*** (0.00077)
Hausman	13.53 [0.4078]		60.31*** [0.0000]	
SLM test			1.80** [0.0364]	3.45*** [0.00028]
OBSERVATIONS	2120	2120	2120	2120
ESTIMATES	**FE**	**RE**	**FE**	**RE**

Notes: Robust standard errors are shown in parenthesis. Square brackets contain p- value. ***, ** and * denote that coefficients are statistically significant at 1, 5 and 10 percent levels respectively. Firm and time specific dummies have been incorporated in the models. SLM test is Sasabuchi–Lind–Mehlum test to validate U-shaped or inverted U-shaped relationship.

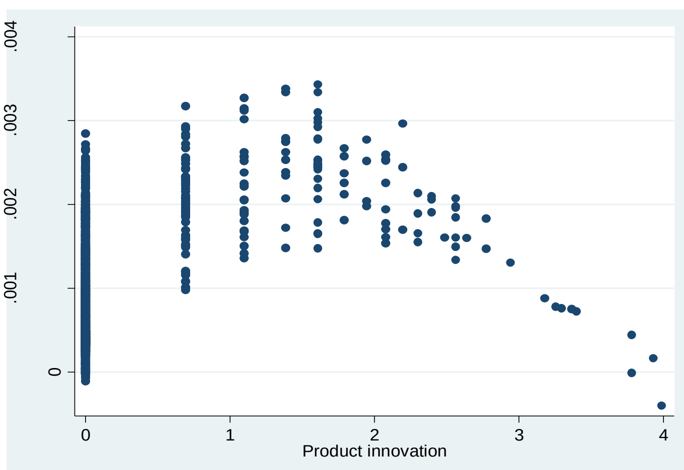

Figure 5.1: Estimated relationship between market power and product innovation. The figure is derived from the regression specified in column III of Table 5.4. SLM test also confirm this inverted U-shaped relationship.

In Columns I-IV of Table 5.5, we report the estimated coefficients of PROC and PROC^2. The basic setup of Table 5.5 is similar to Table 5.4. In columns I and II, we find that PROC has positive and significant impact on the monopoly power. Moreover, the coefficient of PROC^2 is also negative and significant in columns III and IV. Hence, the relationship between process innovation and monopoly power is also inverted-U shaped. Figure 5.2 shows the plot of estimated market power based on coefficients given in column III of Table 5.5. In Table 5.4 and 5.5, we also perform SLM U-test to verify this inverted-U shaped relationship. In all the cases, SLM t-statistics is significant which suggests that there exists inverted U-shaped relationship between patenting and firms' monopoly power. Results of this estimation suggest that both product and process innovation positively affect firms market power up to a level only, afterwards, increasing innovation activities have a negative impact on firms' market power. As a firm continues to innovate in the same product line, it may lose its dominance in the market to new product entries.

With respect to control variables, we find that the coefficient of EXP is significantly positive which suggest that export oriented firms are enjoying more monopoly power. The coefficient of AGE is also positive and significant; however, this significant coefficient exists only with respect to random effect estimates. We do not find any significant impact of IMPI, ADI, and CAPITAL on firms' monopoly power.

Table 5.5: Process patent and firms' market power

	I	II	III	IV
PROC	0.00060*** (0.00023)	0.00130*** (0.00017)	0.00135*** (0.00047)	0.00274*** (0.00042)
PROC^2			-0.00032* (0.00017)	-0.00060*** (0.00016)
IMPI	0.00069 (0.00133)	0.00050 (0.00100)	0.00060 (0.00133)	0.00038 (0.00098)
EXPI	0.00213** (0.00097)	0.00285*** (0.00059)	0.00211** (0.00097)	0.00268*** (0.00057)
ADI	0.00122 (0.00267)	0.00226 (0.00221)	0.00143 (0.00267)	0.00243 (0.00219)
AGE	-0.00030 (0.00106)	0.00069*** (0.00023)	-0.00019 (0.00106)	0.00065*** (0.00023)
CAPITAL	0.00004 (0.00033)	-0.00013 (0.00024)	0.00001 (0.00033)	-0.00016 (0.00024)
CONSTANT	0.00117 (0.00324)	-0.00191** (0.00078)	0.00085 (0.00324)	-0.00180** (0.00076)
Hausman	23.69** [0.0341]		41.36*** [0.0002]	
SLM test			1.08 [0.14]	1.97** [0.0246]
OBSERVATIONS	2120	2120	2120	2120
ESTIMATES	**FE**	**RE**	**FE**	**RE**

Notes: Robust standard errors are shown in parenthesis. Square brackets contain p- value. ***, ** and * denote that coefficients are statistically significant at 1, 5 and 10 percent levels respectively. Firm and time specific dummies have been incorporated in the models. SLM test is Sasabuchi–Lind–Mehlum test to validate U-shaped or inverted U-shaped relationship.

