Patent Policy and Relationship Between Innovation and Monopoly Power: Evidence from Indian High and Medium Technology Industries

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1 Introduction

Relationship between innovation and market structure is widely explored in the industrial organization literature including one-way relationship (Schumpeter 1942; Arrow 1962; Bain 1968). Further developments from Chicago School focused on the feedback effect of innovation on market structure. Firms' innovation activities and its' relationship with the market are evolutionary processes (Nelson and Winter 1982; Nelson 1994) that are influenced by the technological regime including the appropriability conditions among other factors. Studies show that intellectual property rights protection (IPRs) that determine appropriability conditions in a market, influence the relationship between innovation and market structure (Kortum and Lerner 1998; Moser 2005; Correa 2012). IPRs are formal institutions which incentivize firm-level innovations by reducing the transition cost and the uncertainty in the decision-making process (North 2012). Patents, a type of IPRs, are a state-granted monopoly to the innovator. And patent policy changes that increase the innovators' rights affect the innovation activities of a firm and concomitantly market structure of the industry.

There are many changes in the Indian patent policy from 1970 to 2005. Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) came into the picture in 1995 with minimum standards for IPRs legislation for member countries of World Trade Organization (WTO). Evidences show that TRIPs has significantly increased R&D and patenting in India (Chadha 2009; Haley and Haley 2012; Jagadeesh and Sasidharan 2014; Sharma et al. 2018). Due to strong patent laws and

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other IPRs protections, developing countries are now specializing in some fields of technology and are innovating at the frontier of such technology fields (Kumar et al. 1999; Srholec 2007; Fu and Gong 2011).

On the basis of above discussion, this study evaluates the impact of major patent policy change on the relationship between innovation and monopoly power in Indian high and medium technology firms. This study is an attempt to empirically analyze the bidirectional relationship between innovation and monopoly power in two different technology regimes which are 1995–2005 and 2006–2015. The period of 1995–2005 is the transition phase during which the Indian Government three times amended the patent policy to comply with TRIPs agreement. For the period of 2006–2015, the real impact of TRIPs can be realized. The study helps us to understand the implications of TRIPs on the innovation and competition issues in Indian manufacturing sector.

The rest of the paper is organized as follows: Section 2 discusses about various patent policy change in India. Section 3 provides brief review of literature on patent policy change and the relationship between innovation and market structure. Section 4 gives description of variables. Section 5 discusses data sources and descriptive statistics. Section 6 focuses on the results of model estimations. Section 7 presents the conclusion.

2 Patent Policy Change in India

According to The Patent Act 1970 which was finally implemented in 1972, only process innovation could be patented in fields of food and medicine for the duration of 7 years, whereas in other fields of technology, the protection was for 14 years. This act increased the capabilities of domestic firms by increasing adaptive R&D. Under process patent regime, firm can easily copy the external technology and reproduce similar products with efficient cost structure. In summary, process patent regime negatively affects the innovation capacity of a firm, although it increases adaptive R&D expenditure. The Patent (Amendment) Act 1999 was brought into force retrospectively from January 1, 1995. This amendment provides permission to file the application for product patent in the field of pharmaceutical, drugs, and agrochemical. However, such applications were examined only after 2004. This amendment also provides provision of granting Exclusive Marketing Rights (EMRs).[1] Second amendment in the Patent Act 1970 was made in 2002 with the Patent (Amendment) Act 2002. In this act, many changes were made like term of protection was extended up to 20 years, requirement to disclose the source and geographical location of the biological material was introduced, licensing right was removed, publication of application after 18 months was started and provision of pre- and post-grant opposition was also started. The third amendment to the Patent Act 1972 was made through the Patent

[1]EMRs were given based on two conditions (i) a patent should have been granted for the same product in another WTO member country after 1995 and, (ii) marketing approval should have been obtained for this product in the other member country.

Table 1 Average patent application and grant in India during different patent policy regime

Year	Average patent grant	Average patent application
1995–1996 to 1998–1999	1521.00	8676.75
1999–2000 to 2001–2002	1596.66	7973.00
2002–2003 to 2004–2005	1919.66	13848.33
2005–2006 to 2015–2016	7450.09	38059.16

Source Authors' calculations on the basis of information available in annual reports of Indian Patent Office

(Amendment) Act 2004 which was implemented by January 1, 2005. This amendment required the introduction of product patent in all fields of technology. This act also makes the 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. Clearly, these amendments have made imitation of new technology difficult. In new patent regime, survival of a firm on the basis of reverse engineering is not possible.

During the transition phase of patent regime (1995–1996 to 2004–2005), we find that the average patent application in India was 10017.1 and average granted patent was 1663.3. In the new patent regime (2005–2006 to 2015–2016), average number of the patent application and granted patent are 38,059 and 7450, respectively. We observe that around 279.94% surge in the average patent application in new patent regime as compared to transition phase. Similarly, the average of granted patent has increased with a growth rate of 347.90% in new patent regime. Table 1 shows that the patenting has increased tremendously in India with the change in patent policy.

