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The Effects of Patent Attributes and Patent Litigation on Control Rights, Alliance Formation and Technological Innovation

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THE EFFECTS OF PATENT ATTRIBUTES AND PATENT LITIGATION ON CONTROL RIGHTS, ALLIANCE FORMATION AND TECHNOLOGICAL INNOVATION

by

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ABSTRACT
THE EFFECTS OF PATENT ATTRIBUTES AND PATENT LITIGATION ON CONTROL RIGHTS, ALLIANCE FORMATION AND TECHNOLOGICAL INNOVATION

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My dissertation consisting of three essays focuses on the role of technological innovations in value distribution within R&D alliance, and the impact of patent litigation on R&D alliance formation and technological innovation. Essays one and two are intended to extend signaling theory with transaction cost economics (TCE) and social embeddedness perspective. Essays two and three investigate the consequences of patent litigation on R&D alliance formation and technological search, respectively. Essay one investigates the empirical relationships between patent attributes and allocation of control rights, and the relationships between patent attributes and up-front payment in R&D alliance contracts. Patent attributes of focal innovations signal varying dimensions of patent quality. With a sample of R&D alliance contracts between biotechnology and pharmaceutical firms, I find that patent novelty decreases the number of control rights won by biotech firms and that self-citation reduces the amount of upfront payment paid to biotech firms. Essay two examines the effect of firms being litigious about patent enforcement on subsequent R&D alliance formation. Empirical results show that being litigious about patent enforcement increases subsequent R&D alliances and that repeat

ties of litigious firms reduce the positive effect of being litigious on R&D alliance formation. Essay two extends signaling theory by highlighting the understudied role of repeat signal to *unintended* signal receivers. Essay three examines the effects of patent litigation on technological exploration and exploitation of litigious firms. With a sample of public firms in biotechnology and pharmaceutical industry, empirical result suggests that repeat patent litigation is disruptive to exploitative and explorative innovations. This study makes a small step in investigating the unintended consequences of profiting from innovations by repeatedly resorting to patent litigation.

This dissertation is dedicated to my wife Huiying Li whose encouragement and support is incomparable, to my parents Runchen and Chengying, my father-in-law Jin, mother-in-law Guihua, daughter Laura, and son Michael.

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ESSAY 1

PATENT ATTRIBUTES AND CONTROL RIGHTS: COMBINING SIGNALING THEORY WITH TRANSACTION COST ECONOMICS

Introduction

Firms increasingly rely on strategic alliances to conduct joint research and development to share investment risk, access valuable capability, and ultimately gain competitive advantage in the product market (Teece, 1986; Somaya, Kim & Vonortas, 2011). The market for technology has been expanding exponentially. According to the estimate of Arora, Fosfuri, and Gambardella (2001), during the period of 1985-1997, more than 15,000 technology licensing transactions were conducted worldwide, with a total value of over $320 billion.

Prior research sheds insightful light on strategic alliance phenomenon. One stream of strategy research has investigated the independent effects of contractual governance and prior ties, and whether these two governance mechanisms complement or substitute for each other (e.g. Luo, 2002; Parkhe, 1993; Poppo & Zenger, 2002; Reuer & Arino, 2007; Ryall and Sampson; 2009; Zollo, Reuer, & Singh, 2002). A second stream of strategy research explores particular contractual provisions. These contractual provisions include lump-sum payments and royalty rates in technology licensing (e.g. Bessy, Brousseau, & Saussier, 2008), exclusivity and scope restrictions by product or geography (e.g. Somaya et al, 2011), contract duration in strategic alliances (e.g. Reuer & Arino, 2007).

Relatedly, one set of studies in finance and management literatures investigates how external equity market conditions and the supply and demand for alliance partners impact allocation of control rights (e.g. Lerner & Merges, 1998; Adegbesan & Higggins, 2010). Control rights are an essential subset of contractual provisions associated with intellectual property rights, licensing rights, manufacturing rights, and marketing rights (Lerner & Merges, 1998). Control rights "confer the ability to make decisions affecting the distribution of an income stream whose magnitude and even existence are uncertain *ex ante"* (Adegbesan & Higggins, 2010). The allocation of control rights, in essence, measures how jointly created value within alliance is distributed between alliance partners in uncertain and unpredictable market *ex ante* (Adegbesan & Higggins, 2010). Prior empirical research has demonstrated various antecedents of control rights allocation such as equity market conditions, supply and demand for alliance partners in the strategic factor market (e.g. Adegbesan & Higggins, 2010; Lerner & Merges, 1998). While prior research deepens our understanding of determinants of particular contractual provisions, control rights, and upfront payment, how patent attributes impact the allocation of control rights in R&D alliances still awaits theoretical development. I draw on transaction cost economics and signaling theory to develop hypotheses and test them with a sample of R&D contracts between biotech firms and pharmaceutical firms.

Given that market for technology is characterized by information asymmetry, the exchange party with less information may encounter greater measurement cost in assessing value of licensed technology. Considering that the main concern of R&D alliance is whether focal patent of one alliance partner combined with complementary

assets of another can be turned into new product or service, effectively measuring the value of focal patent becomes essential for alliance formation and subsequent allocation of control rights. I propose that patent attributes reduce transaction cost for both parties and allocation of control rights and upfront payment vary with patent attributes. Patent attributes include technological importance, novelty, and generalizability. Patent attributes are measured based on patent citation data. These three patent characteristics represent the pre-certified value of patent quality (Joshi & Nerkar, 2010). Technological importance captures the influence of focal patent on subsequent knowledge generation. Technological importance is measured as the number of citations received by a focal patent (Hall, Jaffe & Trajtenberg, 2001). High number of citations received by a focal patent certifies the high impact of focal patent on subsequent knowledge generation. Knowledge novelty captures the extent to which the focal patent builds on prior knowledge in diverse technology domains (Hall et al, 2001). The more technological classes focal patent spans, the more knowledge inflow to the focal patent, showing high likelihood of knowledge novelty and producing high impact products. Generalizability refers to the extent to which subsequent citations to the focal patent are concentrated in different technology classes (Hall et al, 2001). A focal patent with high generalizability has broad scope and is more generalizable if the technology classes of citing patents span many different technological classes.

I contend that patent attributes (novelty, technological importance, and generalizability) reduce the measurement cost incurred to pharm firms and disclosure risk incurred to biotech firm. Further, patent attributes also signal to other parties about the

value of that technology, and allows for more bidding of the technology possessing firm's knowledge. Thus, patent attributes reliably signal the underlying quality of patent for pharm firms and enable biotech firms to capture economic value as reflected in high upfront payment and large share of control rights.

Further, patent novelty, technological importance of patent, and patent generalizability signal differing dimension of knowledge quality, patent attributes complement or substitute for each other, exerting differential effect on upfront payment and allocation of control rights.

I use a sample contracts from biotech-pharm R&D alliances to test my hypotheses. All these contracts include patents owned by biotech firms. Biotech firms provide patent to capture innovation rent in the alliance with pharm firms. Pharm firms offer complementary capabilities including development experience, lengthy and costly process of conducting human tests and regulatory Food and Drug Administration (FDA) approval, manufacturing and marketing. Patent attributes are measured based on patent citation data from *National Bureau of Economic Research* patent data (Hall, Jaffe & Trajtenberg, 2001). Patent citations have been used to measure patent value in empirical management research (e.g. Hall, Jaffe & Trajtenberg, 2005; Levitas &McFadyen, 2009).

The structure of this paper is as follows. Theory and hypotheses section reviews transaction cost economics and signaling theory in management. Theory of patent attributes as effective mechanism of measurement cost reduction and signals of patent quality is developed. Based on this theory, I develop hypotheses linking patent attributes to allocation of up-front payment and control rights. Method section describes sample

selection, measures of variables, and analysis method. Discussion section concludes with limitations and future avenues for research.

Theory and Hypotheses

Transaction Cost and Signaling Theory in R&D Alliances

In the market for technological know-how and innovations, effectively measuring the value of focal patents can be problematic due to asymmetric distribution of information between exchange partners. Knowledge tacitness may also prevent effective transfer across organizational boundaries. Among the barriers to effectively govern inter-firm alliances, opportunism concerns are particularly severe (Williamson, 1985). Technology licensors may inflate the value of innovation, attempting to optimize licensing rent (Pisano, 1997). Licensees of focal innovation may act opportunistically by appropriating the knowledge if technology licensors fully disclose the information (Oxley, 1997). Measurement cost is larger in R&D alliance context with high information asymmetry, increasing transaction cost to biotech firm and pharm firms. Measurement cost is defined as the cost incurred to pharm firms of obtaining additional information to evaluate the value of focal innovation that biotech firms bring to the alliance.

Socio-structural perspective posits that reputation in the social structure and prior relationships representing organizational trust can mitigate concerns of opportunism and

misappropriation and facilitate inter-firm coordination (e.g. Gulati, 1995; Poppo & Zenger, 2002; Robinson & Stuart, 2007; Ryall & Sampson, 2009). For instance, high reputation in the social structure affords focal firm higher up-front payment in R&D alliances (Robinson & Stuart, 2007).

Transaction cost theorists suggest internalizing R&D activities or governing R&D alliances via contractual provisions to align partner interests (Williamson, 1985; Poppo & Zenger, 2002). For instance, particular contractual terms can vary with asset specificity and collaboration duration (e.g. Reuer & Arino, 2007; Somaya, Kim & Vonortas, 2011).

Prior empirical research has ignored how patent attributes including patent novelty, patent importance, self-citations, and patent generalizability in alliance contracts influence payment structure and control rights allocation. After all, reliably gauging the value of licensed patent is the first important step in alliance formation, contract crafting and implementation. Whether R&D alliance can develop and commercialize new product is to a large extent dependent on the quality of patented knowledge. The critical theoretical relationship between patent attributes and up-front payment and control rights allocation deserve theoretical consideration and empirical test.

Control rights as an important set of contractual provisions also receive increasingly scholarly attention, as 'the allocation of control rights is a central issue in the negotiation of alliances' (Lerner & Merges, 1998: 127). Elfenbein and Lerner (2003) contend that "allocation of control rights are partly determined by efficiency concerns but also by relative bargaining power of the partners". Adegbesan and Higggins (2010) further distinguish pie-splitting control rights representing the *ex ante* allocation of value within

alliance. Allocation of control rights has been found to vary with financial market conditions (Lerner, Shane, & Tsai, 2003), financial resources possessed by biotech firms (Lerner & Merges, 1998) and supply and demand of alliance partners (Adegbesan & Higgins, 2010).

Specifically, I examine signaling effects of four patent attributes on allocation of control rights and upfront payment in R&D alliances between biotech firm and pharm firm. Patent novelty, patent importance, self-citations, and patent generalizability are measured with patent citation data. In the empirical works of strategic management, patents serve as signals of high quality of internal R&D to reduce information asymmetry between firms and investors, and alliance partners. The signal of possessing patents reduces the need to hold cash (Levitas &McFadyen, 2009) and increases the bargaining power of small firms to capture innovation value in R&D alliances (Adegbesan & Higgins, 2010). Scholars further this line of research and examine signaling effect of specific patent attribute to stock markets. Hall, Jaffe and Trajtenberg (2005) posit that patent citation is one measure of importance of firm's patents and empirically find that stock market values the intangible assets embodied in patents, each additional citation increasing firm value by 3%. In addition, Hall and colleagues (2005) demonstrate that self-citations are more valuable than external citations.

As these signals of patent quality are not intended by biotech firms, pharm firms have no concern that the signals about these patent attributes would be distorted by biotech firms. Thus these patent attributes serve as low-cost and effective measurement

of underlying quality of patented knowledge. Pharm firms receive these signals and make inference about patent quality.

Further, the management literature, with the exception of Arthurs, Busenitz, Hoskisson and Johnson (2008) and Agarwal et al. (2009), examines single or multiple positive signals, intentional or unintentional, in multiple contexts (e.g. Gulati & Higgins, 2003; Reuer, Tong & Wu, 2012) with little emphasis on the fact that signals can be negative in interfirm alliances. While information economics emphasize signals that distinguish high quality firms/individuals from low quality firms/individuals, signals are broadly theorized to reduce information asymmetry to facilitate market exchanges, regardless of being positive or negative. For instance, Agarwal and colleagues (2009) show that firms repeatedly litigates other firms for patent infringement send negative signal to competing firms, effectively deterring competitors from hiring departing inventors from litigious firms. This study proposes that patent generalizability, among the four patent attributes, is negatively associated with control right allocation and upfront payment to small biotech firms.

In addition to examining separate signaling effect of each patent attribute, positive or negative, in allocation of control rights and upfront payment to small biotech firms, our study also contends that some patent attributes may interact negatively or positively to impact allocation of control rights and upfront payment to small biotech firms. Arthurs and colleagues (2008) show that signals may substitute for each other. When new firms going through initial public offering (IPO) incur high debt and cause concerns of paying off interest in a timely manner, management can counteract investor concerns by

accepting a longer lockup period in which current shareholders are not allowed to sell their stock shares after the IPO (Arthurs, Busenitz, Hoskisson & Johnson, 2008).

Knowledge novelty

Knowledge novelty refers to the extent to which knowledge or technologies are new to an organization (Ahuja & Lampert, 2001). Knowledge novelty plays an important role in organizational learning and innovation (Rosenkopf &McGrath, 2011). Scholars in innovation research have provided compelling argument, theoretical and empirical, that knowledge novelty enhances impact of resulting innovations (Nerkar, 2003). Knowledge novelty is particularly important to large established firms. Ahuja and Lampert (2001) provide two reasons. First, novel technologies furnish organizations with new perspectives in solving problems. Second, new technologies alter existing cognitive structures within inventors/organizations.

It is imperative that large and established firms forge interfirm alliances with small and innovative biotech firms to overcome local search tendency (Helfat, 1994; Rosenkopf & Almeida, 2003). Jiang, Tan, and Thursby (2010) find that incumbent firms are proactively searching for new knowledge to invent by forming alliances with different partners in early stage of technological change. Novel technologies signal high economic value and attract large number of bidders, increasing the bargaining power of biotech firms.

Increased bargaining power derived from knowledge novelty on the part of small biotech firms is also protected by strong appropriability conditions of biopharmaceutical

industry. The appropriability conditions affect the extent to which firms can capture rents from innovations (Teece, 1986). Empirical studies have offered evidence that biopharmaceutical industry is characterized by stringent patent regime. Patent protection accounts for about 30% of new inventions in pharmaceutical and chemical industries (Mansfield, 1986; cf. Ahuja, Lampert, & Tandon, 2008).

The bargaining power that knowledge novelty affords to biotech firms can be reflected in the large amount of up-front payment. Up-front payment is non-contingent and may be subject to misuse (Robinson & Stuart, 2007). As a result, pharm firms would be less willing to pay large sum of up-front payment if pharm firms do not really need novel knowledge of biotech firms. More certain is knowledge (via patents signaling), less risk biotech is willing to bear, more risk pharma should bear. Thus, I hypothesize that

Hypothesis 1a:
Knowledge novelty of focal patent owned by biotech firms in the alliance contract is positively related to up-front payment specified in alliance contract.