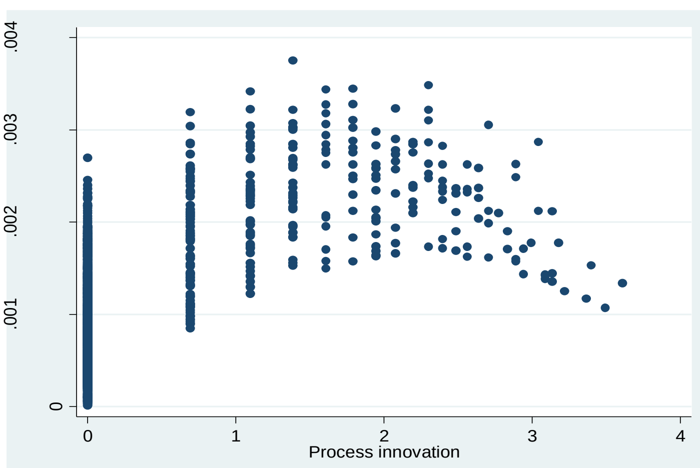

Figure 5.2: Estimated relationship between market power and process innovation. The figure is derived from the regression specified in column III of Table 5.5. SLM test also confirm this inverted U-shaped relationship.

5.6. Key finding

This chapter analyzes the impact of technological innovation on firms' market power in Indian pharmaceutical industry. For empirical testing, we gathered the information on 265 Indian pharmaceutical companies over the period of 2006-2013. Technological innovation is proxied by product and process patent grants. The results of this chapter reveal that both product and process patent have a positive and significant impact on firms' market power. Furthermore, the coefficients of quadratic terms of product and process patents are negative and significant. Overall, we find inverted-U shaped relationship between the types of technological innovations and market power. SLM test also confirms inverted U-shaped relationship between market power and different types of technological innovation.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 Introduction

This chapter summarizes the thesis and its findings, provides policy recommendations and mentions the contributions and limitations of the work undertaken. This thesis includes a general introduction, a chapter on R&D and patenting statistics, three core chapters and a conclusion. This dissertation mainly focuses on a two-way relationship between innovation and market structure in Indian high and medium technology firms. Further, we also highlight the impact of patent policy change on the relationship between innovation and market structure. We further utilize data on different types of technological innovations i.e. product and process to study their impact on market structure. Thus, this thesis provides new insights into the relationship between innovation and market structure in the context of emerging economies such as India. By utilizing firm-level information of Indian high and medium technology industries, we test the predictions of Aghion et al. (2005) inverted U-shaped theory and the Schumpeterian theory of creative destruction in the Indian context. We also control for technology gap effect while analyzing the inverted-U shaped relationship between innovation and market structure as suggested by Aghion et al. (2005).

We classify firms into leveled industry (neck-and-neck) and unleveled industry based on their distribution of the technology (known as technology gap). Most studies in the Indian context captured the competitive pressure at the industry level. Industry-specific measures of market structure are more stable in case of high cross-sectional variation and heavy competition which may underestimate the actual competitive pressure in the market. In this dissertation, we utilize firm level measure of market structure, i.e. weighted Lerner index of market power.

The majority of studies in the Indian context utilize R&D expenditure to proxy firm-level innovation with little attention on patenting as a measure of innovation. Utilization of R&D does not represent the actual technological capabilities of a firm because many firms in the developing country do not report their R&D. All R&D expenditure also may not convert into successful innovation. However, the utilization of patent data overcome these problems as it is the outcome of successful R&D. Patents are also positively associated with the commercialization of new products and as well as new product sales. Moreover, we also focus on types of technological innovations while analyzing the impact of innovation on firms' market power. It is also interesting to point out that, although there are some studies that empirically tested the effects of innovation types on firm performance, studies on the Indian context are negligible; particularly on product and process innovations.