3 Literature Review

According to Grossman and Helpman (1993), strong IPRs encourage entrepreneurs to increase their R&D investment which further increases their post-innovation profit and reduces the cost of future innovations. Strengthening IPRs positively influence technological progress of a country (Kanwar and Evenson 2003; Hausmann et al. 2014; Naghavi and Strozzi 2015; Boring 2015; Zhang and Yang 2016). Successful innovators use new technology by their own and/or they commercialize it by selling or licensing to others. In the weak IPRs regime, innovators do not get full advantage by using and/or selling new technologies as there are high chances of imitation (Autio and Acs 2010). Strong IPRs also increase technology transfer[2] to developing countries which also make firms more innovative (Maskus 2004; Sasidharan and Kathuria 2011; Khachoo et al. 2018). Strong IPRs protection also increases competition in the market by incentivizing the entry of new firms (Djankov et al. 2002; Klapper et al. 2006) that 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 greater for new business formation rather than established ones. However, Gilbert and Newbery (1982) explain that in strong IPRs protection, cost of imitation is very high which increases the monopolistic behavior in the market (Gilbert and Newbery 1982).

Utilizing innovation data from Crystal Palace Exhibition in London (1851) and the Centennial Exhibition in Philadelphia (1876), Moser (2005) suggests that the patent laws are the important determinant of direction of technological change. Kortum and Lerner (1998) and Correa (2012) find upsurge in US 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) analyzed the relationship between market structure and innovation using dataset of 311 firms listed in London Stock Exchange over 1973–1994. This study utilized the establishment of CAFC in 1982 as a structural break in the dataset. This study finds that competition has positive and significant impact on innovation for the period of 1973–1982; however, this relationship becomes 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 Indian context, Sharma et al. (2018) find a positive impact of patent policy change on 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 has 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 expenditure of pharmaceutical firms. According to Haley and Haley (2012), Indian pharmaceutical firms were globally competitive in the production of generics from 1972 to 2004 due to process patent regime. This study suggests that Indian pharmaceutical firms positively responded to changes in patent policy by decreasing the filing of process patents. Study by Chadha (2009) has analyzed the impact of

[2]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).

TRIPs on patenting activities of Indian pharmaceutical firms. This study finds that the patenting activities have been increased in post-TRIPs era.

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

4 Description of Variables

4.1 Endogenous Variables

Both innovation and monopoly power are endogenous variables in this study. We use Lerner index[3] or price cost margin as a measure of monopoly power. PCM also reflects firm-level pricing and cost structure. Following Clerides et al. (2015) and Saraswathy (2018), we calculate the weighted Lerner index (WLI) with market share as the weights. WLI shows the relative position of a firm in a particular industry.

R&D and patenting are some of the major proxies to measure firm-level innovation activities. In the Indian context, studies like Kumar and Saqib (1996), Narayanan (1998), Kathuria (2008), Sasidharan and Kathuria (2011), Basant and Mishra (2014) utilize R&D as a measure of innovation activities which is an input-based measure of innovation. Other studies like Deolalikar and Röller (1989), Chadha (2009), Ambrammal and Sharma (2016), Dhanora et al. (2018), Khachoo et al. (2018), and Dhanora et al. (2019) utilize firm-level patent data to measure innovation activities which is output-based measure of innovation. Patent data is an observer proxy for successful R&D expenditure. Patents acquired by firm are closely associated with newly commercialized technologies. This study utilized patenting as a major proxy of firms' innovation activities.

[3] Koetter et al. (2012) define adjusted Lerner index as: adjusted Lerner = $[(\prod_i + \mathrm{tc}_i - \mathrm{mc}_i q_i)/(\prod_I + \mathrm{tc}_i)]$, where $\prod_i$ is profit, tc_i is total cost, mc_i is marginal cost, andq_i is the output. If we assume that marginal cost is constant, then adjusted Lerner can be defined as: $[(\prod_i / q_i p_i)]$.

4.2 Control Variables

In Sect. 3, we have discussed about the system of two equations, namely innovation and monopoly power equations. We also utilize separate control variables in these equations.

4.2.1 Patenting Equation

With respect to patenting equation, we identify control variables on the basis of literature including size and age of firm, R&D expenditure, exports, embodied and disembodied technologies and advertising. The rationale for introducing these variables is as follows:

Due to availability of finance and economies of scale, large firms do more R&D and patenting activities (Cohen and Levinthal 1989; Sasidharan and Kathuria 2011; Aggarwal 2018). Size (SIZE) and its square term ($SIZE^2$) are important determinants of firms' innovation activities. In knowledge production function, R&D expenditure (RD) determines firms patenting activities (Griliches 1979, 1981; Pakes and Griliches 1980; Crépon et al. 1998). Export-oriented firms are more innovative as they are aware about recent innovations; hence, export intensity (EXPI) positively influence firms patenting (Evenson and Joseph 1999; Ambrammal and Sharma 2014). Technology imports in the form of embodied (EMBD) and disembodied (DISEMBD) also determine firm innovation behavior (Narayanan 1998; Basant and Mishra 2014).[4] Advertisement intensity (ADI) which is a proxy for product differentiation also influences innovation (Basant and Mishra 2014). In differentiated market, firms are more innovative. However, alternative argument is that investment in promotional activities is an alternative strategy to R&D and patenting. We also include age of the firm (AGE) and its nonlinear term (AGE^2) in the patenting equation to explore the possible nonlinear impact of learning by doing (Arrow 1962; Thornhill 2006). In developing country context, patenting performance of multinationals (MNEs) is superior to domestic firms. MNEs have access to technology developed by their parent organization that provides them competitive advantage vis-à-vis domestic firms. Hence, we also incorporate ownership dummy (FOS) in the model. We differentiate between MNEs and domestic firms on the basis of 10% foreign promoters' equity participation (Basant 1997; Ambrammal and Sharma 2014).

