Modes of collaboration in open innovation practice of pharmaceutical firms in India: the analysis of survey and patent data

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Abstract

Purpose – Patents as one of the important components of intellectual capital are emerging as a new source for mining insights on open innovation (OI) practice of the organizations. Their role in value creation through collaboration and the inter-firm differences is yet to be explored in depth.

Design/methodology/approach – To achieve the aim, survey data is analyzed to rank OI practices (collaboration) of the firms, while patent data are analyzed to carry out descriptive and bivariate analysis to study the inter-firm differences in collaboration.

Findings – The survey findings highlight mergers and acquisitions (M&A) and patent pooling as the top two preferred modes of OI, while from patent data M&A has emerged as a predominant OI practice for mainly nonresident firms. At the firm level characteristics, out of firm age, number of granted patents and firm size, firm age has been found to be somewhat significant in few cases of OI practices.

Research limitations/implications – It provides an alternative source, in this case patent data to study open innovation capabilities of firms in India. There is contribution to the patent value theory from profit motive to deriving strategic decisions on collaboration.

Practical implications – The managerial implications of this study lie in realizing granted patents as important business tools for seeking collaboration, tracing competitive intelligence and the geography of innovation of the firms' competitors.

Originality/value – The dataset of granted patents at the Indian Patent office (2005–2017), the sample of pharmaceutical firms drawn from this list of patents, patent data– based OI insights and the use of multiple imputation technique to missing data for meaningful insights are some of the unique aspects of this paper.

Keywords Intellectual capital, Mergers and acquisitions, Collaboration, Open innovation practices, Patent data, Pharmaceutical firms

Paper type Research paper

1. Introduction

The growing importance of intellectual capital(IC) in studies based on multiple perspectives (Hudson, 1993; Edvinsson and Malone, 1997; Sullivan, 1998; Teece, 2000) highlight the capability of IC to create value for a company as well as be value drivers and the need to research on value creation by the different elements of IC (Striukova, 2007). Such extensive coverage of IC and specific reference to the knowledge assets – the intangibles –makes it a relevant topic to research further from yet another angle – their role in open innovation (OI) process.

There is no clear-cut theory on OI due to its embeddedness in practitioner's base, though scholars have been trying to link OI to some of the theories of firms. One of them is resource-based theory (Peteraf, 1993; Hoopes *et al.*, 2003) where heterogeneity in capabilities and resources of firms is one of its cornerstones. This paper explores additionally the firm

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capabilities in the form of OI practices, using one of their resources-intellectual capital (patents) and their ability in creating value for the firms through collaboration at the R&D level, important as dimensions of IC. How firms interpret OI is quite subjective and helps in capturing the heterogeneity factor in the pharmaceutical sector taken up for study in this paper.

OI's role in pharmaceutical industry has never being so pronounced, as in the present times of patent expiration, fall in drug pipeline and the revenues thereof. As opposed to the closed model (Chandler, 1977) where the entire innovative process is carried out internally by firms, in OI, both inbound and outbound knowledge flow occur, resulting in collaborations with several R&D actors. This results in sharing of risks, cutting costs, shorter innovation time and the access to preferential markets.

Studies on OI were primarily based on theoretical considerations and single case studies of leaders in pharmaceutical sector – Pfizer, GSKM and Eli Lilly (Chesbrough, 2003; West, 2006; Hall, 2010; Sambandan *et al.*, 2015). Mostly, the issues were analyzed in large-scale studies (West *et al.*, 2006) and from developed countries.

While keeping in mind the varying degree of importance of OI for different industries, this study is conducted with a single industry focus, the usual management trend (Baseberg, 1963) to capture insights on OI from new sources like patent data and combining it with the survey data to get a holistic view on inter-firm differences(heterogeneity) in OI practice. Their perceptions were captured with the help of a set of eight OI practices identified from literature. Only those firms were considered, which already had patents granted by Indian Patent Office (IPO) between 2005 and 2017. The need to study barriers to OI implementation (Vyas *et al.*, 2012; Tripathi, 2016; Krishna and Jain, 2016) exists as few generic studies from developing countries like India.

This work focuses on the collaboration dimension of OI, by investigating the extent of R&D collaboration activities of the firms. This enlightens the managers to make intelligent use of patents for partner search and collaboration, thus mining insights on OI. The paper is structured as follows: Section I discusses the theoretical background, Section II lays down the methodology, while Section III presents the findings and discussion of the results. Lastly, Section IV summarizes the findings, with limitations and future research direction.

2. Theoretical background

2.1 Patents at the confluence of intellectual capital and resource-based view theory

Intellectual capital of an organization constitutes all the knowledge assets which together contribute to value creation dynamics which leads to competitive edge, enhanced innovative capacity and the overall performance of the firms. Among these knowledge assets, the component intangibles comprising of intellectual property, more specifically the patents (in context to the study) has accelerated the pace of innovation (Lerro *et al.*, 2014) which along with technological capability has been identified by Ferenhof *et al.* (2015) as some of the dimensions of IC among others.

At the strategic management level, resource-based view (RBV) theory (Barney, 2001; Wernerfelt, 1995) assumes that firms are a bundle of resources with VRIN characteristics (V = valuable, R = rare, I = Inimitable, N = Non-substitutable) that confer competitive advantage to the firms and are linked to their performance. Patents are one such resource. The RBV theory proposes ways to examine, directly or indirectly, the increasing importance of these knowledge resources for organizational performance improvements. This theory specifies IC as one of its specific aspects. Scholars have tried to empirically test the IC-based resources theory as a means to partially make up for the shortcomings/challenges (in terms of its too-generic nature, nonprescriptive nature, managerial dilemma over which resources to accumulate for competitive advantage, definition of competitive advantage and tautology) in RBV theory.

The two different strands of literature IC and RBV talk to each other as IC of firms and RBV both converge on competitive advantage derived from the resources–patents as per RBV which are treated as classic proxy for innovation (Griliches, 1991) and technological development, the dimensions of IC. So, an attempt has been made to link these two concepts in this study, using patents at the confluence of IC and RBV. Moreover, from the strategy perspective, as IP owners firms have taken a more active stance regarding their patent portfolios, industry participants increasingly find it necessary to engage in licensing and cross-licensing (Grindley and Teece, 1997) and possibly patent pools which might help in a more strategic management of IC.

The IC and M&A are closely related to the creation and maintenance of competitive advantage in the knowledge economy for sustaining IC. For this, the organizations need to develop their IC to respond to market changes using M&A as one of the tools. While on one side, mergers have emerged as strategic alliances to strengthen the organizations' IC and resources, on the other hand, it has emerged as an important indicator of collaboration process during OI (Al-Ali, 2003).