The rest of the chapter is organized as follows: Section 6.2 presents objectives and data. Section 6.3 presents an overview of the findings. Section 6.4 synthesizes the results. Section 6.5 provides a discussion on the key findings. Section 6.6 presents policy implications and Section 6.7 highlights the contribution of the work. Section 6.8 presents the key limitations of the work.

6.2. Research questions and data

The underlying questions in this dissertation are: a) is there a feedback effect between innovation and market structure in Indian high and medium technology firms? b) do the changes in patent policy influence the relationship between innovation and market structure? c) does the type of technological innovation matter for innovation and market structure relationship? To investigate the bidirectional relationship between innovation and market structure, we utilize information from 991 high and medium technology firms from 2000-2015 (with 322 (32.50%) firms are high technology and 669 (67.50%) are medium technology firms).

For the second research question, firm-level data from 1995-2015 are collected as three major patent policy changes (1999, 2002 and 2005) occurred during this period. However, we compromise with the variable technology gap in the regression analysis as the main focus is on patent policy change. To analyze this objective, we gather information on 1012 with 327 (32.31%) firms in high technology and 685 (67.68%) in medium technology industries. We perform a before and after analysis based on the implementation of TRIPs. After 2005, India fully complied with TRIPs; hence, we classify the sample into two time periods namely; 1995-2005 and 2006-2015. Such classification helps us analyze the impact of patent policy changes on the relationship between innovation and market structure.

The third question of this dissertation is to analyze the impact of technological innovations i.e. product and process innovation on firms' market power. For this purpose, we utilize firm-level data of 265 pharmaceutical companies from 2006-2013. We have used the list of granted product patents issued by CGPDT and its monthly publications to get data on all granted process patents. In the context of India, CGPDT published product patent data for the pharmaceutical industry.

We utilize appropriate econometric techniques to estimate the model. To investigate the first and second objectives, FE2SLS is utilized for empirical estimation. To investigate the third objective, fixed and random effects models are utilized. In the innovation equation, we analyze the nonlinear impact of market power. To verify the nonlinear relationship, we also perform SLM test which fulfils both necessary and sufficient conditions for a nonlinear relationship. Table 6.1 summarizes the details on research objectives and data.

Table 6.1: Objectives, time period and number of observations

Objective	Industry	Time period	Reason for different database	No. of observations
1. To investigate the bidirectional relationship between innovation and market structure	High and medium technology	2000-2015	Technology gap as an independent variable	14887
2. To investigate the relationship between innovation and market structure under different patent regime.	High and medium technology	1995-2015	Three major patent policy changes (1999, 2002 and 2005)	21252
3. To investigate the differential impact of product and process innovations on market structure.	Pharmaceutical	2006-2013	Availability of data on both product and process patents	2120

6.3. Overview of findings

A short summary of the research findings of each objective is presented below:

Objective 1: To investigate the bidirectional relationship between innovation and market structure.

Key findings:

Innovation equation

- We find that the predictions of Aghion et al. (2005) do not hold in the Indian context as market structure has an insignificant impact on innovation.
- After controlling for technology gap effect also, we do not find sufficient support for the linear and nonlinear impact of market power on innovation.
- R&D expenditure and patent policy change have a positive and significant impact on firms' patenting activities whereas age and size of the firms have a nonlinear impact on patenting activities.

Market power equation

- There is a significant feedback effect of innovation on market power as the coefficients of patenting activities are positive and significant.
- We confirm the existence of an inverted U-shaped relationship between innovation and market power in line with the Schumpeterian theory of creative destruction.
- The age of the firms, total factor productivity and market growth rate have a positive and significant impact on firms' market power.

Objective 2: To investigate the relationship between innovation and market structure under the different patent regime.

Key findings:

Innovation equation

- The results of the innovation equation from 1995-2005 suggest that there is a linear positive impact of market power on innovation but only for medium technology firms.
- For the period of 2006-2015, results suggest that there is an insignificant impact of market power on innovation.
- The R&D intensity and advertisement intensity have a positive and significant impact on innovation for the period of 1995-2005 whereas age and size of the firms have a nonlinear impact on innovation.
- The size of a firm has a nonlinear impact on innovation from 2006-2015.