[4]Literature on the transaction cost theory (Williamson 1985; Pisano 1990) and absorption capacity building hypothesis (Cohen and Levinthal 1989; Arora and Gambardella 1990; Patel and Pavitt 1997) give detail explanation on the relationship between in-house R&D and technology imports.

4.2.2 Monopoly Power Equation

With respect to monopoly power equation, control variables include export intensity, advertisement intensity, market growth rate, import intensity, ownership, age, and capital intensity of firm. The rationale for introducing these variables is as follows:

Export intensity captures dynamic characteristics of the firm which positively influence firms' monopoly power (Resende 2007; Yoon 2004). Strickland and Weiss (1976) and Yoon (2004) explain that advertisement expenditure increases market concentration. Differentiated firm enjoys more monopoly in the market. More expenditure on promotional strategies also creates high entry barriers which result in high market concentration (Gupta 1983; Resende 2007). Market growth rate (MGR) is also an important control variable in monopoly power equation. MGR is a demand factor which influences firm profits (Gupta 1983). Import intensity (IMPI) enhances the domestic market competition by increasing the efficiency of resource distribution (Yoon 2004). Narayanan (1998) explains that accumulation of technology by learning by doing gives a firm competitive advantage which results in high concentration in the industry. Hence, we also use AGE as a control variable. Capital intensity (CAPITAL) also determines firms' monopoly power. Efficient utilization of capital makes firm more productive (Kambhampati and Parikh 2003). We also incorporate ownership dummy (FOS) in monopoly power equation.

On the basis of above discussion, we have the following system of two equations:

$$\begin{aligned}\textbf{innovation} &= \mathbf{f}(\textbf{monopoly power}, \textbf{RD}, \textbf{EXPI}, \textbf{DISEMBD}, \textbf{EBMD}, \textbf{ADI}, \\ &\quad \textbf{AGE}, \textbf{AGE}^{\mathbf{2}}, \textbf{SIZE}, \textbf{SIZE}^{\mathbf{2}}, \textbf{FOS}) \\ \textbf{monopoly power} &= \mathbf{f}(\textbf{innovation}, \textbf{EXPI}, \textbf{IMPI}, \textbf{ADI}, \textbf{AGE}, \textbf{CAPITAL}, \\ &\quad \textbf{MGR}, \textbf{FOS})\end{aligned}$$

5 Data

This study utilizes firm-level panel data for Indian high and medium technology industries over 1995–2015. We identify firms in high and medium technology industries on the basis of Organization for Economic Co-operation and Development (OECD) classification and concordance is drawn between International Standard Industrial Classification (ISIC) 2003 Revision 3 and National Industrial Classification (NIC) 2008 via NIC 2004. Major source of data for this study includes Center for Monitoring Indian Economy (CMIE) prowess database and website of Controller General of Patent, Design and Trademark (CGPDT, Government of India). We collected the list of granted patents from monthly publication of CGDTP and Indian Patent Advanced Search System (InPASS).

Dataset for this study include firms which are active in R&D and patenting. Firms which are reporting zero sales are dropped from the sample. After cleaning the data, we are able to collect the information for 686 firms which are active in innovation activities. Out of these 686 firms, 232 (33.81%) firms are high technology and 454 (66.18%) are medium technology firms. We further segregated these firms into domestic- and foreign-owned firms on the basis of 10% foreign promoters' equity participation. Out of 232 high technology firms, 31 (13.36%) firms are foreign firms and 201 (86.63%) are domestic. For medium technology sample, 63 (13.87%) firms are foreign firms and 391 (86.12%) are domestic. Table 2 presents definitions of variables and their data source. Table 3 presents the descriptive statistics of full sample, high and medium technology firms.