In hi-tech industries as pharmaceuticals, the case of merger between Pfizer and Warner-Lambert, where Pfizer paid $90bn to acquire Warner-Lambert Company, led to a comment by Pfizer CFO David Shedlarz "Certainly, the impact on intellectual capital and knowledge is one of the critical things we are trying to achieve." Faster growth together (24% annually) than either could alone (20 percent annually) and better research capability are reported in Wall Street.

However, this study does not focus on competitive advantage, rather makes use of the patents resource in drawing insights from R&D level innovation, using the variables, coinventorship and M&A as measures of inbound and outbound processes (open innovation) beyond the R&D stage. All these are indicative of studying dimensions of IC.

2.2 The multi-dimensional perspective on pharmaceutical sector and open innovation

The newness of OI in strategy and innovation has been debated as nothing new as it has been existing (collaboration, contracts, licensing) since long to facilitate the internal innovation process of the firms (Kielstra, 2011; Remneland and Wikhamn, 2013). OI has been considered as both – concept/ set of practices for profiting from the innovation as well as a cognitive model for creating, interpreting and researching these practices (West *et al.*, 2006, p. 295). In view of this new paradigm, firms' focus nowadays has shifted from know-how to external knowledge and know-who (Dubiansky, 2006; Henkel, 2006). The role of top management in OI in a survey of large firms in US and Europe shows that 70% of the firms practice OI with more than 1% top management support (Chesbrough, 2013).

OI has been studied both by academicians and practitioners from various perspectives as follows: operationalization of measuring constructs and classification of OI processes the what (the content of OI), when (the context dependency) and how (processes) of OI (Huizingh, 2011); the ways in which firms translate the management technology of OI into practice (Christensen, 2008; Bianchi *et al.*, 2011), how small firms innovate (differential success of OI even for different projects within the same company) (Christiansen *et al.*, 2013); the roadmap for integrated technology exploitation to support out-bound decisions (Lichtenthaler, 2010) and the patterns of OI in open source software. Patents' importance in OI has been emphasized by O'Connell (2011) as protecting innovation whether external or internal; patent ownership issue by Wallin and Von Krogh (2010). Kim and Park (2010) found that external R&D had a significant positive effect on innovation output, but external ideas had a negative effect and external knowledge had no impact, in case of SMEs.

Managerial challenges in coordinating for diffusion of knowledge has been highlighted by Alexy *et al.* (2009) and Sieg *et al.* (2010). Collaboration and consortia have been identified as the two topmost OI strategies in pharmaceutical sector, and these are further endorsed by the practitioners (Salah and McColluch, 2011) and Vanhaver-beke *et al.* (2008) to address the "innovation deficit" in order to bring down the cost/risks or avert failure of drug development. In firm capabilities, there are mixed evidence of firm size, from positive (Keupp and Gassmann, 2009; Schroll and Mild, 2011; Michelino *et al.*, 2015) to negative. Literature does not consider firm age as predictor of degree of openness though Michelino's study shows a negative correlation for the same. A host of scholars (Brower and Kleinknecht, 1999; Hertzfeld *et al.*, 2006; Jensen and Webster, 2009) opine that firms that engage more in R&D cooperative innovation strategies tend to have a higher patent propensity and are stronger in sharing costs and risks (Belderbos *et al.*, 2010). A strong linkage between firm age and innovation activities (patenting) has been established for the older firms by Sorensen and Stuart (2000) while comparing the aging and innovation process in firms from different industries including semi-conductors and biotechnology.

Literature review to trace the progress, theory development, managerial implications and a suggested framework has been done by Elmquist *et al.* (2009), Hossain *et al.* (2016) where the latter reports increase in micro studies of OI. Teplev *et al.* (2019) prove the differences which are even within the industries/academia and free-wheeling as an unanimously accepted OI practice by the firms. Residents and nonresidents show traditional and innovative mode of patenting (Qiao, 2008, 2017) respectively as revealed from the data on patent renewal. This study indirectly contributes to OI studies. In general, a lot has been emphasized on innovation in pharmaceutical industry (Scherer, 1998, 2000a,b) including the emerging importance of OI in this sector.

2.3 Patent data and insights on open innovation

Extensive studies have been conducted to understand patent management through the OI practices, and a recent study by Jones Evans *et al.* (2018) has identified intellectual capital (intellectual property) as one of the important pillars in OI framework. In measurement system of OI, patent has been identified as an important variable for managers studying patent management issues in OI practices of firms (Kale *et al.*, 2002).

A lot of studies have explored the collaboration at R&D level (in the form of coinventorship pattern) within and across borders employing network analysis, to study the geography of innovation as well as to find patent collaboration as an effective form of cooperative innovation activity (Liu *et al.*, 2019). Having gained attention of economists (Schmookler, 1966; Griliches, 1991; Lerner, 1994) and lawyers (Merges and Nelson, 1990), patent use in management research still remains limited (Marksman *et al.*, 2004). As classic proxy for innovation and with ease of availability, patents are replete with information on technology domain, invention/inventors, their territorial distribution for the possibility to study collaboration patterns/trends of the firms (Krishna and Jain, 2015). Before 1966, patent data had major constraints in their use (the way patent documents were filed, the lack of expertise in examination of the patents and the patent system itself) (Goto and Motohashi, 2007). Patent data have differential impact in different industries and sectors. In pharmaceutical firms, they are the most effective means of gaining returns on investments and achieve competitive advantage (Levin *et al.*, 1987). Use of patent information offers new empirical evidence about whether it involves open or closed innovation and it can be achieved without surveying inventors. Moreover, structured/unstructured patent information have been extensively used in technology partner selection studies (Jeon *et al.*, 2011).

2.4 Modes and patterns of collaboration as an open innovation practice

To meet the challenges of changing environments, firms find it difficult to contain and capitalize on all relevant knowledge. This forces them to collaborate at different levels/stages to complement their capabilities and generate new products and technologies (Dittrich and Duysters, 2007). OI paradigm is being seen as a mode toward collaborations for innovation across organizational boundaries (Bierly *et al.*, 2009). How these firms join hands can be a source of competitive advantage since it gives access to external sources and information (Belderbos *et al.*, 2004). For these reasons, R&D collaborations and strategic technological alliances are increasingly part of companies' innovation model (Archibugi and Pianta, 1996). The increasing trend in collaboration across industry borders has challenged the traditional modes, rather forced them to explore the alternatives such as patent data information (Jeon *et al.*, 2011).

A deeper understanding of innovation strategies, the ownership issues in multi-stakeholders' collaboration in projects is equally important for research and practice (Gassmann, 2006; Chesbrough and Crowther, 2006). Dahlander and Gann (2010) classify the collaborative activity into one of four categories of OI: (1) inbound acquiring (2) inbound sourcing (3) outbound revealing or 4) outbound selling. Some of the OI strategies that have been in practice in the pharmaceutical industry are in-licensing, out-licensing, spinning out of new ventures, supply of technical and scientific services, acquisitions, joint ventures, purchase of technical and scientific services, nonequity alliances, corporate venturing investments (Bianchi *et al.*, 2011).

