FRAGMENTATION OF TECHNOLOGY OWNERSHIP AND ACQUISITION STRATEGY OF FIRMS

ABSTRACT. This paper examines how the fragmented ownership of complementary intellectual property (IP) rights affects firms' acquisition behavior. We theorize that the more fragmented the ownership of complementary IP rights, the higher the rate at which a focal firm engages in technology acquisitions. Our predictions suggest that firms will expand their IP portfolios through acquisitions as strategy to continue innovating when the ownership over strategic IP becomes exceedingly spread among technology holders. Further, also we propose that this positive relationship between fragmentation and acquisitions will be stronger for firms that are at a higher risk of being "fenced in" due to the lack of control over relevant IP. Using a unique longitudinal dataset on the biopharmaceutical industry, we find empirical support for our hypotheses.

INTRODUCTION

"Invention, and particularly modern invention...is a drama enacted on a crowded stage."
(Polanyi, 1944, p.71)

Firms innovate by combining technological knowledge generated through their R&D with inputs generated outside the firm (Kogut & Zander, 1992). While seeking to use technology components in new ways, firms need to manage their innovation strategy to avoid infringing the intellectual property (IP) rights of other technology holders (Arora, Fosfuri, & Gambardella, 2001). Obtaining access to complementary IP rights is critical for firms to generate and appropriate value from their investments in innovation as technology owners can demand unreasonable royalties and upfront payments or engage in costly litigation. Thus, appropriability is a significant challenge for firms in fragmented markets for technology characterized by widely dispersed ownership of IP rights (Heller, 2008; Heller & Eisenberg, 1998). In extreme cases, the arduous task of assembling all relevant IP rights can prevent firms from innovating as they risk being "fenced in" by other technology holders (Ziedonis, 2004). Simply put, a firm has its R&D activities fenced in when outside owners of IP rights[1] can block or impose prohibitively high remuneration conditions for technologies relevant to the firms' innovation activities.

Understanding how firms access and assemble complementary IP rights has increased in importance over the last few decades with the growing fragmentation of IP ownership (Ahuja, Lampert, & Tandon, 2008; Burk & Lemley, 2009). This phenomenon has driven firms to actively deploy strategies that allow them to access externally generated IP rights that can be subsequently incorporated into their ongoing R&D efforts (Laursen & Salter, 2006; Tushman, Smith, Wood, Westerman, & O'Reilly, 2010). Among these strategies, one of the commonly observed is the use of technology-related acquisitions in which the acquirer firm takes ownership

of the target firm in order to access its IP rights (Schweizer, 2005; Sears, 2017; Wubben, Batterink, Kolympiris, Kemp, & Omta, 2015).

Yet, our understanding of how fragmented ownership of complementary IP rights relates to firms' use of technology acquisitions is still limited. Our paper sheds light on this issue. We propose that the structure of IP ownership is an essential determinant of the use of technology acquisitions as a value-appropriation mechanism. In particular, we argue that the degree of fragmentation of IP rights is positively related to the rate at which firms engage in technology acquisitions. Furthermore, this positive relationship is stronger for firms that are at a higher risk of being fenced in by owners of external IP rights. Using a unique longitudinal dataset on the biopharmaceutical industry from 1986 to 2004, we test and find empirical support for our hypotheses.

Our study makes several contributions to the literature. Building on the pioneering work of Teece (1986), scholars introduced appropriability as an important factor that influences firms' governance choices. While Teece (1986) suggests that firms may internalize complementary manufacturing and distribution assets required to bring new inventions to market, we suggest that distribution of ownership of another important asset, complementary IP rights, impacts firms' acquisition behavior. To our knowledge, ours is the first paper to identify the fragmented ownership of complementary IP rights as a driver of firms' use of technology acquisitions. In doing so, we provide a novel theoretical perspective on the antecedents of one of the most commonly observed strategies innovative firms use to access and assemble needed IP rights: technology acquisitions. We also contribute to the literature on value appropriation in markets for technology (Arora et al., 2001; Ziedonis, 2004). While Ziedonis (2004) shows that firms expand their IP portfolios in response to appropriability problems in fragmented markets for IP

rights, this paper examines the use of technology acquisitions as an alternative strategy for strengthening appropriability when the IP ownership is fragmented. Overall, this paper advances our understanding of the use of technology acquisitions in fragmented markets for technology.

THEORY AND HYPOTHESES

Acquisitions in Fragmented Markets for Technology

IP rights protect knowledge elements (Bessen & Meurer, 2008; Levitas & Chi, 2010) that firms combine and recombine to create value (Arora & Gambardella, 2010; Kogut & Zander, 1992). Firms assemble IP rights for innovation purposes through acquisitions (Ahuja & Katila, 2001), alliances (Mowery, Oxley, & Silverman, 1998; Rosenkopf & Schilling, 2007), or licensing contracts (Laursen, Leone, & Torrisi, 2010; Laursen, Moreira, Reichstein, & Leone, 2017). However, assembling the complementary IP rights can be challenging when the ownership of such IP rights is dispersed across many firms (Heller, 2008; Heller & Eisenberg, 1998). Having to negotiate with multiple technology owners simultaneously exposes the innovating firm to environmental uncertainty and risk of opportunistic behaviour from other firms, resulting in coordination issues and prohibitive costs (Diestre & Rajagopalan, 2012).

Therefore, the ownership structure of complementary IP rights has important implications for firms' ability to appropriate value from innovation. As the ownership of IP rights becomes more fragmented, firms' ability to appropriate value from innovation becomes increasingly threatened by the risk that external IP owners may "fence in" a firm's innovation activities (Heller & Eisenberg, 1998; Ziedonis, 2004). The dispersion of IP rights, and resulting uncertainty over ownership, makes it harder to assemble the IP rights that the innovating firm might be infringing (von Graevenitz, Wagner, & Harhoff, 2013). For instance, the pharmaceutical firm Bristol-Myers

Squibb announced that *"it would exclude from its drug research and would, thus, not pursue any investigations into more than 50 proteins possibly involved in cancer. The patent holders, the company explained, either would not allow it or were demanding unreasonable royalties."* (Heller, 2008:1). As this example illustrates, even if the highly dispersed owners can be identified and contacted, the potentially severe problems of metering and royalty stacking (Lemley & Shapiro, 1991) can render the piecemeal access of necessary technologies through licensing contracts infeasible.

The problem posed by fragmented ownership of IP rights is similar to the "hold-up" problem featured in the transactions cost literature (Klein, Crawford, & Alchian, 1978; Williamson, 1985, 1993). In the context of innovation, hold-up occurs when a firm expropriates rents from another firm, weakening its ability to appropriate value from its innovation. Transaction cost theory suggests that firms should respond to the appropriability threats posed by an increased fragmentation of IP rights by building a larger portfolio of IP rights to be able to "exchange hostages", thereby improving their bargaining positions vis-à-vis other firms (Cuypers, Hennart, Silverman, & Ertug, 2020; Williamson, 1983). Indeed, innovative firms often seek to mitigate value appropriation threats and improve their bargaining position by patenting aggressively (Ceccagnoli, 2009; Ziedonis, 2004). However, generating IP rights internally through own R&D tends to have long development cycles and uncertain outcomes (Chesbrough, 2003; Malerba & Orsenigo, 2002). Therefore, generating IP rights internally from scratch may not provide the firm, particularly in the short-term, with access to the specific technology rights it needs to protect and commercialize its existing innovations and continue innovating.

An alternative strategy innovative firms can use to amass a larger IP portfolio is to pursue technology acquisitions. Through technology acquisitions firms can acquire and access the entire

IP portfolio of target firms, which could improve the appropriability of their innovation efforts (Grimpe & Hussinger, 2014). In what follows, we develop theory and hypotheses on how the fragmentation of ownership of IP rights relates to firm's technology acquisition behavior.