Table 4 analyzes R&D and patenting during different patent policy changes. For high technology firms, average R&D intensity (in terms of % of sales) for the period of 1995–1999 is 0.94% which increased to 2.06% over 2006–2015. Average granted

Table 2 Definition of variables and source of data

Variables	Definition	Source of data
Total patent (TOPI)	Number of total patent 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)
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 sales	CMIE (Prowess)
Advertisement intensity (ADI)	Advertisement expenditure divided by sales	CMIE (Prowess)
Capital intensity (CAPITAL)	Gross fixed assets divided by sales	
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)	Import of finished goods and raw materials divided by sales	CMIE (Prowess)
Foreign ownership dummy (FOS)	Value 1 to those firms which have at least 10% foreign equity participation and 0 otherwise	CMIE (Prowess)

Table 3 Descriptive statistics

Variables	Full sample			High technology			Medium technology		
	1995–2015	1995–2005	2006–2015	1995–2015	1995–2005	2006–2015	1995–2015	1995–2005	2006–2015
WLI	0.00488	0.00458	0.00526	0.00592	0.00521	0.00669	0.00435	0.00425	0.00447
	−0.02	−0.014	−0.025	−0.025	−0.017	−0.032	−0.017	−0.013	−0.021
TOPI	0.50916	0.04598	1.02599	0.72434	0.08424	1.42844	0.3992	0.02643	0.80925
	−4.663	−0.987	−6.664	−5.054	−1.632	−7.055	−4.446	−0.335	−6.409
RD	0.00846	0.00687	0.00958	0.0158	0.01135	0.02069	0.00471	0.00458	0.00484
	−0.033	−0.028	−0.034	−0.054	−0.044	−0.063	−0.011	−0.012	−0.01
EXPI	0.11849	0.103	0.13582	0.15099	0.12554	0.17898	0.10189	0.09149	0.11333
	−0.17	−0.159	−0.179	−0.201	−0.177	−0.222	−0.149	−0.148	−0.148
AGE	3.35638	3.15605	3.57837	3.27939	3.06134	3.51925	3.39573	3.20445	3.60613
	−0.626	−0.689	−0.454	−0.66	−0.728	−0.472	−0.604	−0.664	−0.444
SIZE	6.25424	6.01915	6.52368	6.0768	5.72288	6.46611	6.34492	6.17054	6.53673
	−1.773	−1.736	−1.777	−1.738	−1.695	−1.702	−1.783	−1.737	−1.814
ADI	0.00612	0.0059	0.00637	0.00688	0.00658	0.00721	0.00574	0.00555	0.00594
	−0.017	−0.016	−0.019	−0.018	−0.016	−0.02	−0.017	−0.015	−0.018
CAPITAL	0.56281	0.54821	0.57696	0.56665	0.53484	0.60163	0.56085	0.55504	0.56724
	−0.61	−0.517	−0.696	−0.634	−0.524	−0.734	−0.598	−0.513	−0.679
MGR	12.68256	12.70926	12.64272	13.34845	13.78658	12.8665	12.34228	12.15874	12.54417
	−11.474	−10.637	−12.363	−10.217	−10.351	−10.047	−12.053	−10.739	−13.348
IMPI	0.10319	0.09241	0.11521	0.1174	0.10645	0.12944	0.09593	0.08523	0.1077
	−0.163	−0.149	−0.176	−0.186	−0.149	−0.22	−0.148	−0.149	−0.148

(continued)

Table 3 (continued)

Variables	Full sample			High technology			Medium technology		
	1995–2015	1995–2005	2006–2015	1995–2015	1995–2005	2006–2015	1995–2015	1995–2005	2006–2015
EBMD	0.01085	0.01242	0.009	0.01114	0.01091	0.0114	0.0107	0.0132	0.00795
	−0.071	−0.095	−0.027	−0.061	−0.077	−0.037	−0.076	−0.103	−0.021
DISEMBD	0.002421	0.0024	0.00246	0.00196	0.00164	0.00232	0.00265	0.00278	0.0025
	−0.008	−0.008	−0.009	−0.008	−0.005	−0.01	−0.008	−0.009	−0.007
OBS	14406	7546	6860	4872	2552	2320	9534	4994	4540

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

Table 4 Average R&D and patenting during different patent policy regime

	Year	Patent granted	R&D intensity
Full sample	1995–1999	0.01107	0.00629
	2000–2002	0.03352	0.00644
	2003–2005	0.11661	0.00828
	2006–2015	1.01865	0.01020
High technology	1995–1999	0.00689	0.00947
	2000–2002	0.04885	0.01005
	2003–2005	0.24856	0.01577
	2006–2015	1.42844	0.02069
Medium technology	1995–1999	0.01321	0.00466
	2000–2002	0.02569	0.00459
	2003–2005	0.04919	0.00440
	2006–2015	0.80925	0.00491

Source Authors' calculations on the basis of information available in CMIE and CGPDT

patent for this industry is 0.006 for 1995–1999 which increased to 1.42 for 2006–2015. For medium technology firms, the average R&D for 1995–1999 is 0.46% which increased to 0.49% over 2006–2015. For the same industry, average granted patent increased from 0.01 to 0.80 from 1995–1999 to 2006–2015. In Table 4, we observe that patent policy change positively influenced R&D and patenting in high technology firms. The average R&D and patenting activities are higher for high technology firms in comparison to medium technology firms.

6 Results of the Model Estimation

Two-stage least square estimation (2SLS) is utilized for empirical estimation (Lunn 1986; Shan et al. 1994; Koeller 1995, 2005). We utilize error component two-stage least square (EC2SLS) for econometric specifications. In simultaneous panel data model, EC2SLS has more instruments than generalized two-stage least square (G2SLS) (Baltagi and Li 1992). Baltagi and Li (1992) explain that in the case of infinite sample, the difference between asymptotic variance of G2SLS and EC2SLS tends to zero; however, in finite sample, EC2SLS is more efficient than G2SLS.