Market power equation

- For the period of 1995-2005, results suggest that patent application and grants have a positive and significant impact on market power.
- With respect to full sample and medium technology firms, we find an inverted-U shaped relationship between market power and patent application.
- For the period of 2006-2015, we find an insignificant impact of patenting on market power.
- For the period of 1995-2005, the age of a firm has a positive and significant impact on market power whereas capital intensity has a negative and significant impact on market power.
- For the period of 1995-2005, age of the firms and export intensity has a positive and significant impact on market power whereas capital intensity has a negative and significant impact.

Objective 3: To investigate the differential impact of product and process innovations on market structure.

Key findings:

- Both product and process patent have a positive and significant impact on market power.
- We also find an inverted-U shaped relationship between types of technological innovations and market power.
- Export intensity and age have a positive and significant impact on firms' market power.

Table 6.2.1: Summary of results for objective 1

	Dependent variable: PATENTAP	**Dependent variable: PATENTGR**	**Dependent variable: PATENTAP**	**Dependent variable: PATENTGR**
Independent variable	**Unleveled industry**	**Unleveled industry**	**Neck-and-neck firms**	**Neck-and-neck firms**
Full sample				
WLI	Insignificant	Insignificant	Insignificant	Insignificant
WLI^2	Insignificant	Insignificant	Insignificant	Insignificant
High technology firms				
WLI	Insignificant	Insignificant	Insignificant	Insignificant
WLI^2	Insignificant	Insignificant	Insignificant	Insignificant
Medium technology firms				
WLI	Insignificant	Insignificant	Insignificant	Insignificant
WLI^2	Insignificant	Insignificant	Insignificant	Insignificant

Table 6.2.2: Summary of results for objective 1

		Dependent variable: WLI	
Independent variable	**Full sample**	**High technology firms**	**Medium technology firms**
PATENTAP	Positive and significant	Positive and significant	Positive and significant
$PATENTAP^2$	Insignificant	Insignificant	Negative and significant
PATENTGR	Positive and significant	Positive and significant	Positive and significant
$PATENTGR^2$	Negative and significant	Insignificant	Insignificant

Table 6.3.1: Summary of results for objective 2

Variables	Dependent variable: PATENTAP	Dependent variable: PATENTGR	Dependent variable: PATENTAP	Dependent variable: PATENTGR
Independent variable	**Pre-TRIPs (1995-2005)**	**Pre-TRIPs (1995-2005)**	**Post-TRIPs (2006-2015)**	**Post-TRIPs (2006-2015)**
		Full sample		
WLI	Insignificant	Insignificant	Positive and significant	Insignificant
WLI^2	Insignificant	Insignificant	Insignificant	Insignificant
		High technology firms		
WLI	Insignificant	Insignificant	Insignificant	Insignificant
WLI^2	Insignificant	Insignificant	Insignificant	Insignificant
		Medium technology firms		
WLI	Positive and significant	Positive and significant	Insignificant	Insignificant
WLI^2	Insignificant	Insignificant	Insignificant	Insignificant

Table 6.3.2: Summary of results for objective 2

	Dependent variable: monopoly power	Dependent variable: monopoly power
Independent variable	**Pre-TRIPs (1995-2005)**	**Post-TRIPs (2006-2015)**
Full sample		
PATENTAP	Positive and significant	Insignificant
$PATENTAP^2$	Negative and significant	Insignificant
PATENTGR	Positive and significant	Insignificant
$PATENTGR^2$	Insignificant	Insignificant
High technology firms		
PATENTAP	Insignificant	Insignificant
$PATENTAP^2$	Insignificant	Insignificant
PATENTGR	Insignificant	Insignificant
$PATENTGR^2$	Insignificant	Insignificant
Medium technology firms		
PATENTAP	Positive and significant	Insignificant
$PATENTAP^2$	Negative and significant	Insignificant
PATENTGR	Insignificant	Insignificant
$PATENTGR^2$	Insignificant	Insignificant

Table 6.4: Summary of results for objective 3

Independent variable	Dependent variable: monopoly power
PROD	Positive and significant
$PROD^2$	Negative and significant
PROC	Positive and significant
$PROC^2$	Negative and significant

