Do Stronger IPR Regimes Influence R&D Efforts? Evidence from the Indian Pharmaceutical Industry

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Abstract

This article is an attempt to empirically analyze the technology behaviour (R&D) of the Indian Pharmaceutical Industry (IPI) during the post Trade Related Aspects of Intellectual Property Rights (TRIPS) regime. This study is based on firm level data of 424 firms belonging to the IPI for the period 1994–2010. The empirical analysis is based on pooled cross sectional and random effects panel tobit models. The results of the study indicate that the TRIPS regime had a significant positive impact on R&D in the IPI. Firms owned by Indian groups are found to be more R&D intensive compared to stand-alone private and foreign firms. Further, export intensity and size are found to have significant impact on R&D intensity.

Introduction

The Indian Pharmaceutical Industry (IPI) has gone from merely converting imported bulk drugs into formulations, at the turn of the twentieth century, to manufacturing the entire range of drugs, by the beginning of the twenty-first century. Most of this technological capacity was developed in the decades after 1970, and the intellectual property regime brought about by the Patent Act of 1970 was crucial for this growth. The Patent Act of 1970 allowed only process patents for foods, pharmaceuticals and agricultural chemicals, which enabled reverse engineering, which in turn led to the development of domestic technological capability. Process innovation enabled growth, because it carried lower risk of failure[1] and entailed lower costs of development[2]; and lower costs implied that the product could be marketed at lower prices to a large market—domestically and abroad.

India signed the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS agreement) in 1994. The aim of TRIPs is to strengthen patent protection worldwide—particularly in developing countries like India, which did not provide strong intellectual property rights (IPR) protection for pharmaceuticals and agricultural chemicals. India complied with the TRIPS agreement in a phased manner, and the Patent (Amendment) Act of 2005 completed the transition to product patents. Now, Indian firms that wish to expand their activities beyond the production of off-patent drugs have to develop completely new drugs through research, or license molecules from innovator firms.

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It is argued that the new patent regime will drive up the costs of medical care, as people are forced to buy expensive patented drugs (Lanjouw, 1999). However, the proponents of the TRIPS agreement argue that it would result in overall gains to the society. This is in consonance with economic theory, where static welfare losses, in the form of higher costs created by monopolies,[3] are offset by dynamic welfare gains through greater innovation. However, it can be argued that the benefits of patent protection (welfare gains from innovation) would accrue to the developed countries, while developing countries would pay higher prices for patented products (welfare losses). The benefits of patent protection accrue to developed countries, since they undertake the majority of the research in the world.[4] Several studies have found that a harmonization of patent regimes would benefit the developed nations at the cost of developing nations (Grossman and Lai, 2004). Further, Deardorff (1992) finds that the number of drugs developed under the new patent regime would have to be three times the previously available amount, to keep consumers in less developed countries equally well off. In this context, an emerging economy like India needs to enhance its innovation through increased R&D investments. The IPI has been a shining example of development of world class technological capacity indigenously. In order to meet the current requirements, it needs to shift the focus from process to product innovation to survive and grow in the TRIPS regime. Against the above backdrop, the present study attempts to analyze the effect of the TRIPS agreement on the R&D activities of the IPI.

The remainder of the article is organized as follows. Evolution of the IPI is given in the second section. The third section discusses the theoretical background and relevant literature. Data source and variable descriptions are presented in the fourth section. The fifth section describes the methodology employed in the empirical analysis. The findings of the empirical analysis are presented in the sixth section. The final section concludes.

Indian Pharmaceutical Industry—Evolution

India is one of the few countries in the world where MNCs do not dominate the pharmaceutical market. It is the third-largest market in the world in terms of volume, and 14th in terms of value.[5] The fact that India has 75 US Food and Drug Administration (USFDA) approved manufacturing facilities, the highest in any country other than the US, is testament to its technological capabilities.

The current scenario is almost diametrically opposite to what was prevailing at the time of Independence. The industry was in the hands of a few MNCs; drug prices were among the highest in the world; technology for the production of essential drugs was denied to India; and the only manufacturing activity was the conversion of imported bulk drugs into formulations (Chaudhuri, 2005). By the early 1950s, very few drugs, such as tetanus anti-toxins, were produced from the initial stages. Domestic production capabilities grew over time, and by the 1970s about 100 essential drugs were produced from the initial stages. Currently, the IPI produces the entire range of bulk drugs ranging from anti-infective to anti-diabetes. The IPI has grown from meeting the needs of 20 per cent of the domestic market in 1970 to supplying 95 per cent of the market in 2006 (Haley and Haley, 2011).

The dramatic growth of the IPI is due to success in developing generic drugs through reverse engineering. However, relatively few Indian firms engage in R&D. Though, the number of R&D spenders has almost doubled from 1994 to 2010, the percentage of firms that undertake R&D has almost remained constant. The average R&D intensity of the IPI is around 1.5 per cent, compared to 15 per cent in the West.