Hypotheses Development

While accessing complementary IP rights in a fragmented market for technology, firms get exposed to the risk of opportunistic behaviour by other technology owners who may impose prohibitively high remuneration conditions for technologies that are relevant for the innovating activities of the focal firm. In such a situation firms seek to safeguard their investments (Reitzig & Puranam, 2009; Ziedonis, 2004). Yet, ex ante solutions to the problem are restricted because IP boundaries are not easy to demarcate and some of the IP related to "cumulative chain of innovation" are often unknown in advance (Merges & Nelson, 1990). Further, the potential costs and delays arising from a myriad of negotiations with diffused IP owners (Ziedonis, 2004) before developing or commercializing an innovation render ex ante solutions to threats to value appropriation infeasible. As ex ante contractual solutions are less feasible, firms respond to the appropriability threats posed by an increased fragmentation of IP rights by amassing IP rights that improves their bargaining positions vis-à-vis other firms (Cuypers et al., 2020; Williamson, 1983).

The acquisition of firms that own valuable IP rights is a key strategy an innovative firm can use to promptly augment its portfolio of IP rights needed to sustain and profit from innovation. The strategy of using technology acquisitions to consolidate needed IP rights, and thereby strengthen a firm's value appropriation ability, is vividly illustrated by the following statement made by John Maraganore, CEO of Anylam Pharmaceuticals: *"The reason we did the IP*

consolidation strategically was to avoid the fragmentation of value that occurred in the settings of other big platform technologies and to be the leading company for pharma collaborations… In one case we acquired a company… because they had some critical patents. So, it was a very explicit strategy to bring it all together … frankly there was not as much data to support its potential ... we had the persistence and the conviction that we wanted to consolidate IP this way, which would give us the whole lion's share of the value (Shih & Chai, 2010: 4)."

Technology acquisitions can improve a firm's ability to protect its innovations from the value-capture efforts of others via enhanced bargaining power resulting from a greater ability to cross-license (Cohen, Nelson, & Walsh, 2000) or threaten reciprocal suits (Chen, Liu, Liu, & Huang, 2016; Cohen et al., 2000; Hall & Ziedonis, 2001). Furthermore, acquiring a firm holding valuable IP rights can promptly reduce the need to engage in extensive individual negotiations for specific IP components, or can facilitate the development of needed technology in-house from scratch. Thus, the incentives for a firm to engage in technology acquisitions thus in part depend on the value they place on improving their bargaining positions in the face of potential threats to their innovation efforts in the future. Therefore, as the fragmentation of IP rights weakens the appropriability of innovations, one would expect firms to engage in more technology acquisitions as the fragmentation of IP rights increase.

> ***Hypothesis 1 (H1):*** *The more fragmented the ownership of complementary IP rights, the higher the rate at which a focal firm engages in technology acquisitions.*

Furthermore, using technology acquisitions when the ownership of complementary IP rights is fragmented should be particularly important when a firm is at a higher risk of being fenced in, i.e., at a higher risk of facing restrictions or prohibitively high remuneration conditions by outside owners of IP rights for using technologies relevant to its innovation activities. Firms

holding IP rights that are less valuable relative to industry peers will be more vulnerable to the value capture efforts of other firms as the fragmentation of ownership of IP rights increases (Noel & Schankerman, 2013; Ziedonis, 2004). They will find themselves in a relatively weaker bargaining position when negotiating access to others' IP rights in the future, and thus are exposed to the risk of opportunistic behaviour by other technology owners. This means that for a firm that faces a higher risk of having its innovation activities fenced in by competitors, the potential benefits of acquisitions will be relatively higher than for a firm that is less exposed to such a threat.

While aggressively applying for IP rights can enhance firms' bargaining position (Ziedonis, 2004), firms holding less valuable IP rights portfolios might lack the capability to pursue this option (Reitzig & Puranam, 2009). Even if they succeed, they might face threats to value appropriation from the owners of backdated IP rights (Lemley & Shapiro, 2005). Therefore, to improve their bargaining position and safeguard investments in innovation and commercialization, for any given level of costs associated with a technology acquisition, firms holding less valuable IP rights will be more likely to pursue acquisitions as a way of accessing relevant IP rights.

Conversely, firms with more valuable IP rights portfolios than those of competitors will be better positioned to protect their innovation efforts. Valuable IP rights provide firms with a flexible set of "hostages" for use in negotiations. Therefore, even if some of the critical IP rights are owned by other firms, the owners of a valuable IP rights portfolio will have the bargaining power to engage in cross-licensing (Cohen et al., 2000) or to threaten a reciprocal lawsuit (Chen et al., 2016; Cohen et al., 2000; Hall & Ziedonis, 2001). As the number of potential IP rights that can be accessed through an acquisition goes down with higher degree of fragmentation of IP

rights, the benefits of an additional acquisition become very similar to those of contractual mechanisms such as cross-licensing (Grindley & Teece, 1997) for firms with valuable IP portfolios.

Based on the arguments above, we expect that for firms with a high risk of being fenced in the benefits of technology acquisitions will be high for any level of IP rights fragmentation. Thus, we hypothesize:

> ***Hypothesis 2 (H2):*** *The positive relationship between the fragmentation of ownership of complementary IP rights and a focal firm's rate of technology acquisitions will be stronger for firms that are at a higher risk of being fenced in.*

METHODS

Empirical Context

To test our hypotheses, we used data on firms operating in the biopharmaceutical industry. We chose this empirical setting for several reasons. First, the biopharmaceutical industry has been experiencing increasing fragmentation of its IP rights. This has been largely driven by the fact that, since the early 1990s, the industry has seen a steady influx of new players dedicated to the identification and development of new molecules and treatments (Pisano, 2006). Although many firms in this industry, particularly smaller ones, may have no intention of pushing new drugs through FDA clinical trials approval, their investments in R&D often result in patents (Henderson & Cockburn, 1994; McGrath & Nerkar, 2004). This results in a wide variety of firms holding strategic IP rights. Furthermore, the industry accounts for one of the largest shares of patents granted in the U.S. (Lim, 2004). In line with our theoretical predictions, we expect that, particularly for biopharmaceutical firms, innovation costs will be strongly related to increasing number of patent holders. Indeed, in this industry the "*proliferation of intellectual property*

rights upstream may be stifling life-saving innovations further downstream in the course of research and product development" (Heller and Eisenberg, 1998, p. 698). These characteristics push firms into using a different range of mechanisms, such as acquisitions, to deal with dispersed ownership of complementary IP rights.

It is also worth noting the deleterious effect of increasing IP fragmentation on the innovation activities of biopharmaceutical firms. For example, despite the strategic importance of gene therapy for the development of several new treatments, "*no single company or organization, however, has the resources to develop any significant fraction of the genetic information present in an organism. If proprietary information is not freely available or licensed in an affordable manner, researchers will be precluded from using these protected nucleic acids to develop new therapeutics and diagnostics*" (Jeanne, Piccolo, Stanton, & Tyson, 2000: 3). In the absence of proprietary technologies, firms can turn to technology licensing, which partly explains the large number of deals commonly observed in this industry. Although the market for technology in the biopharmaceutical industry is relatively well developed (Anand & Khanna, 2000; Erden, Klang, Sydler, & von Krogh, 2014), technology holders frequently ask for prohibitively expensive remuneration conditions (Laursen et al., 2017; Moreira, Cabaleiro, & Reichstein, 2018). In extreme situations, for specific therapeutic areas, firms may find themselves excluded from innovating and from making strategic R&D investments due to the costs or infeasibility of accessing multiple IP rights[2].

In fact, the issues related to ownership fragmentation of IP rights faced by biopharmaceutical firms has been extensively documented and described in prior studies. For example, Heller and Eisenberg (1998) apply the "tragedy of the commons" metaphor to explain how the presence of multiple technology holders and IP rights may damage the R&D investments and developments

in this industry by holding back development of fewer and less useful drugs and treatments. In another example, Huang and Murray (2008) document how the presence of multiple technology holders related to the IP ownership of the human genome hinders the future development of scientific work in this area.

Second, not only are R&D costs in this industry high, but so are failure rates (Nerkar & Roberts, 2004). This creates significant uncertainty over firms' capacity to recover their investments in R&D (Munos, 2009). One way for firms to mitigate this risk is by ensuring legal access to relevant IP rights. For example, firms will not embark on clinical trials without either applying for patents related to the underlying technologies that will be tested or acquiring access to the patents protecting them. Indeed, as prior studies have pointed out, "*If the innovating company begins FDA process before USPTO filing, then it runs the risk of another company patenting the invention before them. Consequently, the innovating company would have to license the biopharmaceutical, losing royalties, market exclusivity, and company value; or would have to abandon the FDA process and forfeit millions spent in research and development*" (Fernandez & Huie, 2004: 510). This pushes firms to actively manage their innovation and IP strategy to improve appropriability of their innovations.