6.4. Synthesis of findings

In this section, we have synthesized the results as obtained from the empirical investigations performed in the Chapters 3, 4 and 5. While investigating the relationship between innovation and market structure for objectives 1 and 2, we have two equations namely; innovation equation and market structure equation. The results of the first and second objectives suggest that market structure is not a significant determinant of firms' level innovation activities in Indian high and medium technology industries. Hence, there is no inverted-U shaped relationship between innovation and market structure as suggested by Aghion et al. (2005). Such findings differ from the developed countries context where most studies have positioned a significant relationship between innovation and market structure including an inverted-U shaped, and positive and increasing positive relationship. This result highlights a very important factor that has been withholding innovation by firms in a country like India, where the vast majority of the contribution to R&D is from the government sector. However, factors such as the size of a firm, age, R&D expenditure, advertisement expenditure and patent policy changes are important determinants of firm level patenting activity in Indian high and medium technology firms.

While analyzing the impact of market structure on innovation, we have also controlled the model for technology gap effect. Earlier studies do not consider the technology gap among the firms while understanding the relationship between innovation and market structure in the Indian context. In the innovation equation, after controlling for this effect, we do not find sufficient support for the linear and nonlinear impact of market structure on innovation. Even while analyzing the separate sample of neck-and-neck firms, the impact of market power is insignificant (in the early stage of competition, neck-and-neck firms derive positive relationship between innovation and competition). These findings confirm that unlike other developed economies, competitive forces are not driving innovation among Indian manufacturing firms. Therefore, the lack of such a relationship and a lesser extent of competition in the emerging market could be a significant reason for the laggardness of the developing economies in terms of technological change.

Further, this study finds a significant feedback effect of innovation on the market structure. This finding concludes that in-house technology creation is a vital source of market dominance in Indian firms. Moreover, we also confirm the existence of an inverted U-shaped relationship which is in line with the Schumpeterian theory of creative destruction. Apart from patenting; the age of a firm, market growth rate, capital and export are also important determinants of firms' market power. From the summary of results, it is also noted that the relationship between innovation and market structure is conditional upon types of manufacturing industry namely; high technology and medium technology industry.

Moreover, innovation types namely product and process innovations influence firms' market power albeit through different channels. In the case of the Indian pharmaceutical industry, such an impact holds with different types of technological innovations, i.e. product and process innovation. Up to a certain level, patents have a positive impact on market power. However, after an optimal level, further patent protection has an adverse impact; an inverted-U shaped relationship.

Patent policy change is also a vital factor which influences the overall relationship between innovation and market structure. When we analyze the innovation and market structure relationship for two separate time periods namely; pre-TRIPs (1995-2005) and post-TRIPs (2006-2015), we find different results in comparison to findings produced during the aggregate time period i.e. 2000-2015. More importantly, the impact of innovation on market power turns out to be insignificant for the post-TRIPs period (2006-2015). However, we attribute this result to the availability of a large number of non-innovative firms in the database.

6.5. Discussion of results

In this thesis, we find an insignificant impact of market power on innovation in most cases. Moreover, the results also recommend the absence of a nonlinear relationship between innovation and market structure; hence, the prediction of Aghion (2005) model does not hold in the Indian context. Empirical studies based on developed economies have also produced diverse results on this relationship. We attribute this result to (i) insignificant technological competition in the industry; and, (ii) the influence of exogenous policy incentives. Based on sample firms in Chapter 3, the average technology gap is 0.58 with around 57.4% observations above the value. This high gap indicates that the firms in an industry are not very technologically savvy and thus do not pose a credible threat to the leading firms. The leading innovative firms are large and old as we find a significant positive correlation between the size and age of firms. In line with the Schumpeterian hypothesis, our findings suggest that large and experienced firms potentially innovate due to strategic reasons.

India’s legacy of a regulated market continues to influence the type of competition in the industry. Though liberalization has paved the way for firms to be innovative, the nature of competition is such (prevalence of technologically laggards firms) that it does not drive innovation activity. According to Bas and Paunov (2018), the removal of License Raj, a pro-competition policy has an unequal effect on firms’ innovation performance in India. The impact of such a policy is conditional upon the size of a firm and the business conditions in which it operates. Hence, a large firm located in a richer state is likely to benefit more from the liberalization policy. Our result corroborates these findings and further complements it by highlighting that a mere increase in the competition in an industry will not drive firms to innovate. The competition needs to be intense in terms of low technological differences among the firms.