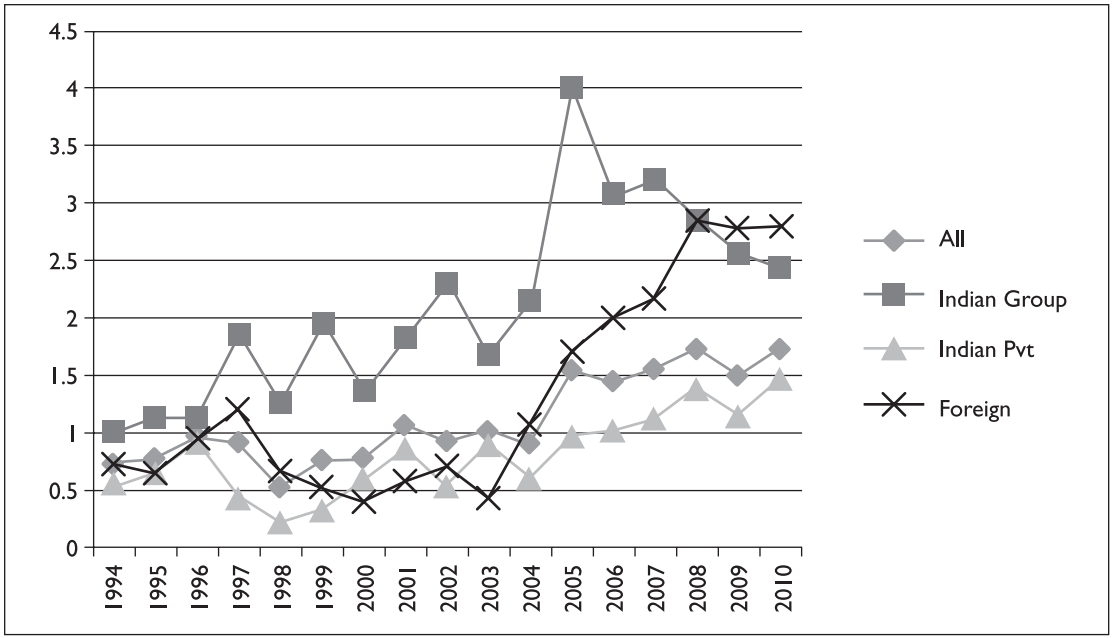

Figure 1. Trends in R&D intensity of IPI

Source: Own calculations based on CMIE PROWESS database.

Even when we consider the R&D intensity of only the largest Indian companies, it is only one-third of their Western counter parts.

When we examine the trends in R&D intensity of IPI (Figure 1), it is evident that there has been an increase of almost 50 per cent (from around 1 per cent in 2004 to around 1.5 per cent by 2010) when all firms are considered together. The R&D intensity of Indian private firms has increased even more dramatically from around 0.5 per cent to around 1.5 per cent in the period 2004–2010. It is interesting to note that foreign firms are increasingly using India as a base for their R&D efforts. During the study period, it was observed that the average R&D intensity of foreign firms increased from less than 0.5 per cent to around 3 per cent. However, in the case of Indian business group affiliates the R&D intensity increased sharply around 2005, and then declined steadily.

Since the adoption of the new IPR regime, there have been an increasing number of patent filings, and an accompanying increase in the patents granted—both by Indian and US patent offices. Table 1 examines the patent applications filed by leading Indian generics firms at the global level. We can notice that among the Indian firms, Ranbaxy leads the pack with an almost 20-fold increase in patent filings (from around 14 in 1999 to 259 in 2005). Almost all the firms in the table show similar patterns in patenting, with Sun Pharmaceuticals and Aurobindo Pharma being the exceptions.

Since the development of drugs from initial to final stage is prohibitively expensive, Indian companies initially adopted the model of developing new molecules up to a certain stage, and then licensing it out to MNCs. Due to failures in this licensing model, the IPI has moved on to other means of research collaboration such as joint development and sharing of costs with specialized research companies.

Table 1. Worldwide Patent Applications by Leading Indian Generics Firms

Firms	1999	2000	2001	2002	2003	2004	2005
Ranbaxy Laboratories Ltd.	14	31	53	69	127	208	259
Cipla Ltd.	0	5	15	12	21	38	56
Dr. Reddy's Laboratories Ltd	3	5	5	25	69	77	49
Lupin Ltd.	12	9	8	8	12	25	32
Cadila Healthcare Ltd.	1	2	3	9	14	19	29
Wockhardt Ltd.	2	0	3	14	14	18	25
Orchid Chemicals and Pharmaceuticals Ltd.	0	1	1	7	31	48	25
Nicholas Piramal India Ltd.	0	0	1	7	4	8	11
Sun Pharmaceuticals India Ltd.	1	0	2	0	2	8	4
AurbindoPharma Ltd.	0	0	0	5	6	9	2
TOTAL	**33**	**53**	**91**	**156**	**300**	**458**	**492**

Source: Dhar and Gopakumar (2008).