According to Balietta and Callahan (1992), collaboration has been defined as the development of knowledge through relationships with specific partner organizations (universities or research institutes). Tripathi has (2016) highlighted collaboration in case of OI in the manufacturing industry as inbound acquisition of firms/technology (Vanhaverbeke *et al.*, 2002), external commercialization of technology (Kutvonen, 2011), co-creation of patents (Lin *et al.*, 2012) etc. Tripathi (2016) has also compiled a list of important modes of collaboration as follows: university–industry collaborations (UIC) (Mansfield, 1986; Belderbos and Carree, 2004); external acquisition of knowledge (Fey and Birkinshaw, 2005; Huang and Rice, 2009; Inauen and Schenker-Wicki, 2011); licensing out and licensing in (Tsai and Chang, 2008). M&A has been identified as an indicator of OI studies and as a mode of patent acquisition (Vyas, 2012; Cao, 2013). Decarolis (2003) suggests combination of internal and external learning or the recombining of internal knowledge as modes of enhancing competencies. External commercialization of technology (Kutvonen, 2011), R&D alliance (Fey and Birkinshaw, 2005; Lin and Wu, 2010), manufacturing alliance (Dahlander and Gann, 2010; Suh and Kim, 2012) are also reported as modes of OI. The importance of collaboration modes/patterns in literature justifies the selection of coinventorship and M&A as indicators of OI.

2.5 Suggestions for research on open innovation

Chesbrough *et al.* (2006) present a comprehensive list of research concerns in context to OI, which varies from heterogeneity, firm characteristics and differential adoption rates to the drivers of motivations (for the individuals) and incentives for the inventions to be made (at the firm level). Studies from developing countries (Asia, Latin America) can complement the existing findings. The suggestions to use patent data beyond the case studies/surveys (West *et al.*, 2006; Chesbrough, 2013; Podmetina *et al.*, 2014b) has been implemented in this paper to understand the collaborative patterns of residents and nonresidents firms in India.

2.5.1 Research gaps.

(1) Information on OI from Indian pharmaceutical industry is lacking and scarce.

(2) Where along the innovation continuum, OI is being effectively adopted and by whom?

Based on these, three research questions have been formulated:

2.5.2 Research questions.

(1) Are all firms equally aware of OI or do they differ in their awareness/practicing of OI?

(2) Which OI practices are being adopted by the pharmaceutical firms in India?

(3) How much patent data speak on the aspects of OI and patent management?

Ultimately, this led to the framing of three important research objectives:

(1) To identify the importance order of firms' OI practice.

(2) To study the inter-firm differences in the mode of OI implementation

(3) To compare the collaboration trend of resident and nonresident firms in India

2.6 Firm's collaborative behavior in open innovation, a contextual interpretation

Literature has mixed evidence on the behavior of firms toward OI due to a variety of factors which impact the adoption of OI. Firms' characteristics like age and size have been reported as reasons for heterogeneity in patenting propensity and adoption of innovation practices.

That acquisitions can be an integral component of OI was first thought upon by Chesbrough (2003), leading to the development of another measuring scale for inbound acquisition activities like acquisition of patents, licenses and firms. Acquisition of inbound acquisition has been studied as a more important mode of OI adopted by European firms (Carlsson *et al.*, 2011). It is important for Indian firms to form mergers and strategic alliances with MNCs to meet the challenges imposed by TRIPS product patent regime. Over the last three years, pharmaceutical segment has accounted for more than 70% of M&A deals and in the first nine months of 2015. In general, collaborative behavior in pharmaceutical firms has been linked with patenting (Brower and Kleinknech, 1999; Hertzfeld *et al.*, 2006; Jensen and Webster, 2009) and by Alexy *et al.* (2009).

These studies apparently suggest that firms which engage more in cooperative innovation strategies tend to have a higher patent propensity. The following testable hypotheses have been formulated:

H1. Resident and nonresident firms differ significantly in their collaboration at invention level.

H2. Resident and nonresident firms differ significantly in their collaboration pattern of M&A.

H3. The patent grant intensity is not a differentiator of the coinventorship pattern between resident and nonresident firms.

3. Research methodology

The research methodology consists of quantitative study combining insights from survey, patent data and data on M&A, all of which lead to findings on OI practices of the pharmaceutical firms. Using, information on coinventorship from patents and data on M&A (both of these variables are indicators of collaboration) the inter-firm differences in this sector has been studied.

While the sample of firms has been decided on the basis of judgmental sampling (detailed further), the number of patents for each firms, the information on coinventorship have been selected randomly. A major source of the secondary data is the IPO (ipindia.nic.in), while the source of data on M&A is the ace equity, company websites, press releases.

Data cleaning and preprocessing were done in Excel for patent data to eliminate any ambiguity in terms of the entered information related to the name of assignee, inventors or missing record if any. For survey data, forms with incomplete/ambiguous responses were excluded from analysis, and missing demographic details were compensated from the company's websites.

The units of analysis in this study are both, the firms and the patents. Each set of these data was checked for outliers, and their descriptive features were defined through SPSS (version 20). The reliability and validity of the survey responses were also checked. After the data were ready to be analyzed, they were subjected to various statistical techniques ranging from univariate (mean), to bivariate (independent sample *t*-test, one- way ANOVA) (Pallant, 2013) and multiple imputation(MI) technique (Field, 2013) to take care of missing data beyond 5%. The use of MI prevented the loss of a respectable proportion of secondary data in a field like intellectual property and pharmaceutical sector, where sensitive nature and the element of confidentiality often impede the process of adequate data collection during survey or even in case of patent data.

The methodology adopted in this study is unique in the sense that it uses patent data along with survey to draw insights on OI practice of the firm. Prior empirical studies on OI are primarily covered through survey or case studies. There are scattered instances of use of patent data information for OI study in the extant literature. For, e.g. Jeon *et al.* (2011) used structured and unstructured patent information for technology partner selection, while Yoon and Song (2014) identified technological opportunity and necessary technologies to explore potential partners from information in patents by adopting a hybrid approach for designing informative indices.

3.1 Sampling

A total of 400 firms of mixed origin (50 resident and 50 nonresident firms) constituted the population, out of which, a sample of 100 Bombay Stock Exchange (BSE) listed firms was selected on the basis of judgmental and convenience sampling. Each of these 100 firms was represented by two randomly selected granted patents which resulted in a total of 200 granted patents. The data were taken from 2005 since proper online documentation of patent data at IPO started from this year. The questionnaire contained eight items to measure OI (Figure 1).