First, we estimate the results for patenting equation for full panel which include both high and medium technology industries and then segregate the panel into high and medium technology firms. We also perform the analysis differently for 1995–2005 and 2006–2015. Similarly, we estimate the results of monopoly power equation. For econometric estimations, all the variables used are in logarithmic scale.

6.1 Innovation Equation

The results of patenting equation are presented in Table 5. Columns I and II present the result of full sample, columns III and IV for high technology, and columns V and VI for medium technology firms. In full-sample estimation, the coefficient of WLI is positive and significant in column II only. This result indicates that firms' monopoly power has positive influence on patenting activities in post-TRIPs era. We also find that this positive relationship is driven by only medium technology firms. For medium technology firms, the coefficient of WLI is positive and significant in columns V and VI. Schumpeter (1942) explains that firms with high market power conduct more innovation activities. This positive relationship is also known as Schumpeterian effect

Table 5 Impact of monopoly power on innovation

	Full sample		High technology		Medium technology	
	I	II	III	IV	V	VI
	1995–2005	2006–2015	1995–2005	2006–2015	1995–2005	2006–2015
WLI	1.86642 (2.51374)	17.62421*** (5.99690)	−3.54014 (2.58065)	0.59001 (4.47396)	4.60537** (1.89046)	31.77513*** (9.15025)
EBMD	−0.00423 (0.01559)	−0.26099 (0.25292)	0.01759 (0.04674)	0.02793 (0.24920)	0.00001 (0.01497)	−0.44993 (0.49849)
DISEMBD	−0.30901 (0.26212)	0.95324 (0.95196)	−0.52740 (1.26182)	0.461742 (0.84840)	0.03770 (0.18501)	1.35272 (2.35017)
EXPI	−0.00035 (0.01354)	−0.09126 (0.06154)	−0.02782 (0.02923)	−0.03872 (0.06374)	−0.00678 (0.01412)	−0.03386 (0.11987)
RD	0.08852* (0.05430)	0.14622 (0.20000)	0.08282 (0.07931)	0.16999 (0.16419)	−0.03961 (0.12742)	1.29417 (1.25098)
ADI	0.64719** (0.16024)	0.75229 (0.67794)	0.28423 (0.28404)	1.09093 (0.72793)	1.14066*** (0.19433)	−0.35192 (1.24753)
AGE	−0.01178 (0.01861)	−0.55095 (0.40342)	0.01300 (0.03179)	−0.75132 (0.53359)	−0.04954** (0.02078)	−0.02048 (0.64976)
AGE^2	0.00178 (0.00329)	0.09642* (0.05840)	−0.00450 (0.00580)	0.12356* (0.07671)	0.00852*** (0.00346)	0.02124 (0.09500)
SIZE	−0.02056 (0.01368)	−0.01850 (0.03064)	−0.07801*** (0.02091)	−0.10096** (0.04005)	0.01102 (0.01101)	−0.00334 (0.04431)
$SIZE^2$	0.00196 (0.00172)	0.00193 (0.00298)	0.00942*** (0.00255)	0.01403*** (0.00381)	−0.00150 (0.00123)	−0.00132 (0.00380)
FOS	0.02714** (0.01286)	0.12354 (0.09374)	0.00253 (0.02549)	0.22679** (0.11187)	0.02419** (0.01053)	0.03237 (0.15918)
CONSTANT	−0.03719 (0.10213)	−0.05194 (0.79205)	0.12595** (0.05008)	1.33690 (0.92288)	−0.14872 (0.07573)	−1.40570 (1.31082)
SLM (AGE)	–	–	–	–	2.27** [0.0116]	–
SLM (SIZE)	–	–	3.58*** [0.00017]	2.51*** [0.00602]	–	–
OBSERVATION	7546	6860	2552	2320	4994	4540

Notes This table presents estimations using EC2SLS technique. Dependent variable is patent grants. 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 industry-specific dummies have been incorporated in the models. SLM test is Sasabuchi–Lind–Mehlum test to verify U-shaped or inverted U-shaped relationship of competition on innovation (Aghion et al. 2005). Larger and dominant firm have more incentive to innovate due to availability of finance, economies of scale, strong patent protections, and other competitive strategies.

We also explore possible nonlinear impact of WLI on patenting.[5] For this purpose, we introduce WLI^2 as a new variable in innovation equation and results for same are reported in Table 6. The basic setup of Table 6 is same as Table 5. In columns II, IV, and VI, we find a significant inverted U-shaped relationship between monopoly power and patenting. Here, we notice that this nonlinearity prevails only in post-TRIPs era. This result suggests that having monopoly power positively influence patenting up to an optimal level only and afterwards patenting goes down with further increase in the monopoly power. We also perform Sasabuchi–Lind–Mehlum (SLM)[6] to verify this nonlinear relationship. In Columns II, IV, and VI, the SLM test statistics also confirm this inverted U-shaped relationship of Table 6.