Theoretical Underpinnings and Previous Studies

According to economic theory, there are several factors that affect R&D decisions. The most important ones are size and market concentration. Schumpeter's hypothesis states that only large firms can have the large amount of resources required to undertake R&D, and large firms are most likely to occur in concentrated markets (Schumpeter, 1942). Bain (1954) suggests that a less competitive market structure leads to expectations of higher returns, which acts as an incentive for innovation. Therefore, size and market concentration have a positive effect on R&D. With this theoretical framework in place, the relevant literature is examined in this section. The studies surveyed can be broadly classified into (*i*) the determinants of R&D and (*ii*) the effect of patent regimes on innovation.

Determinants of R&D

In one of the earliest studies on firm level determinants of R&D in India, Siddharthan and Agarwal (1992) investigated the factors that determine R&D decisions of Indian firms. The study reported that larger firms had a greater possibility of engaging in R&D but the intensity of R&D declines with size. Ray and Ur-Rahman (2000) examined the behavioural differences between multinational and local firms in the IPI, using a case study of two large firms in the IPI—Ranbaxy and Pfizer. It finds that the multinational firm Pfizer's commitment to local R&D is aligned with the parent firm, while the domestic firm is strongly committed to R&D. The MNC's unwillingness to conduct R&D in India is attributed to the unsatisfactory patent regime. Kumar and Aggarwal (2005) analyzed the determinants of the R&D behaviour of Indian enterprises in the context of the reforms of 1991. The authors find differences in motivation for R&D between local firms and multinational affiliates, while the former aim to absorb and adapt imported technology, the latter undertake research to support that of their parent companies. Kathuria (2008) examined the impact of Foreign Direct Investment (FDI) inflows on R&D activities of Indian manufacturing enterprises in the post liberalization period. The study found that FDI inflows had a negative impact on R&D in the first period, but had no significant impact in the second

period. Ghosh (2009) examined the factors influencing R&D in Indian manufacturing enterprises. The author concludes that larger companies have a higher probability of pursuing R&D, although with lower intensity. In a recent study of R&D strategy of small and medium enterprises (SME) in India, Pradhan (2010) finds that age, export intensity and profit margin have significant positive impact on R&D.

Patent Regimes and Innovation

Scherer and Weisburst (1995) studied the economic effects of Italy's adoption of pharmaceutical patents in 1978, and found that product patents did not spur an increase in research and development.[6] Sakakibara and Branstetter (2001) examined the impact of broadening of patent scope in Japan in 1988 on the R&D spending of manufacturing firms in general as well as pharmaceutical companies specifically. The study concluded that there was no increase in R&D spending due to patent reform—both for the entire sample and pharmaceutical firms in particular. Based on a cross-section of countries, Qian (2007) analyzed the impact of introduction or strengthening of pharmaceutical patents on domestic innovation. The study reports that the implementation of patent laws alone cannot promote innovation; and that there is an optimal level of IPR protection, beyond which strengthening tends to discourage innovation. Ryan (2010) studied bio-medical innovation projects in Brazil, in the aftermath of patent reform in 1996, to determine whether stronger patent regimes promote development of indigenous technology. The study was based on five in-depth case studies of bio-medical innovation projects in the state of Sao Paulo. The study found that patents encouraged investments in R&D and facilitated technology markets.[7] Czarnitzki and Toole (2011) examined the efficacy of patents, as a mechanism for appropriating returns, for the German manufacturing sector. The main finding was that patent protection reduced firms' sensitivity to market uncertainty, leading to greater investment in R&D. Lo (2011) attempted to determine the impact of strengthening patent rights in a developing economy, by examining the 1986 Taiwanese patent reforms. The main finding of the study was that reforms induced additional innovative activity and patenting, especially in industries where patent protection is considered an effective strategy for appropriating returns and in R&D intensive industries.

Gehl Sampath (2007), studying the impact of the TRIPS agreement on R&D in the IPI, found that patent protection had a negative impact on the number of R&D projects pursued by the IPI. Chaudhuri (2007) examines the motivation behind a dramatic increase in R&D expenditure by certain IPI firms in the TRIPS regime. The study concludes that the primary reason driving patenting was the product patent regime in the developed countries, and the TRIPS agreement had not made any impact on the R&D behaviour of IPI firms. Chadha (2009) examined the impact of a stricter patenting regime on the IPI. The study reported that stronger patent laws have induced more patenting activity. Haley and Haley (2011) analyze the impact of patent law changes on innovation in India's pharmaceutical industry. The study concludes that growth of innovation has declined under the product patent regime.

Based on the exhaustive survey of literature, we find that size and outward orientation have a positive influence on R&D investment expenditures. Studies examining the effect of patent regime changes and R&D investments are largely inconclusive. In this study, we use a rich firm level data from 1994 to 2010 to analyze the effect of the new TRIPS regime on R&D efforts of the IPI.