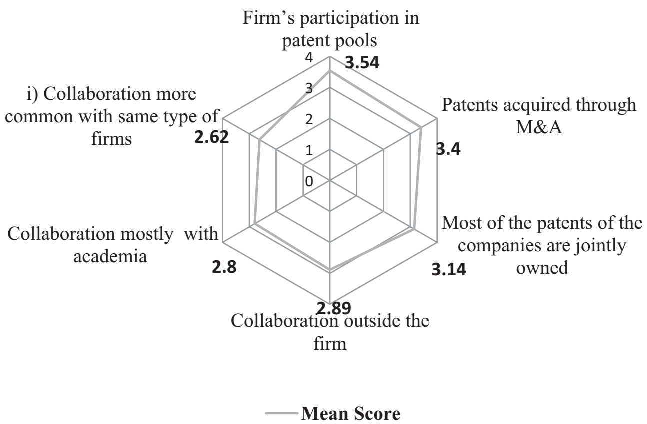

Figure 1.
Ranking of open innovation practices by pharmaceutical firms

The items were adapted from the literature by Van de Vrande *et al.* (2009), Chesbrough (2003, 2010) and Laursen and Salter (2006).

3.2 Data collection

Data were collected in two stages. Firstly, the secondary data were collected from the IPO website. In the first step, the three different lists on pharmaceutical patents (2005–2006; 2007–2010 and 2011–2014) were compiled into one list to get a consolidated data of granted patents for the period 2005–2014 and further updated till 2017 using INPASS, the search facility at IPO. This resulted in a total of 4,390 granted patents (the population for this study). In the second step, the list was sorted to group the patents by category of assignees as follows: firms, research institutes, universities and individuals. More than 90% (91.34) patent assignees were firms accounting for 4,010 patents. The remaining patents (380, 9.66%) belonging to the rest of the assignees (universities, research institutes and individuals) were excluded from the study. This was done to ensure homogeneity in the sample of firms. Later, patent data were segregated into firm categories based on the number of granted patents. While there were 1,000 firms, each with 1 patent, there were 430 firms with >two patents. The number of granted patents ranged from as low as 1 to as high as 167. Both, firms and patents were taken as the unit of analysis.

In the second stage, a survey of the key informants – IP managers and research scientists – from the sampled firms was conducted to elicit responses on the modes of OI adopted by these firms or to capture their preferences for OI. For survey, only 400 out of 430 firms were approached due to missing/incomplete contact information on 30 firms. The survey was responded mainly by the resident firms, with negligible responses from nonresident firms.

3.3 The survey instrument: questionnaire

The questionnaire had both closed and open-ended items. Items seeking both dichotomous and multiple-choice responses were constructed of which the latter types were measured on a 5-point Likert scale, where 1 = lowest and 5 = highest. The questionnaire after validation from IP experts was sent to the 400 target firms. A homogenous sample of 60 resident firms was taken up for the survey study, but for the patent analysis both residents and nonresidents firms were studied. A total of 100 firms was considered for patent data study. The approach of selecting BSE listed firms and analyzing data sourced from their annual reports for studying OI has also been used by Mazzola *et al.* (2012). Moreover, the business or management context of this industry in literature is scarce in India. To fill this gap, survey of individual firms is a good way to draw useful insights.

4. Results and analysis

In the first stage of survey data, ranking based on mean score was employed to rank the OI items of only resident firms. This was followed by comparing the importance firm age and size in OI practice. The key informants were IP managers and R&D scientists

Later, the secondary data on patent and M&A was explored to gain insights on OI practices, of both the resident and nonresident firms. Collaboration as an indicator of OI was measured by two proxies –number of co-inventors and number of M&A, both important for IC.

4.1 The extent of OI practiced by pharmaceutical firms: insights from survey

In the survey for OI practices, the intention was to ascertain whether the firms were aware of the OI practice or not and further to know what form/s of OI practices the firms were either implementing or intended to do so in future. Basically, out of the eight, only six items elicited complete responses on knowledge sharing and collaboration as indicators of OI practice (Podmetina *et al.*, 2014a, b; Tripathi, 2016).

Firms' propensity to patent depends on a series of factors, related to the nature of innovation, the characteristics of the firm, the level of competition within the industry and the broader institutional context in which firms operate. To study some of these differences, the descriptive statistics and demographic details (age and size of the firm) of the sample are presented. The mean age of the respondent firms was found to be 37.52 years, while the mean patent grant intensity was 13.54 patents. From the size perspective, 42% firms were small firms (<500 employees), while 58% were large firms (>500 employees) making it more or less a balanced sample.

4.1.1 Mean score–based ranking of the OI practices. The analysis of responses (Figure 1) indicated that majority of the sample firms (45, 75%) were aware of the dimension of IC, i.e. open innovation and agreed to the existence of some or other forms of OI practice or what they felt should be done (as a response to "any other suggestions"). In case of dichotomous items, on cross-licensing and in-licensing, majority of the firms either skipped giving responses or responded as no. Further, while testing the extent of OI practice and ranking of the items, respondents returned scanty that too negative responses on the two items -in bound and out bound practices(in-licensing and out-licensing), hence only six items with complete responses were taken up for analysis($60 \times 6 = 360$ observations). From among these six items, "participation through patent pools" was ranked as the most important (mean score = 3.54) followed closely by "mergers and acquisitions" (mean score = 3.4). "Most of the patents of the firms are jointly owned" has been ranked third (mean score = 3.14) indicating not a very high preference for collaboration at the coinvention level. "Collaboration outside the firm" has been ranked fourth followed by "collaboration with academia" (mean score = 2.98). A low rank to "collaboration with firms of the same type" (mean score = 2.54) incidentally is quite an unexpected finding, indicating the firms' conservative view on collaboration. In context to the open-ended question, only two firms were candid enough to mention about continuing their traditional horizontal business model with only in-house activities. 20% respondents suggested alternative modes of collaboration as follows: in-licensing, manpower sharing, technology development and innovator companies licensing out to generic companies to build a patent pool around their branded drugs. However, these were more of their personal suggestions rather than the company's views.

4.1.2 OI practice based on firm size and firm age perspective. In the second stage, survey data on OI practice were subjected to independent sample *t*-test to study the inter-firm differences based on firm's size and age.

4.1.2.1 OI practice and firm age. In literature, firm's age does not seem to be a predictor of the degree of openness (Keupp and Gassmann, 2009; Schroll and Mild, 2011), the same result was observed in this study since the p-value for each of the 6 OI practices has been reported as insignificant (ranging from $p = 0.375$ to $p = 0.982$, which is > 0.005) (Table 1).

4.1.2.2 OI practice and firm size. Firm size seems to be significant while deciding the interfirm variation in responding toward OI practices with respect to only two items" participation with patent pools" ($p = 0.001$) and "collaboration mostly with academia" ($p = 0.001$) (Table 2). In the case of remaining 4 items, there was no significant differences in their mean score (p-value >0.005). This implies overall firm size does not account for inter-firm variation in OI practice of the studied sample, rather both small and large firms share almost the same perception about OI. This finding contrasts with that of Sadao and Walsh (2009) in case of US and Japan, where cross-organizational coinventions (a form of OI) increase as firm size declines.