Finally, several studies have shown that acquisitions are prevalent in this industry (e.g. Danzon, Epstein, & Nicholson, 2007; Higgins & Rodriguez, 2006; Ruckman, 2005). Biopharmaceutical firms are commonly involved in acquisitions, whether as acquirer or target (Munos, 2009). While the industry saw many horizontal mergers between large firms in the 1980s, the acquisition of smaller companies due to strategic R&D decisions became more prevalent from the 1990s (Danzon et al., 2007). This offers an appropriate empirical context in

which to examine whether IP ownership fragmentation is a driver of biopharmaceutical firms' tendency to acquire.

Data and Sample

Our database was compiled based on information combining four main data sources: Recap Deal Builder, Pharmaprojects, Compustat North America, and the NBER patent project. The combination of these four different data sources gave us a unique dataset that allowed us to perform a longitudinal analysis for the period 1986–2004. We defined 1986 as the starting year based on the availability of consistent acquisition data from Recap, and 2004 as the ending year based on the availability of patent data in NBER. The NBER data is compiled based on patents granted by the United States Patent and Trademark Office (USPTO). We decided to rely on this version of the patent data because, to the best of our knowledge, it is the most accurate dataset to identify the IP rights holder of a patent at a given point in time *unambiguously*. Indeed, this *particular* dataset allows us to follow longitudinal changes in IP ownership *dynamically* (Bessen, 2009). This is critical, as patents are often repeatedly reassigned through sale or M&A events.

We began constructing our sample by identifying public firms listed in Compustat that belong to either SIC code 2834, *Pharmaceutical Preparations,* or 2836, *Biological Products*. These two are the most relevant SIC codes for companies that operate in the biopharmaceutical industry. The public firms operating in these SICs are the most relevant industry players in terms of patenting activity and acquisitions. Furthermore, these are the firms responsible for the largest share of new drugs at the US Food and Drug Administration (FDA) and of patenting activity, which are critical in this industry.

We used the firm names listed on Compustat to connect each observation in the sample with Recap Deal Builder. Recap is known as one of the most accurate and comprehensive sources of

information regarding M&A deals and technology exchange involving biopharmaceutical firms (Schilling, 2009). Using the Recap dataset, we could identify all deals in which a focal firm was listed as an acquirer or a target during our period of observation. This dataset also provided access to important control variables, such as licensing and alliance activities. It allowed us to access detailed information regarding the M&A deals, and also to unambiguously identify the acquirer and acquired firm for a given deal. Having connected these two datasets, we were able to access detailed information regarding each acquisition. We only included completed deals where the acquirer bought a *majority stake* in a target that was not already a subsidiary. This ensured that the IP rights of the target were transferred to the acquirer upon acquisition.

Next, we captured information regarding firms' innovation activity and patent portfolio using the NBER patent database (Hall, Jaffe, Trajtenberg, & Berglass, 2001). To avoid noise produced by differences in evaluation procedures across countries, we focused on the patents granted by the USPTO. Given that the U.S. represents one of the world's main markets for new drugs and treatments, firms have strategic incentives to apply for patents at the USPTO as early as possible (Henderson & Cockburn, 1994).

Finally, we matched the firms in our sample with Pharmaprojects, which contains pharmaceutical trial data regarding the development of new drugs at the FDA. Using this database, we extracted the R&D pipeline for each firm in our sample to capture its drug-development activities (Hess & Rothaermel, 2011). Based on trial data, we could track and identify the firms that had been actively involved in drug development.

The resulting sample was structured as a panel in which we observe each firm *i* in a given year *t*. Therefore, we use the firm-year combination as our unit of analysis. The final sample

comprised 306 unique firms appearing 6.5 times on average (min: 2; max: 18). The empirical analysis was performed based on 1,984 firm-year observations 1986–2004.

Measures

Dependent variables

Technology acquisitions. We scrutinized Recap to identify each acquisition deal that was connected to the firms in our sample. Because we were interested in identifying the acquisitions driven by fragmentation of IP rights, we excluded deals that involved targets that had *no patents accumulated* in the preceding seven years. We did this by also connecting all the target firms described in our sample with the NBER patent database. Furthermore, we also removed from the sample *reverse* and *minority acquisitions,* as these types of deals are unlikely to be motivated by the intention to access strategic IP rights. Our measure captures the total number of acquisitions that firm *i* had engaged in year *t* as the acquirer firm. Finally, we follow prior studies (e.g., Hagedoorn & Duysters, 2002; Servaes & Zenner, 1996) and reduce the skewness of the variable by using the logarithm of (*Technology acquisitions* +1) as our final measure (The results are robust to using count of technology acquisitions as the dependent variable).

Independent Variables

Fragmentation of IP rights. Following Ziedonis (2004), we used a Herfindahl-based measure to estimate whether the ownership of a firms' complementary IP rights (complementary patents) is widely dispersed. We computed the *Fragmentation of IP rights* using the following formula:

$$Fragmentation\ of\ IP\ rights = \left[1 - \sum_{j=1} \left(\frac{NBCITES_{ij}}{NBCITES_i}\right)^2\right] X\ 100 \quad , i \neq j$$

where *j* refers to each unique firm that is cited by patents in the portfolio of firm *i* (i.e., the number of backward citations, or NBCITES). For simplicity, time subscripts are omitted. We

defined a firm's patent portfolio using a 10-year moving window (The results are robust to using moving windows of different lengths, such as moving windows of 1, 3, and 5 years). Citations to a firm's own publications are excluded during the computation they do not pose a threat to firms' innovation efforts. Following Ziedonis (2004) and Hall (1992), we normalized the measure to correct for statistical bias that may arise for firms that have few patents in their portfolio. To do so, we multiplied the $Fragmentation\ of\ IP\ rights$ by a correction factor of $\frac{NBCITES_i}{NBCITES_i - 1}$, where $NBCITES_i$ is the total number of citations listed in the patents assigned to firm *i*.

Risk of being fenced in. To capture the risk of a focal firm being fenced in, we looked at the value of its IP portfolio. This measure was computed to vary by each firm cross-sectionally and longitudinally. The rationale is that firms with a stronger IP portfolio are more likely to build future innovations based on their own technologies, as opposed to using other firms'. To compute this variable, we first constructed the portfolio of patents owned by firm *i* in a given year *t*. We defined a firm's patent portfolio using a 10-year moving window (The results are robust to using moving windows of different lengths, such as moving windows of 1, 3, and 5 years). Next, we identified the value of each patent based on the number of forward citations it had received. We then summed the total value of a firm's portfolio and compared it to the average value of the portfolios of other firms operating in the same SIC code in a given year. Because we wanted to compute the risk of being fenced in, we inverted this variable by multiplying it by (-1). Accordingly, increasing values indicate a higher risk of being fenced in.

Controls

We controlled for a number of variables that may be simultaneously related to firms' rate of technology acquisitions and fragmentation of IP rights. For acquiring firm innovation

characteristics, we controlled for firm *Patenting experience* as accumulated experience in managing and generating IP rights using the number of years from the firm's first patent application to year *t*. As R&D investments of a firm can impact its acquisition decisions, we controlled for a firm *R&D intensity* by dividing its total amount of R&D investment divided by the total number of employees of the firm in year *t*. Another characteristic that can impact acquisition strategy of a firm is its *Drug pipeline.* We controlled for Drug pipeline using a dummy variable that took a value of 1 if a firm had at least one drug in its pipeline in year t, and 0 otherwise. To account for the extent to which firms build on their own technologies, we include in our econometric models the *Knowledge base specificity* as the ratio of self-citations to total citations received by a firms' IP portfolio in the three years prior to the year *t*. As alliance activities can both increase firm innovation output and facilitate acquisitions, we also account for *Strategic alliances* measured as the cumulative number of alliances that a firm had within three years from year *t*. We further controlled for *Litigation* by including a dummy variable that took a value of 1 if a firm had been sued at least once for infringing another firm's patents within three years prior to year *t,* and 0 otherwise. Finally, we controlled for two strategies that the firms use to mitigate the risks of fragmentation. First, based on Recap data, we compute *Technology licensing* using the cumulative number of technology licensing-in deals, that a firm had within three years from year *t*. Second, we account for patenting activity (Ziedonis, 2004) as the logarithm of the number of patent applications filed by a firm *i* in year *t*.