Knowledge novelty can also help biotech firms win more control rights. Control rights refer to "those that confer ownership and control over activities and intermediate outputs that directly affect the allocation of portions of the overall value to be created by an alliance" (Adegbesan and Higggins, 2010: 191). Elfenbein and Lerner (2003) suggest that allocation of control rights are partly determined by relative bargaining power of the partners as well as by efficiency concerns. Adegbesan and Higgins (2010) identify 10 control rights which are decomposed into four categories: intellectual property rights, licensing rights, manufacturing rights, and marketing rights. Patent with high novel knowledge signals to the potential technology buyers the high likelihood of producing

high impact product, increasing the number of buyers and enhancing the ability of small firms possessing novel patents to negotiate with other parties for large share of control rights.

Hypothesis 1b:
The more novel the focal patent owned by biotech firms in the alliance contract the larger share of control rights biotech firms retain.

Technological importance

Technological importance captures the influence of focal patent on subsequent knowledge generation. Technological importance is measured as the number of citations received by a focal patent (Hall, Jaffe & Trajtenberg, 2001). High number of citations received by a focal patent certifies the high impact of focal patent on subsequent knowledge generation.

Most of patents have relatively low value and only highly cited patents have high value (Trajtenber, 1990; cf Ahuja & Lampert, 2001). Technologically important patents have higher scientific and technical significance, providing patent owners in strong IPP an effective approvability means (Joshi & Nerkar, 2010).

Technologically important patents are likely to be noticed by competing and potential partners, as granting patents to focal owners concurrently discloses the knowledge elements embedded in the patents. As biopharmaceutical industry has strong patent regime, economically valuable patent as measured by high number of citations send positive signal to pharm firm. At the same time, highly cited focal patent in alliance contract helps small biotech firms to gain greater bargaining power, thus extracting high

percentage of innovation rent reflected by high upfront payment and large share of control rights in contractual alliances.

Hypothesis 2a: Technological importance of focal patent owned by biotech firms in the alliance contract increases the bargaining power of biotech firms such that the greater the technological importance of the focal patents, the higher the up-front payment from pharmaceutical firms.

Hypothesis 2b:
Technological importance of focal patent owned by biotech firm in the alliance contract increases the bargaining power of biotech firms such that the greater the technological importance of the focal patent, the more control rights that biotech firms retain.

Self-citation

Citations to a focal patent can be made by external patents owned by other firms (external citations). Patents owned by one firm can also cite patents owned by the same firm (self-citations). Self-citations differ from other citations in two respects. First, when one firm cites its own patent on a regular basis, it shows that the focal patent is the foundational technology. A patent with multiple self-citations not only indicates its economic value but also the strategic stakes-the substantial extent to which a firm builds on its own technology (Somaya, 2003). Firms are less likely to settle a patent infringement lawsuit if either party has strategic stakes on the controversial patent. (Somaya, 2003). Second, the number of self-citations reflects the extent to which existing knowledge is exploited or reused (Katila & Ahuja, 2002). Multiple self-citations indicate that firms acquire a deeper understanding of the underlying knowledge by repeatedly revisiting the focal patent.

High number of self-citations implies high ability to appropriate value in strategic alliance. Firms in biotech industry with strong IP regime can effectively protect key

patent with multiple self-citations in lawsuits, because self-citing firm's own patent shows to the court the visible knowledge development along technology trajectory. Constantly revisiting the underlying knowledge elements embodied in a patent not only deepens understanding the association between knowledge elements, but also quickens the speed of research progress. When biotech firm owns a patent with multiple self-citations, such patent signals potential buyers the high likelihood of launching a new product in uncertain R&D alliance.

Ahuja, Lampert, and Novelli (2012) distinguish two types of appropriability: primary and generative. Primary appropriability "refers to a firm's effectiveness in exploiting a given invention by translating it into a product or licensable solution for users" (Ahuja et al, 2012:3). Generative appropriability refers to "a firm's effectiveness in capturing the greatest share of future *inventions* spawned by its existing inventions. A patent with multiple self-citations constitutes the foundation of subsequent innovations and spawns future innovations, thus signaling to pharm partners the high ability of creating new innovations. Patents with multiple self-citations thus increase the generative appropriability of biotech firm to capture innovation value in R&D alliance.

Hypothesis 3a: When a focal patent owned by biotech firms has multiple self-citations, the focal patent tends to earn a higher upfront payment from the pharm firm.

Hypothesis 3b: When a focal patent owned by biotech firms has multiple self-citations, the focal patent tends to earn a higher share of control rights.

The above hypotheses concerns the effects of positive signals from patent attributes such as knowledge novelty, technological importance, and self-citations on upfront payment and allocation of control rights. Signals can also be negative (Connelly, Certo,

Ireland, & Reutzel, 2011). For example, when new firms going through initial public offering (IPO) incur high debt and have concerns of paying off interest in a timely manner, the market reacts negatively and IPO firms experience high IPO underpricing, a negative market response (Arthurs, Busenitz, Hoskisson & Johnson, 2008). In the following hypothesis, I contend that knowledge generalizability, another patent attribute, however, sends out a negative signal to pharm firms, lowering upfront payment and share of control rights to biotech firm in R&D alliance.

Knowledge generalizability

Generalizability refers to the extent to which subsequent citations to the focal patent are concentrated in different technology classes (Hall et al, 2001). If focal patent is cited by patents from diverse technology classes, the focal patent has high generalizability. A focal patent with high generalizability is broad in scope and more generalizable.

A general patent means that the knowledge of focal patent is spread over a wide range of technology fields. High generality means that a firm may encounter high legal enforcement cost, as large number of firms can cite the high generality patent and suing these firms can be financially expensive. Further, defendants can ally to counter-sue the plaintiff firm owning the high generality patent. Put differently, appropriating return from high generality patent may be costly (Hall, Jaffe & Trajtenberg, 2005). It can be reasonably argued that focal patent with high generality does not afford much bargaining power to biotech firm due to its inability to appropriate value in a cost efficient manner for biotech firm. Thus, I hypothesize that

Hypothesis 4a:
Technological generalizability of focal patent in biotech firms decreases the bargaining power of biotech firms such that technological generalizability of focal patent is negatively associated with up-front payment from pharmaceutical firms.

Hypothesis 4b:
Technological generalizability of focal patent in biotech firms decreases the bargaining power of biotech firms such that technological generalizability of focal patent is negatively associated with share of control rights.

The foregoing hypotheses examines effect of each individual signal (e.g. knowledge novelty, patent importance, patent generalizability), positive and negative, on allocation of upfront payment and control rights to biotech firms. Pharm firms will examine the patent attributes as a whole instead of looking at one individual patent attribute without considering other attributes. As a result, it is theoretically important to examine interaction effects between these patent attributes. Prior research in IPO context has shown signals can substitute for each other (e.g. Arthurs et al, 2009). As signal receivers like pharm firms in market for technology can receive multiple signals for interpretation. Each signal may be positive or negative or the signals can reinforce each other (e.g. Connelly et al, 2011; Levitas & McFaydan, 2009; Tong et al, 2012).

Implicit in the argument of prior empirical research is that different signals from either focal firm or focal individual are complementing or reinforcing the high quality. For instance, Reuer and colleagues (2012) contend that relationships with prestigious VCs, investment banks and alliance partners complement rather than substitute each other in signaling high quality of target IPO firms. Arthurs, Busenitz, Hoskisson and Johnson's (2009) study in the context of IPO extend signaling theory by contending that when multiple signals are present, substitution effect can occur. Specifically, a longer lockup

period as signal of shareholder commitment to IPO firm can substitute for VC and prestigious underwriter backing. While prior research mainly focuses on how signals act as bonding or commitment mechanism (e.g. Arthurs et al, 2009), our study of patent attributes theorizes signals of patent attributes act as low cost measurement of underlying knowledge codified in patents.

Interaction effect of patent novelty and self-citations

In biopharmaceutical industry, biotech firms are specialized in upper stream of value chain: biotech firms conduct activities in research while pharmaceutical firms have strong capabilities in the downstream: strong capability in new product application through Food and Drug Administration, commercializing and marketing new products (Rothaermel, 2001). The signal that focal patent is novel and is solidly built on biotech firm's prior knowledge would enhance the prospects of launching a successful product. Large number of self-citations signals that biotech firm has insights about and masters its foundational knowledge. Combined, self-citations and knowledge novelty imply high probability of successful product development. Thus, I hypothesize that

Hypothesis 5a:
The relationship between patent novelty and up-front payment from pharm firms increases in the presence of high self-citations of the focal patent that biotech firm brings to the alliance contract.

Hypothesis 5b:
The relationship between patent novelty and share of control rights that biotech firm wins increases in the presence of high self-citations of the focal patent that biotech firm brings to the alliance contract.

Interaction effect of patent novelty and patent generalizability

As high patent generalizability suggests that the innovation may spill over to many different fields, and increases the enforcement cost in protecting its innovation, high patent generalizability weakens the ability of patent owner to appropriate innovation rent. While knowledge novelty signals high quality of underlying knowledge, high patent generalizability mitigates the bargaining power of biotech firm and the desirability of the focal patent. Thus, I hypothesize that

Hypothesis 6a:
The relationship between patent novelty and up-front payment from pharm firms decreases in the presence of high patent generalizability of the focal patent that biotech firm brings to the alliance contract.

Hypothesis 6b:
The relationship between patent novelty and share of control rights that biotech firm wins decreases in the presence of high patent generalizability of the focal patent that biotech firm brings to the alliance contract.

Data and Methods

This study relies on the contract information between biotech firms and pharm firms. The alliance information is obtained from Recombinant Capital (Recap), which is based on California and bought by Deloitte. I focus on the contracts involving a patent license where a biotech firm provides patented knowledge and pharm firm offers complementary capabilities. The R&D alliance concerns mainly with valuation and payment for focal patents of biotech firm and allocation of control rights between biotech firm and pharm firm. The sample period covers years 1991-2005. The time period captures a dramatic

increase in pharmaceutical biotechnology alliances (Adebesan & Higgins, 2010). To be consistent with prior research, alliances that fall into the following categories are eliminated (Adebesan & Higgins, 2010; Lerner et al, 2003):

(1) One party to the alliance is government agency, university or nonprofit organization;

(2) No research component exists in the alliance;

(3) More than three parties enter into a R&D alliance.

In addition, as this study investigates the effect of patent attributes on allocation of control rights and upfront payment, the contract must explicitly specify patent numbers which are licensed out. Since some firms are not publicly listed, many R&D alliance contracts don't disclose the involved patent numbers. When contracts list patent application numbers, I search USPTO website to find the corresponding patent numbers. Out of 1330 contracts signed between biotech and pharm firms, 104 contracts explicitly list the patents or patent application numbers for license. Due to missing values on some variables, the sample size is 97 when dependent variable is upfront payment and 103 when the dependent variable is control rights.

Dependent Variables

There are two dependent variables in this study. (1) Upfront payment of client firm to R&D firm. Ideally, this measure is the ratio of upfront payment to sum of milestones plus upfront payment and royalties if any. Since some firms choose to not disclose milestone payment in the contracts available from Recap, such missing information makes ratio

measure infeasible. The amount of upfront payment is viewed as the net present value of innovation rent of focal patent. Due to incentive misalignment concern, pharm firm tends not to pay a large amount of upfront payment, as cash payment to biotech firm may be subject to misuse for other research projects within biotech firm (Elfenbein & Lerner , 2003). This variable captures the valuation from pharm firm and the bargaining power from biotech firm in capturing its innovation value. I take the following steps to code upfront payment. When there is upfront payment and the amount is disclosed, this amount is logarithmically transformed. When there is not upfront payment, this variable is coded zero. For undisclosed upfront payment, it is coded as missing value.

(2) Control rights. Control rights are used in this research context as proxies for value division between alliance partners. I hypothesize that control rights are a function of patent attributes including patent novelty, technological importance, and patent generalizability. Biotech firms gain or lose control rights depending on the patent attributes while pharm firms evaluate the underlying quality of patent based on the signals from these patent attributes. The allocation of control rights reflects the negotiation between alliance partners. Adegbesan and Higggins (2010: 191) define pie splitting control rights as "those that confer ownership and control over activities and intermediate outputs that directly affect the allocation of portions of the overall value to be created by an alliance". Adegbesan and Higgins (2010) identify 10 control rights associated with intellectual property rights, licensing rights, manufacturing rights, and marketing rights. To be consistent with prior research, we adopt the same coding scheme of Adebesan and Higgins (2010). The control right is coded from the perspective of

pharm firm. The author and a second coder separately coded the control rights and discern which control right is won by pharmaceutical firm. When disagreement occurs regarding which control right is won by pharm firm, the two coders discussed based on coding scheme of Adebesan and Higgins (2010) until they reach the consensus. The control right is a count variable of how many control rights are won by pharm firm.

The independent variables of patent attributes are measured based on patent citations. Patented knowledge is built on previous knowledge such as scientific journal publications and previously issued patents. While patent citation is an imperfect measure of knowledge flow, patent citations provide researchers the tool to measure the extent to which a focal patent builds on previous patented knowledge and its influence on subsequent knowledge generation (e.g. Ahuja & Lampert, 2001; Rosenkopf & Almeida, 2003). This study uses the NBER patent dataset compiled by Hall, Jaffe and Trajtenberg (2001) available at GOOGLE website. Patent novelty measures the extent to which cited patents of focal patent span technological fields. The wider range of technological fields that cited patents cover, the higher originality score. This measure is based on Hall, Jaffe and Trajtenberg (1997).

Technological importance of the focal patent captures the technological and economic value of patents. It is measured as the total citations made to the focal patent (Hall et al, 2001). Subsequent citations to the focal patent have been shown to have high economic value. Lanjouw and Schankerman (2004) uses citations and other measures of patent quality for hypotheses test and find that patents with high citations are more likely to be litigated. Empirically, buyers and sellers in market for technology use citations to

estimate patent value. In a survey of patent owners, Harhoff et al (1999) find that estimated patent value that patent owners offer for sale is positively related to subsequent citations (cf. Hall et al, 2005). In assessing value of licensed patent, firms very likely use citations as a reliable and efficient measure. Joshi and Nerkar (2010) find that licensing firms are more likely to put patents with technological importance in the patent pool, suggesting that both licensing firms and licensee firms use citations for indicators of patent value.

Self-citation captures the extent to which a firm reuses and exploits its extant knowledge. High self-citations show that the focal patent occupies a foundational place in the firm technological trajectory. In their study of new product development, Katila and Ahuja (2002) proposes the construct of search depth and measures it with self-citations. Their empirical finding is that search depth has a curvilinear relationship with new product development. Put differently, knowledge reuse as measured by self-citations helps new product development substantially. Also, focal patent with high self-citations increases firm's exclusionary ability to appropriate innovation rent due to the consistent knowledge development path. This helps firms, if patent litigation arises, to defend their intellectual property.

Generalizability of the focal patent captures the extent of knowledge impact of focal patent on subsequent knowledge generation. The generalizability measures technological classes concentration of citations. If most citations are concentrated in a few technological classes, the concentration score is low. Otherwise, the focal patent has a

high generalizability score, meaning that citations to the focal patent span many technological classes.