Table 1. Comparison of open innovation practices in group of firms differentiated by age

S.No.	Modes of open innovation	Firm age	Mean	Standard deviation	Standard error	*t*	*p*
1	Participation in patent pools	Young firms	2.68	1.121	0.192	0.598	0.553
		Old firms	2.46	1.050	0.291	0.616	0.544
2	Patents through M&A	Young firms	2.70	1.237	0.215	−0.895	0.375
		Old firms	3.08	1.441	0.400	−0.837	0.413
3	Ownership issues settled at the time of invention	Young firms	3.53	1.306	0.238	−0.025	0.980
		Old firms	3.55	1.572	0.474	−0.023	0.982
4	Collaboration outside the firm	Young firms	3.16	1.221	0.216	0.168	0.867
		Old firms	3.08	1.443	0.417	0.155	0.878
5	Collaboration mostly with academia	Young firms	2.68	1.121	0.192	0.598	0.553
		Old firms	2.46	1.050	0.291	0.616	0.544
6	Collaboration more with same type of firms	Young firms	2.82	1.158	0.202	−0.667	0.508
		Old firms	3.07	1.269	0.339	−0.642	0.527

Note(s): Sig 2-tailed ($p < 0.05$); Old firms ≥ 50 years and Young firm ≤ 50 years

Table 2. Comparison of open innovation in group of firms differentiated by size

S. No.	Modes of open innovation	Firm size	Mean	SD	SE	*t*	*p*
1.	Participation in patent pools	Small firms	3.20	0.951	0.213	3.508	0.001
		Large firms	2.19	1.001	0.193	3.535	0.001
2	Patents through M&A	Small firms	2.85	1.387	0.310	0.208	0.836
		Large firms	2.77	1.243	0.244	0.205	0.839
3	Ownership issues settled at the time of invention	Small firms	3.94	0.899	0.218	1.634	0.110
		Large firms	3.25	1.567	0.320	1.785	0.082
4	Collaboration outside the firm	Small firms	3.42	0.902	0.207	1.309	0.198
		Large firms	2.92	1.47	0.294	1.394	0.171
5	Collaboration mostly with academia	Small firms	3.20	0.951	0.213	3.508	0.001
		Large firms	2.19	1.001	0.193	3.535	0.001
6	Collaboration more with same type of firms	Small firms	2.90	0.912	0.204	0.031	0.975
		Large firms	2.89	1.368	0.263	0.033	0.974

Note(s): Sig 2-tailed ($p < 0.05$); large firms ≥ 500 employees and small firm ≤ 500 employees

4.2 The extent of OI practiced by pharmaceutical firms: insights from patent data and M&A

The analysis of the secondary-data patents and data on M&A is done with an intention to gather further insights on OI from additional sources since survey data reflected resident firms' collaboration preferences as a weak link. Data on coinventors and M&A helped in exploring collaboration of these firms at the R&D level (the stage of building/sharing intellectual capital) as well as beyond the R&D level (the stage of acquiring other firm's intellectual capital), respectively.

4.2.1 Selection of variables and their operationalization. Inbound OI processes are more in use than the outbound processes (Schroll and Mind, 2011) of OI. Two inbound activities M&A and number of co-inventors are selected as dependent variables based on their importance in literature. For the purpose of analysis, the variable M&A means the "inbound acquisition of firms" (Vanhaverbeke *et al.*, 2002) and the variable "coinventorship" (Lin *et al.*, 2012) means the collaboration at the invention (R&D) level.

The firms are categorized on the basis of a) firm's nature (resident or nonresident) and b) number of granted patents (patent grant intensity). Each of the two dependent variables is studied separately for the comparative analysis of OI in firms. The dependent variables are operationalized as follows:

4.2.1.1 Dependent variables.

(1) Mergers and Acquisitions (M&A).

M&A is an important measure for collaboration and competitive edge of the firms in pharmaceutical sector (Vyas *et al.*, 2012), and a top ranking variable in this survey. Data on M&A have been collected for the last five years, considering 2016 as the year of analysis (i.e. 2011–2015) from a variety of sources as follows: Ace Equity database, company's websites and industry/press reports. It is a count variable, representing the number of acquisitions made by the acquirer between 2011 and 2015.

(2) Coinventorship (NCoI)

This variable is used as an indicator of how open and collaborative the firm is in knowledge-sharing process (OECD, 2009) at the R&D stage. Co-invented patents have increased in numbers, and collaboration between inventors is more active than collaboration between technology owners (Lei *et al.*, 2013). Data for *NCoI* were taken from the patent documents of the sampled firms. This variable is measured by the average of the inventors in a set of two randomly selected patents from the total granted patents to the firms. A discrete variable, it is defined as an integer greater than or equal to 1 and has been used by Sapsalis *et al.* (2006) and Liu (2014).

4.2.1.2 Independent variables.

(1) Firm Size

In context to this study, firm size is recorded in 2016 and refers to the number of employees (OECD, 2009) as it relates to the growing need for more labor for the expanding firm's activity. Based on this, firms are categorized as large and small. In some cases, it is measured as total assets, and firm size has been found to be positively correlated with patent propensity (De Carolis, 2003), implying thereby that large firms engage more in patenting activity. Firm size therefore is an important variable for OI especially for big pharmaceuticals (Chesbrough, 2013) where it is largely practiced. Firms of different sizes interpret OI differently (Teplov *et al.*, 2019).

(2) Firm Age

Firm age refers to the number of years, as calculated from its date of incorporation to 2016, the year of analysis for this study. Firm's age does not seem to be a predictor of the degree of openness as reported in some literature (Keupp and Gassmann, 2009; Schroll and Mild, 2011). Michelino (2015) reported a negative correlation of openness with the age of the company. Firm age has implications for innovative activities for firms (Sorensen and Stuart, 2000), which in this study can be referred to the total number of granted patents to the firm. Firms in the sample are categorized as young (<50 years) or old firms (>50 years).

(3) Firm category based on location

This is a categorical variable which takes the value 1 for resident firm and 2 for the nonresident firm. Resident and nonresident categorization is done based on the firm's location whether it is domiciled in India or outside India, respectively.