For acquiring firm resources and capabilities characteristics, we controlled for *Downstream commercial capabilities as* the amount that a firm had spent on Selling, General, and Administrative Expenses (SG&A) in year *t* (Rothaermel & Boeker, 2008). We also incorporate in our models a firm's *Size* using natural logarithm of reported total assets for a firm in year *t*.

Additionally, we also account for *Slack*, i.e., the amount of firms' unused resources, based on the ratio between current liabilities and total assets of a firm in year *t*. As the equity valuation of a firm impacts its acquisition strategy, we take into account the *Price to book ratio* using the ratio of market value to book value of a firm in year *t*. We controlled for the financial status of the acquirer using *Return on assets* and *Leverage*. *Return on assets* is measured as the ratio of earnings before interest, tax, depreciation and amortization to total assets of firm in year *t* while *Leverage* is measured as the ratio of long-term debt to total assets of a firm in year. We also controlled for *Capital intensity*, which is measured as ratio of the net property, plant, and equipment to the total number of employees at the end of the previous year. Since, acquiring firms might follow different rhythms of acquisitions over time, we controlled for *Time since last acquisition*. We also account for competition and industry characteristics faced by the acquiring firm. We controlled for *Firm market share,* measured as the share of the market a firm had in year *t, and Advertisement intensity,* measured as the ratio of advertisement expenses to total sales for a firm in year *t*. Additionally, we also controlled for *Industry growth* based on the change in total sales achieved by firms in the same SIC code as the focal firm between years *t*-1 and *t*.

MODELS

To test our hypotheses, we used ordinary least squares panel regressions with firm and year fixed-effects, and robust standard errors. We opted to use firm fixed effects to account for firm-related time-invariant unobservable heterogeneity that could correlate with our error term and our main explanatory variables simultaneously. We also captured time trends employing year fixed effects. To avoid issues related to reverse causality, we lagged the explanatory variables in our model by one year relative to the dependent variable.

We ruled out using a poisson or a negative binomial model to test our first two hypotheses because with a firm fixed-effects specification these estimators would exclude firms for which the dependent variable—in this case, *Technology acquisitions*—has no within-firm variation for the period of analysis (Allison & Waterman, 2002). In our context, employing these models could induce significant sample selection issues in our estimations (Cameron & Trivedi, 2010: 623). Furthermore, concerning the use of a negative binomial model specifically, this estimator does not allow the use of robust standard errors in conjunction with fixed effects, which is an important specification to account for heteroscedasticity (Allison & Waterman, 2002).

RESULTS

Table 1 reports the descriptive statistics and simple pairwise correlations between the variables used to test our hypotheses. The *Fragmentation of IP rights* has a mean of 0.80 and standard deviation of 0.29. Except for the correlations between *Size* and *Patenting experience*, the results of pairwise correlations raised no significant concerns regarding multicollinearity involving our explanatory variables. The high correlation among the above control variables is in line with theoretical expectations, but to test whether this was a concern, we estimated our models entering these control variables separately, and our main results remained unchanged. Additionally, the mean of Variance Inflation Factors (VIF) associated with our variables does not raise further concerns (Mean VIF= 3.2).

Insert Table 1 about here

Table 2 reports the results of fixed-effects panel-regression estimations in three different specifications (Models 1 to 3) to test *hypotheses 1* and *2*. Model 1 reports a baseline estimation

that does not include *Fragmentation of IP rights*. In Model 2, we introduce the *Fragmentation of IP rights* to test *hypothesis 1*. The coefficient estimates from this model provide support for *hypothesis 1*. The coefficient of *Fragmentation of IP rights* is positive and statistically significant ($\beta = 0.067\ ,\ p - value <\ 0.01$). In Model 3, we introduce interaction terms to test *hypothesis 2*. The interaction term between the *Fragmentation of IP rights* and firms' *Risk of being fenced* is positive and significant ($\beta = 0.036\ ,\ p - value < 0.01$), providing support for *hypothesis 2*.

Insert Table 2 about here

We checked the robustness of our results with additional tests and alternative specifications. We measured our main independent variables, *Fragmentation of IP rights* and *Risk being fenced in* using firm's patent portfolio that is defined over a 10-year period. We re-estimated the models with the independent variables measured using patent portfolio defined over different time windows (1, 3, and 5 years). Our results are robust to using these alternative measures. We also performed a robustness check by adding the fragmentation measure at the industry level as a control variable in our models used to test *hypotheses 1* and *2*. In line with our expectations, controlling for fragmentation at the industry level did not change our results of the relationship between Fragmentation of IP rights and firms' decision to engage in technology acquisitions. Further, we performed a robustness check by controlling for the *Product market competition* faced by the firm using the dataset compiled by Hoberg & Phillips (2010). Hoberg & Phillips (2010) categorized firms having pairwise product similarities with a focal firm that are above a threshold to identify direct competitors. Their database provides Herfindahl-Hirschman Index measured using sales of direct competitors for each firm-year from 1989 onwards[3]. The results are robust to the inclusion of this additional control.

In spite of the limitations of logistic or count models (discussed in the "Empirical Models" subsection above), we used them for robustness tests. We tested whether our results were sensitive to the way we measured our main dependent variable. First, we generated a new dummy dependent variable that took a value of 1 if firm *i* made at least one technology acquisition in a given year *t*, and 0 otherwise. We re-estimated the models with this alternative dependent variable using a panel logit model with fixed effects and the same independent and control variables as those reported in Table 2. The results are similar to those reported earlier. Finally, we re-estimated the models using a count dependent variable. Second, we used the count of technology acquisitions that a firm *i* engages in year *t* as the dependent variable. We re-estimated the models with this count based dependent variable using panel poisson and negative binomial regressions with fixed effects and the same independent and control variables as those reported in Table 2. The results are robust to these alternate measures. In sum, all of the above tests yielded further evidence in support of the robustness of our findings.

Supplementary Analyses

Many prior studies have examined different mechanisms through which firms can generate and acquire IP rights as part of their innovation strategy, including licensing contracts (Contractor & Reuer, 2014; Laursen et al., 2017), strategic alliances (Norman, 2004; Oxley, 1999), and increasing patenting activity (Reitzig & Puranam, 2009; Ziedonis, 2004). We extended our analysis by testing whether these three specific mechanisms are complementary to, or substitutes for, technology acquisitions in a context of increasing fragmentation of IP rights. We used Recap to compute, first, the number of licensing contracts that a focal firm *i* has entered into in a given year *t* as a licensee, and second, the number of research alliances for the same period. Finally, using the NBER database, we calculated the patents a firm has applied for in a given year.

Table 3 reports the results, using the same sample and empirical setup as in Table 2. Model 4, 5, and 6 introduce the interaction between the *Fragmentation of IP rights* and *Technology licensing, Strategic alliances, and Patenting activity,* respectively. In model 4, the coefficient of the interaction term of *Technology licensing* and *Fragmentation of IP rights* is positive and significant ($\beta = 0.009$, $p - value < 0.10$). The results suggest that firms consider technology acquisitions and license-in deals as complements as the fragmentation of IP rights increases. In model 5, the coefficients of the interaction terms between *Fragmentation of IP rights* and Strategic alliances are not significant at conventional levels. These results provide no evidence as to whether alliances will be deployed as complements or substitutes of acquisitions under increasing fragmentation of IP rights. In model 6, the coefficient of the interaction term of *Patenting activity* and *Fragmentation of IP rights* is positive and significant ($\beta = 0.001$, $p - value < 0.05$), The results indicate that, under increasing IP rights fragmentation, firms that patent more will also be more likely to engage in acquisitions. However, at higher levels of fragmentation of IP rights firms use aggressive patenting and technology acquisitions as substitutes.