Data Source, Variable Description and Sample Characteristics

The firm level data are obtained from the Prowess database provided by the Centre for Monitoring Indian Economy (CMIE). Prowess covers more than 25,000 firms including all companies trading on India's major stock exchanges belonging to manufacturing, services, utilities and financial sectors. The companies included in Prowess account for 75 per cent of all corporate taxes, 60–70 per cent of organized sector output and 95 per cent of excise duties collected (Goldberg et al., 2010). The database includes both listed and unlisted firms. Data from Prowess have been used in several previous studies such as Pradhan (2010) and Kumar and Aggarwal (2005).

For the purpose of the present study, we followed two truncation rules while cleaning the data. First, those firms reporting negative or zero values for sales, gross fixed assets were dropped. Second, from the remaining observations, firms with data for 4 years or more were selected for the final analysis. After this process, the final sample consists of an unbalanced panel data of 4,444 observations belonging to 424 firms. The period of the study is 1994–2010.

Explanatory Variables

The firm's investment in R&D depends on a number of factors such as resource availability, technology sourcing choice and availability of finance and ownership pattern. The present section discusses, in detail, the role of various factors in influencing the R&D efforts of firms. Table 2 presents the summary of explanatory variables and their expected sign.

Table 2. Summary of Explanatory Variables

Variable Name	Description	Expected Sign
Dependent variable		
R&D intensity (RDINT)	R&D expenditure as a percentage of total sales of *i*th firm in *t*th year	
Independent variables		
Size (LNSALES)	Deviation of log sales from median values of respective year	+
Size2 (LNSALES2)	Square of size	−
Age (AGE)	Years since incorporation	+
Age2 (AGE2)	Square of age	−
Profitability (PROFIT)	Profit as a percentage of sales	?
Export intensity (EXPINT)	Exports as a percentage of sales	+
Capital goods import intensity (CGINT)	Capital goods imports as a percentage of sales	+
Royalty intensity (TECHIMPINT)	Royalty as a percentage of sales	+
Return on assets (ROA)	Profits as a percentage of gross fixed assets	?
Indian group dummy (IGD)	Takes value of 1 if firm belongs to Indian group, else 0	+
Foreign dummy (FD)	Takes value of 1 if firms is foreign owned, else 0	?
Trips dummy 1999 (TD1999)	Takes the value 1 for the year 1999 onwards and 0 otherwise, to account for the first amendment to the Indian Patent Act (1970)	+

Variable Name	Description	Expected Sign
Trips dummy 2005 (TD2005)	Takes the value 1 for the year 2005 onwards and 0 otherwise, to account for the final amendment to the Indian Patent Act (1970), in order to comply with the TRIPS agreement	+
Time trend (TIMETREND)	Takes value of 1 for 1994 and increases by 1 per year, till 17 for 2010	−

Source: Own calculations.

Age

The age of a firm, measured as the number of years since its incorporation, captures firm experience and knowledge accumulation and is used a proxy for differences in efficiency (Erikson and Pakes, 1995). According to Klepper's (1996) product life cycle model, there is an inverse relation between age and propensity to innovate, since older firms face less technological opportunities and are therefore less inclined to spend on R&D. However, Ghosh (2009) finds a positive relationship between age and R&D spending in the Indian context—the intensity and the probability of undertaking R&D initially declines for older firms, but subsequently firms are forced to innovate in the face of competition. Similar results were obtained by Goldar and Reganathan (1998). Hence, we expect a quadratic relation between age and R&D intensity along these lines.

Size

Sales is used as a proxy for the size of the firm and is measured as the deviation of log of total sales of the firm, from the median values for each year. Klevorick et al. (1995) find that increasing firm size had a positive effect on R&D intensity, because larger firms are able to appropriate more returns from their innovative activity. In addition, Blumenthal (1979) argues that the relationship depends on several other factors such as the nature of R&D, the degree of risk aversion of private firms, government participation in/support for high-risk projects and industry structure. Therefore, we expect a positive relationship between size and R&D intensity.

Technology Imports

Based on the existing studies, in order to accurately capture the role of technology imports, one can make further classification of the same as (*i*) embodied technology imports and (*ii*) disembodied technology imports.

Capital Goods Imports Intensity (Embodied)

Capital goods imports are also called embodied technology imports, as the technology is embodied within the machine that is imported. It is measured in terms of capital goods imports as a percentage of total sales of the firm. The existing studies have found a positive relationship between capital imports and R&D activities in the case of Indian manufacturing firms (Basant, 1997; Kumar and Aggarwal, 2005). Therefore, we posit a positive relationship between the two variables.

Royalty Intensity (Disembodied)

In the present case, royalty intensity is measured as expenditure on royalties and licensing fees as a percentage of total sales. The literature on Indian firms, by and large, supports complementarity between disembodied technology imports and R&D expenditure (Deolalikar and Evenson, 1989; Katrak,

1985; Kumar, 1987; Lall, 1983). However, Kumar and Saqib (1996) found neither complementarity nor substitution effect dominating the relationship. We expect a positive relationship between royalty intensity and R&D intensity.