I use the generalizability measure developed by Hall, Jaffe and Trajtenberg (1997).

$$Generality\ or\ Generalizability_i = 1 - \sum_j^{n_i} s_{ij}^2$$

"where s_{ij} denotes the percentage of citations received by patent i that belong to patent class j, out of n_i patent classes (note that the sum is the Herfindahl concentration index)" (Hall, Jaffe and Trajtenberg (1997).

I also include a few control variables based on prior contractual research. Patent stock of R&D firm can increase bargaining power of R&D firms. This variable is measured as the number of filed patents in the year when the alliance contract is signed. If there are missing values, prior year's patent count is used. To address skewness issue, I take the natural log of patent count. Prior alliance with other pharmaceutical firms or biotech firm endorses the quality of a biotech firm's research and management. This can also enhance the bargaining power of R&D firms (Adegbesan & Higgins, 2010). The variable is measured as the number of alliances with other firms in the year when the contract is signed. As R&D contract may involve more than one patent, I include the number of licensed patents as a control variable. As this variable is not statistically significant, it is not included in the presented models. Year effect is added to control for market conditions and general economic environment. Finally, the number of backward citations in a licensed patent reflects how extensively the patent knowledge is built on

prior knowledge. It may also influence the valuation made by client firm. As a result, I include backward citations as a control variable.

To test the first set of hypotheses with dependent variable as upfront payment to R&D firm, I use ordinary linear squares (OLS) regression with robust standard errors. Since the dependent variable the number of control rights is count variable, Poisson regression is used instead of negative binomial, as there is no overdispersion problem.

Results

The descriptive statistics and correlations are presented in Table 1 and Table 2, respectively. Since some firms choose not to disclose the amount of upfront payment, the number of contracts with complete information in this regard decreases to 98 from 104. On average, the number of control rights won by R&D firms is four while the average amount of upfront payment from client firm is $116746 U.S. dollars (4.76 exponentiated times 1000). There is a positive correlation between patent stock of a R&D firm and upfront payment received, showing that patent stock increases bargaining power of R&D firms. This is consistent with prior theory that patent production signals high research capability of R&D firms (e.g. Levitas & McFaden, 2009) and that patent production is positively associated with the pre-money values of R&D firms (Lerner, 1994).

Table 3 presents the results of OLS regression of patent attributes on upfront payment. Models 1-9 test the effects of patent attributes and their interactions on upfront payment received by R&D firms. Model 1 is the baseline model which includes only control variables. Models 2-5, respectively, test the hypothesized positive effects of four patent

attributes on upfront payment, including patent originality (H1a), technological importance of patent (H2a), self-citations (H3a) and generality (H4a). H1a, H2a, and H4a are not supported. While the coefficient for self-citations is significant at .01 level, the sign is negative which is contrary to the hypothesized direction. As a result, H3a is not supported. To test two interaction effects (H5a, H6a), I centered variables of self-citations, patent originality and patent generality on their means. Model 7 testing the interaction effect of self-citations and patent originality is not significant. Model 9 tests the interaction effect of generality and novelty. It is not statistically significant. Therefore, H5a and H6a are not supported.

Results of Poisson regression of patent attributes on the number of control rights won by client firm are presented in Table 4. As the main interest in this study is the control rights won by R&D firm, I expect to see negative relationships between patent attributes and the number of control rights won by client firms. Model 1 includes the control variables only. It shows the backward citations of focal patent increases the number of control rights won by R&D firms. Model 2 tests H1b that patent originality is positively associated with the number of control rights won by R&D firms. The coefficient is significant at .1 level with a positive sign, indicating the patent originality actually reduces the number of control rights won by R&D firms. So H1b is not supported. Models 3-5 test the hypothesized effects of technological importance (H2b), self-citation (H3b), and generality (H4b) on the number of control rights won by R&D firms. Since the coefficients are not significant, these hypotheses are not supported. Interaction effects

of self-citation and originality, generality and originality are tested in Model 7 and Model 8, respectively. Both hypotheses are not supported due to insignificant coefficients.

Table 1 Descriptive Statistics

Variable	N	Mean	Std Dev	Minimum	Maximum
Control rights	104	4.00	1.11	1	7
Upfront pay(dollars)	98	4.76	2.81	0	7.90
Self-citation	104	0.63	1.60	0	12.00
Technological importance	103	3.19	1.27	0.69	6.37
Patent novelty	104	0.35	0.36	0	1.00
Generality	104	0.54	0.27	0	1.00
Prior alliances	104	0.67	1.25	0	7.00
Patent stock	104	0.55	0.57	0	2.21
Backward citations	103	1.50	0.95	0	3.69

Table 2 Correlations

Variable	1	2	3	4	5	6	7	8
1. Control rights								
2. Upfront pay(dollars)	0.06							
3. Self-citation	-0.098	-0.16						
4. Tech importance	-0.05	-0.16	0.20**					
5. Patent novelty	0.05	0.02	0.17*	0.34***				
6. Generality	-0.01	-0.02	0.05	0.31***	0.17*			
7. Prior alliances	0.09	0.05	-0.14	0.19*	0.01	-0.01		
8. Patent stock	0.19*	-0.002	0.09	-0.005	0.06	0.03	0.27**	
9. Backward citations	-0.17*	0.13	0.35***	0.20**	0.58***	-0.05	-0.08	0.007

Table 3 OLS Regression of Patent Attributes on Upfront Payment (in dollars)

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Prior alliances	0.309**	0.323**	0.339**	0.228	0.310**	0.243	0.234	0.329**	0.298*
	(0.149)	(0.149)	(0.146)	(0.155)	(0.152)	(0.155)	(0.161)	(0.154)	(0.152)
Patent stock	-0.260	-0.243	-0.241	-0.130	-0.260	-0.111	-0.092	-0.245	-0.248
	(0.458)	(0.463)	(0.456)	(0.482)	(0.462)	(0.487)	(0.494)	(0.467)	(0.482)
Backward citation	0.375	0.539	0.479*	0.597**	0.375	0.776**	0.743*	0.562	0.612
	(0.285)	(0.361)	(0.284)	(0.290)	(0.288)	(0.364)	(0.385)	(0.372)	(0.374)
Year	included	included	included	included	included	Included	included	included	included
Novelty		-0.736				-0.789	-0.840	-0.818	-0.688
		(1.034)				(1.021)	(1.009)	(1.056)	(1.033)
Tech importance			-0.342						
			(0.291)						
Self-citation×Novelty							-0.367		
							(0.857)		
Self-citation				-0.394***		-0.397***	-0.348*		
				(0.147)		(0.149)	(0.183)		
Generality					0.0601			0.317	0.044
					(1.244)			(1.286)	(1.230)
Generality×Novelty									-3.731
									(3.197)
Constant	-340.1**	-345.7**	-240.1	-341.4**	-340.2**	-347.998**	-339.714**	-347.172**	-339.045**
	(144.8)	(146.9)	(160.5)	(143.6)	(145.2)	(145.698)	(150.470)	(146.789)	(146.564)
Observations	97	97	97	97	97	97	97	97	97
R-squared	0.068	0.074	0.086	0.113	0.068	0.119	0.121	0.074	0.087

Robust standard errors in parentheses *p<.05, ** p<.01, ***p<.001; Two-tailed tests for all variables

Table 4 Poisson Regression of Patent Attributes on Control Rights

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Prior alliance	0.0161	0.0139	0.0152	0.0139	0.0157	0.0119	0.0116	0.0128	0.0132
	(0.0223)	(0.0242)	(0.0226)	(0.0222)	(0.0223)	(0.0238)	(0.0241)	(0.0243)	(0.0240)
Patent stock	0.0695*	0.0674*	0.0690*	0.0735*	0.0699*	0.0709*	0.0720*	0.0680*	0.0678*
	(0.0365)	(0.0355)	(0.0365)	(0.0377)	(0.0367)	(0.0370)	(0.0386)	(0.0355)	(0.0353)
Backward citation	-0.0530**	-0.0845***	-0.0564**	-0.0464*	-0.0535**	-0.0781**	-0.0796**	-0.0883***	-0.0902***
	(0.0263)	(0.0310)	(0.0268)	(0.0274)	(0.0264)	(0.0328)	(0.0326)	(0.0312)	(0.0319)
Year	included	included	included	included	included	included	included	included	included
Novelty		0.141*				0.138*	0.135	0.154*	0.155*
		(0.0803)				(0.0802)	(0.0855)	(0.0805)	(0.0798)
Tech importance			0.0108						
			(0.0255)						
Self-citation				-0.0118		-0.0107	-0.00827		
				(0.0286)		(0.0303)	(0.0282)		
Generality					-0.0392			-0.0737	-0.0733
					(0.100)			(0.0979)	(0.0983)
Self-citation×Novelty							-0.0180		
							(0.115)		
Generality×Novelty									0.0720
									(0.261)
Constant	-22.86	-21.20	-25.99	-22.77	-22.63	-21.07	-20.67	-20.53	-20.79
	(15.08)	(15.04)	(16.11)	(14.86)	(14.93)	(14.82)	(14.44)	(14.77)	(14.69)
Observations	103	103	103	103	103	103	103	103	103

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; Two-tailed tests for all variables

Discussion

This study investigates the signaling role of patent attributes and how patent novelty, technological importance, self-citation and patent generalizability impact the upfront payment and the allocation of control rights to biotech firm. This study is an attempt to address the intriguing problem of information asymmetry in R&D alliance. I draw on measurement branch of TCE and contend that patent attributes serve as reliable and cost efficient measurement for both biotech and pharm firms to evaluate the technological and commercial value of underlying knowledge in the imperfect market for technology. Second, these patent attributes signal various level of knowledge quality and influence the bargaining power of both parties in upfront payment and control rights distribution.

This study makes three theoretical contributions to strategic alliance literature. First, this study extends signaling theory by demonstrating that some signals can be negative in highly information asymmetric R&D alliance context. Patent novelty is hypothesized to be a positive signal of patented knowledge, as large organizations seek knowledge novelty to break from organizational inertia. Empirical evidence shows the opposite. Patent novelty actually reduces the number of control rights won by biotech firms. One explanation is that patent novelty may likely imply high development cost for pharm firm. To compensate the high risk from patent novelty, biotech firms have to yield more control rights to pharm firms. Prior empirical research in management with the exception of Arthurs, Busenitz, Hoskisson and Johnson (2008) examine the positive role of various signals in communicating high quality of focal firms or individuals. This comes with an expense that some signals can be negative. In studying the signaling effect of lockup

period, Arthurs and colleagues (2008) demonstrate that longer lockup period that shareholders agree to hold shares of initial public firms substitute signals of venture capital and prestigious investment bank backup.

Second, this study focuses on the measurement branch of TCE: patent characteristics reduce information impactedness by providing reliable and accurate indicators of underlying attributes of focal innovation. These characteristics not only help licensees to evaluate independently the value of focal innovations, but also help licensors to know which patent characteristic brings more innovation value in terms of up-front payment and control rights in the alliance contract. While TCE is criticized for being focused on transaction cost instead of transaction value (Zajac & Olson, 1992), broadly speaking, this study shifts the focus of TCE from transaction cost to transaction value, showing that TCE also explains how transaction value is distributed between transaction partners.

Third, this study investigates licensing from the perspective of licensors at the alliance governance phase and shows how licensors use patent characteristics to capture innovation value from big pharm firms. Prior research primarily focuses on the firm level characteristics to explain the allocation of control rights and upfront payment. Pharm firms with abundant financial resources and complementary capabilities are portrayed as dominant players in capturing an unfair amount of control rights (e.g. Adegbesan & Higggins, 2010; Lerner & Merges, 1998; Lerner, Shane & Tsai, 2003). Recent literature on alliance formation shows that small and new firms are active players in partner selection decisions. New biotech ventures possess much discretion in choosing with whom to ally (e.g. Diestre &Rajagopalan, 2012; Katila, Rosenberger, and Eisenhardt,

2008). Self-citation reduces the amount of upfront payment to biotech firm. While self-citation is not significantly related to the control rights won by R&D firms, the direction of the relationship is negative as hypothesized. Biotech firms having patents with high self-citation may accept low upfront payment in exchange for a large share of control rights to capture economic value in the patent knowledge. My follow-up research is to address this tradeoff that biotech firms make in capturing innovation value. This study makes a small step in pointing out that at alliance governance stage biotech firms also play strategically in securing innovation value.

This study also offers practical significance for managers and firms. Managers should pay close attention to patent characteristics when crafting alliance contractual terms. On the part of small and young firms focusing on the upper stream of value chain, taking advantage of patents demonstrating high backward citations helps small firms to gain the negotiation leverage and capture a large share of innovation value. In terms of strategizing, licensee firms may avoid patent with high originality, as it could incur high development cost. At the same time, firms must make tradeoff when multiple patent attributes, positive and negative, are present.

This study offers fertile ground for future research in alliance contracts. I have examined the variance in upfront payment and control rights as a function of patent attributes. Contractual terms may also change due to behavioral uncertainty of alliance partners (Parkhe, 1993). When firms have already shown this opportunistic behavior like suing other firms for patent infringement, how would one alliance partner craft contract to handle this demonstrated opportunism? With respect to alliance formation, how such

demonstrated opportunism such as being litigious affect the pool of alliance partners? In my second essay, I will investigate the latter question.

ESSAY 2

THE EFFECT OF FIRM PATENT LITIGATION REPUTATION ON R&D ALLIANCE FORMATION

Introduction

Firms in technology intensive industries use various patent strategies to protect and capture value. One strategy is to constantly sue other firms for patent infringement (Agarwal, Ganco, & Ziedonis, 2009) to prevent knowledge spillover by departing inventors. Firms having strategic stakes in the litigated patent, as measured by patent self-citations, are less likely to settle the dispute (Somaya, 2003). However, some firms are restrained in suing their competitors in that deterring imitation by resorting to legal means may drive the competitor to produce substitute innovations (Polidoro & Toh, 2011). Prior research on patent litigation has investigated its determinants (Polidoro &Toh, 2011; Somaya, 2003), characteristics and motivations (Lanjouw & Schankerman, 2001). Research on the effect of firm reputation of being litigious on subsequent alliance formation has remained relatively unexplored. While having a reputation for toughness in patent enforcement can bring benefits to focal firms such as preventing knowledge spillovers by departing employee inventors to competitors (Agarwal, Ganco, & Ziedonis, 2009), signaling strategic stakes in the dispute technological space (Somaya, 2003), and deterring rivals from allocating inventive efforts in research domain of strategic value to focal firms (Clarkson & Toh, 2010); patent litigation aggressiveness can also have costs. The costs of being litigious include not only direct lawsuit costs but also indirect costs of

consuming precious time and energy of managers, lawyers, and scientists (cf. Somaya, 2003).