To sum up, these tests provide evidence that technology licensing and patenting activity act as complements for technology acquisitions as the fragmentation of IP rights increases. Furthermore, we find no evidence that strategic alliances are used as complements or substitutes for technology acquisitions at different levels of fragmentation of ownership of IP rights.

DISCUSSION

This paper examines how the ownership structure of complementary IP rights is related to technology acquisitions. We argue that the fragmentation of IP rights is positively related to firms' rate of technology acquisitions. We also argue that this relationship varies across firms,

such that it is stronger for firms that have a higher risk of being fenced in by owners of external IP rights. Using a unique longitudinal dataset on acquisitions in the biopharmaceutical industry over the period 1986 to 2004, we find empirical support for our hypotheses.

Our study makes several contributions. First, we contribute to the literature on technology acquisitions (Ahuja & Katila, 2001; Schweizer, 2005; Sleuwaegen & Valentini, 2006) which has primarily focused on the learning (Vermeulen & Barkema, 2001) and capability development (Sears & Hoetker, 2014) benefits of acquisitions. Building on pioneering work of Teece (1986) on profiting from technological innovation, existing studies have also examined whether firms acquire complementary manufacturing and distribution assets required to bring new inventions to market (eg., Inkpen, Sundaram, & Rockwood, 2000). In contrast, we propose that the fragmented ownership of another important asset, complementary IP rights, impacts firms' acquisition behavior. To our knowledge, ours is the first paper to identify the fragmented ownership of complementary IP rights as a driver of firms' use of technology acquisitions. Moreover, we suggest that the risk of being fenced in by owners of external IP rights is an important moderator of the positive relationship between the fragmentation of ownership of IP rights and the rate at which a focal firm engages in technology acquisitions.

Second, we contribute to the literature on value appropriation in markets for technology (Arora et al., 2001; Grimpe & Hussinger, 2014; Ziedonis, 2004). While this stream of literature has largely focused on IP filing strategies that firms use to deal with appropriability challenges (Ziedonis, 2004), it has given limited attention to the use of technology acquisitions as a value appropriation mechanism. An important exception is Grimpe & Hussinger (2014), who examine how the price that acquirer firms pay for targets is influenced by the value-appropriation benefits offered by the target's patent portfolio. We extend this stream of literature by examining the use

of technology acquisitions as a means of strengthening appropriability when the ownership of complementary IP rights is fragmented.

Our theory and results have broader implications for other research streams as well, such as research at the nexus of the resource-based view and economics of property rights. While the resource-based view (Barney, 1991; Foss, Klein, Kor, & Mahoney, 2008; Peteraf, 1993) presupposes value appropriation (Reitzig & Puranam, 2009), research on the economics of property rights (Alchian & Demsetz, 1973; Demsetz, 1974; Foss & Foss, 2005) has suggested that value appropriation is threatened by potential constraints on the usage rights of the elements that constitute a resource. Indeed, recent research has started to explore in greater depth how firms strategize to improve their value appropriation by securing or protecting usage rights over value-generating resources (Ceccagnoli, 2009; Townsend & Busenitz, 2008; Ziedonis, 2004). Our study has implications for this line of work. We extend the literature by showing that when the ownership of complementary IP rights is fragmented firms increase the rate at which they engage in technology acquisitions to assemble needed IP rights and avoid being constrained in their innovation efforts.

Our study also has implications for research on IP rights that has been primarily concerned with licensing and alliance deals as market mechanisms to grant access to IP rights generated by other firms (Laursen et al., 2010, 2017; Norman, 2004; Oxley, 1999). We extend this research stream by providing evidence that technology acquisitions are also a mechanism that firms use to manage their access into markets for technology. We also propose that under high levels of fragmentation of IP rights, there can be gaps in a firm's IP portfolio that are best filled through technology acquisitions.

Furthermore, our study also has implications for the literature on "M&A waves". While the extant literature on M&A waves has focused on wave determinants such as valuation levels (Rhodes-Kroph & Viswanathan, 2004), exogenous industry shocks (Harford, 2005; Öberg & Holtström, 2006), or behavioral biases (Auster & Sirower, 2002), our study points to the fragmentation of IP rights in an as an additional driver of M&A activity and clustering.

Limitations and Future Research

While this paper deepens our understanding of the use of technology acquisitions as a mechanism for value appropriation in fragmented markets for IP rights, it has limitations that future research could address. First, our study focuses on a single mechanism for strengthening a firm´s ability to appropriate value under conditions of increasing dispersion of complementary IP rights: technology acquisitions. Future research could compare the use of different value-appropriation mechanisms and examine how they are combined, sequenced, and interrelated. For instance, do firms that apply for IP rights aggressively also engage in more technology acquisitions as fragmentation of IP rights increases, or are these two mechanisms combined, sequenced, and/or prioritized differently at different levels of fragmentation? These questions are fundamental from both a policy and managerial perspective and warrant additional research. In our paper, we have made an initial step towards exploring this question by performing supplementary analyses extending our main theoretical perspective.

Second, although we employ an extensive list of relevant control variables in our econometric models, endogeneity problems might still be an issue; however, we believe that our empirical strategy substantially reduces concerns over unobserved heterogeneity and omitted variables bias. In addition to a range of control variables, we also use firm and year fixed-effects, which

should deal with unobserved heterogeneity coming from both time-trends and individual firm time-invariant characteristics such as industry affiliation. Nevertheless, future studies could test our predictions in different empirical settings and using different research designs (i.e., quasi-natural experiments), where it is possible to fully isolate the effect of IP rights fragmentation on a firm's acquisition behavior.

Third, our study examines how the fragmentation of IP rights relates to technology acquisitions in just one sector (biopharmaceuticals). While biopharmaceuticals provide an appropriate context, future research could examine the generalizability of our findings to other technological or industrial settings such as semiconductors or software. Another direction would be to examine which of our arguments and findings generalize to a setting where standard development organizations can make essential IP rights available to everyone on Fair, Reasonable, and Non-Discriminatory (FRAND) terms and conditions. For instance, the introduction of FRAND commitments in cellular phone development and manufacturing significantly mitigated the value appropriation challenges firms face (Teece, 2018). Thus, future research could also examine the relationship between the fragmentation of IP rights and the prevalence and value impact of technology acquisitions in FRAND contexts.

Furthermore, our theory and findings suggest that firms at greater risk of being fenced in are more likely to expend resources on costly appropriation efforts in the form of technology acquisitions. Yet, a firm could also invent around the IP positions of other firms to alleviate potential threats, which may be easier for firms possessing a decomposable knowledge base that provides greater malleability or capacity for change (Yayavaram & Ahuja, 2008). Future research could examine the interactions between the characteristics of a firm's knowledge base and its risk of being fenced in and, thereby, shed light on the optimal value-appropriation

strategy in a given IP landscape. Furthermore, our theory development is from the point of view of the acquirer, yet research has shown that targets also seek benefits from being acquired (Huang & Walkling, 1987) and actively try to make themselves more attractive to potential acquirers (Zingales, 1995). Therefore, future studies could extend the current theorization to the benefits sought and actions undertaken by potential targets at different levels of IP rights fragmentation. More broadly, future research is needed to improve our understanding of the contextual and competitive conditions impacting the benefits and costs of alternative value-appropriation strategies.

REFERENCES

Ahuja, G., & Katila, R. 2001. Technological acquisitions and the innovation performance of acquiring firms: a longitudinal study. ***Strategic Management Journal***, 22(3): 197–220.

Ahuja, G., Lampert, C. M., & Tandon, V. 2008. Moving Beyond Schumpeter: Management Research on the Determinants of Technological Innovation. ***The Academy of Management Annals***, 2(1): 1–98.

Alchian, A. A., & Demsetz, H. 1973. The Property Right Paradigm. ***The Journal of Economic History***, 33(1): 16–27.

Allison, P. D., & Waterman, R. P. 2002. Fixed-Effects negative binomial regression models. ***Sociological Methodology***, 32(1): 247–265.

Anand, B. N., & Khanna, T. 2000. Do firms learn to create value? The case of alliances. ***Strategic Management Journal***, 21(3): 295–315.