(4) Firm type based on patent grant intensity

Firm type is a categorical variable based on the total count of granted patents to a firm between the year 2005–2017, similar to categorization of patentees by Serrano (2010). It is constructed on the premise that openness in innovation is related to stronger motives to patent which ultimately results in more patents. Previous empirical studies have indicated that single patent count is correlated with innovativeness of the firms. Moreover, it rests on the plausible assumption that more number of granted patents means more market share of the firm (Harhoff and Reitzig, 2000). Based on these assumptions, firms in the sample are divided into three groups

4.2.2 Comparison of firms on the basis of their nature (resident and nonresident). Each of the two dependent variables, coinventorship and M&A are tested separately for the comparative analysis of firms based on their nature. There were more missing data for M&A (residents (43) and nonresidents (39)) than for number of coinventors (residents (48) and nonresidents (51))

The data on the number of inventors were almost 100%, and a *t*-test performed for this indicated no significant differences between the coinvention pattern of the resident and nonresident firms (F-statistic = 0.018 and the *p*-value of 0.267 (>0.005)). The statistics for collaboration at the coinvention level were nearly similar for resident firms (N = 48) (M = 3.31; SD = 1.847) and nonresident firms (M = 3.73; SD = 1.801) (Table 3) The Hypothesis (H1) that residents and nonresident firms differed in their coinventorship collaboration pattern was rejected due to no statistical significant difference (0.267) between the two categories of firms.

The independent sample *t*-test was repeated to compare the M&A pattern in the resident and nonresident firms. However, a significant percentage of data (20%) was missing in this case. This missingness was handled by employing sophisticated modern techniques of maximum likelihood estimation and multiple imputation (MI) (Schafer and Graham, 2002). These are widely recommended in the methodological literature (Schafer and Olsen, 1998; Allison, 2002; Enders, 2006) and have been employed in the case of OI study. The appropriateness of techniques depends on the nature of the missing data problem, which can be missing completely at random (MCAR), missing at random (MAR) or missing not at random (MNAR) i.e. systematic (Rubin, 1976, 1987). Accordingly, the given data on M &A are first of all analyzed for missing pattern through SPSS (version 20) which is MCAR in this case, so multiple imputation technique for MCAR is performed to get the mean value for the missing data through the iteration process. The iteration process produces multiple sets of complete data to finally replace all the missing values with imputed values in the original data. This complete dataset is then subjected to the required statistical tests depending on the type of test (independent sample *t*-test in this case) identified by imputation process. The so obtained results from pooled data are then compared with the results from the original data.

The descriptive statistics for the original and pooled data on M&A and the respective *t*-test results with equality of variance and means are shown in Table 4 and Table 5 respectively.

Descriptive statistics							
Variables	Frequency	Minimum	Maximum	%	Mean	Standard deviation	Standard error
Resident firms	48			48.0	3.31	1.847	0.267
Nonresident firms	51			51.0	3.73	1.801	0.252
No of coinventors		1	10		3.53	1.826	
Total (N)	99			99.0			

Independent sample *t*-test Results	*F*	Sig	*t*	df	Sig.
Number of coinventors	0.018	894	−1.126	97	0.267

Table 3. Comparison of coinventorship practice of the firms based on their nature

Variables	Frequency	Minimum	Maximum	%	Mean (*M*)	SD	SE	
	Descriptive statistics (with missing data)							
Resident firms	43			2.49	1.69	1.10	1.77	
Non-resident firms	39			3.21	2.76	2.76	0.422	
No. of M&A		1	11					
Total (*N*)	82							
Comparison of descriptive statistics of original and imputed data								
Resident firms	39				1.69	1.10	0.177	Original
Non-resident firms	43				3.21	2.76	0.422	
Resident firms	49				1.72	*	0.225	Imputed
Non-resident firms	50				3.16	*	0.390	

Note(s): SD: Standard deviation and SE: Standard error
*SD not reported while running MI

Table 4. Comparative descriptive statistics on original and pooled data on M&A activity of the firms

Variables	Levene's test of equality of variance *F*	Sig.	*t*-test for equality of means *t*	Sig. (2-tailed)
Collaboration through coinventors	0.018	0.894	−1.126	0.267
Collaboration through M&A (original data)	18.204	0.000	3.201	0.002
Collaboration through M&A (pooled data)			−3.180	0.002

Table 5. Summary of result on comparison of coinventorship and M&A in resident and nonresident firms

The assumption of homogeneity of variances was tested, and with no violation of homogeneity, the *t*-test showed no difference in the results of original and pooled data, i.e. before and after the replacement of missing values in M&A, as the *p*-value is significant and same (0.002) in both the cases. Hypothesis 2, as stated, resident and non-resident firms differ significantly in their collaboration pattern of M&A, was accepted with statistically significantly different mean in the incidence of collaboration (M&A) of these firms. The multiple imputation technique thus helped in avoiding bias in result which could have been caused due to missingness. It rather helped in avoiding the loss of this 20% data and deriving meaningful conclusion from the sample analysis.

To summarize the comparison of results on coinventorship and M&A, no significant differences between the coinvention pattern of the resident and nonresident firms (F-statistic = 0.018 and the *p*-value of 0.267 (>0.005)) was observed. However, in case of M&A comparison, the resident firms ($N = 43$) were associated with a smaller incidence of collaboration $M = 1.69$ (SD1.104) vis- a -vis nonresident firms ($N = 39$) which showed comparatively higher incidence of collaboration $M = 3.21$(SD = 0.422), a finding corroborating the survey result on collaboration preferences of firms in this study. But this result needs to be interpreted with caution as survey findings are only representative of the sampled resident firms.

Table 5 shows a statistically significant difference between the firms with respect to their collaboration through M&A. This can be explained possibly on the basis that while sharing of knowledge and resources at the stage of invention is common and prevalent in both the resident and nonresident firms, collaboration through M&A is subject to the need, requirement, absorptive capacity and mutual compatibility of the respective firms and hence the difference.

4.2.3 Comparing firms on the basis of different patent grant intensity. In the second type of firm categorization, firms were categorized on the basis of their number of granted patents (patent grant intensity). The firms were divided into three groups according to their patent grant intensity (group 1 (low intensity): 36, group 2 (moderate intensity): 33 and group 3 (high intensity) 31 (Table 6). The descriptive statistics for coinventorship and M&A were ($M = 3.53$; $SD = 18.26$) ($M = 2.8$; $SD = 23.17$), respectively. The interfirm differences in collaboration were studied through one-way between-groups ANOVA technique.

For M&A, since 20% missing data is being reported, MI technique based on the missing pattern of data was employed and one-way ANOVA was performed on the imputed data to test the hypothesis that patent grant intensity has an impact on the two types of collaborations, coinventorship and M&A. The p-value obtained in ANOVA using the missing data is 0.541, and the p-value obtained as a result of replaced missing values by running MI is 0.300. In both cases, p-value is insignificant ($p > 0.005$) despite a decrease in p-value obtained in pooled data.

The test for homogeneity of variance reveals no violation of assumption in both the cases of collaboration since F-statistic p-value is 0.388 and 0.514 (>0.05) for coinventorship and M&A, respectively. One-way ANOVA test confirms the between- group differences in case of M&A ($p = 0.000$), but there is no significant difference in case of coinventorship ($p = 0.093$). There was no statistically significant difference ($p > 0.05$ level) in case of both coinventorship and M&A score for the three firm groups, eliminating the need to perform the post hoc comparisons.