This research focuses on an unintended consequence associated with firms being litigious in patent enforcement - low alliance formation rate in research and development (R&D). Investigating the impact of being litigious in patent enforcement on alliance formation has theoretical implications. First, I build on prior research on patent litigation and strategic alliances to extend signaling theory. Drawing on a sample from the U.S. semiconductor industry, Agarwal and colleagues (2009) find that firms being aggressive in patent enforcement effectively mitigate knowledge spillover from departing employee inventors. Further, they find that being litigious has more deterrence effect to entrepreneurial firms than to established firms, as entrepreneurial firms are disadvantaged in financial resources and managerial experience in handling patent litigations. While constantly suing other firms for patent infringement signals the commitment of litigious firms to protecting intellectual property, firms being litigious in patent enforcement also signal higher propensity to behave opportunistically in R&D collaboration relative to firms without such litigation history.

Firms form strategic alliances to gain both strategic and social benefits (Eisenhardt & Schoohoven, 1996). Strategic gains include accessing partner's complementary resources and maintaining competitive advantages. Forming strategic alliances from the social perspective helps firms to grasp business opportunities (Eisenhardt & Schoohoven, 1996). Being litigious can curtail the formation of alliances in R&D characterized by high information asymmetry and ambiguity. Litigiousness signals the protective stance of

litigious firms on intellectual properties and affords little chance for partner firms to learn from the collaboration. Further, being litigious may indicate possible opportunistic behavioral intentions of litigious firms in collaboration and thus increases the appropriation concerns of potential partner firms. As suggested by Katila, Rosenberger and Eisenhardt (2008), smaller partners should not only consider resource requirements but also resource misappropriation in interorganizational relationships.

Drawing on and extending signaling theory in management and entrepreneurship research, I propose two competing hypotheses. First, *repeat* signal of being litigious sends negative signals about the litigious firm and increases appropriation concerns of potential alliance partners, thereby reducing alliance formation rate of litigious firms in research and development (R&D). Being litigious on enforcing patent rights also signals the high capability in R&D to potential alliance partners, thus increasing the alliance formation rate in highly uncertain markets for R&D partners.

Further, I specify two contingencies that delineate the boundary of signaling theory. Prior research has demonstrated the contingent effects of characteristics of signals and the signal environment. The benefits of interorganizational relationships are contingent on the informational environment of signals (Gulati & Higgins, 2003; Reuer et al, 2012). Also, timing of previous signals and uncertainty about firm prospects moderate the strength of a firm's signal (Janney & Folta, 2006). I argue that competition intensity, the extent to which firms compete in an industry, attenuates the litigiousness-alliance formation rate. Increasing competition in the product/service market indicates that survival logic prevails over appropriation concerns.

I also propose that the embeddedness perspective can complement and delineate the boundary conditions of signaling theory. The embeddedness perspective on strategic alliance provides the social remedy to reducing information asymmetry (e.g. Gulati & Higgins, 2003). This perspective stresses the significant role of social structures in shaping decision making of organizations (Granovetter, 1985). Firms situated in interfirm networks utilize and interpret information obtained from interactions with other organizations as well as market signals. Prior ties with litigious firms provide the partner firms substantive information and trust which may mitigate the appropriation concerns emanating from signals of being litigious in patent enforcement.

This study contributes to the IP strategy and strategic alliance fields in three respects. First, it extends signaling theory by considering one understudied type of signal – a *repeat* signal in the context of R&D collaboration. A repeat signal of bringing other firms to court for patent infringement indicates firm litigiousness. Second, a repeat signal of being litigious highlights the negative effect on alliance formation, emphasizing that a signal can be negative as well as positive (Fischer & Reuber, 2007; Perkins & Hendry, 2005). Third, this study also complements signal theory with the embeddedness construct from network theory, delineating the boundary conditions of signaling theory.

The structure of this study is as follows. In the first section of Theory and Hypotheses, I review signaling theory and the embeddedness concept and explain their utility in explaining the relationship of being litigious-R&D alliance formation rate. Hypotheses are developed based on these two theories. In the Methodology section, I introduce the sample selection, measurement of dependent and independent variables and

analysis method. The Results section follows and the study is concluded with a discussion of managerial implications and avenues for future research.

Theory and Hypotheses

Signaling theory and patent litigation

Signaling theory is proposed to solve the problem of information asymmetry in the market (Spence, 2002). As information is disproportionately distributed among market participants, one way to diminish the information gap is to send the signal to the market. According to Stiglitz (2000), two types of information are important to market participants: information about quality and information about intent (cf. Connelly, Certo, Ireland, & Reutzel, 2011). The signal conveying the private information of the sender which can be the individual, firm or top management team of initial public offer (IPO) firms signals the underlying quality about the sender. Information about quality is particularly important to investors having no access to the private information about the characteristics of the transacting party. Behavioral uncertainty or intentions of the transacting party seem to be more important in interfirm collaborations such as strategic alliances (Das & Teng, 2000).

An effective signal must possess two characteristics: observability and signal cost (Connelly et al, 2011). First, the signal must be observable to the receiver. In the market for technological know-how, when a firm sues other firms for infringing its patent which forms the plaintiff firm's foundation of knowledge assets, the plaintiff firm is sending an observable signal to competitors that the firm has strategic stakes in the patent (Lanjouw & Schankerman, 2001). Signaling through patent litigation is effective. Empirical

evidence shows that litigated patents compared to nonlitigated patents of the same age are more likely to be cited after patent litigation (Lanjouw & Schankerman, 2001). Second, sending signals incurs cost. Signaling the intention or the underlying quality about a product, individual or firm is not without cost. High quality senders can afford the cost of sending signals while low quality senders may imitate the actions of high quality senders but cannot sustain signaling actions due to its high costs (Moulin, 1982, cf. Ndofor & Levitas, 2004). Sending signals through patent litigation can be very expensive. The average cost of patent litigation ranges from $3 to $5 million, according to an estimate by the American Intellectual Property Law Association (ALPLA, 2007, c.f. Agarwal et al., 2009).

With the exception of Agarwal and colleagues (2009), the extant strategy and entrepreneurship literatures mainly examine single signals or multiple signals that reflect a high quality of underlying attributes and bring about positive organizational outcomes. In addition, prior studies mainly apply signaling theory to the relationship between firms/managers and investors and demonstrate that signals have different strengths (Park & Mezias, 2005). Janney and Folta (2003) show that the private equity placement of post-IPO firms sends a strong signal to the public equity market that the focal firm is undervalued and that the private equity placement bundled with research partnerships increases the signal strength measured as positive abnormal returns in the public equity market. Further, Janney and Folta (2003) argue that signal frequency, defined as more prior private equity placements, reduces the information asymmetry in a dynamic environment. Similarly, Gulati and Higgins (2003) find that the strength of signals from

different interorganizational partnerships such as ties with venture capital firms and investment banks, and strategic alliances depends on the extent to which investors attend to different types of market uncertainty. Reuer, Tong, and Wu (2012) find that target post-IPO firms within five years of going public capture higher acquisition premiums by engaging in interorganizational relationships with prominent venture capital firms, investment banks and alliance partners, because target firms lease the reputation of these reputable organizations to indicate high quality to acquiring firms. Reuer and colleagues (2012) suggest that the strength of single signals from these interorganizational relationships goes beyond IPO performance and can last as long as five years in the M&A market.

What has been downplayed in the strategy literature is the *repeat* signal and *unintended* receivers of a signal in the market. A repeat signal can enhance the observability of a signal to market participants, not limited to intended receivers. A repeat signal is more salient than a single signal in that a repeat signal is consistent over time and is more credible to receivers. When a firm brings other firms to court for patent infringement for multiple times, the repeat signal of being aggressive in patent protection creates a reputation for the firm of being aggressive in patent enforcement and demonstrates the firm's commitment to being tough (Agarwal et al, 2009).

In addition, a repeat signal increases the visibility to receivers, effectively revealing intentions and attributes of litigious firms. Second, the observability of a repeat signal can also reach *unintended* receivers. The extant strategy and entrepreneurship literatures focus on the effectiveness of signals to intended receivers. Signals are intentionally

targeted toward particular groups such as competitors, consumers, investors, capital and labor markets, and board of directors (e.g. Carter, 2006; Chung & Kalnins, 2001; Ndofor & Levitas, 2004; Park & Mezias, 2005; Perkins & Hendry, 2005; Zhang & Wiersema, 2009).

Spence (1974:1 cf. Ndofor & Levitas, 2004) defines signals as "activities or attributes of individuals in a market which by design or accident, alter the beliefs of, or convey information to, other individuals in the market". Interpreting Spence's definition of a signal reveals that a signal can be intentional or *unintentional*, depending on whom the receivers are. While litigious firms intend to send signals to competitors, their current and potential collaborator in research and development (R&D) can also notice this signal due to the salience of the repeat signal. The aggregate effect of repeat signals on *unintended* receivers such as current and potential collaborators has not been studied. My research is to rediscover and interpret the overlooked part in signaling theory applied in the strategy literature.

In this study, I argue that a signal of being aggressive in protecting patent rights sends two messages to unintended signal receivers. First, being litigious causes appropriation concerns to small and young firms. Second, because firms usually litigate valuable patents which constitute foundation knowledge for the litigious firms, being litigious signals a high R&D capability of the focal firm.

Appropriation concerns and litigious firms

R&D alliances are characterized by the behavioral uncertainty of partners (Gulati & Singh, 1997). Partners may act opportunistically and appropriate an unfair share of the generated gains. To address the problem of opportunistic behavior, prior research has proposed three mechanisms: partner selection, alliance governance and alliance scope (e.g. Li, Eden, Hitt, & Ireland, 2008; Gulati & Singh, 1997; Oxley & Sampson, 2004). Partner selection involves the problem of with whom to ally. Li et al. (2008) juxtapose partner selection along with alliance governance and alliance scope to guard knowledge assets of collaborating firms. Li and colleagues (2008) propose a typology of alliance partners which fall into the categories of friends, acquaintances and strangers, depending on prior alliance experience. One of their empirical findings is that the radicality of innovation goals is positively associated with friends rather than strangers, as friends are more trustworthy and less likely to appropriate focal firm's valuable technological assets. Equity-based governance structure is more effective in protecting key knowledge assets than non-equity based structures (Gulati, 1995). Alliance scope exerts its effect of knowledge protection through either limiting or enlarging the scope of contacts between partner firms (Oxley & Sampson, 2004). As this research investigates how firms being litigious in enforcing intellectual properties affect subsequent alliance formation, partner selection rather than alliance governance and alliance scope is more relevant to this discussion.

Litigious firms can affect alliance decisions of potential R&D collaborators in two ways. One is the deterrence effect. Being litigious sends out a strong signal that the focal

firm has strategic stakes in that technological domain and the focal firm is determined to prevent potential competitors from entering that domain (Clarkson & Toh, 2010). Such a signal of being litigious is magnified through media coverage, as media closely monitor and cover patent litigations (Agarwal et al, 2009). In addition, being aggressive in intellectual property (IP) enforcement indicates that a focal firm may act opportunistically in R&D collaborations. Firms are more likely to prosecute those firms who cite the disputed patent and are active in technologically related fields (Lanjouw & Schankerman, 2001). Litigiousness deters potential partners from entering into an alliance. Firms are motivated to form alliances for many reasons (Kogut, 1988). One reason is to gain knowledge and other resources that they don't possess. Another motivation is to learn critical knowledge. Being litigious signals that the litigious firm is aggressive in protecting its key knowledge assets and indicates little chance for potential partners to learn. Second, litigiousness-induced appropriation concerns substantially increase potential alliance costs compared to alliance gains.

One of the characteristics of litigated patents is that a litigated patent is economically valuable (Lanjouw & Shankerman, 2001). If the resulting patent from an R&D collaboration is valuable, potential partners may infer that litigious firms are very likely to appropriate the patent by resorting to lawsuits. Given the high legal costs and managerial time involved in such litigations, potential firms may tend to avoid allying with litigious firms in R&D.

The signaled litigiousness in patent enforcement may cause more concern to small and entrepreneurial firms. Small, private, entrepreneurial firms lack the financial

resources to fight against expropriation claims (Agarwal, Ganco, & Ziedonis, 2009). Summarizing the above arguments, I predict that

H1a. One firm's litigiousness for IP enforcement will reduce the subsequent R&D alliance formation rate of that firm.

The other effect of being litigious is disclosing and marketing the firm's key capability in the litigated technological domain. The market for technological know-how is imperfect and full of uncertainty and ambiguity. Due to the unevenly distributed information among technology intensive firms, verifying R&D capability and intentions of potential R&D partners is difficult. A lemons problem has been found to exist in the R&D alliance market. Pisano (1997) finds that firms tend to license out projects with poor prospects and commercialize research projects with high prospects internally.

When a firm is known to be litigious about patents, the litigious firm's key stakes and capability in technological domain stand out among peer firms. Media coverage of patent litigation also increases the publicity of litigious firms (Agarwal et al., 2009). This increased exposure of a litigious firm to potential partners decreases the information asymmetry regarding R&D capability, reducing the hazard of adverse selection in the market for technological know-how. Meanwhile, a firm search for R&D partners is rationally bounded by limited attention of decision makers (Ocasio, 1997). The salience of a repeat signal of consistent prosecution for patent infringement would very likely attract the attention of decision makers searching for R&D partners, as decision maker attention is stimulated by the environment in which the decision makers are situated (Ocasio, 1997). Therefore, strong signals of being litigious attract potential partner firms

to evaluate and identify the complementarities with the technological domain of the litigious firm. However, whether these potential partners choose to ally with litigious firms depends on firm characteristics such as bargaining power, firm size and technological distance between the two firms.

Large firms may very likely have bargaining power in terms of financial resources to mitigate the potential expropriation hazard (Lanjouw & Lerner, 2001). Seeing the complementarity, large firms may very likely form R&D alliances. Small firms, on the other hand, are disadvantaged if a patent dispute arises from the collaboration with the litigious firm. Lanjouw and Schankerman (2004) find that small firms are handicapped in settling patent disputes for two reasons. First, small firms have less bargaining power in trading IP rights, as they have smaller patent portfolios compared to those of large firms. Second, small firms are less likely to have in-house legal counsel compared to large firms, placing small firms at a cost disadvantage if any patent dispute arises. While lack of in-house legal counsel and shortage of bargaining power constrains small firms, some small firms may have to choose these litigious firms for R&D alliance if they lack financial resources and complementary assets to conduct promising R&D projects. Lerner, Shane and Tsai (2003) suggest that when the financial market is not conducive to financing R&D projects through issuing equity, small firms in biotechnology industry are more likely to ally with big firms and concede a large percentage of control rights to large partners. In such situations, survival concerns may dominate appropriation concerns. Technological distance between small firms and a litigious firm may mitigate appropriation concerns from the small firms. Further, potential partners known to be

litigious can also counteract the deterrence effect exerted from the litigious firm. Thus, I hypothesize that

> *H1b. One firm's litigiousness for IP enforcement will increase the subsequent R&D alliance formation rate of that firm.*

Interorganizaitonal trust derived from multiple prior transactions can further reduce the information asymmetry arising from the behavioral uncertainty in an R&D alliance. Williamson (1996) proposes three mechanisms to reduce transactional uncertainty, which includes trust built up through multiple transactions, greater information disclosure and bonding. The social embeddedness perspective also highlights the vital role of trust. Embeddedness perspective can complement signaling theory (Granovetter, 1987; Uzzi, 1996). The embeddedness perspective on economic transactions emphasizes the role of trust and reciprocity in reducing opportunistic behavior when information asymmetry is high (Polidoro et al., 2011). Economic transactions such as alliance formation are embedded in social structures (Granovetter, 1987). Firms make alliance decisions in a holistic way, taking into account other relevant information from trusted sources. The literature on alliance formation has recognized the important roles and interplay of embeddedness and competition. Among others, Eisenhardt and Schoohoven (1996) find that firms led by a well-connected top management team tend to form alliances and that high competition increases alliances. Polidoro and colleagues (2011) investigate the effect of network embeddedness on joint venture dissolution and find that when firms in the same industry have a strong economic incentive to compete and behave opportunistically, network embeddedness such as the presence of common third parties diminishes the antagonistic behavior in the interfirm relationship. The reduced

probability of joint venture dissolution is attributed to potential penalties from the common third parties: Opportunistic partners can be directly retaliated by third parties or are excluded from future collaborations. I argue that placing interpretation of signals in the social structure represents a more realistic and complete tale of alliance formation for litigious firms.