Arora, A., Fosfuri, A., & Gambardella, A. 2001. ***Markets for technology : the economics of innovation and corporate strategy***. MIT Press.

Arora, A., & Gambardella, A. 2010. Ideas for rent: an overview of markets for technology. ***Industrial and Corporate Change***, 19(3): 775–803.

Auster, E. R., & Sirower, M. L. 2002. The Dynamics of Merger and Acquisition Waves. ***The Journal of Applied Behavioral Science***, 38(2): 216–244.

Barney, J. 1991. Firm Resources and Sustained Competitive Advantage. ***Journal of Management***, 17(1): 99–120.

Bessen, J. 2009. ***Matching Patent Data to Compustat Firms***.

Bessen, J., & Meurer, M. J. 2008. Do Patents Perform Like Property? ***Academy of Management Perspectives***, 22(3): 8–20.

Burk, D. L., & Lemley, M. A. 2009. ***The Patent Crisis and How the Courts Can Solve It***. University of Chicago Press.

Cameron, A. C., & Trivedi, P. K. 2010. ***Microeconometrics using Stata***. Stata Press.

Ceccagnoli, M. 2009. Appropriability, preemption, and firm performance. ***Strategic Management Journal***, 30(1): 81–98.

Chen, Y. M., Liu, H. H., Liu, Y. S., & Huang, H. T. 2016. A preemptive power to offensive patent litigation strategy: Value creation, transaction costs and organizational slack. ***Journal of Business Research***, 69(5). https://doi.org/10.1016/j.jbusres.2015.10.030.

Chesbrough, H. 2003. ***Open Innovation: The New Imperative for Creating and Profiting, from Technology***. Boston: Harvard Business School Press.

Clark, J., Piccolo, J., Stanton, B., & Tyson, K. 2000. ***Patent pools: a solution to the problem of access in biotechnology patents?***

Cohen, W., Nelson, R., & Walsh, J. 2000. ***Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)***. no. 7552, Cambridge, MA.

Contractor, F. J., & Reuer, J. J. 2014. Structuring and Governing Alliances: New Directions for Research. ***Global Strategy Journal***, 4(4): 241–256.

Cuypers, I., Hennart, J.-F., Silverman, B., & Ertug, G. 2020. Transaction Cost Theory: Past Progress, Current Challenges, and Suggestions for the Future. ***Academy of Management Annals***. https://journals.aom.org/doi/abs/10.5465/annals.2019.0051.

Danzon, P. M., Epstein, A., & Nicholson, S. 2007. Mergers and acquisitions in the

pharmaceutical and biotech industries. ***Managerial and Decision Economics***, 28(4–5): 307–328.

Demsetz, H. 1974. Toward a Theory of Property Rights. ***Classic Papers in Natural Resource Economics***: 163–177. London: Palgrave Macmillan UK.

Diestre, L., & Rajagopalan, N. 2012. Are all 'sharks' dangerous? new biotechnology ventures and partner selection in R&D alliances. ***Strategic Management Journal***, 33(10): 1115–1134.

Erden, Z., Klang, D., Sydler, R., & von Krogh, G. 2014. Knowledge-flows and firm performance. ***Journal of Business Research***, 67(1). https://doi.org/10.1016/j.jbusres.2012.09.001.

Fernandez, D. S., & Huie, J. T. 2004. Balancing US patent and FDA approval processes: strategically optimizing market exclusivity. ***Drug Discovery Today***, 9(12): 509–512.

Foss, K., & Foss, N. J. 2005. Resources and Transaction Costs: How Property Rights Economics Furthers the Resource-Based View. ***Strategic Management Journal***, 26: 541–553.

Foss, N. J., Klein, P. G., Kor, Y. Y., & Mahoney, J. T. 2008. Entrepreneurship, subjectivism, and the resource-based view: toward a new synthesis. ***Strategic Entrepreneurship Journal***, 2(1): 73–94.

Grimpe, C., & Hussinger, K. 2014. Resource complementarity and value capture in firm acquisitions: The role of intellectual property rights. ***Strategic Management Journal***, 35(12): 1762–1780.

Grindley, P. C., & Teece, D. J. 1997. Managing Intellectual Capital: Licensing and Cross-Licensing in Semiconductors and Electronics. ***California Management Review***, 39(2): 8–41.

Hagedoorn, J., & Duysters, G. 2002. External Sources of Innovative Capabilities: The Preferences for Strategic Alliances or Mergers and Acquisitions. ***Journal of Management Studies***, 39(2): 167–188.

Hall, B. H., Jaffe, A. B., Trajtenberg, M., & Berglass, E. 2001. ***The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools***. no. 8498.

Hall, B. H., & Ziedonis, R. H. 2001. The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995. ***RAND Journal of Economics***, 32(1): 101–128.

Harford, J. 2005. What drives merger waves? ***Journal of Financial Economics***, 77(3): 529–560.

Heller, M. 2008. ***The gridlock economy : how too much ownership wrecks markets, stops innovation, and costs lives***. Basic Books.

Heller, M. A., & Eisenberg, R. S. 1998. Can Patents Deter Innovation? The Anticommons in Biomedical Research. ***Science***, 280(5364): 698–701.

Henderson, R., & Cockburn, I. 1994. Measuring Competence? Exploring Firm Effects in Pharmaceutical Research. ***Strategic Management Journal***, 15(S1): 63–84.

Hess, A. M., & Rothaermel, F. T. 2011. When are assets complementary? star scientists, strategic alliances, and innovation in the pharmaceutical industry. ***Strategic Management Journal***, 32(8): 895–909.

Higgins, M. J., & Rodriguez, D. 2006. The outsourcing of R&D through acquisitions in the pharmaceutical industry. ***Journal of Financial Economics***, 80(2): 351–383.

Hoberg, G., & Phillips, G. 2010. Product Market Synergies and Competition in Mergers and Acquisitions: A Text-Based Analysis. ***Review of Financial Studies***, 23(10): 3773–3811.

Huang, Y.-S., & Walkling, R. A. 1987. Target abnormal returns associated with acquisition announcements: Payment, acquisition form, and managerial resistance. ***Journal of Financial Economics***, 19(2): 329–349.

Inkpen, A. C., Sundaram, A. K., & Rockwood, K. 2000. Cross-border acquisitions of U.S. technology assets. ***California Management Review***, (3): 50–71.

Klein, B., Crawford, R. G., & Alchian, A. A. 1978. Vertical Integration, Appropriable Rents, and the Competitive Contracting Process. ***Source: Journal of Law and Economics***, vol. 21.

Kogut, B., & Zander, U. 1992. Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology. ***Organization Science***, 3(3): 383–397.

Laursen, K., Leone, M. I., & Torrisi, S. 2010. Technological exploration through licensing: New insights from the licensee's point of view. ***Industrial and Corporate Change***, 19(3).

Laursen, K., Moreira, S., Reichstein, T., & Leone, M. I. 2017. Evading the Boomerang Effect: Using the Grant-Back Clause to Further Generative Appropriability from Technology Licensing Deals. ***Organization Science***, 28(3).

Laursen, K., & Salter, A. 2006. Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms. ***Strategic Management Journal***, 27(2): 131–150.

Lemley, M. A., & Shapiro, C. 2005. Probabilistic Patents. ***Journal of Economic Perspectives***, 19(2): 75–98.

Levitas, E., & Chi, T. 2010. A look at the value creation effects of patenting and capital investment through a real options lens: the moderating role of uncertainty. ***Strategic Entrepreneurship Journal***, 4(3): 212–233.

Lim, K. 2004. The relationship between research and innovation in the semiconductor and pharmaceutical industries (1981–1997). ***Research Policy***, 33(2): 287–321.

Malerba, F., & Orsenigo, L. 2002. Innovation and market structure in the dynamics of the pharmaceutical industry and biotechnology: Towards a history-friendly model. ***Industrial and Corporate Change***, 11(4).

McGrath, R. G., & Nerkar, A. 2004. Real options reasoning and a new look at the R&D investment strategies of pharmaceutical firms. ***Strategic Management Journal***, 25(1): 1–21.