That the number of granted patents of the firms do not account for the difference in their collaboration pattern (Co-inventorship and M &A trends) leads to the acceptance of Hypothesis 3. The two modes of OI practice have been studied across both the categories of firms.

5. Discussion

The patterns of OI are easily observed, but the details on collaborations and deals are not being fully transparent; neither survey draws complete picture of OI due to elements of confidentiality and sensitive nature of the pharmaceutical sector and IP domain. As an alternative, collaborative patterns from the information contained in firms' patents has brought out a unique perspective and important contribution to the literature on IC through empirical findings of OI.

The study offers a small theoretical contribution in the sense that on one hand it studies the use of resources(patents) as per RBV theory in mapping innovation (open innovation),while on the other hand it emphasizes the importance of studying IC dimensions, innovation and technological development, (Ferenhof *et al.* (2015)) through the patents.

Despite the trend toward OI(Chesbrough and Crowther, 2006; Laursen and Salter, 2006), many firms are still quite reluctant to open up their innovation processes.This is evident in this study, but nonresident firms show better degree of openness vis-à-vis the resident firms.

The preliminary findings on OI sync with Chesbrough and Bogers (2014) notion that merely performing certain activities should not be considered as an exclusive indicator for OI

Table 6.
Segregation of firms on the basis of patent grant intensity

	Category of patent grant intensity	Number of granted patents	Number of firms
1	Low intensity	1–5	36
2	Moderate intensity	6–20	33
3	High intensity	>20	31
			Total ($N = 100$)

adoption. Instead, OI activities should be analyzed with respect to firm strategy and business model. Both of these aspects have been covered in this study.

The industry–academia link has been recognized as an important outbound process by Dahlander and Gann (2010) and Tripathi (2016), but in this study it has scored a low mean score and rank. If this is interpreted in terms of findings by Belderbos *et al.* (2004), Faems *et al.* (2010) where collaboration with universities and research institutes is positively linked to radical innovation, perhaps such a finding indicates that the sampled firms in this study do not seem to pursue radical innovation.

The unrelatedness between firm age and the degree of openness in this study echoes the findings by Keupp and Gassmann (2009); Schroll and Mild (2011). Contrary to Teplov *et al.* (2019) who report that firms of different size interpret OI differently, in this study, overall firm size has not found to be a differentiator of OI practices of the firms. It also refutes Sadao and Walsh (2009) findings in context to Japanese and US firms, where cross-organizational coinventions increase as firm size declines.

The secondary data study reiterate the findings of Hufker and Alpert (1994) that patent data provide insights on collaborative pattern of firms at R&D level. This could be attributed perhaps to the small sample size and the nature of the firms. The resident firms with limited OI practice show a tendency for vertical integrated models so they are less likely to collaborate.

Both survey and patent data indicate a weak collaboration tendency outside the firms, with a probability of limited opening up of firms' boundaries. This holds good only for the resident firms since OI insights were derived from two sources, while for nonresidents, only patent data were explored. M&A have emerged as an important measure for collaboration for both the categories of sampled firms, and this echoes the findings by Vyas *et al.* (2012). In case of residents, this has been affirmed from the survey as well. As for the external validity the finding on M&A (mean score = 3.4) contrasts with Schroll and Mild (2011) mean score of 2.8 for inbound acquisitions.

In particular, the studied sample has shown that open innovation proxied through M&A is mainly driven by larger companies, especially the large firms which are primarily represented by nonresident firms. Large companies are less likely to rely upon only internal activities because of their diverse technological knowledge (Veugelers and Cassiman, 1999). Moreover, large firms are more organized and ready to adopt open innovation with their sufficient resources (Kale *et al.*, 2002; Rothaermel and Deeds, 2006; Heimeriks *et al.*, 2007). As a result, their innovation processes have been opened up more strongly.

6. Conclusion

In an attempt to respond to the need for adequate information on open innovation (OI) in pharmaceutical industry in India, this study has been conducted with a novel dataset combining survey data, the IC-patent data and data on M&A. The empirical study is a descriptive and partially inferential study on OI practice, which has not been explored in this manner. The survey responses on the modes of OI practice have revealed significant heterogeneity from the perspective of firm age which has been found to be significant for some OI practices, vis- a- vis firm size. Even the number of patents granted to the firm has no impact on OI practices. The overall findings reaffirm the importance of OI for nonresidents, and the increasing importance of OI for the resident firms of India can be seen more at the invention level rather than at the M&A level. Residents firms show comparatively lesser tendency for M&A vis-a-vis the nonresident firms.

This study is an add-on to the theory of RBV and IC by using a common element, patents, as resource for mapping OI as well as realize the importance of IC in studying OI.

Further research can look into the patent pooling process in this sector as a solution to the difficulty in finding potential licensing partners. Due to the nature and restricted scope of the study, the research gap, where along the innovation continuum OI is being effectively adopted and by whom could not be addressed adequately. A larger sample size and a more in-depth study on OI might take care of this.

The study though brings forth new insights, with few limitations, it cannot account for generalization of the results, but for sure, it provides a comprehensive view on OI with a single-industry focus, keeping in mind the cross industry bias and the varying importance of intellectual property for each of them. For future, a cross industry focus might perhaps help in widening the scope of the study and comparing the present findings with those from other industries.

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Appendix 1

Items on open innovation

The original questionnaire had studied 4 dimensions. Open innovation is one of them.

The same has been reproduced as used in this paper.

10. Factors indicative of open innovation practice? (Put a (√) mark against your choice)						
(1)	Cross-licensing	**Yes**			**No**	
(2)	In-licensing	**Yes**			**No**	
(3)	Out-licensing	**Yes**			**No**	
11.	**Please indicate the extent of open innovation practices in your firm**					
		Lowest	**Low**	**Moderate**	**High**	**Highest**
		1	**2**	**3**	**4**	**5**
(1)	Your firm's participation in patent pools					
(2)	In-licensing					
(3)	Out-licensing					
(4)	Patents acquired through mergers and acquisitions					
(5)	Most of the patents of the company are jointly owned.					
(6)	Collaboration outside the firm					
(7)	Collaboration with academia					
(8)	Collaboration more common with same type of firms					
	Any other (please specify)					