A prior transaction relationship with the litigious firm provides the partner direct and reliable information about the litigious firm (Gulati, 1995). As Granovetter (1987) points out, "Even better is information from one's own past dealings with that person", because acquiring such information is inexpensive, the information is more trustworthy, business partners are motivated to behave honestly to secure future transactions, and social expectations resulting from business relations promote trust. Empirical research on relational embeddedness shows that previous direct ties increase trust and diminish opportunistic behavior. Gulati and Garguilo (1999), for instance, suggest that prior mutual alliances increase the probability of forming a new alliance due to trust developed in previous cooperation. Interfirm trust emerging from repeated alliances also reduces the need to use equity-based governance for subsequent partnership (Gulati, 1995).

At the same time, forming an alliance "is simultaneously a relation between two or more firms… and a commercial activity with effects on market competition" (Greve, Baum, Mitsuhashi, & Rowley, 2010: 303). In the following discussion, I propose two contingencies that moderate the relationship between being litigious and alliance formation rate.

Moderating effects of prior alliance experience

While firms use repeat signals in the market to evaluate potential R&D partners, they also rely on their own informational source such as prior alliance experience with litigious firms. Repeat signals about firm attributes such as firm capability and intentions are evaluated with other information. Scholars have emphasized the important role of interorganizational trust in reducing information asymmetry between alliance partners. Williamson (1996) proposes three mechanisms to reduce transactional uncertainty, which include 1) trust built up through multiple transactions, 2) greater information disclosure and 3) bonding.

The social embeddedness perspective also highlights the vital role of trust. Economic transactions do not exist in an atomistic manner. Firms are embedded in social relations (Granovetter, 1985). The social aspect of prior relations with partners who are litigious is likely to reduce the negative effect on subsequent alliance formation. First, firms that have formed trusting relations with partners have more confidence in predictability of counterparts, reducing appropriation concerns (Granovetter, 1985). Constant interactions with litigious firms enable previous partner firms to have other information to verify the intentions of litigious firms and their innovation goals. The alliance routines developed through repeat alliances, for example, allows partner firms to exchange information which could not have disclosed through signals of being litigious. Second, repeated ties between litigious firms and partner firms mitigate adverse selection (Gulati & Singh, 1998). Prior alliances with litigious firms are likely to produce trust derived from familiarity with partners and reduced information asymmetry (Gulati, 1995). Li et al.

(2008) suggests that when innovations are radical, alliance partners tend to look for their friend firms who have two or more alliances in the past five years. Further, trust generated through prior alliances also makes it less likely to govern subsequent alliance with an equity-based contract, a shared ownership structure deterring opportunistic behavior (Gulati, 1995). As a result, when an alliance opportunity occurs, firms would still choose litigious firms rather than strangers with no prior alliance relations[1]. Thus I predict that:

> *H2a. Prior ties of collaborating firms with litigious firms mitigate the negative relationship proposed in H1a such that the more prior ties, the higher the R&D alliance formation rate of the litigious firm.*

Moderating effects of competitive intensity

In addition to the social factor of prior alliances with litigious firms, another contingency constraining the negative relation between being litigiousness and subsequent alliance formation is competitive intensity. Barnett (1997) defines it as "the effect that a firm has on other firms' survival chances" (cf. Ang, 2008). Prior research shows that competition intensity is positively related to alliance formation. Shan (1990) draws on a sample from new biotechnology firms and finds that market followers are more likely than market leaders to form alliances for product commercialization. Analyzing a sample of collaborations in the manufacturing industry from Singapore, Ang (2008) suggests that competitive intensity determines the propensity to collaborate. Also

[1] Because H1b predicts the signaling effect of being litigious on potential new R&D partners, prior ties have no role to play in this relationship. As a result, I didn't propose any moderating effect of prior ties in the relationship proposed in H1b.

Eisenhardt and Schoonhoven (1996) find that firms with vulnerable strategic positions form alliances to compete in highly competitive industries. The central theme among these findings is that intense competition squeezes the profit margin and demands that firms compete with alliances to survive in the technologically intensive industry. Furthermore, alliances with other firms may provide the focal firm a chance to foreclose rivals' alliance opportunities. Silverman and Baum (2002) find that competitive intensity that firms experience is positively associated with the number of alliances that rival firms build. To summarize, when competition prevails over appropriation concern, potential partners may choose to ally with litigious firms.

H3a. Competition intensity weakens the negative relationship between one firm's being litigious for IP enforcement and the subsequent R&D alliance formation rate of that firm.

H3b. Competition intensity strengthens the positive relationship between one firm's being litigious for IP enforcement and the subsequent R&D alliance formation rate of that firm.

Methodology

I test the hypotheses in the context of U.S. technology intensive industries. Publicly listed firms in biotechnology and pharmaceutical industries (SIC 2834 and 2836) comprise the sample. These two industries heavily rely on research and development to generate revenue and sustain growth, and it is essential for these firms to protect valuable intellectual resources embodied in patents and concurrently form new R&D partnerships

to discover, research and develop new drugs. Thus, these two industries provide appropriate contexts to test the effects of being aggressive on patent protection on R&D alliance formation. Consistent with prior studies (e.g. Allison, Lemley & Walker, 2009), the sample cases of patent litigations would eliminate patent trolls (nonpractising entities). Patent trolls are entities which demand patent enforcement without contributing to invention or new technologies (Davis, 2008; cf. Allison et al., 2009). The time period of the sample spans from 2000 to 2010. To alleviate sample selection bias, firms listed on the U.S. stock exchanges in 2000 or 2010 are selected into the sample, resulting in 346 firms in SIC 2834 and 2836. Since the focus of this study is on patent litigation, 93 firms are dropped from the sample due to having no granted patent during time period of 2000 to 2010. The final sample includes 253 firms. This unbalanced cross-sectional time series dataset has 2200 firm year observations. As I use the moving sum of five-year alliances between a focal firm and other firms and missing values occur in this panel data, the final dataset used for analysis has 1002 firm-year observations.

The litigation data are collected from the Stanford IP Litigation Clearinghouse which collects intellectual property litigations starting from 2000. The author and a second coder coded all patent litigations in USPTO classes of 424 and 514 which comprise drug, bio-affecting and body treating compositions. The patent litigation information includes filing date, names of plaintiffs and defendants, and patent numbers involved in the patent lawsuit. When a patent lawsuit involves one patent, that patent number is matched to USPTO patent data at the firm level. If more than one patent are involved, a random patent is selected and matched to a firm level identifier in the USPTO patent data. The

sample firms are limited to U.S. public firms from 2000 to 2010 to facilitate gathering financial information on control variables (R&D expenditure, ROE and total assets) in the COMPUSTAT/CRSP merged dataset.

Measures of DV and IVs The dependent variable, *R&D alliance formation*, is a count variable. It is measured as the number of new R&D alliances formed between a focal firm and other firms in each year during the time period of 2005 to 2010. SDC dataset records alliances formed among firms since the 1980s with various types of partnerships (R&D, marketing, licensing and production). With regard to the representativeness of alliances in SDC database, Schilling (2009) compares five databases of SDC, MERIT-CATI, CORE, RECAP, and BIOSCAN and replicates prior studies of alliance activity. Schilling (2009) finds consistent results in using different alliance databases. Therefore, it is appropriate to use SDC database to code the R&D alliances.

The independent variables include *litigiousness*, *repeat alliances* and *competitive intensity*. Consistent with prior research on litigiousness (Agarwal et al, 2009), *litigiousness* is a time varying variable. It is measured as the moving sum of patent law suits initiated within a three-year time window. The three-year window captures the cumulative strength of repeat patent lawsuits against other firms. *Repeat alliance* is used to capture the extent to which the partner firm trusts the litigious firm. Repeated alliances allow firms to interact frequently and develop trust between top management teams. Gulati (1995) uses the number of previous alliances to approximate the interfirm trust. Similarly, Li and colleagues (2008) view a firm as a friend of a focal firm if there are more than five alliances between the dyad in the previous years. The logic is that without

such interfirm trust, subsequent new alliances could not have occurred. Thus, this variable represents the social relations between the litigious firm and the partner firm. This variable is measured by the number of repeat alliances between the focal firm and other firms in the previous five years from 2000 to the focal year (Gulati, 1995). *Competitive intensity* captures the extent to which firms compete in technological resources. It is measured by the number of firms that a focal firm operates in the 2-digit SIC code in each year. To avoid a skewness problem, I take the natural log of this variable. This information is obtained from the COMPUSTAT/CRSP merged dataset.

Control variables. *Portfolio of alliances* is found to affect subsequent alliance formation. Thus, I control for the total number of previous alliances of each type (marketing, licensing, production, and R&D) in the previous five years from SDC database. Firms form alliances to access partner's technological resources. I add the natural log of R&D expenditures in year *t-1* as a control. *Firm size* is measured by the natural log of total assets in year *t-1*. *Firm age* is also added as an additional control. It is measured as the natural log of the difference between a focal year and a founding year. *Year effect* is used to control for the general conditions of market and economy.

Estimation method. As the dependent variable is a count variable measured as the number of R&D alliances, the distribution is right-skewed. The features of the distribution require that analysis approaches employed avoid heteroscedasticity and non-normal residuals (Hausman, Hall, & Griliches, 1984). There are two methods choices available which address this concern: a Poisson regression model or a negative binomial regression model which is a generalized form of Poisson regression (Hausman et al.,

1984). As the test shows that the conditional mean of the dependent variable is not equal to the conditional variance, the assumption of a Poisson distribution, there is an overdispersion problem, so I use the negative binomial model (Huang & Murray, 2009). To test the moderator effects of repeat ties and competitive intensity, I interact the main independent variable of litigiousness with repeat alliance and competitive intensity.

Results

The descriptive statistics and correlations among these variables are reported in Table 5. Repeat alliance is highly correlated with R&D alliances (0.8). R&D expenditures and Assets also have a correlation of .86. This raises the concern of multicollinearity. I use STATA _rmcoll command to check collinearity among a group of variables. If collinearity occurs, _rmcoll can identify and flag the variables. As no independent variable is flagged due to collinearity, I believe that the multicollinearity concern is alleviated.

Table 6 reports the results of fixed effect negative binomial regression analysis. Model 1 only includes the control variables. Repeat alliance is positively associated with R&D alliances, which is consistent with prior research findings that previous alliances enhance interfirm trust (Gulati, 1995; Xia, 2011). Repeat alliances facilitate new alliances between the same partners, especially when the innovation goal is radical (Li et al., 2008). Model 2 tests the competing hypotheses that being litigious about patent enforcement will reduce (H1a) or increase (H1b) R&D alliances. As patent litigation is statistically

significant and positive (b=0.08, $p<0.05$), H1b is supported. H2a stated that the negative relationship of being litigious and R&D alliance formation would be mitigated by repeat alliances. Model 2 adds the interaction effect of being litigious and repeat alliances. This interaction term is statistically significant and negative (b=-0.05, $p<0.01$). Because the direction of the relationship is opposite to the proposed one, H2a is not supported. H3a and H3b predict the moderating effect of competition intensity in the relationship of being litigious and R&D alliance formation. Model 4 tests competing hypothesis 3a and hypothesis 3b. Since Model 4 does not fit the data better than Model 1 and the interaction term of patent litigations and competitors is not statistically significant, neither of the two hypotheses is supported.

Table 5

Descriptive Statistics and Correlations

Variable	N	Mean	s.d.	Min.	Max.	1	2	3	4	5	6	7
1.R&D alliances	2200	0.14	0.51	0	9							
2.Patent litigations	1462	0.41	1.84	0	26	0.07**						
3.Repeat alliances	2200	0.25	0.78	0	12	0.80***	0.12***					
4.Competitors	2200	6.22	0.06	6.07	6.28	0.067**	-0.12***	0.05*				
5.Age	2171	2.58	1.17	0	5.08	0.06**	0.37***	0.09***	-0.32***			
6.Assets	1946	5.22	2.15	0.73	12.27	0.29***	0.43***	0.33***	-0.05*	0.42***		
7.R&D expenditure	1947	3.60	1.83	0	9.41	0.30***	0.43***	0.34***	-0.07**	0.30***	0.86***	
8.Prior alliances	1013	1.4	2.74	0	24	0.44***	0.26***	0.51***	0.004	0.23***	0.49***	0.51***

* p<.05; **p<.01; ***p<.001

Table 6

Results of Negative Binomial Regression on Number of R&D Alliances

Variable	Model 1	Model 2	Model 3	Model 4
Patent litigations			-0.05**	
×Repeat alliances			(0.02)	
Patent litigations				-0.28
×Competitors				(0.44)
Patent litigations		0.08*	0.14**	1.79
		(0.04)	(0.04)	(2.69)
Repeat alliances	1.09***	1.13***	1.06***	1.12***
	(0.21)	(0.17)	(0.08)	(0.17)
Competitors	16.76	14.69	33.41	13.81
	(35.38)	(31.50)	(24.09)	(30.8)
Age	0.01	-0.07	0.0008	-0.05
	(0.12)	(0.13)	(0.11)	(0.14)
Assets	-0.19	-0.19	-0.20	-0.18
	(0.13)	(0.13)	(0.12)	(0.13)
R&D expenditure	0.29*	0.26*	0.25	0.26
	(0.16)	(0.16)	(0.15)	(0.16)
Prior alliances	-0.01	-0.02	-0.006	-0.01
	(0.03)	(0.03)	(0.02)	(0.03)
Intercept	-106.31	-93.44	-207.6	-88.29
	(215.21)	(191.62)	(146.5)	(187.33)
Observations	1002	1002	1002	1002
Log likelihood	-217.42	-216.06	-213.34	-215.86
Differnce in log likelihood vis-a-via the base model		2.72^{+}	8.16*	3.12

Year effect is included in these models and is not reported for brevity.