Merges, R. P., & Nelson, R. R. 1990. On the Complex Economics of Patent Scope. ***Columbia Law Review***, 90(4): 839.

Moreira, S., Cabaleiro, G., & Reichstein, T. 2018. Licensing decision: a rent dissipation lens applied to product market competition, openness to external knowledge and exogenous sunk costs. ***Industrial and Corporate Change***, 28(4): 773–792.

Mowery, D. C., Oxley, J. E., & Silverman, B. S. 1998. Technological overlap and interfirm cooperation: implications for the resource-based view of the firm. ***Research Policy***, vol. 27.

Munos, B. 2009. Lessons from 60 years of pharmaceutical innovation. ***Nature Reviews Drug Discovery***, 8(12): 959–968.

Nerkar, A., & Roberts, P. W. 2004. Technological and product-market experience and the success of new product introductions in the pharmaceutical industry. ***Strategic Management Journal***, 25(89): 779–799.

Noel, M., & Schankerman, M. 2013. Strategic Patenting and Software Innovation. ***The Journal of Industrial Economics***, 61(3): 481–520.

Norman, P. M. 2004. Knowledge acquisition, knowledge loss, and satisfaction in high

technology alliances. ***Journal of Business Research***, 57(6). https://doi.org/10.1016/S0148-2963(02)00395-8.

Öberg, C., & Holtström, J. 2006. Are mergers and acquisitions contagious? ***Journal of Business Research***, 59(12). https://doi.org/10.1016/j.jbusres.2006.09.015.

Oxley, J. E. 1999. Institutional environment and the mechanisms of governance: the impact of intellectual property protection on the structure of inter-firm alliances. ***Journal of Economic Behavior & Organization***, 38(3): 283–309.

Penrose, E. 1959. The theory of the growth of the firm. ***The Theory of the Growth of the Firm***. Oxford University Press.

Peteraf, M. A. 1993. The cornerstones of competitive advantage: A resource-based view. ***Strategic Management Journal***, 14(3): 179–191.

Pisano, G. 2006. Profiting from innovation and the intellectual property revolution. ***Research Policy***, 35(8): 1122–1130.

Polanyi, M. 1944. Patent Reform. ***The Review of Economic Studies***, 11(2): 61–76.

Reitzig, M., & Puranam, P. 2009. Value appropriation as an organizational capability: the case of IP protection through patents. ***Strategic Management Journal***, 30(7): 765–789.

Rhodes-Kroph, M., & Viswanathan, S. 2004. Market Valuation and Merger Waves. ***The Journal of Finance***, 59(6): 2685–2718.

Rosenkopf, L., & Schilling, M. A. 2007. Comparing alliance network structure across industries: observations and explanations. ***Strategic Entrepreneurship Journal***, 1(3–4): 191–209.

Rothaermel, F. T., & Boeker, W. 2008. Old technology meets new technology: Complementarities, similarities, and alliance formation. ***Strategic Management Journal***, 29(1): 47–77.

Ruckman, K. 2005. Technology sourcing through acquisitions: evidence from the US drug industry. ***Journal of International Business Studies***, 36(1): 89.

Schilling, M. A. 2009. Understanding the alliance data. ***Strategic Management Journal***, 30(3): 233–260.

Schweizer, L. 2005. Organizational Integration of Acquired Biotechnology Companies into Pharmaceutical Companies: The Need for a Hybrid Approach. ***The Academy of Management Journal***, 48(6): 1051–1074.

Sears, J. B. 2017. When are acquired technological capabilities complements rather than substitutes? A study on value creation. ***Journal of Business Research***, 78. https://doi.org/10.1016/j.jbusres.2017.04.021.

Sears, J., & Hoetker, G. 2014. Technological overlap, technological capabilities, and resource recombination in technological acquisitions. ***Strategic Management Journal***, 35(1): 48–67.

Servaes, H., & Zenner, M. 1996. The Role of Investment Banks in Acquisitions. ***The Review of Financial Studies***, 9: 787–815.

Shih, W. C., & Chai, S. 2010. Alnylam Pharmaceuticals: Building Value from the IP Estate. ***Harvard Business School Case***, 611–009: 611–009.

Teece, D. 1986. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. ***Research Policy***, 15(6): 285–305.

Teece, D. 2018. The "tragedy of the anticommons" fallacy: a law and economics analysis of patent thickets and FRAND licensing. ***Berkeley Technology Law Journal***, 32(5).

Townsend, D. M., & Busenitz, L. W. 2008. Factor payments, resource-based bargaining, and the creation of firm wealth in technology-based ventures. ***Strategic Entrepreneurship Journal***,

2(4): 339–355.
Tushman, M., Smith, W. K., Wood, R. C., Westerman, G., & O'Reilly, C. 2010. Organizational designs and innovation streams. ***Industrial and Corporate Change***, 19(5).
Vermeulen, F., & Barkema, H. 2001. Learning through acquisitions. ***Academy of Management Journal***, 44(3): 457–476.
von Graevenitz, G., Wagner, S., & Harhoff, D. 2013. Incidence and Growth of Patent Thickets: The Impact of Technological Opportunities and Complexity. ***The Journal of Industrial Economics***, 61(3): 521–563.
Williamson, O. 1983. Credible Commitments: Using Hostages to Support Exchange. ***The American Economic Review***, 73(4): 519–540.
Williamson, O. E. 1985. ***The Economic Institutions of Capitalism***. New York: Free Press.
Williamson, O. E. 1993. Transaction cost economics and organization theory. ***Industrial and Corporate Change***, 2(1).
Wubben, E. F. M., Batterink, M., Kolympiris, C., Kemp, R. G. M., & Omta, O. S. W. F. 2015. Profiting from external knowledge: The impact of different external knowledge acquisition strategies on innovation performance. ***International Journal of Technology Management***, 69(2): 139–165.
Yayavaram, S., & Ahuja, G. 2008. Decomposability in Knowledge Structures and Its Impact on the Usefulness of Inventions and Knowledge-base Malleability. ***Administrative Science Quarterly***, 53(2): 333–362.
Ziedonis, R. H. 2004. Don't Fence Me In: Fragmented Markets for Technology and the Patent Acquisition Strategies of Firms. ***Management Science***, 50: 804–820.
Zingales, L. 1995. Insider Ownership and the Decision to Go Public. ***The Review of Economic Studies***, 62(3): 425.

FOOTNOTES

1. Since we are interested in examining how firms protect their R&D activities from being fenced in, we focus on one particular type of IP rights, patent rights, which grant the patentee the right to exclude others from using the patented invention for a period of time. We use the terms IP rights and patent rights interchangeably hereon.

2. We extended our theory by testing whether alternative mechanisms to augment patent portfolios are complementary to, or substitutes for, technology acquisitions in a context of increasing industry fragmentation of IP rights (see supplementary analysis).

3. The dataset complied by Hoberg and Phillips (2010) is available at the following webpage: https://hobergphillips.tuck.dartmouth.edu/