Most firms in developing countries are small, particularly in comparison to their international counterparts. Small firms do not have a stable source to finance their innovation activities that require long-term risky investments. Hence, short term fluctuations in competition may not affect patenting activities in developing countries. Where competition cannot achieve the desired results, policy attempts to make headway. In the first objective, we note that TRIPs related changes in the patent law significantly influence firm-level innovation. Furthermore, several government R&D support schemes in India are available to support small firms. In a competitive market, the probability of laggard firms to innovate decreases (Aghion et al. 2005). Thus, government support helps firms to overcome the challenges to innovate by reducing the cost of innovating and providing external funds (Polder &Veldhuizen 2012).

On the other hand, the results of the market structure equation suggest that patenting has a positive and significant impact on market power. Innovative firms dominate the market by more patenting, which further results in higher output, product differentiation and cost minimization. Estimated results also highlight that there is an optimal level of patent protection above which further patent protection may decline firms' performance. Nemlioglu and Mallick (2017) also find a positive impact of R&D and intangible assets on firms' overall performance only up to an optimal level.

We also note that the relationship between innovation and market structure also depends upon patent policy change. With the Patent (Amendment) Act 2004, India's IPRs are harmonized and have become globally stronger. With this Act, India adopted minimum standards of IPRs protection which are relatively stronger than the earlier Act. This Act re-introduced product patent in all fields of technology which increased patenting activity in India. It also increased foreign patenting in India. This Act also influenced the market structure as it incentivized the entry of new firms and encouraged firms to conduct more innovation for superior market performance. Hence, we have utilized 2005 as a break in the dataset. Interestingly, we also note that the relationship between innovation and market structure also changes in pre and post-TRIPs regimes. However, in most cases, the impact of market structure is insignificant on firms' patenting. These results also confirm the non-existence of an inverted-U shaped relationship between innovation and market structure in pre and post-TRIPs regimes. With respect to the market structure equation in two different regimes, we report significant changes in this relationship. In the medium technology industry, we find an inverted-U shaped relationship between innovation and market structure equation in the pre-TRIPs regime. However, in the post-TRIPs regime, there is an insignificant relationship between innovation and market structure. When we utilize a dummy variable for TRIPs based on the Patent (Amendment) Act 2004 in the innovation equation (for 2000-2015), we find that it has a positive and significant impact on firms' patenting. Hence, we have expected a positive impact of innovation on market structure under the post-TRIPs regime. However, our findings have produced an insignificant relationship. As mentioned in Table 6.1, while analyzing the relationship between innovation and market structure from 2000-2015, we have demonstrated that the technology gap is an important independent variable in the innovation equation. All such firms which are not reporting information on wages and salaries, power and fuel consumption and raw material consumed are deleted from the dataset. Hence, the remaining firms in the dataset for 2000-2015 are innovation intensive firms as these indulge in more R&D and patenting. As a result, there is a positive association between patent policy dummy and patenting activity. When the market structure equation is analyzed under pre and post-TRIPS regimes, we have all those firms which are reporting their sales data. The number of firms is larger; moreover, those firms are also available in the dataset which are performing minimal or no innovation activities. Hence, the availability of non-innovative firm could be an important reason for the insignificant impact of innovation on market power. Furthermore, when we analyze the impact of innovation on market power of firms in pharmaceutical industry, we find a significant relationship. The pharmaceutical industry is R&D and patent sensitive industry and most firms indulge in such innovation activities. Hence, innovation drives market power. Moreover, such results also hold with both product and process innovation. The availability of such a significant relationship for innovation intensive industries such as pharmaceuticals adds to the confidence for attributing insignificant relationship between innovation and competition to the presence of non-innovative firms (as discussed earlier).

6.6. Policy Implications

This dissertation has policy suggestions for both managers as well as policymakers. Our results may have implications for managers in industry in deciding the amount of R&D expenditure for new products and processes for enjoying market benefits. After the TRIPs agreement, member countries of the WTO have experienced a massive increase in patent applications and grants in patent sensitive industries. Generally, early entrants and larger firms spend more on R&D, which results in more patenting. This strategy helps them to sustain their monopoly power by restricting the entry of others in a particular market segment. Our results highlight that the strategy of filing more patents is only fruitful up to an optimal level. Later, the net benefits of a company may decline because of certain diseconomies.