In Table 5, we find that the coefficient of ADI is positive and significant in columns I and V. For medium technology firm, high product differentiation is a source of innovation; however, ADI becomes insignificant for post-TRIPs regime. In Column V, the coefficient of AGE is negative and AGE^2 is positive and both are significant which indicates a significant U-shaped relationship between age of the firm and patenting. This U-shaped relationship is also supported by SLM test. For high technology firm, the coefficients of SIZE and $SIZE^2$ also suggest a significant U-shaped relationship with patenting. SLM test in columns III and IV of Table 5 also confirms this nonlinear relationship between SIZE and patenting. The coefficient of ownership dummy (FOS) is positive and significant in columns I, IV, and V. For high technology firms, foreign firms are more active in patenting in post-TRIPs regime. In new patent regime, foreign firms are protecting their newly invented products and process by filing more patents in developing countries. For medium technology firms, we find that the coefficient of FOS is positive and significant for 1995–2005 only. In Table 6, we note that coefficients of some of the control variables are sensitive with addition of WLI^2 in the innovation equation. Coefficient of RD is positive and significant in columns I and VI. The coefficient of EBMD is negative, DISEMBD is positive and both are significant in column II. In column II, we also find that the coefficient of EXPI is negative and significant. However, once the sample is segregated into high and medium technology firms, these coefficients do not produce strong impact on patenting activities.

[5]Aghion et al. (2005) follow Schumpeter (1942) and Arrow (1962). According to Arrow (1962), there exists negative effect of monopoly power on innovation. Competition is a source of efficiency and productivity which leads to more innovation activities.

[6]This test is based on framework of likelihood ratio test of Sasabuchi (1980) and named by Sasabuchi–Lind–Mehlum (SLM) U test.

Table 6 Nonlinear impact of monopoly power on innovation

	Full sample		High technology		Medium technology	
	I	II	III	IV	V	VI
	1995–2005	2006–2015	1995–2005	2006–2015	1995–2005	2006–2015
WLI	−0.04249 (2.25498)	45.55250*** (8.71013)	−3.55314 (3.00746)	12.11499* (7.48629)	6.81873* (4.18884)	50.60706*** (9.01017)
WLI^2	31.10412 (21.56962)	−48.65505*** (12.06315)	5.45539 (21.87598)	−14.00184** (7.07439)	6.96595 (42.00714)	−55.97990*** (18.52718)
EBMD	−0.02015 (0.02054)	−0.58653** (0.25515)	−0.01544 (0.05366)	−0.14902 (0.28229)	−0.00068 (0.01624)	−0.55042* (0.30512)
DISEMBD	−0.31530 (0.30441)	1.73262* (0.93026)	1.87649 (1.28624)	0.78816 (0.92805)	0.07596 (0.21719)	1.45777 (1.44395)
EXPI	−0.00396 (0.01240)	−0.13089** (0.05948)	−0.04069* (0.02412)	−0.07379 (0.07055)	−0.00269 (0.01715)	−0.04243 (0.07340)
RD	0.20148*** (0.06830)	0.26223 (0.19407)	0.16011* (0.08927)	0.19318 (0.17700)	−0.08812 (0.14212)	1.55015** (0.76964)
ADI	1.35550*** (0.13770)	0.10873 (0.67106)	0.33665 (0.23930)	0.92035 (0.78695)	0.43213 (0.33880)	−0.68683 (0.77097)
AGE	−0.04378** (0.01730)	−0.27165 (0.38845)	0.00067 (0.03289)	−0.69622 (0.57069)	−0.06702** (0.03195)	0.01507 (0.40408)
AGE^2	0.00729*** (0.00280)	0.05591 (0.05588)	−0.00154 (0.00558)	0.11742 (0.08184)	0.01009* (0.00578)	0.01217 (0.05983)
SIZE	−0.00133 (0.01142)	0.04827 (0.03368)	−0.06874*** (0.02099)	−0.06480 (0.04708)	0.01988 (0.01749)	0.05472* (0.03330)
$SIZE^2$	0.00037 (0.00127)	−0.00688* (0.00358)	0.00836*** (0.00237)	0.00883* (0.00491)	−0.00284 (0.00213)	−0.00797** (0.00323)

(continued)

Table 6 (continued)

	Full sample		High technology		Medium technology	
	I	II	III	IV	V	VI
	1995–2005	2006–2015	1995–2005	2006–2015	1995–2005	2006–2015
FOS	0.02483*** (0.00618)	0.10795 (0.08452)	−0.00040 (0.01616)	0.24272** (0.11718)	0.03031 (0.02480)	0.02327 (0.10660)
CONSTANT	−0.10149 (0.06576)	−1.43620* (0.81360)	0.11955*** (0.04380)	1.22054 (0.98819)	−0.19557 (0.15212)	−1.98637 (0.85389)
SLM (WLI)	–	3.06*** [0.00111]	–	1.62* [0.0529]	–	1.88** [0.0303]
SLM (AGE)	2.53*** [0.00571]	–	–	–	1.09 [0.138]	–
SLM (SIZE)	–	–	3.27*** [0.00054]	1.37 [0.0849]	–	1.63* [0.052]
OBSERVATION	7546	6860	2552	2320	4994	4540

