

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

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ABSTRACT

This study investigates the empirical relationship between patent attributes and allocation of control rights, and the relationship between patent attributes and up-front payment in R&D alliance contracts. Patent attributes of focal innovations reduce measurement costs for the party with less information. Patent novelty, patent importance, self-citations, and patent generalizability are reliable and cost-effective signals for underlying knowledge embodied in the patent. Drawing on signaling theory, I argue that signals of patent novelty and technological importance reinforce each other such that biotech firms gain higher upfront payment and a large share of control rights. Further, patent novelty and patent generalizability negatively interact with each other such that biotech firms gain lower upfront payment from pharm firms and smaller share of control rights. Hypotheses are tested with a sample of R&D alliance contract between biotechnology firms and pharmaceutical firms in biotechnology industry.

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 & Higgins, 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 & Higgins, 2010). The allocation of control rights, in essence, measures how jointly created value within an alliance is distributed between alliance partners in uncertain and unpredictable market *ex ante* (Adegbesan & Higgins, 2010). Prior empirical research has demonstrated various antecedents of control rights allocation such as equity market conditions, and supply and demand for alliance partners in the strategic factor market (e.g. Adegbesan & Higgins, 2010; Lerner & Merges, 1998). While prior research deepens our understanding of determinants of particular contractual provisions like 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 the market for technology is characterized by information asymmetry, the exchange party with less information may encounter greater measurement cost in assessing the value of licensed technology. Considering that the main concern of a R&D alliance is whether the focal patent of one alliance partner, combined with complementary assets of another, can be turned into a new product or service, effectively measuring the value of a focal patent becomes essential for alliance formation and the subsequent allocation of control rights. I propose that patent attributes reduce transaction costs 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 a focal patent on subsequent knowledge generation. Technological importance is measured as the number of citations received by a focal patent (Hall, Jaffe & Trajtenberg, 2001). A high number of citations received by a focal patent certifies the high impact of the 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 a focal patent spans, the more knowledge inflow to the focal patent, showing a high likelihood of knowledge novelty and production of 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 pharma firms and disclosure risk incurred by biotech firms. 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 the patent for pharma firms and enable biotech firms to capture economic value as reflected by high upfront payments and a large share of control rights. Further, patent novelty, technological importance of patent, and patent generalizability signal differing dimensions of knowledge quality, patent attributes that either complement or substitute for each other, which exert a differential effect on upfront payment and allocation of control rights.

I use sample contracts from biotech-pharma R&D alliances to test my hypotheses. All these contracts include patents owned by biotech firms. Biotech firms provide the patent to capture innovation rent in

the alliance with pharma firms. Pharma firms offer complementary capabilities including development experience, the lengthy and costly process of conducting human tests, and regulatory Food and Drug Administration (FDA) approval, manufacturing and marketing. Patent attributes are measured using patent citation data from the *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. The theory and hypotheses section reviews transaction cost economics and signaling theory in management. The theory of patent attributes is developed as an effective mechanism of measurement cost reduction and signals of patent. Based on this theory, I develop hypotheses linking patent attributes to allocation of up-front payment and control rights. The Method section describes sample selection, measures of variables, and the analysis method. The 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 the R&D alliance context with high information asymmetry, increasing the transaction cost to biotech firms and pharma firms. Measurement cost is defined as the cost incurred to pharma firms for obtaining additional information in order to evaluate the value of focal innovation that biotech firms bring to the alliance.

The Socio-structural perspective posits that a firm's reputation in the social structure, as well as its prior relationships symbols of 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, a focal firm with a high reputation in the social structure affords 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 (see Figure 1). 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 Higgins (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).

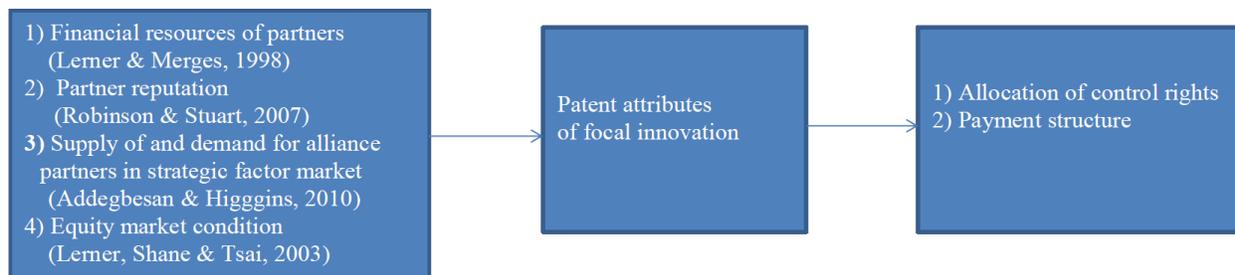


FIGURE 1

Specifically, I examine signaling effects of four patent attributes on allocation of control rights and upfront payment in R&D alliances between a biotech firm and a pharma 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 the signaling effect of specific patent attributes to stock markets. Hall, Jaffe and Trajtenberg (2005) posit that patent citation is one measure of the importance of a firm’s patents, and empirically find that the 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 the focus of biotech firms, pharma firms have no concern that the signals about these patent attributes would be distorted by biotech firms. Thus these patent attributes serve as a low-cost and effective measurement of underlying quality of patented knowledge. Pharma firms receive these signals and make inferences about patent quality.