$^{+}$p<0.1; *p<.05; ** p<.01; ***p<.001

Discussion

Prior research on toughness in patent enforcement (Agarwal et al, 2009) examines its positive effect in preventing knowledge spillover through inventor mobility. Building on this line of research, this study draws on the literatures of strategic alliance and IP strategy and makes a theoretical attempt to integrate these two literatures within signaling theory. I investigate the effect of firms being litigious about patent enforcement on subsequent R&D alliance formation. I propose two competing hypotheses: being litigious is negatively associated with subsequent R&D alliance formation when this signal is interpreted as appropriation intention by potential partners; the relationship of being litigious and R&D alliance formation is positive when being litigious signals high R&D quality of the litigious firm. Empirical results show that being litigious is positively associated with R&D alliance formation. This empirical evidence provides support to the idea that aggressively protecting patented intellectual property signals the R&D capability of the litigious firm to potential partners. Given that patent litigation is a costly firm strategy, being aggressive on patent enforcement not only prevents knowledge spillover via R&D employee turnover but also attracts new partners in uncertain R&D market.

Further, drawing on theoretical insights from embeddedness perspective, I propose two contingencies for the relationship of repeat ties and competitive intensity. Repeat ties with litigious firms and high competition moderate the relationship of being litigious and R&D alliance formation rate. While being litigious sends signal of litigious firm's R&D capability and results in more R&D alliances, repeat alliances negatively moderate this

positive relationship such that repeat alliances reduce the number of R&D alliances. This finding may suggest the negative effect of being embedded in existing networks.

This research builds on signaling theory and extends it in two respects. First, this study examines the effect of a *repeat* signal on unintended receivers such as potential alliance partners. A repeat signal, being litigious about patent enforcement in this case, has higher salience to market participants. Consistently prosecuting other firms for patent infringement increases the observability of a signal and the firm incurs the high costs of sending such a signal. Therefore, a repeat signal is effective in conveying the strategic intentions and firm attributes to intended and *unintended* receivers. While the extant strategy literature using signaling theory has deepened our understanding of various phenomena (e.g. Chung & Kalnins, 2001; Ndofor & Levitas, 2004; Park & Mezias, 2005), less scholarly attention, however, is given to *repeat* signals. Further, the strategy literature seems to place emphasis on the positive effects of signals to intended receivers with the exception of Perkins and Hendry (2005). My study rediscovers and reinterprets signaling theory in the strategy literature by emphasizing the initial theoretical tenet that signals can be both intentional and unintentional at the same time (Spence, 1974:1 cf. Ndofor & Levitas, 2004). It is intentional, because being aggressive in IP enforcement is intended to deter a competitor from entering the technological space of the litigious firm. It can be simultaneously *unintentional* because the signal of being litigious on patent enforcement is also received by potential R&D alliance partners. My research highlights that being litigious can also have a positive effect on R&D alliance formation, as

potential alliance partners view litigiousness as a signal that the litigious firm has strong technological capability in the litigated patents.

Second, signaling theory is interpreted and applied in an atomistic manner, downplaying the role that social structures have played in interpreting signals (Granovetter, 1987). The undersocialized view of signals indicates that social remedies to adverse selection in situations of high information asymmetry provide boundary conditions of signals (Reuer et al., 2012). Firms not only receive and interpret signals, but also evaluate substantive information from other trusted sources, such as prior relations with litigious firms. By placing interpretation of repeat signals in social structures, I complement and extend signaling theory with the social embeddedness construct.

Managerial implications

The findings of this research will inform managers in technology intensive industry of the unintended negative effects of being aggressive in protecting patents in the formation of strategic alliance. Patent strategy, such as being aggressive in suing firms for patent infringement, is beneficial on one hand. Being litigious keeps a competitor from entering the technological domains that a litigious firm has strategic stakes. This enables a litigious firm to capture the rents generated from their own foundational patents (Clarkson & Toh, 2010) and prevent knowledge spillover through inventor mobility (Agarwal et al, 2009). On the other hand, bringing firms to court incurs huge amounts of legal costs. The average cost of patent litigation ranges from $3 to $5 million, according to the estimates by the American Intellectual Property Law Association (ALPLA, 2007,

cf. Agarwal et al., 2009). Moreover, a firm aggressive in IP enforcement increases appropriation concerns of small firms, which lack adequate financial resources to squander to protect their key patents. For firms that adopt such an aggressive patent strategy, it is cautioned that they may drive away valuable small R&D partners, limiting their innovation capability and adaptability in future competition. The negative consequence of choosing an aggressive patent strategy is also documented by Polidoro and Toh (2011), finding that aggressive suing firms for patent infringement may induce rivals to create substitute products. Thus, it is advised that firms must balance between being litigious and securing valuable R&D partners.

ESSAY 3

THE EFFECT OF PATENT LITIGATION ON TECHNOLOGICAL INNOVATION

Introduction

This study investigates whether and how patent litigation impacts technological innovation of firms which repeatedly bring other firms to court for patent infringements (litigious firms). By resorting to patent litigation, firms protect their intellectual assets and profit from innovations (Lanjouw & Schankerman, 2001; Somaya, 2012). Prior research has shown that by being litigious in protecting their patented intellectual property, firms prevent knowledge outflow (Agarwal, Ganco, & Ziedonis, 2009) and deter competitors (particularly small firms) from entering their technological space (Lanjouw & Schankerman, 2004). Despite the many benefits, patent litigation is a costly strategic action. It takes 2.3 years from filing the complaint to the trial stage in court (PWC, 2013). The out-of-pocket litigation cost can be $600,000 for both plaintiff and defendant in the discovery phase and reach $1,200,000 for the trial stage (ALPLA, 1996; cf. King, 2003).

When managerial attention, substantial financial resources, and R&D personnel time are shifted to patent litigation, they can influence the innovative path of litigious firms. However, whether and how patent litigation influences technological search behavior of litigious firms has received less scholar attention. Given the vital importance of balancing exploration and exploration for organizational adaptation to technological and

market changes (March, 1991; Levinthal & March, 1993), studying the effect of patent litigation on technological search bears theoretical and practical significance. Whereas exploiting existing knowledge and capabilities ensures profitability to be viable in the present competition, experimenting with new knowledge and searching beyond their current knowledge base adapts organizations to future competition (March, 1991). In this paper, organizational activities are restricted to technological search in knowledge domain. Exploration entails "a pursuit of new knowledge" while exploitation involves "the use and development of things already known" (Levinthal & March, 1993). I also follow the initial theorization of March (1991) that technological exploration and exploitation are mutually exclusive.

I draw on a knowledge recombination perspective to develop my hypotheses. The main premise of knowledge recombination perspective is that new innovations emerge from recombining existing knowledge elements or knowledge structure (Ahuja, Lampert, & Tandon, 2008; Fleming, 2001; Kogut & Zander, 1992). The larger the knowledge base, the higher the number of recombination possibilities, and the more likely the firm will generate new knowledge. Firms can refine and improve existing knowledge (exploitative innovations) through exploiting the knowledge base within firms: searching over large time spans and recombining current knowledge with old knowledge (Nerkar, 2003). Firms can also generate new knowledge through exploratory activities to increase their knowledge base (exploratory innovations): crossing the organizational boundaries through alliance formation and inventor mobility (Rosenkopf & Almeida, 2003).

I predict that patent litigation leads litigious firms toward generating exploitative innovations and limiting exploratory innovations. Three mechanisms constrain litigious firms from increasing knowledge base through recombination and exploring new opportunities. First, patent litigation shifts attention of managers and R&D personnel to exploiting existing knowledge. Patent litigation reflects a managerial approach of strategic management of technological assets (Somaya, 2012). Patent litigation is, in essence, to protect and leverage existing knowledge assets. While firms tend to localize their search in neighboring knowledge domain (Helfat, 1994), patent litigation can further reinforce the exploitation tendency of litigious firms. In addition, R&D personnel are deeply involved in the time consuming patent litigation process through finding and photocopying research documents (Walsh, Arora & Cohen, 2003), delaying the research process. By revisiting old knowledge embodied in the litigated patents rather than learning new knowledge, R&D personnel limit themselves to fixed level of knowledge base and very likely generate incremental innovation by refining and deepening their understanding of existing knowledge elements and structures.

Second, financial resources spent on litigation incur high opportunity cost. Costly litigation restricts a litigious firm's ability to invest in new research projects which could have produced new knowledge for further combination. Third, being litigious deters small firms from entering into the technological space of litigious firm (Lanjouw & Schankerman, 2004). This can restrict small firms from contributing new knowledge in the technological domain of litigious firms and limit the possibility of increasing knowledge base for further experiment. Overall, patent litigation perpetuates the tendency

of litigious firms to exploit existing knowledge as represented by the litigated patent. Further, based on the premise that exploitation and exploration are incompatible (March, 1991; Gupta, Smith, & Shalley, 2006), patent litigation induced exploitation crowds out technological exploration.

This study makes two contributions. First, this study contributes to organizational learning literature by exploring the impact of patent litigation on organizational technological search. While prior literature has shed insightful light on antecedents of patent litigation, characteristics of patent litigation, and benefits of being litigious on patent enforcement (e.g. Argarwal et al, 2009; Lanjouw & Shankerman, 2001), this study extends prior literature by relating patent litigation to organizational learning. In addition, Benner and Tushman (2002, 2003) shows that process management shifts the balance of exploitation and exploration toward exploitative innovations at the expense of adaptation. This study demonstrates the unintended consequences of overly exploiting and leveraging existing intellectual assets by resorting to patent lawsuits.

Second, this study extends knowledge recombination perspective. Emerging literature has shown that "the knowledge base is a dynamic entity and that elements of knowledge vary in their salience and importance in the recombinatory process over time (as demonstrated by the revealed preferences of inventors using citation data)" (Ahuja et al, 2008:67). Patent litigation limits the attention of R&D personnel to internal knowledge. Thus, resorting to patent litigation is stifling creation of large knowledge base for new knowledge recombination.

The structure of the paper is as follows. The Theory and Hypotheses section develops theory linking patent litigation to technological search. The Methods section describes sample selection, variable measurement, analysis method and empirical result. The Discussion section discusses contributions and future research avenues.

Theory and Hypotheses

Patent litigation and knowledge recombination

Firms sue other firms for patent infringement for various purposes. The litigation motivation can vary with appropriability regime at the industrial level[2], as intellectual property protection changes with industrial environment (Cohen, Nelson, & Walsh, 2000). In strong appropriability regimes such as biotechnology and pharmaceutical industries, firms employ patent lawsuits as an isolating mechanism of protecting their valuable intellectual assets (Somaya, 2003). Patent litigation is also one of the patent strategies that firms adopt to appropriate innovation value (Teece, 1986; Somaya, 2012). Prior empirical research has shown that patent litigation effectively deters competitors from investing in the technological trajectory of litigious firms (Lerner, 1995), signals the strategic stakes in the technological domain reflected by the litigated patent (Somaya, 2003) and prevents knowledge spillovers to rival firms (Agarwal et al, 2009).

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[2] Recent years have seen a surge of patent lawsuits initiated by non-practicing entities (NPEs). They are also called patent trolls. NPE do not engage in R&D or manufacturing. They simply acquire patents and sue other firms for patent infringement to capture innovation rent. NPEs are frequently found in semiconductor industry (e.g. Golden, 2006; Lemley, 2007). The sample in this study excludes NPEs.

Notwithstanding, enforcing patent rights incurs costs. First, the direct legal cost can range from one to three million U.S. dollars for the plaintiff or defendant alone (ALPLA, 1997; cf. Somaya, 2003). Initiating patent lawsuits also destroys market value of both plaintiff and defendant firms (Bhagat, Brickley & Coles, 1994; cf. Lerner, 1995). Further, having little litigation experience and limited financial resources, small firms avoid investing in technological domains in which litigious firms have patents (e.g. Argarwal et al, 2009; Lerner, 1995).

While prior research has shed insightful light on patent litigation, whether and how patent litigation influences technological innovation of litigious firm has remained underdeveloped. After all, in order to survive and adapt to technological change, maintaining appropriate balance of exploitation and exploration in technological search is quite essential (March, 1991; Lavie et al, 2010). I draw on knowledge recombination perspective and organizational learning literature to develop my argument (Benner & Tushman, 2002, 2003; March, 1991; March & Levinthal, 1993; Nerkar, 2003).

In order to adapt to environmental change, organizations must balance exploitation and exploration (March, 1991).Exploitation is defined as "refinement, choice, production, efficiency, selection, implementation and execution" whereas exploration entails "search, variation, risk-taking, experimentation, play, flexibility, discovery, and innovation" (March, 1991:71). Levinthal and March (1993:105) further narrows the scope of these two notions to knowledge domain: while exploration refers to "a pursuit of new knowledge," exploitation involves "the use and development of things already known". Exploitation means local search, searching for solutions to technological problems in

neighboring technological domains. Empirical research demonstrates that firms tend to search locally (Helfat, 1994). In contrast, exploration is to search distantly, across organizational and/or technological boundaries (Rosenkopf & Almeida, 2003). Benner and Tushman (2002) empirically shows that process management activities enhance exploitative innovation by leveraging a firm's existing knowledge and crowding out exploratory innovations.

The technological innovation literature mainly relies on a knowledge recombination perspective. This perspective suggests that innovations are generated by recombining knowledge elements or knowledge structure (Ahuja et al, 2008). Knowledge elements are defined as prior knowledge codified in patents. For example, if firm X cites patent A and patent B from firm Y and Z, respectively, to create patent C with its own patent D , then patent C is created by combining knowledge elements codified in patents A, B and D. This example shows firm can recombine knowledge within its own knowledge base and with knowledge from other firms' knowledge bases. Theoretically, knowledge recombination as manifested by patent citations does not suffer from knowledge resource constraints, as the number of patents available for citations is unlimited (Gupta, Smith, & Shalley, 2006). Empirical research, however, shows that knowledge recombination is subject to many influences (Flemming, 2001).

Knowledge recombination in terms of patent citation is particularly subject to managerial and R&D personnel's attention. Patent litigation consumes valuable time from managers and research and development (R&D) personnel (Somaya, 2003). First, since senior managers play an important role in balancing exploration and exploitation

(Tushman & O'Reilly, 1996), shifting attention to exploitation mode can direct technological search to exploiting existing knowledge elements. Li and colleagues (2012) demonstrate the importance of managerial attention to technological search in new product introduction. Initiating multiple patent litigations manifests strategic use of patented knowledge. It demonstrates managerial focus on capturing value from their existing knowledge assets rather than exploring new possibilities.

Second, the patent litigation action of litigious firms focuses the attention and time of the R&D personnel to existing knowledge represented by the litigated patents. Research shows that organizations show differential citation preferences to patents, within and across firm knowledge bases (Ahuja et al, 2008). Litigated patents are more likely to be cited in the trial-state during and after litigation period (McGahee & Turner, 2011). In the knowledge recombination process, some firms favor familiar, mature knowledge and knowledge in neighboring knowledge domain, whereas other firms show the tendency to combine technologies which are novel, emerging and pioneering (Ahuja & Lampert, 2001). Further, organizations demonstrate temporal differences in patent citations when engaged in technological knowledge recombination (Nerkar, 2003).