Notes This table presents estimations using EC2SLS technique. Dependent variable is patent grants. 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 industry-specific dummies have been incorporated in the models. SLM test is Sasabuchi–Lind–Mehlum test to verify U-shaped or inverted U-shaped relationship

6.2 Monopoly Power Equation

The results of innovation equation are presented in Table 7. The coefficient of TOPI is positive and significant in all the columns which confirm that there is a feedback effect of innovation on monopoly power. Studies like Gupta (1983), Lunn (1986), Koeller (1995), Delorme et al. (2002) and Yoon (2004) also confirm positive impact of innovation on monopoly power. This significant relationship holds for both pre- and post-TRIPs era. Firms' patenting is a positive source of monopoly power by increasing pricing structure through product differentiation and also by minimizing cost of production (Dhanora et al. 2018).

Following recent studies by Lokshin et al. (2008), Berchicci (2013), Nemlioglu and Mallick (2017), and Dhanora et al. (2018), we explore nonlinear impact of innovation on monopoly power by introducing nonlinear term of patenting ($TOPI^2$) and report the results in Table 8.[7] In columns I, III, and V, we find that the coefficient

Table 7 Impact of innovation on monopoly power

	Full sample		High technology		Medium technology	
	I	II	III	IV	V	VI
	1995–2005	2006–2015	1995–2005	2006–2015	1995–2005	2006–2015
TOPI	0.10559*** (0.01367)	0.02708*** (0.00219)	0.03771*** (0.00885)	0.02734*** (0.00414)	0.08804*** (0.02040)	0.02386*** (0.00296)
IMPI	0.00046 (0.00147)	0.00065 (0.00200)	0.00103 (0.00214)	0.00277 (0.00365)	0.00072 (0.00128)	−0.00139 (0.00242)
EXPI	−0.00033 (0.00181)	0.00122 (0.00235)	0.00060 (0.00225)	0.00271 (0.00420)	−0.00028 (0.00172)	0.00120 (0.00317)
ADI	−0.02564 (0.02193)	−0.04812 (0.02593)	−0.01005 (0.02268)	−0.06182 (0.04981)	−0.00932 (0.02550)	−0.00757 (0.03255)
AGE	0.00311*** (0.00093)	−0.00253** (0.00125)	0.00090 (0.00117)	−0.00143 (0.00315)	0.00467*** (0.00100)	−0.00224 (0.00162)
CAPITAL	−0.00092** (0.00047)	−0.00060 (0.00060)	−0.00073 (0.00062)	−0.00100 (0.00136)	−0.00099** (0.00043)	−0.00057 (0.00068)
MGR	0.00002 (0.00001)	0.00007*** (0.00002)	0.00001 (0.00002)	0.00020** (0.00008)	0.00001 (0.00002)	0.00004** (0.00002)
FOS	−0.00274 (0.00311)	−0.00227 (0.00159)	−0.00051 (0.00485)	−0.00787* (0.00429)	−0.00206 (0.00344)	0.00052 (0.00204)
CONSTANT	0.02871** (0.01377)	0.05082*** (0. 00830)	−0.00189 (0.00380)	−0.00479 (0.01042)	0.02278* (0.01254)	0.04809*** (0.00951)
OBSERVATION	7546	6860	2552	2320	4994	4540

Notes This table presents estimations using EC2SLS technique. Dependent variable is weighted Lerner index. 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 industry-specific dummies have been incorporated in the models

[7] Lokshin et al. (2008) and Berchicci (2013) explain negative relationship between innovation and firms' performance in terms of diseconomies of scale, high monitoring, and coordination costs associated with high level of innovation activities. Nemlioglu and Mallick (2017) also find inverted U-shaped relationship between innovation and firm performance in the manufacturing firms of the

Table 8 Nonlinear impact of innovation on monopoly power

	Full sample		High technology		Medium technology	
	I	II	III	IV	V	VI
	1995–2005	2006–2015	1995–2005	2006–2015	1995–2005	2006–2015
TOPI	0.51052*** (0.17189)	0.02559** (0.00994)	0.52329*** (0.08626)	0.01130 (0.01417)	0.72356*** (0.19260)	0.02616** (0.01273)
$TOPI^2$	−0.20113** (0.08774)	0.00046 (0.00354)	−0.18116*** (0.03814)	0.00661 (0.00550)	−0.35206*** (0.10574)	−0.00072 (0.00410)
IMPI	−0.00036 (0.00337)	0.00087 (0.00201)	0.00242 (0.00674)	0.00150 (0.00372)	−0.00125 (0.00364)	−0.00150 (0.00253)
EXPI	−0.00108 (0.00389)	0.00173 (0.00244)	−0.00144 (0.00578)	0.00259 (0.00424)	0.00167 (0.00421)	0.00116 (0.00314)
ADI	−0.06620 (0.04812)	−0.04330 (0.02691)	0.03254 (0.05890)	−0.07008 (0.04798)	−0.13510* (0.07833)	−0.01020 (0.03291)
AGE	0.00126 (0.00138)	−0.00241* (0.00138)	0.00117 (0.00136)	−0.00211 (0.00275)	0.00047 (0.00124)	−0.00226 (0.00157)
CAPITAL	−0.00119 (0.00105)	−0.00067 (0.00063)	−0.00030 (0.00189)	−0.00051 (0.00133)	−0.00098 (0.00112)	−0.00057 (0.00068)
MGR	−0.00003 (0.00005)	0.00007*** (0.00002)	−0.00003 (0.00010)	0.00023** (0.00009)	−0.00006 (0.00006)	0.00004** (0.00002)
FOS	−0.00006 (0.00335)	−0.00229 (0.00177)	0.00348 (0.00336)	−0.01002** (0.00407)	−0.00113 (0.00243)	0.00047 (0.00198)
CONSTANT	0.03685*** (0.01405)	0.05028*** (0.00918)	−0.00264 (0.00550)	−0.00264 (0.00925)	0.04068*** (0.01001)	0.04822*** (0.00922)
SLM (TOPI)	2.09** [0.0185]	–	4.23*** [0.00001]	–	3.05*** [0.00116]	–
OBSERVATION	7546	6860	2552	2320	4994	4540