TABLE 1: Descriptive statistics and correlations

	Variables	Mean	S.D.	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
[1]	Technology acquisitions	0.05	0.19	1											
[2]	Fragmentation of IP rights	0.80	0.29	0.11	1										
[3]	Risk of being fenced in	-1.52	1.11	-0.14	0.04	1									
[4]	Patenting experience	8.26	7.52	0.23	0.07	-0.03	1								
[5]	R&D intensity	125.20	123.10	-0.01	0.23	0.26	-0.33	1							
[6]	Drugs in pipeline	0.77	0.42	0.09	0.45	0.32	-0.01	0.36	1						
[7]	Knowledge specificity	0.10	0.12	0.02	0.00	-0.06	0.29	-0.08	0.1	1					
[8]	Technology licensing	2.87	5.3	0.29	0.15	0.10	0.53	-0.09	0.21	0.11	1				
[9]	Strategic alliances	0.35	0.96	0.21	0.14	0.15	0.34	0.00	0.16	0.09	0.52	1			
[10]	Patenting activity	19.07	49.63	0.23	0.05	-0.04	0.65	-0.21	0.07	0.28	0.65	0.34	1		
[11]	Litigation	0.23	0.42	0.15	0.14	0.03	0.53	-0.23	0.00	0.13	0.39	0.22	0.42	1	
[12]	Capital intensity	62.85	50.79	0.09	0.13	0.06	0.22	0.03	0.14	0.14	0.28	0.21	0.2	0.29	1
[13]	Return on assets	-0.02	0.04	0.11	-0.10	-0.11	0.42	-0.47	-0.19	0.07	0.22	0.12	0.28	0.32	0.18
[14]	Leverage	0.01	0.02	0.11	0.03	-0.04	0.15	-0.05	0.01	0.09	0.06	0.08	0.05	0.12	0.17
[15]	Advertisement intensity	0.01	0.04	0.03	-0.14	-0.13	0.27	-0.20	-0.11	0.09	0.08	0.00	0.16	0.13	-0.09
[16]	Size	11.64	2.14	0.30	0.10	-0.02	0.69	-0.23	0.10	0.24	0.60	0.36	0.65	0.55	0.38
[17]	Slack	0.03	0.08	0.02	-0.02	-0.07	0.15	-0.08	-0.02	0.03	0.09	0.04	0.13	0.08	-0.02
[18]	Downstream commercial capabilities	0.81	0.86	0.17	-0.10	-0.14	0.60	-0.51	-0.2	0.11	0.37	0.16	0.46	0.4	0.13
[19]	Price to book value	6.44	6.7	0.00	0.06	0.03	0.02	0.09	0.12	0.05	0.05	0.06	0.05	0.01	-0.07
[20]	Market share	0.01	0.04	0.12	0.00	-0.11	0.35	-0.15	0.00	0.08	0.31	0.20	0.37	0.35	0.28
[21]	Time since last acquisition	3.46	3.38	-0.27	0.17	0.14	0.37	-0.12	0.05	0.15	-0.09	-0.04	-0.04	0.14	0.09
[22]	Industry growth	0.15	0.10	-0.09	-0.18	-0.07	-0.18	0.01	-0.08	-0.03	-0.11	-0.07	-0.11	-0.10	-0.07

	Variables	Mean	S.D.	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]
[13]	Return on assets	-0.02	0.04	1									
[14]	Leverage	0.01	0.02	0.06	1								
[15]	Advertisement intensity	0.01	0.04	0.11	0.08	1							
[16]	Size	11.64	2.14	0.54	0.20	0.20	1						
[17]	Slack	0.03	0.08	-0.08	0.04	0.09	0.05	1					
[18]	Downstream commercial capabilities	0.81	0.86	0.47	0.14	0.29	0.62	0.12	1				
[19]	Price to Book value	6.44	6.70	-0.20	0.19	0.04	-0.11	0.06	-0.02	1			
[20]	Market share	0.01	0.04	0.26	0.00	0.08	0.45	0.05	0.38	0.03	1		
[21]	Time since last acquisition	3.46	3.38	0.11	0.02	0.00	0.03	0.00	0.13	0.04	-0.01	1	
[22]	Industry growth	0.15	0.10	-0.07	-0.10	-0.07	-0.14	-0.04	-0.16	0.02	0.09	-0.13	1

TABLE 2: Fixed effects panel regression models of technology acquisitions

VARIABLES	Model [1]	Model [2]	Model [3]
Fragmentation of IP rights		0.067***	0.051*
		(0.026)	(0.027)
Risk of being fenced in	0.031***	0.031***	-0.011
	(0.010)	(0.010)	(0.022)
Fragmentation of IP rights X Risk of being fenced in			0.036***
			(0.014)
Patenting experience	-0.004	-0.008**	-0.008**
	(0.003)	(0.004)	(0.003)
R&D intensity	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
Drugs in pipeline	-0.030	-0.031	-0.042*
	(0.022)	(0.022)	(0.022)
Knowledge specificity	-0.056	-0.051	-0.041
	(0.055)	(0.054)	(0.053)
Technology licensing	0.002	0.003	0.003
	(0.003)	(0.003)	(0.003)
Strategic alliances	0.011	0.011	0.011
	(0.008)	(0.008)	(0.008)
Patenting activity	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
Litigation	-0.046*	-0.047*	-0.056**
	(0.025)	(0.025)	(0.025)
Capital intensity	-0.000*	-0.000*	-0.000*
	(0.000)	(0.000)	(0.000)
Return on assets	-0.510**	-0.492**	-0.497**
	(0.202)	(0.202)	(0.204)
Leverage	0.374	0.397	0.405
	(0.359)	(0.355)	(0.354)
Advertisement intensity	-0.000	-0.002	0.001
	(0.029)	(0.028)	(0.029)
Size	0.012	0.010	0.012
	(0.008)	(0.008)	(0.008)
Slack	-0.032	-0.034	-0.029
	(0.045)	(0.045)	(0.044)
Downstream commercial capabilities	0.008	0.010	0.010
	(0.010)	(0.010)	(0.010)
Price to book value	-0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.001)
Market share	0.374*	0.375*	0.453**
	(0.217)	(0.217)	(0.199)
Time since last acquisition	0.008***	0.009***	0.009***
	(0.003)	(0.003)	(0.003)
Industry growth	0.003	0.001	-0.003
	(0.075)	(0.076)	(0.075)
Constant	-0.123	-0.111	-0.101
	(0.094)	(0.095)	(0.092)
Observations	1,984	1,984	1,984
Number of firms	306	306	306
Firm FE	YES	YES	YES
Year FE	YES	YES	YES
R-squared	0.077	0.079	0.085

TABLE 3: Supplementary analysis: Fixed effects panel regression models of technology acquisitions

VARIABLES	Model [4]	Model [5]	Model [6]
Fragmentation of IP rights	0.045	0.072***	0.055**
	(0.030)	(0.027)	(0.026)
Fragmentation of IP rights X Technology licensing	0.009*		
	(0.005)		
Fragmentation of IP rights X Technology Licensing		-0.038	
		(0.056)	
Fragmentation of IP rights X Technology licensing			0.001**
			(0.001)
Technology licensing	-0.006	0.003	0.002
	(0.005)	(0.003)	(0.003)
Strategic alliances	0.010	0.046	0.011
	(0.008)	(0.053)	(0.008)
Patenting activity	-0.000	-0.000	-0.002**
	(0.000)	(0.000)	(0.001)
Risk of being fenced in	0.030***	0.032***	0.026**
	(0.011)	(0.011)	(0.011)
Patenting experience	-0.007**	-0.008**	-0.008**
	(0.004)	(0.004)	(0.003)
R&D intensity	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
Drugs in pipeline	-0.033	-0.031	-0.037*
	(0.022)	(0.022)	(0.021)
Knowledge specificity	-0.050	-0.051	-0.045
	(0.054)	(0.055)	(0.054)
Litigation	-0.048*	-0.048*	-0.056**
	(0.025)	(0.025)	(0.025)
Capital intensity	-0.000*	-0.000*	-0.000*
	(0.000)	(0.000)	(0.000)
Return on assets	-0.502**	-0.491**	-0.494**
	(0.203)	(0.202)	(0.204)
Leverage	0.416	0.414	0.446
	(0.350)	(0.347)	(0.346)
Advertisement intensity	-0.002	-0.001	0.007
	(0.029)	(0.028)	(0.028)
Size	0.010	0.010	0.010
	(0.008)	(0.008)	(0.008)
Slack	-0.035	-0.033	-0.033
	(0.046)	(0.046)	(0.045)
Downstream commercial capabilities	0.010	0.010	0.011
	(0.010)	(0.010)	(0.010)
Price to book value	-0.001	-0.001	-0.001
	(0.000)	(0.000)	(0.000)
Market share	0.388*	0.373*	0.405*
	(0.214)	(0.216)	(0.207)
Time since last acquisition	0.009***	0.009***	0.009***
	(0.003)	(0.003)	(0.003)
Industry growth	0.004	0.002	-0.001
	(0.075)	(0.075)	(0.074)
Constant	-0.099	-0.106	-0.080
	(0.094)	(0.094)	(0.092)

Observations	1,984	1,984	1,984
Number of firms	306	306	306
Firm FE	YES	YES	YES
Year FE	YES	YES	YES
R-squared	0.081	0.080	0.084