Because R&D personnel are the agents who search for technologies on which to build new knowledge, how R&D personnel spend their research time and whether they direct their attention to within-firm patents or external patents has a significant impact on resulting patents. Qualitative evidence shows that patent litigation disrupts innovation activities of R&D personnel (Walsh, Arora & Cohen, 2003). Scientists from pharmaceutical firms and biotech firms suggest that litigation takes them significant

amount of work time and delays research process (Walsh et al, 2003). Repeated patent litigation may thus direct R&D personnel's attention to existing knowledge codified in litigated patents. This may shift the attention of firms from exploring new knowledge to exploiting current knowledge base.

This exploitation tendency would be reinforced when firms engage in multiple patent litigations. Managerial inclinations toward knowledge exploitation through patent litigation may underlie the path dependency of technological search. As indirect evidence, Lavie and Rosenkopf (2006) empirically show that accumulated experience of exploration or exploitation in particular domain reinforces organizations tendency to explore or exploit.

Focusing on the knowledge base within a firm deepens R&D personnel's understanding of knowledge elements and associations between knowledge elements, thereby enhancing search depth (Katila & Ahuja, 2002). Searching extensively and deeply in the existing knowledge base provides three benefits: stabilizing search routines, increasing experience and efficiency, and deepening understanding of concepts (Ahuja & Lampert, 2001). Agarwal and colleagues (2009) find that firms having a reputation of suing other firms repeatedly for patent infringement can effectively deter knowledge spillover. This finding suggests by keeping valuable knowledge within firm boundary, litigious firms have gained time advantage to familiarize and deepen the understanding of knowledge elements and their associations.

Knowledge reuse or exploitation helps R&D personnel familiarize and deepen their understanding of firm's existing knowledge. The resulting innovation is likely to be incremental rather than radical. Therefore, I propose the following hypothesis:

Hypothesis1. Being litigious on protecting patented technological knowledge is positively related to exploitative innovation of litigious firm.

The foregoing argument suggests that being litigious is associated with exploiting within-firm knowledge elements, resulting in incremental innovations. Repeated patent litigation raises the salience of litigated patents, attracting managerial and R&D personnel attention at the cost of losing sight of knowledge in other firms. Put differently, patent litigation leads R&D personnel and mangers to ignore new and emerging knowledge elements in other technological trajectories and other organizations.

First, financial resources spent on litigation incur high opportunity cost. Costly litigation restricts litigious firm's ability to invest in new research projects which could have produced new knowledge for further combination. Patent litigation is a costly strategic action for firms. According to 2011 survey by American Intellectual Property Law Association (AIPLA, 2011), the average cost of litigation ranges from $1.6 million to $2.8 million. For large controversy amounts (more than 25 million) of patent lawsuit, litigation cost can run up to $6 million. Further, all these costs exclude judgment and damages awarded. Given the fixed amount of financial resources and limited attention of R&D personnel and mangers, allocating more valuable financial resources to patent litigation reduces the resources for explorative search.

In addition to exorbitantly high financial cost, patent litigation also consumes valuable time and attention of managerial and R&D personnel (Agarwal et al, 2009). This

focus on patent litigation and existing knowledge base also reduces the time allocated for searching novel solutions to technological problems. Indirect evidence comes from the study of Shane and Somaya (2007). Examining the impact of universities suing firms for infringing university-owned patents on university licensing activity, Shane and Somaya (2007) find that patent litigation disrupts activities of Technology Licensing Office and diminishes the time and resources for technology marketing and license establishment.

Third, being litigious deters small firms from entering into the technological space of litigious firm (Lanjouw & Schankerman, 2004), restricting the creation of larger knowledge base for further experiment. The empirical research shows that crossing organizational and technological boundaries helps to create more novel innovations due to the enlarged knowledge base for knowledge recombination. For instance, Rosenkopf and Almeida (2003) demonstrate that allying with other firms and allowing scientists to move across organizations help firms to overcome local search tendency. Patent litigation's induced focus on existing knowledge base narrows the scope of technological search and result in less innovative solutions. Prior organizational research on knowledge novelty suggests that in order to make breakthrough innovations, firms must recognize and assimilate new and emerging knowledge generated by other firms (e.g. Ahuja & Lampert, 2001; Nerkar, 2003). For example, organizations sourcing from international origin coupled with technological proximity are more likely to make breakthrough innovation. This stream of research suggests that knowledge novelty or explorative innovations very likely derive from knowledge search across organizational, technological and geographical boundaries (Joshi & Nerkar, 2010).

Focusing on an internal knowledge set restricts the number of possibilities of knowledge recombination by excluding knowledge bases residing in other firms. Knowledge recombination perspective (Fleming, 2001; Kogut & Zander, 1992) posits that technological innovations derive from recombining of existing knowledge elements. Thus, "innovation output can be increased by enhancing the recombinatory set or set of knowledge elements that can be accessed by the firm" (Ahuja, Lampert, & Tandon, 2008:65). For instance, Ahuja and Katila (2001) posit that the merger of firms enhances technological knowledge base available for recombination and empirically demonstrate that the size of merged knowledge base and overlap between them generate high innovation output.

As technological knowledge search is a continuum, exploration and exploitation are contradictory learning, which require different sets of knowledge, skills and competencies and organizational routines (March, 1991). Exploitation of internal knowledge very likely results in less explorative innovations.

Hypothesis 2. Being litigious on protecting patented technological knowledge is negatively associated with exploratory innovations of litigious firm.

Data and Methods

This study investigates the effect of being litigious on patent enforcement on technological search. To test the two hypotheses, I construct a sample of U.S. public firms in biotechnology and pharmaceutical industry (SIC codes 2834, 2836) between the years 2000 and 2010. These industries are characterized with strong approriability regime, meaning that patent litigation in biopharmaceutical industry is an effective strategy to capture innovation value. The litigation motivation can vary with appropriability regime at the industrial level[3] (Cohen, Nelson, & Walsh, 2000). Strong intellectual property protection enhances the efficacy of patent litigation as an effective means to capture innovation rents. In addition, patent thicket problem differs across industries. Patent thicket refers to a situation in which "an overlapping set of patent rights requiring that those seeking to commercialize new technology obtain licenses from multiple patentees" (Shapiro, 2001:119). Firms in semiconductor industry characterized by patent thicket problem engage in patent litigation in order to hold up competitors and obtain cross licensing. In contrast, patents in biotechnology and pharmaceutical industry have fewer problems with patent thickets. Empirical studies have offered evidence that biopharmaceutical industry is characterized by stringent patent regime (Mansfield, 1986; cf. Ahuja, Lampert, & Tandon, 2008). Mansfield (1986) finds that patent protection accounts for about 30% of new inventions in pharmaceutical and chemical industries. Thus, testing our hypotheses in biotech and pharmaceutical industry is appropriate.

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[3] Recent years have seen a surge of patent lawsuits initiated by non-practicing entities (NPEs). They are also called patent trolls. NPE do not engage in R&D or manufacturing. They simply acquire patents and sue other firms for patent infringement to capture value (e.g. Golden, 2006; Lemley, 2007).

Firms must meet the following criteria to be selected into the sample. (1) A firm must be publicly listed on U.S. stock exchanges in 2000 or 2010; (2) A firm's primary SIC code in COMPUSTAT/CRSP merged dataset must be 2834 or 2836; (3) A firm has at least one patent issued by United States Patent and Trademark Office during the time period of 2000 to 2010. 346 unique firms meet the first two criteria. 93 firms have zero patents issued during 2000-2010 time period, reducing the number of sample firms to 253. As this dataset is an unbalanced panel, there are 2200 firm-year observations.

I collected patent litigation data from Intellectual Property Litigation Clearinghouse (IPLC). This dataset contains patent litigation information on plaintiffs, defendants, patents involved, case filing date and termination date (if available) from 2000 and onwards. The author and a second coder, a PhD in Management Science, coded all patent lawsuits from year 2000 to year 2010 in USPTO classes of 424 and 514 (drug, bio-affecting and body treating compositions) at IPLC. When there is only one patent asserted in the lawsuit, we recorded the patent number. If more than one patent is asserted in the patent lawsuit, the coders chose the first listed patent in the patent section of the patent lawsuit. This coding scheme is consistent with prior research on patent litigation (e.g. Somaya, 2003). Based on the first patent involved in the patent lawsuit, I match the patent number to patent data provided by Noah Stoffman at Indiana University. Stoffman and colleagues (2012) match Google patent data to corporations in CRSP database. With this firm level identifier in database of Stoffman and colleagues (2012), I can link the litigated patent with plaintiff firms and merge them with financial information available at COMPUSTAT/CRSP merged database. As this study examines the effects of being

litigious on firm explorative and exploitative innovations, I use the lagged dependent variable research design to delineate the cause-effect relationship. Specifically, I use previous three-year patent litigations (*t-3*,*t-2*, *t-1*) to predict its effects on innovations at time *t*. Due to the lagged variable structure, the number of firm-year observations changes from 2200 to 1442.

Dependent variables

Exploitative innovations and exploratory innovations. As biotech and pharmaceutical industry is knowledge intensive and mainly relies on intellectual assets to generate value, using the patenting activity of firms is appropriate to measure the extent of drawing on prior knowledge. Patent citation provides a paper trail of technological search within and across organizations. Prior research in management uses patent citation from United State Patent and Trademark Office to measure interfirm knowledge flow (e.g Agarwal et al, 2009; Rosenkopf & Almeida, 2003), firm own technological search (Katila & Ahuja, 2002) and signaling property of patenting activity (Levitas & McFadyen, 2009). I use USPTO utility patents issued from 1976 to 2010 to construct the two dependent variables (Bhaven, 2011).

Each patent provides a list of citations to previous patents which constitute the prior art. When a firm draws on existing knowledge to innovate, its patent citation can be categorized into self-citation and repeat citation. Self-citation refers to the innovation efforts where a firm cites its previously issued patent while repeat citation is to repeatedly

cite a patent owned by other firms. These two categories of self-citation and repeat citation represent a firm's technological exploitation of prior knowledge. If a firm departs entirely from its prior knowledge as indicated by zero self-citation and zero repeat citation, this patent represents the most explorative one for the focal firm. As this is a rare case, exploration is measured as the number of patents per year per firm that cite 20 percent or less prior knowledge of the focal firm. Firm exploration is measured by the number of patents per year per firm that cite 80 percent or more its prior knowledge as represented by self-citation and repeat citation. To illustrate, firm A is granted a patent which lists 10 citations. Among the 10 cited patents, two cited patents are owned by firm A, thus falling into the category of self-citations. Three cited patents have also been cited by firm A in its previous patenting activity, thus being categorized as repeat citations. These five citations are counted as firm A exploitation effort. The other five citations are firm A first-time citations, thus representing firm A explorative activity. The extent to which firm A draws on its existing knowledge is measured as 0.5 (5/10). I take two steps to calculate these two measures. First, I assess the extent to which each issued patent draws on its existing technological knowledge. Second, I count the number of patents per firm year that cite 20% or less its previous knowledge (exploration), and the number of patents per firm year that cite 80% or more previous knowledge (exploitation). To avoid skewness problem, I logarithmically transformed both measures.

Independent variables

Patent litigation is a time varying variable. Firms may vary in their extent to sue other firms for patent infringement year by year. To capture this cumulative effect of patent litigiousness on explorative and exploitative innovations, it is measured as moving sum of patent litigations that a firm initiates in prior three years with the focal year being excluded. A firm may sue the same firm multiple times over the same patent in the same year at different venues and countersuits may also occur. We code this scenario as one patent litigation in one year. This coding scheme is consistent with prior research on patent litigation (Agarwal et al, 2009).

Control variables

Firm size is measured as the natural log of total assets of firms in the year t-1. The relation of firm size and exploration-exploitation is ambiguous in the extant empirical literature. Beckman, Haunschild, and Phillips (2004) find positive association between firm size and exploration alliance; while Rothaermel and Deeds (2004) show negative effect of size on exploration. Young firms suffering from liability of newness tend to explore in order to survive (Stinchcombe, 1965; cf Lavie et al, 2010) whereas old firms due to strong inertial pressures very likely engage in exploiting existing knowledge (Hannan & Freeman, 1984). For example, in the study of semiconductor and biotech firms, Sorenson and Stuart (2000) show that mature firms tend to exploit existing knowledge as reflected by increased number of self-citations (cf. Lavie el al, 2010). *Firm age* is measured as the natural log of number of years since its founding year to focal year.

The variable is coded based on the founding year information in the initial public offering dataset provided by Professor Jay Ritter at University of Florida at his personal website. Missing values of founding years of some of sample firms are hand collected via Google search, firm own website, Bloomberg Businessweek and Google Finance.

R&D expenditure is measured as the natural log of R&D expenditures. This construct represents absorptive capacity of a firm. Absorptive capacity refers to the ability to assess, internalize and apply external knowledge (Cohen & Levinthal, 1990). High absorptive capacity enables organizational learning within and across organizations. Data on firm size and R&D expenditure come from Compustat/CRSP Merged dataset from 2000 to 2010.

Alliance experience is measured as the moving sum of previous three-year alliances including research and development, marketing, production, license, and joint venture in excluding the focal year. Collaborating with other firms enables resource and information exchange across organizations and thus affects a firm's balance of exploration and exploitation (Lavie & Rosenkopf, 2006). This variable is compiled from the Securities Data Corporation strategic alliance database between 2000 and 2009. *Patent stock* is measured as the log of total utility patents granted to focal firm in the previous five years. To control for the influence of time varying market and economic conditions on firm technological search, I also include year dummies of 2003-2010. Year 2010 is the reference year.

Analysis and Results

The dependent variables in this study, the number of patents, are count variables. I use panel negative binomial regression. Since the study examines the effects of being litigious on firm innovation, the primary focus is to look at the within firm variation in innovations. A fixed effect estimator can serve this purpose. Fixed effect regression eliminates alternative explanation from time invarying interfirm differences. To further control for alternative explanations, I include one year lagged dependent variable. Table 7 and Table 8 show the descriptive statistics and correlations for all variables. On average, firms initiate 0.41 patent lawsuits in a three-year time window. The average number of explorative patents per firm year is 0.65 while the average number of exploitative patents is 0.83. In Tables 7 and 8, the highest correlation comes from the one between R&D expenditure and firm size. This probably results from the positive correlation between firm total assets and R&D expenditure. To check whether there is multicollinearity problem among independent variables, I ran STATA _rmcoll command which is a collinearity check for a group of variables and found no independent variable to be omitted due to collinearity. Also the variance inflation factor for all variables is less than 10, the threshold VIF value. As a result, multicollinearity is not a concern in these panel data models.