Notes This table presents estimations using EC2SLS technique. Dependent variable is weighted Lerner index. 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 industry-specific dummies have been incorporated in the models. SLM test is Sasabuchi–Lind–Mehlum test to verify U-shaped or inverted U-shaped relationship

of TOPI is positive and $TOPI^2$ is negative and both are significant. These estimations suggest a significant inverted U-shaped relationship between patenting and monopoly power. We also note that this nonlinearity exists only during 1995–2005. During post-TRIPs era, we do not find any nonlinear relationship. In post-TRIPs phase, firms are focusing more on R&D and patenting activities as a source of monopoly power. There are other strategic reasons for increased patenting in post-TRIPs regime like protection against infringement, strengthening competitive advantage, creation of entry barriers, and protection from litigation. Firms' in new patent regime are engaged in efficient production through technological innovations and effective coordination through other non-technological innovations.[8] Contract research and collaborative R&D has also increased among Indian firms. Firms' technological strategies like interaction between in-house innovations and technology imports also sustain the long-term positive relationship between innovation and firms' performance.

UK. Further, Dhanora et al. (2018) also find inverted U-shaped relationship between product and process innovation and firms' monopoly power in Indian pharmaceutical industry.

[8]Non-technological innovations include marketing and organizational innovations.

Table 9 Summary of the results

		Transition phase (1995–2005)		Post-TRIPs phase (2006–2015)	
		High technology	Medium technology	High technology	Medium technology
Impact of market power on innovation	Linear	Insignificant	Positive significant	Insignificant	Positive significant
	Nonlinear	Insignificant	Insignificant	Negative significant	Negative significant
Impact of innovation on market power	Linear	Positive significant	Positive significant	Positive significant	Positive significant
	Nonlinear	Negative significant	Negative significant	Insignificant	Insignificant

In Table 7, the coefficient of AGE is positive and significant in columns I and V which suggest that older and experience firms are enjoying more monopoly power. The coefficient of CAPITAL is negative and significant in columns I and V. Kambhampati and Parikh (2003) also reported same results for Indian manufacturing firms. They explain this negative relationship in terms of under utilization of capital as a factor of production. Market growth rate (MGR) has significant and positive influence on WLI in post-TRIPs regime. In Table 8 also we find that MGR is positively influencing WLI.

7 Conclusion

This study explores the impact of patent policy change on the relationship between innovation and monopoly power spanning from 1995 to 2015. We have classified analysis into two time period as 1995–2005 and 2006–2015. With the third amendment to the Patent Act 1970 which was introduced through the Patents (Amendment) Ordinance, 2004, with effect from January 1, 2005, which was later replaced by the Patents (Amendment) Act 2005, Government of India complied with TRIPs agreement. The period 1995–2005 was the transition phase for patent policy change as three amendments (1999, 2002 and 2005) were made in the Patent Act 1970. For the period 2006–2015, real implications of strengthening patent policies can be realized on R&D, patenting, and monopoly power. We utilized weighted Lerner index as a measure of monopoly power and granted patents to measure firm-level innovation activities.

Empirical analysis based on high and medium technology firms suggest interdependence between innovation and monopoly power; however, this relationship varies with change in patent policy. For high and medium technology firms, there is nonlinear impact of monopoly power on patenting activities in post-TRIPs regime; however, this relationship is insignificant during transition phase of patent policy change. While examining the impact of patenting on monopoly power, we find that patenting has positive and significant impact on firms' monopoly power in both pre- and post-TRIPs regime. While examining nonlinear relationship, we find inverted U-shaped relationship between patenting and monopoly power during 1995–2005 only.

Based on empirical analysis, this study has important policy implications for developing countries like India. In Indian context, this study suggests that in-house innovation activities are also potential source of firms' monopoly power as the causality also runs from innovation to monopoly power. This relationship is stronger in post-TRIPs era as we do not find any nonlinear impact of innovation on monopoly during this period. An innovative firm can dominate the market by conducting more technological innovations.

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