Note(s): Negligible responses on Items 2 and 3 of Q11

Appendix 2

	List of firms (resident and non-residents) used as sample for studying OI through patent data						
	(Section 4.2-Page 16 in the paper)						
	Assignee Pharma Firms	**POWER**	**Code for POWER**	**Av. NCoI**	**PGI**	**Code for PGI**	**NM&A (2015)**
	Non-Resident Firms						
1	Access Bioscience Cjsc	2	F	3	1	1	1
2	Alfa Wassermann S. P. A.	2	F	2	1	1	5
3	Ciba Holding Inc.	2	F	6	1	1	2
4	Crititech, Inc.	2	F	4	7	2	2
5	Fresenius Kabi Deutschland Gmbh	2	F	9	1	1	4
6	Isis Pharmaceuticals, Inc.	2	F	1	1	1	
7	Mendes S. R. L.	2	F	1	1	1	
8	Ramscor Inc.	2	F	1	1	1	
9	Calgene Llc	2	F	3	2	1	5
10	Centocor Inc	2	F	5	2	1	1
11	Cephalon Inc	2	F	1	6	2	4
12	Chemocentryx Inc.	2	F	4	2	1	
13	Choongwae Pharma Corporation	2	F	4	2	1	1
14	Jago Research Ag	2	F	4	2	1	2
15	Nv Organon	2	F	2	22	3	1
16	Kissei Pharmaceutical Co.Ltd.	2	F	8	2	1	2
17	Lg Life Sciences Ltd.	2	F	3	2	1	5
18	Elsai	2	F	3	2	1	4
19	Macleods Pharmaceuticals Limited	2	F	1	3	1	4
20	Basf	2	F	3	6	2	
21	Biogen Inc	2	F	4	8	2	1
22	Euro-Celtique S.A.	2	F	6	12	3	
23	Lek Pharmaceutical And Chemical Company D.D.	2	F	4	8	2	

(*continued*)

24	Abbott Gmbh & Co Kg	2	F	3	11	2	3
25	Allergan, Inc.	2	F	5	12	2	2
26	Acadia Pharamaceuticals Inc	2	F	5	23	3	
27	Boehringer Ingelheim Pharma Gmbh & Co. Kg.	2	F	2	24	3	
28	Gilead	2	F	6	25	3	10
29	Pharmacia Corporation	2	F	3	15	2	
30	Otsuka Pharmaceutical Co Ltd	2	F	2	17	2	4
31	Astellas Pharma Inc	2	F	6	24	3	2
32	Aventis Pasteur	2	F	6	23	3	2
33	Altana Pharma Ag	2	F	3	31	3	2
34	Solvay	2	F	4	31	3	2
35	Takeda Pharamaceutical Company Ltd	2	F	2	32	3	6
36	Bristol- Mayers Squibb Co,	2	F	6	37	3	10
37	Schering Corporation	2	F	3	46	3	5
38	Glaxo Smith Kline Biological Sa	2	F	6	49	3	5
39	Teva Medical Ltd.	2	F	2	49	3	10
40	Bayer Aktiengesellschaft	2	F	5	55	3	4
41	Janssen Pharmaceutica N.V	2	F	10	61	3	3
42	Merck &Co	2	F	2	65	3	1
43	Astra Zeneca Ab	2	F	7	77	3	6
44	Eli Lilly And Company	2	F	3	83	3	11
45	Pfizer Products Inc.	2	F	6	92	3	3
46	Novozymes A/S	2	F	4	97	3	
47	Sanofi Aventis Deutschland Gmbh	2	F	2	148	3	6
48	Novartis	2	F	4	153	3	4

(*continued*)

49	F Hoffmann La Roche Ag	2	F	6	167	3	4
50	Tianjin Tasly Pharmaceutical Co.,Ltd	2	F	3	2	1	2
	Resident firms						
1	Ind-Swift Laboratories	1	D	3	6	2	5
2	Piramal Enterprises Limited	1	D	3	6	2	2
3	Strides Arcolab Limited	1	D	2	3	1	2
4	Jubilant Lifesciences Limited	1	D	2	5	2	1
5	Elder	1	D	2	4	1	
6	Bharat Biotech International Limited	1	D	2	7	2	4
7	Usv	1	D	4	7	2	
8	Dr Reddys Lab	1	D	1	8	2	1
9	Suven Life Sciences Limited	1	D	4	8	2	4
10	Matrix Laboratories Ltd.	1	D	3	64	3	
11	Bharat Immunologicals	1	D	2	1	1	1
12	Bharat Serums And Vaccines Ltd	1	D	2	20	2	
13	Cadila Healthcare Limited	1	D	5	37	3	1
14	Eupharma Labs	1	D	2	2	1	
15	J B Chemical & Pharmaceuticals Ltd	1	D	3	6	2	1
16	Natural Remedies Private Ltd	1	D	2	1	1	
17	Rpg Lifesciences	1	D	3	5	1	4
18	Wockhardt Limited	1	D	3	6	2	1
19	Mankind	1	D	4	0	1	2
20	Indoco Remedies Limited	1	D	5	1	1	2
21	Indus Biotech Private Limited	1	D	2	1	1	1

(*continued*)

22	Divis	1	D	3	2	1	1
23	Ranbaxy Laboratories Limited	1	D	5	2	1	6
24	Themis Laboratories Private Limited	1	D	2	2	1	4
25	Unichem	1	D	4	2	1	1
26	Medreich Limited	1	D		1	1	2
27	Shilpa	1	D	5	1	1	2
28	Symed Labs Limited	1	D	1	1	1	4
29	Immunogen, Inc	1	D	4	4	1	1
30	Lyka	1	D	2	9	2	1
31	Glenmark	1	D	1	10	2	1
32	Torrent Pharmaceutical Ltd,	1	D	1	10	2	2
33	Venus	1	D	2	10	2	1
34	Sun Pharmaceutical Industries Ltd	1	D	2	12	2	4
35	Emcure	1	D	6	14	2	2
36	Alembic	1	D	**4**	**15**	2	**1**
37	Ipca Laboratories Ltd.	1	D	4	16	2	1
38	Biocon Limited	1	D	4	21	2	1
39	Hetero Drugs Limited	1	D	5	23	2	1
40	Lupin Laboratories Ltd	1	D	3	17	2	1
41	Panacea Biotec Limited	1	D	3	18	2	1
42	Microlabs	1	D	2	19	2	2
43	Natco Pharma Limited	1	D	2	19	3	4
44	Umedica	1	D	2	20	3	3
45	Cipla Limited	1	D	2	23	3	4
46	Aurobindo	1	D	**6**	**43**	3	**1**
47	Orchid Chemicals & Pharmaceuticals Ltd	1	D	2	149	3	1
48	Charak Pharma	1	D	2	5	1	
49	Indoco Remedies Ltd.	1	D	2	2	1	1
50	Dabur	1	D		2	1	

(continued)

	Variables		Code		Total firms (100)	50 residents	50 non-residents
		Domestic/resident	D/R				
		Non-resident	F/NR		Available Data for M&A	Residents	43/50
						Non-residents	39/50
		Av. number of co-inventors	NCoI			Total	82/100
		Patent grant intensity	PGI				
		Patent ownership	POWER		Available data for Av. NCoI	Residents	48/50
		No. of M&A	M&A			Non-residents	50/50
						Total	98/100
			Missing data				

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