Table 9 reports the results of negative binomial regression analysis with fixed effect estimator. Model 1 and 2 are used to test hypothesis 1 that being litigious on protecting patented knowledge is positively associated with exploitative innovations of litigious firms. Model 1 is the baseline model and includes control variables. Firm age is

negatively associated with exploitation (b=-.16 and p<0.001). Firm R&D expenditure enhances exploitative innovations (b=.1 and p<.1). Model 2 adds the main independent variable of patent litigations. Log likelihood chi square test shows that Model 2 significantly improves the model fit (2*(-799.6-(-801.8))=4.4, df=1) at p<.1 level. Patent litigation is negatively associated with exploitative innovation (b=-.02, and p<.05), showing that aggressively protecting patented intellectual property via repeat patent litigations hampers exploitative innovation. The empirical result does not support H1 which states the opposite. Model 3 and Model 4 test H2 which argues that being litigious on protecting patented knowledge reduces explorative innovations. Model 3 is the base model and shows that firm age is negatively associated with firm explorative innovations and R&D investment boosts explorative innovations. Model 4 adds the independent variable of patent litigation. As log likelihood ratio statistic shows that Model 4 provides a better model fit compared to Model 3 (2*(-869.9-(-871.9))=4, df=1, and p<.1), it is appropriate to interpret the effect of patent litigation in Model 4. Patent litigation is negatively associated with explorative innovations. This effect is statistically significant at 0.1 level, supporting H2. I explain the effect in terms of Incidence Rate Ratio (IRR). IRR explains the change in the dependent variable in term of percentage increase or decrease when there is one unit increase in the independent variable. The IRR (0.98) for patent litigation in Model 2 indicates that one unit increase in patent litigation reduces the number of exploitative innovations by 2 percent. The IRR for patent litigation in Model 4 is 0.97. It suggests that the number of explorative innovations decreases by 3 percent (1-0.97=0.03) with every one unit increase in patent litigation.

Table 7
Descriptive Statistics and Correlation (DV: Explore_20)

Variables	n	Mean	s.d.	Mini-mum	Maxi-mum	1	2	3	4	5	6
1.Explore_20	2200	0.65	0.93	0	4.88						
2. Patent litigations	1462	0.41	1.84	0	26.00	0.39					
3. Firm age t-1	2171	2.58	1.17	0	5.08	0.19	0.37				
4. Firm size t-1	1946	5.22	2.15	0.73	12.27	0.66	0.43	0.42			
5. R&D expenditure t-1	1947	3.60	1.83	0	9.41	0.68	0.43	0.30	0.86		
6. Patent stock	2200	1.16	1.63	0	7.17	0.31	0.38	0.38	0.39	0.45	
7. Prior alliances	1462	0.80	1.69	0	17	0.39	0.24	0.21	0.46	0.47	0.25

All correlations are significant at .0001 level

Table 8
Descriptive Statistics and Correlation (DV: Exploit_80)

Variables	n	Mean	s.d.	Mini-mum	Maxi-mum	1	2	3	4	5	6
1.Exploit_80	2200	0.83	1.12	0	5.24						
2. Patent litigations	1462	0.41	1.84	0	26.00	0.42					
3. Firm age t-1	2171	2.58	1.17	0	5.08	0.23	0.37				
4. Firm size t-1	1946	5.23	2.15	0.73	12.27	0.62	0.43	0.42			
5. R&D expenditure t-1	1947	3.60	1.83	0	9.41	0.66	0.43	0.30	0.86		
6. Patent stock	2200	1.16	1.63	0	7.17	0.40	0.38	0.38	0.39	0.45	
7. Prior alliances	1462	0.80	1.69	0	17	0.32	0.24	0.21	0.46	0.47	0.25

All correlations are significant at .0001 level

Table 9

Negative Binomial Regression of Patent Litigation on Exploration and Exploitation

	DV: Exploit_80			DV: Explore_20	
Variable	Model 1	Model 2		Model 3	Model 4
Intercept	-1.00***	-1.08***		-1.88***	-1.96***
	(0.16)	(0.16)		(0.19)	(0.19)
Patent litigations		-0.021*			-0.026^{+}
		(0.011)			(0.013)
Exploit_80 (lag 1)	0.56***	0.55***	Explore_20 (lag 1)	0.45***	0.45***
	(0.04)	(0.04)		(0.05)	(0.05)
Firm age t-1	-0.16***	-0.14***		-0.10**	-0.08*
	(0.04)	(0.04)		(0.04)	(0.04)
Firm size t-1	-0.03	-0.04		0.04	0.04
	(0.04)	(0.04)		(0.04)	(0.04)
R&D expenditure t-1	0.10*	0.11*		0.11*	0.12*
	(0.05)	(0.05)		(0.05)	(0.05)
Patent stock	0.12***	0.13***		0.12***	0.14***
	(0.03)	(0.03)		(0.03)	(0.03)
Prior alliances	-0.01	0.02		0	0
	(0.01)	(0.01)		(0.01)	(0.02)
Year dummies	Included	Included		Included	Included
Observations	1442	1442		1442	1442
Incidence rate ratio		0.98			0.97
Deviance	900.5	896.1		825.8	821.8
Difference in log likelihood vis-a-via the base model		4.4*			4*
df	1428	1427		1428	1427

$^{+}$p<.1;* p<.05; **p<.01; ***p<.001

Discussion

Drawing on a sample of firms in biopharmaceutical industry, this empirical study examines the effect of patent litigation on technological search of litigious firms. The results suggest that repeatedly suing other firms for patent infringement results in reduced number of explorative and exploitative innovations. This study extends prior literature on patent litigation by highlighting the unintended consequences of being litigious about protecting patented intellectual property on exploitative and explorative search. Prior management research on patent litigation has examined the characteristics of patent litigation (Lanjouw & Schankerman, 1997, 2001), determinants of not to settle patent litigation (Somaya, 2003), the reputation of being litigious in preventing knowledge spillover via inventor mobility (Agarwal et al, 2009) and its disruptive effect on university licensing efforts. Managers in biotechnology and pharmaceutical industry can take advantage of stringent patent regime in biopharmaceutical industry by resorting to patent litigation to protect their valuable technological resources. Repeated patent litigation successfully prevents knowledge spillover to competitors particularly to small firms (e.g. Argarwal et al, 2009). However, capturing innovation value via patent litigation carries a nontrivial cost. This study proposes three mechanisms that patent litigation causes more exploitation and less exploration. First, patent litigation increases the salience of litigated patents to management and R&D personnel in the knowledge recombination process, reinforcing the tendency to exploit the firm's existing knowledge base. Second, patent litigation is financial expensive and incurs high opportunity cost, impeding explorative innovations. Third, overemphasis on internal knowledge base induced by patent litigation, due to the incompatibility of exploration and exploitation,

hinders technological search across organizational and technological boundaries, thus restricting technological exploration. Among these three mechanisms, the mechanism of expensive and disruptive patent litigation seems to be more reasonable explanation of its negative effect on both exploitation and exploration. The finding in this study concurs with prior notion, qualitative and quantitative, that patent litigation is expensive and disruptive.

Patent litigation consumes valuable and precious managerial time. It also disrupts the innovation activities of R&D personnel (Walsh et al, 2003). Further, patent litigation diverts valuable financial resources from R&D expenditure to legal fees amounting to millions of dollars (ALPLA, 1997; cf. Somaya, 2003). While managerial focus on exploiting patent intellectual property in a strong patent regime may lead to financial gains in the short run, overuse of costly patent litigation disrupts technological search with both exploitation and exploration being negatively affected. This finding is consistent with prior research. Shane and Somaya (2007) find negative impact of patent litigation on university licensing efforts. Their interviews with technology licensing office directors suggest that patent litigation is disruptive and diverts time and resources for technology marketing and license establishing (Shane & Somaya, 2007). Walsh and colleagues (2003) cite CellPro case to illustrate how expensive a patent lawsuit can be: the attorney fees alone were $8 million U.S. dollars. There is also opportunity cost associated with patent litigation. Money spent on patent war can have been used to fund a drug discovery program. Walsh and colleagues (2003) also provide qualitative evidence from 16 industry respondents who suggest that patent litigation places a big burden on managers and scientists.

The finding in this study has implications for organizational adaptation. As March (1991) and other scholars on organizational learning demonstrate that imbalance of exploitation and exploration hampers organizational ability to adapt to changing technological and marketing environments. While resorting to patent litigation can help litigious firms to prevent knowledge spillover to competitors, disruptive patent litigation prevents firms from effectively engaging in technological innovation, explorative and exploitative.

This study makes two contributions to extant literature. First, while prior literature on patent litigation has shed insightful light on its antecedents, characteristics of patent litigation, and benefits of being litigious on patent enforcement (e.g. Argarwal et al, 2009; Lanjouw & Shankerman, 2001), this study extends prior literature by examining the negative consequences of overly exploiting and leveraging existing intellectual assets. Second, this study connects profiting from innovation via patent litigation (opportunity seizing) with capability building. It shows that patent litigation decreases exploitative innovation and exploratory innovation at the same time. The patent litigation delayed technological search may prevent litigious firms from building new technological capabilities for future adaptation. As March (1991) points out, managing the balance between exploration and exploitation has both theoretical and practical significance to organizational adaption and competition.

This study also opens avenues for future research. First, this study examines the effect of repeat patent litigation on technological exploitation and exploration. The performance implication of this relationship has remained unaddressed. Does the reduced amount of knowledge exploitation and knowledge exploration via patent litigation benefit short term

financial performance? What's the consequence of decreased technological exploitation on financial performance in the short run versus in the long run? Lavie and his colleagues (2010) also call on empirical research to address the short-term and long-term impact of balancing exploitation and exploration.

Second, this study proposes one mechanism influencing patent litigation-technological search relationship. Prior studies have shown various approaches that organizations can adopt to balance exploration and exploitation. Lavie and Rosenkopf (2006) have shown that organizations can balance two modes of organizational learning in alliance portfolios over time and across distinctive domains. Balancing exploration and exploitation can also be accomplished through organizational separation of these two contradictory activities (Tushman & O'Reilly, 1996). Senior management must recognize rather than deny and manage the contradictions embedded in exploitation and exploration (Smith & Tushman, 2005). However, how these balancing mechanisms work together remains unanswered. Therefore, examining moderating variables in the negative relationship of patent litigation and technological search warrants further research. Finally, this study tests the hypotheses in the context of biopharmaceutical industry. Therefore, caution is warranted as to generalizing the empirical relationship to other industrial contexts. It would further enrich the patent litigation research by examining whether this relationship still holds in other industries.

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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.

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EDUCATION

Ph.D. Management Science
University of Wisconsin-Milwaukee: August, 2014
Specialization: Strategic Management & Technological Innovation
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Dissertation Chair: Dr. Edward F Levitas

Doctoral student
University of Texas-Pan American August, 2008- July 2010

M. A. Cross-Cultural Management
University of International Business and Economics Beijing, China July 2006

Graduate Certificate, Finance
University of International Business and Economics Beijing, China July 2006

B.A. English Education July 2000
Liaoning Normal University Dalian, China

PEER REVIEWED PUBLICATIONS

Liang, X., Liu, Y., Wu, S., & Zhang, S. (2012). Fending knights or masked kings: Toward a theoretical framework of interim CEO succession. *Corporate Governance*, *12*(3), 367-377.

Abebe, M., Angriawan, A & Liu, Y. (2011). CEO power and organizational turnaround in declining firms: Does environment play a role? *Journal of Leadership and Organizational Studies, 18*(2), 260-273.

REFEREED CONFERENCE PAPERS AND PRESENTATIONS

Liu, Y. CEO overconfidence, CEO celebrity and firm risk taking. Presented at *Strategic Management Society Conference*, Miami, FL, November 2011.

Abebe, M., and Liu, Y. Executive attention patterns, environmental dynamism and corporate turnaround performance. *Annual Meeting of Decision Sciences Institute,* San Diego, CA, November 2010.

Liang, X, Wu, S, Liu, Y, and Zhang, S. Fending knights or masked kings: Toward

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ACADEMIC POSITIONS AND COURSES TAUGHT

University of Wisconsin-Milwaukee, Sheldon B. Lubar School of Business

Instructor of Strategic Management (Management Analysis 600, undergraduate capstone class) Summer 2013, Fall 2013, Spring 2014, Summer 2014

Instructor of Intro to Entrepreneurship & Small Business Formation
Fall 2013, Spring 2014

Teaching Assistant September 2012-May 2013
Teaching Assistant to Dr. Jude Rathburn in Organization Behavior class

Project Assistant September 2011-May 2012
Research Assistant to Dr. Sali Li and Dr. Maria Goranova

University of Texas-Pan American, College of Business Administration

Research Assistant
Research Assistant to Dr. Michael Abebe June 2009 – July, 2010
Research Assistant to Dr. Lai Liu June 2009 - July 2009
Research Assistant to Dr. Sibin Wu August 2008 -August 2009

North China Electric Power University **Beijing, China**

Lecturer of Business English September 2007-July 2008
Macroeconomics (for undergraduates), Microeconomics (for undergraduates)
Instructor of English September 2000- August 2007
Advanced Listening Comprehension (for English majors)
College English (for non-English majors)
A New English Course (for English majors)

WORK EXPERIENCE

Hongyuan Yingxin Consulting Corporation Ltd January 2002 - July 2003
Cofounder and owner in charge of marketing and coordinating activities of management Members

AWARDS & HONOR

University of Wisconsin-Milwaukee **Milwaukee, WI**
Sheldon B. Lubar Doctoral Scholarship September 2012-July 2013
Graduate Student Research Presentation Travel Award 2010, 2011
Chancellor's Graduate Student Award September 2010-July 2011

Academy of Management Annual Conference 2013 **Orlando, FL**
BPS Doctoral Consortium (competitive admission)

Academy of Management Annual Conference 2012 **Boston, MA**
Outstanding Reviewer Award (Business Policy and Strategy Division)

Southern Management Association Annual Conference 2009 **Asheville, NC**
Doctoral Consortium (competitive admission)

North China Electric Power University **Beijing, China**
Outstanding Class Advisor Award September 2001-July 2002

PROFESSIONAL SERVICE ACTIVITIES

Reviewer Corporate Governance: An International Review 2011
Reviewer Academy of Management Annual Conferences 2010-2013
Reviewer Southern Management Association Annual Meeting, St. Pete Beach, FL, 2010
Supervisor North China Electric Power University Beijing, China
Advised two undergraduate theses January 2007-July 2008
Class advisor North China Electric Power University Beijing, China
September 2001-July 2002

PROFESSIONAL AFFILIATION AND MEMBERSHIP

Academy of Management, Entrepreneurship Division, BPS Division, and TIM Division

PROFESSIONALWORKSHOPS ATTENDED

Teaching Workshops at University of Wisconsin-Milwaukee
Center for Instructional & Professional Development
Designing learner-centered course (Part 1 & Part 2) June & July, 2013
How learning works (book chapter discussions, Chapter 5, 6) June &July, 2013
Meeting where students are March, 2013

University of Wisconsin-Milwaukee **Learning Technology Center**
Developing small group work in online and blended courses June, 2013
Grading your students: Assessment in online and blended courses June, 2013

Importing question banks and developing effective quizzes in D2L June, 2013
Creating a teaching portfolio May 2013

University of Wisconsin-Milwaukee Sheldon B. Lubar School of Business
Six Years of Lessons on Teaching Critical Analytical Thinking March, 2013
Guest speaker: JD Schramm, Stanford Graduate School of Business

Research Workshops
Use of patent data for empirical management research
Academy of Management annual conference San Antonio August, 2011

Strategy Symposium on Emerging Markets
Jesse H. Jones Graduate School of Business, Rice University April, 2010