Exports Intensity

Firms that compete globally need to invest in R&D activities to undertake product and process adaptations for foreign markets. Those firms with greater outward orientation are likely to undertake R&D than those oriented toward domestic markets. The literature on emerging economies is mainly in support of this hypothesis—for instance Braga and Willmore (1992) for Brazil and Goldar and Renganathan (1998) for India. According to Zimmerman (1987), exports are likely to increase the returns to investment in R&D activities by increasing the size of the markets. Other Indian studies such as Ghosh (2009), Kumar and Saqib (1996), Kumar and Aggarwal (2005), Rao et al. (1994) find that exporting firms undertake more R&D than domestically oriented ones. Based on the results of the previous studies, we expect a positive relationship between export orientation and R&D intensity.

Ownership

Sources of finance also affect the decision to undertake R&D. Since investment in R&D is risky and uncertain, firms find it difficult to obtain funds. The firms included in our study belong to three ownership groups: stand-alone firms, foreign and business group affiliates. Since foreign owned firms and affiliates of Indian business groups have access to resources from the parent firms, they are in a better position to undertake investments in R&D. Ghosh (2009) found that in the case of Indian manufacturing industries, foreign firms exhibit the lowest R&D intensity. Similar results were reported by some of the previous Indian studies such as Kumar and Saqib (1996) and Kumar and Aggarwal (2005). On the contrary, Pradhan (2010) in his study on SME in India reports that foreign affiliates tend to have high R&D intensities.

Profitability

As returns from R&D are highly uncertain, lenders might be unwilling to finance it, and firms will have to depend mainly on internally generated resources. Profits are the main source of internally generated resources. Pradhan (2010) finds a positive relationship between profit margins and R&D intensity for Indian firms. However, based on a comparative study of R&D activities of Indian and foreign firms, Kumar and Aggarwal (2005) report a negative relationship between profit margins and R&D expenditure. Mensch (1979) argues that during economic adversity firms with declining profits would undertake R&D investments to capture markets. Inderrieden et al. (1990) report R&D expenditure of Australian firms increased when past R&D efforts had failed and past economic performance had been poor. Similarly, Hundley et al (1996) found that Japanese firms increase R&D in response to declining profits. Due to the inconclusive results of the existing studies, we are uncertain about the possible relationship of this variable to R&D intensity.

Return on Assets (RoA)

RoA is used as an alternative measure of profits. It is measured by taking gross profits as a percentage of gross fixed assets. The only previous study that used this measure is by Ghosh (2009) for Indian manufacturing firms. Ghosh (2009) finds a positive relation between this variable and R&D intensity.

TRIPS

In order to capture the effect of the TRIPS regime, we include two dummy variables. A partial implementation of the TRIPS agreement was made in 1999 and complete transition to the TRIPS regime was made by 2005, with the implementation of product patents. Therefore, dummy variables representing 1 for the concerned year (1999 or 2005) and 0 otherwise are included in the model specification. A positive effect is expected for the TRIPS dummies, since the new patent regime would induce firms to engage in more R&D activities.

Time Trend

A time trend taking the value of 1 for 1994, and increasing in value by 1 every year has been included to capture any underlying trends that are not captured by any of the variables. We expect that the model is correctly specified and hence the time trend will be negative.

Summary Statistics

Table 3 reports the summary statistics of the variables included in the study. During the period of the study, mean R&D intensity of the sample firms has more than doubled (0.73 per cent–1.73 per cent). However, the average profitability and return on assets have declined. The export intensity has increased from 11 to 19 per cent. Royalty intensity has more than doubled (0.02 per cent–0.05 per cent). Capital import intensity has also increased on a similar scale (0.24 per cent–0.66 per cent). However the royalty intensity and capital import intensity continue to be very low in absolute terms. The mean age of the sample is around 22 years.

Empirical Model

The econometric modelling undertaken in this study has taken into account the censoring problem of the dependent variable (R&D), that is, there are a large number of firms with zero values for R&D. Therefore, the present study uses random effects panel tobit and pooled cross-sectional tobit models, following Czarnitzki and Toole (2011). Under the assumption of no firm specific effects, a pooled cross-sectional

Table 3. Summary Statistics of the Explanatory Variables

Variable	Entire Sample	1994	2010
R&D intensity	1.15(3.47)	0.72(1.74)	1.73(4.09)
Age	21.56(17.56)	18.21(18.66)	27.24(17.68)
Size (ln of sales)	2.36(0.93)	2.18(0.8)	2.67(1.07)
Profitability	−4.22(124.28)	11.79(17.27)	−3.96(104.58)
Return on assets	26.49(81.91)	51.22(74.80)	26.97(96.07)
Export intensity	15.94(24.04)	11.13(19.63)	19.69(26.87)
Royalty intensity	0.04(0.29)	0.02(0.09)	0.05(0.42)
Capital import intensity	0.70(3.83)	0.24(0.96)	0.66(2.39)