Existing firms conduct incremental innovation to continually dominate the market. These firms enjoy an early mover advantage in the market and accordingly generate high entry barriers for new entrants. With respect to new entrants and small firms which face tough competition from older and larger firms, our study suggests that they should avoid innovating on the same product lines. These firms should rather structure their R&D in such a way that their product and process innovations are diversified. Thus, product diversification can be one alternative strategy for new entrants and small firms to successfully grab the market.

Indian industries are dominated by large firms which are small in numbers. We also know that large firms are R&D and patent-intensive, export-oriented and more profitable. However, the availability of large numbers of small and laggard firms makes competitive pressure insignificant. Such firms are inefficient in competing with large and dominated firms in the market; hence, the nature of the market is monopolized. From the policy makers' perspective, our results suggest that there is a need to incentivize small domestic firms through various government schemes so that healthy competitive environment can be generated in the market.

As discussed, Indian domestic firms are mostly small and medium-sized, and also laggards. As per sample statistics, about 57.4% observations lie above the average technology gap. This statistic reveals that Indian domestic firms are technologically laggards. Hence, based of Article 66 of TRIPs which concerns Least-Developed Countries (LDC), the Indian Government can request technology transfer from developed countries to such laggard firm which can be helpful in making domestic firms technologically superior through promotion and encouragement of updated technology transfer.

The Indian Government has introduced various innovation incentive schemes for the promotion of firm-level innovation activities. For example, the R&D tax credit scheme in India was introduced in 2001 (and further amended in 2011). However, such schemes are horizontal in the nature as the eligibility conditions only consist of Department of Scientific and Industrial Research (DSIR) affiliation and the availability an in-house R&D centre. As we know, the market is dominated by large firms which are already innovation intensive firms. Hence, such horizontal R&D promotion schemes may not be helpful for small domestic and laggard firms. There is a need to develop separate innovation incentive schemes/policies for small and laggard firms.

Other measures like compulsory licensing and parallel imports can be used to maintain a healthy competition in the market. Compulsory licensing can maintain imitation dynamics of domestic firms which were present during the process patent regime.

6.7. Contributions of the Study

This study contributes to the existing literature (especially in the developing country context) by analyzing a two-way relationship between innovation and market structure in Indian high and medium technology firms. We test the predictions of Aghion et al. (2005) inverted U-shaped theory and the Schumpeterian theory of creative destruction in the Indian context. Further, we have also empirically analyzed the influence of patent policy change on the relationship between innovation and market structure in Indian firms.

Earlier studies have focused on R&D expenditure as a measure of innovation in developing countries. However, the use of patent data is limited in such economies. We have analyzed the innovation and market structure relationship by employing firm level patent data. Moreover, we have also utilized both patent applications and grants to verify the results.

We have separately analyzed the impact of types of technological innovation on firms' market power in the Indian pharmaceutical industry. For this purpose, we have classified patents into product and process patents. We undertook a manual search to prepare the list of granted patents from the weekly journal of CGPDT. On the basis of the Patent (Amendment) Act 2005, CGPDT began publishing the Official Journal of the Patent Office on its website since 2005. This is a weekly journal which contains information on early publications, publications after 18 months and publication under section 43(2) with respect to the grants. Before 2005, the Indian Patent Office published patent data, but only in hard copies (known as Official Gazettes).

To analyze the nonlinear impact of technological innovation (product and process), we have developed a theoretical model; and based on the propositions of the model, we have empirically verified the relationship between product and process innovation, and market power of firms

6.8. Limitations

This dissertation uses both patent applications and grant data as means of innovation. Quality-adjusted patents (such as patent citations) better measure innovation. However, in the Indian context, we are limited as citation data is not available with the Indian Patent Office. There are also firms which may not patent their innovations. In such cases, the number of new products and processes are considered as better proxies for innovation. Such information can be gathered by conducting an innovation survey. However, the results of such a survey are currently not available. This study incorporates only high and medium technology firms, as these firms are more patent-intensive. In future, low technology firms can be incorporated by utilizing a number of new products and processes as a measure of innovation. With respect to the types of technological innovation, we incorporate such information only for the pharmaceutical industry as the availability of data is a constraint for other industries. In future studies, we can further extend the use of different types of technological innovations for other industries as well. It will require the manual classification of the patent as product v/s process.

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