Source: Own calculations.
Notes: Figures in parentheses are standard deviations.

model can be employed. The model has the advantage that it is not necessary to maintain the strict exogeneity assumption. In the second version of the model, we assume that there is a firm-level heterogeneity, and a random-effects panel tobit model is employed. Consistency of the random-effects model requires the strict exogeneity assumption. Further, the random-effects tobit is based on the assumption of absence of correlation between the firm specific effect and the explanatory variables. Since the random effects panel tobit is based on the strong assumptions stated above, Czarnitzki and Toole (2011) suggest that the panel specification is not necessarily superior to the pooled cross-sectional results.

The model can be represented as:

$$y_{i,t} = \max(0, z_{i,t}\,\beta + v_i + u_{i,t})$$

$i = 1, 2, \ldots, n$ indexes firms; $t = 1, 2, \ldots, k$ indexes time periods.

$$u_{i,t}|x_{i,t}, c_{i,t} \sim N(0, \sigma^2_u)$$

where $y_{i,t}$ is the dependent variable, $z_{i,t}$ represents the set of regressors, β the coefficients of the parameters, the individual unobserved firm specific effect is given by $v_{i,t}$ and $u_{i,t}$ is the random error term.

An estimation issue faced during the empirical analysis is the potential endogeneity of several explanatory variables. While export oriented firms might engage in more R&D, it could also be that firms engaging in R&D are able to capture export markets. Similarly, while technology imports influence R&D efforts, firms that engage in more R&D might import more technology. Owing to the limitation of the data set in obtaining good instruments, to overcome the endogeneity problem, one year lagged values of explanatory variables are used. Further, we use boot strapped standard errors to deal with potential heteroskedasticity in all models.

Two specifications are used. The first specification has R&D intensity as the dependent variable, the TRIPS dummy for 2005 and the set of control variables. In the second specification the quadratic terms of age and size are added to the first specification to capture any non-linear relations between these control variables and the dependent variables. Both these specifications are repeated, with TRIPS dummy 1999 replacing TRIPS dummy 2005. The final specifications used in the empirical analysis are given below.

$$\begin{aligned}\mathrm{RDINT}_{i,t} = {} & \beta_0 + \beta_1 Z + \beta_2 \mathrm{AGE}_{i,t-1} + \beta_3 \mathrm{LNSALES}_{i,t-1} + \\ & \beta_4 \mathrm{PROFIT}_{i,t-1} + \beta_5 \mathrm{EXPINT}_{i,t-1} + \beta_6 \mathrm{TECHIMPINT}_{i,t-1} + \beta_7 \mathrm{CGINT}_{i,t-1} \\ & + \beta_8 \mathrm{ROA}_{i,t-1} + \beta_9 \mathrm{IGD}_{i,t} + \beta_{10} \mathrm{FD}_{i,t} + \beta_{11} \mathrm{TIMETREND}_{i,t} + u_{i,t}\end{aligned} \tag{1}$$

$$\begin{aligned}\mathrm{RDINT}_{i,t} = {} & \beta_0 + \beta_1 Z + \beta_2 \mathrm{AGE}_{i,t-1} + \beta_3 \mathrm{AGE2}_{i,t-1} + \beta_4 \mathrm{LNSALES}_{i,t-1} + \beta_5 \mathrm{LNSALES2}_{i,t-1} + \\ & \beta_6 \mathrm{PROFIT}_{i,t-1} + \beta_7 \mathrm{EXPINT}_{i,t-1} + \beta_8 \mathrm{TECHIMPINT}_{i,t-1} + \beta_9 \mathrm{CGINT}_{i,t-1} + \beta_{10} \mathrm{ROA}_{i,t-1} + \beta_{11} \mathrm{IGD}_{i,t} + \\ & \beta_{12} \mathrm{FD}_{i,t} + \beta_{13} \mathrm{TIMETREND}_{i,t} + u_{i,t}\end{aligned} \tag{2}$$

where Z = TRIPS dummy for 1999 and 2005, respectively.

Results and Discussion

Specification A

The results of the Specification A are discussed first (Table 4). Coming to the main variable of interest, TRIPS dummy 2005, we find a positive and significant effect. The results are robust to both pooled cross-section and panel tobit methodology. The result confirms our basic hypothesis, and indicates that the IPI has made suitable changes to its R&D strategy after the transition to product patents in 2005. This finding is similar to that of Chadha (2009) who reports that stronger patent laws have induced more patenting activity in the IPI; our results are in line with Ryan (2010) who concluded that patents provide incentives to make risky investments in innovation in Brazil. Similarly, Czarnitzki and Toole (2011) report that patents mitigate uncertainty and induced more R&D in Germany and Lo (2011) showed that patent reform encouraged R&D across industries in Taiwan.

Export intensity has a significant positive impact on R&D intensity in both models. This is in accordance with our expectation and supports the results of the existing studies of Ghosh (2009), Kumar and Saqib (1996) and Kumar and Aggarwal (2005). Export oriented firms have access to large foreign markets and can reap more rewards from innovation. They also have to compete with highly innovative foreign firms. Hence, they are likely to undertake more R&D.

Table 4. Determinants of R&D in the IPI with TRIPS Dummy 2005

	Specification A		Specification B	
Variable	Pooled Cross-Sectional Tobit	Random Effects Panel Tobit	Pooled Cross-Sectional Tobit	Random Effects Panel Tobit
td2005	0.891(0.358)***	1.165(0.477)***	0.869(0.454)**	1.178(0.402)***
Trend	0.0(0.037)	−0.036(0.052)	−0.016(0.042)	−0.063(0.042)
Indgrpdummy	0.690(0.254)***	1.387(0.764)**	0.450(0.289)*	1.101(0.786)
Fordummy	–0.068(0.318)	1.514(1.087)	0.326(0.322)	1.29(0.979)
Lagsalesmd	3.875(0.264)***	3.909(0.710)***	3.7(0.247)***	3.880(0.656)***
lagsalesmd2	–	–	0.533(0.254)***	0.666(0.673)
Lagage	0.006(0.005)	0.031(0.018)*	0.035(0.015)***	0.071(0.038)**
lagage2	–	–	−0.0004(0.0002)***	−0.0005(0.0004)
Lagprofit	–0.002(0.007)	−0.004(0.003)	−0.0004(0.010)	−0.003(0.004)
Lagexportint	0.036(0.005)***	0.034(0.012)***	0.035(0.005)***	0.031(0.011)***
Lagcapimpint	0.088(0.047)**	0.067(0.056)	0.085(0.051)*	0.071(0.055)
Lagroyint	0.994(0.458)**	0.341(0.366)	0.987(0.402)***	0.411(0.440)
Lagroa	−0.003(0.002)**	−0.003(0.003)	−0.003(0.002)**	−0.003(0.002)
Constant	–4.272(0.557)***	−6.237(0.862)***	−4.607(0.596)***	−6.649(1.100)***
Log likelihood	−5,710.586	−5,148.09	−5,701.08	−5,140.225
Pseudo R2	0.090	–	0.092	–
Wald Chi^2	285.41***	113.02***	488.38***	130.16***
No. of observations	3,866	3,866	3,866	3,866

Source: Own calculations.

Notes: Figures in parentheses are standard errors generated through bootstrap. ***, ** and * indicate 1 per cent, 5 per cent and 10 per cent level of significance, respectively.

Size is highly significant in both models and has a positive impact on R&D intensity. This result is as per the expectation and in consonance with that of previous Indian studies such as Katrak (1985), Lall (1983) and Kumar and Saqib (1996). Larger firms have more resources to spend on R&D, and therefore they can bear the risk of failure involved. Further, they also have a large market share, enabling them to reap greater benefits from the results of innovation. Age is found to be insignificant in both the models. This is contrary to our expectation and can be attributed to the rapidly changing technology and market dynamics in the pharmaceutical industry, which make accumulated knowledge less relevant to the current scenario.

Firms owned by Indian groups are shown to have higher levels of R&D as compared to other Indian firms. This result is in line with the findings of Ghosh (2009). Similar to Kumar and Saqib (1996) and Kumar and Aggarwal (2005), we find that foreign ownership has no significant impact in any model. Profitability turned out to be insignificant. This is contrary to expectations. Since investment in R&D is a continuous and long-term process, it may not be affected by short-term fluctuations in profitability. The coefficient of RoA is negative and significant in the pooled cross sectional model, with very small magnitude. The negative relation is similar to those found in Mensch (1979), Hundley et al. (1996) and Kumar and Aggarwal (2005). Firms with decreasing return on assets might be undertaking R&D to enlarge market share or capture new markets with innovative products. As expected, royalty intensity and capital import intensity have a positive impact. However, both are significant only in the pooled cross sectional model.

Specification B

The results of Specification B are broadly along the same lines as Specification A (Table 5). The impact of TRIPS dummy 2005 is positive and significant in both models. Export intensity is highly significant and has a positive impact on R&D intensity. Size is found to have a significant and positive impact in both models while the square of age is significant and positive only in the pooled cross sectional model. We can conclude that the relationship between size and R&D intensity is not non-linear in nature. Age is also found to have a significant positive impact in both models. Unlike the previous specification we find, the impact of the age squared is negative and significant, but with very small magnitude. This could indicate the presence of non-linear relationship, which is similar to those found by Ghosh (2009) and Goldar and Reganathan (1998). Similar to Specification A, the Wald Chi^2 is of a large magnitude and highly significant in both models.

The results of replacing TRIPS dummy 2005 with TRIPS dummy 1999 in the two specifications are almost identical. The main finding is that the TRIPS dummy 1999 is not significant in both pooled cross sectional and random effects panel tobit models. This indicates that first amendments to the Indian Patent Act in 1999 failed to have any impact on the R&D behaviour of firms in the IPI.

Conclusions

Based on the empirical analysis, the present study finds that the Patent (Amendment) Act of 2005, undertaken to comply with the TRIPS agreement, has had a significant positive impact on the R&D

Table 5. Determinants of R&D in the IPI with TRIPS Dummy 1999

	Specification A		Specification B	
Variable	Pooled Cross-Sectional Tobit	Random Effects Panel Tobit	Pooled Cross-Sectional Tobit	Random Effects Panel Tobit
td1999	−0.565(0.385)	−0.55(0.344)*	−0.555(0.394)	−0.570(0.394)
Trend	0.120(0.034)***	0.106(0.044)***	0.100(0.043)***	0.081(0.049)*
Indgrpdummy	0.687(0.245)***	1.377(0.865)*	0.447(0.334)	1.093(0.702)*
Fordummy	−0.074(0.271)	1.449(1.253)	−0.332(0.408)	1.227(0.918)
Lagsalesmd	3.874(0.209)***	3.921(0.865)***	3.696(0.257)***	3.888(0.547)***
lagsalesmd2	–	–	0.532(0.201)***	0.661(0.510)
Lagage	0.006(0.005)	0.031(0.016)**	0.035(0.013)***	0.073(0.042)*
lagage2	–	–	−0.0004(0.0001)***	−0.0006(0.0004)
Lagprofit	−0.002(0.008)	−0.003(0.006)	−0.000(0.008)	−0.002(0.004)
Lagexportint	0.036(0.005)***	0.034(0.011)***	0.035(0.006)***	0.031(0.010)***
Lagcapimpint	0.089(0.05)**	0.069(0.054)	0.086(0.044)**	0.074(0.057)
Lagroyint	0.989(0.378)***	0.336(0.369)	0.983(0.402)***	0.407(0.528)
Lagroa	−0.003(0.002)**	−0.003(0.004)	−0.003(0.002)**	−0.002(0.003)
Constant	−4.652(0.432)***	−6.735(1.156)***	−4.986(0.484)***	−7.17(0.805)***
Log likelihood	−5,711.917	−5,152.172	−5,702.3671	–5144.488
Pseudo R2	0.09	–	0.092	–
Wald Chi^2	720.06***	110.88***	530.51***	135.98***
No. of obs	3,866	3,866	3,866	3,866

Source: Own calculations.

Notes: Figures in parentheses are standard errors generated through bootstrap. ***, ** and * indicate 1 per cent, 5 per cent and 10 per cent level of significance, respectively.

intensity of IPI firms. This confirms the expectations of policymakers and the suitability of the phased transition in patent regime. The beneficial effect of the strengthening of patent regime could be because the IPI had developed a threshold of absorptive capacity through its efforts in reverse engineering. The study reveals that export intensity has a significant and positive impact on R&D intensity of IPI firms. This could imply that firms are engaging in R&D to develop new products and create knowledge assets, that can enable it to establish a foothold in international markets. Further, our results could also imply the existence of a 'learning by exporting' effect on R&D. The analysis also reveals that size, foreign ownership and Indian business group affiliation have a significant and positive impact on R&D intensity of IPI firms.

The main limitation of the current study is that it is not able to give a complete picture of the innovation process, due to the unavailability of firm level patent data, that is, only R&D, expenditure which is the input to the process of innovation, is covered, and patents, which are the output of the innovation process, are not covered. This study can be extended in several ways. Detailed case studies can be undertaken to obtain qualitative information to support findings.

Notes

1. According to the Pharmaceutical Research and Manufacturers of America (PhRMA)—Pharmaceutical Industry Profile 2005, only one in five drugs that undergo clinical trials are approved by the USFDA. In the case of process innovation the usability of the final product is proven.
2. Firms do not have to bear the costs of proving the safety and efficacy of the drugs through clinical trials, since these trials have already been conducted by the original inventor.
3. A patent essentially gives the inventory monopoly rights over the marketing of the invention, for a legally specified period of time.
4. According to the UNESCO Global Investment in R&D 2011 factsheet, in 2007 the United States, European Union and Japan accounted for 32.6 per cent, 23.1 per cent and 12.9 per cent respectively of global R&D, making a total of 68.6 per cent.
5. Taking wings, Ernst and Young (2009).
6. However, the authors admit that prevailing price control on pharmaceuticals may have had a confounding effect on results.
7. The state of Sao Paulo is the second largest investor in R&D in Latin America, ahead of Mexico and Argentina. The state government has invested in basic life sciences research at its universities and governmental research centres for decades through the State of Sao Paulo Research Foundation (Ryan, 2010).

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