Further, the management literature, with the exception of Arthurs, Busenitz, Hoskisson and Johnson (2008) and Agarwal, Ganco, and Ziedonis (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 litigate other firms for patent infringement, which sends a negative signal to competing firms, and effectively deters 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 the 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 the initial public offering (IPO), incur high debt that leads to concerns about paying off the 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). Innovation research scholars have provided compelling theoretical and empirical arguments that knowledge novelty enhances the 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 proactively search for new knowledge to invent by forming alliances with different partners in the early stages of technological change. Novel technologies signal high economic value and attract a 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 the 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 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, pharma firms would be less willing to make a large up-front payment if pharma firms do not really need novel knowledge from biotech firms. Conversely, the more certain knowledge via patents signaling is, the less risk a biotech firm will be willing to bear.

Hypothesis 1a:

Knowledge novelty of focal patents owned by biotech firms in the alliance contract is positively related to the ratio of up-front payment to total 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 Higgins, 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. A patent, with high novel knowledge, signals to the potential technology buyers the high likelihood of producing a high impact product, thereby increasing the number of buyers and enhancing the ability of small firms possessing novel patents to negotiate with other parties for a 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 a focal patent on subsequent knowledge generation. Technological importance is measured as the number of citations received by a focal patent (Hall, Jaffe & Trajtenberg, 2001). A high number of citations received by a focal patent certifies the high impact of a focal patent on subsequent knowledge generation.

Most 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 with strong intellectual property protection (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 a 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 ratio of up-front payment to total payment from pharmaceutical firms.

Hypothesis 2b:

Technological importance of a 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.

A high number of self-citations implies a high ability to appropriate value in a strategic alliance. Firms in the biotech industry, with a strong IP regime, can effectively protect key patents with multiple self-citations in lawsuits, because self-citing the firm's own patent shows to the court the visible knowledge development along the 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 a biotech firm owns a patent with multiple self-citations, such patent signals potential buyers the high likelihood of launching a new product in an 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 pharma partners the high ability of creating new innovations. Patents with multiple self-citations increases the generative appropriability of a biotech firm to capture innovation value in a 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 ratio of upfront payment to total payment from the pharma 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 an initial public offering (IPO)—incur high debt and have concerns of paying off the interest in a timely manner, the market reacts negatively and IPO firms experience high IPO underpricing. (Arthurs, Busenitz, Hoskisson & Johnson, 2008). In the following hypothesis, I contend that knowledge generalizability, another patent attribute, however, sends out a negative signal to pharma 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 a high generality patent may be costly (Hall, Jaffe & Trajtenberg, 2005). It can be reasonably argued that a focal patent with high generality does not afford much bargaining power to a biotech firm due to its inability to appropriate value in a cost efficient manner for the biotech firm, leading to the following hypotheses.

Hypothesis 4a:

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

Hypothesis 4b:

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

The foregoing hypotheses examine the positive and negative effect of each individual signal (e.g. knowledge novelty, patent importance, patent generalizability), 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 IPO context

research has shown signals can substitute for each other (e.g. Arthurs et al, 2009), as signal receivers, like pharma firms in the 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 the focal firm or the focal individual are either complementing or reinforcing the high quality. For instance, Reuer and colleagues (2012) contend that relationships with prestigious venture capitalists (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— assert that when multiple signals are present, substitution effect can occur. Specifically, a longer lockup period, as a 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 the biopharmaceutical industry, biotech firms are specialized in the upper stream of the value chain: biotech firms conduct activities in research. Pharmaceutical firms have strong capabilities in the downstream: strong capabilities in new product application through the Food and Drug Administration, namely, commercializing and marketing new products (Rothaermel, 2001). The signal that a focal patent is novel and is solidly built on a biotech firm's prior knowledge enhances the prospect of launching a successful product. A large number of self-citations signals that a biotech firm has insights about and has mastered its foundational knowledge. Combined, self-citations and knowledge novelty imply high probability of successful product development, leading to the following hypotheses.

Hypothesis 5a:

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

Hypothesis 5b:

The relationship between patent novelty and the share of control rights that a biotech firm wins increases in the presence of high self-citations of the focal patent that a 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 the 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, which leads to the following hypotheses.

Hypothesis 6a:

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

Hypothesis 6b:

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

DATA AND METHODS

This study relies on the contract information between biotech firms and pharma firms. The alliance information is obtained from Recombinant Capital (Recap), which is based in California and was acquired by Deloitte. The focus is on the contracts involving a patent license where a biotech firm provides patented knowledge and a pharma firm offers complementary capabilities. The R&D alliance is mainly concerned with the valuation and payment for focal patents of the biotech firm and the allocation of control rights between the biotech firm and the pharma firm. The sample period is from 1991 to 2005. This 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 either a 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.

Additionally, since this study investigates the effect of patent attributes on allocation of control rights and upfront payment, the contract must explicitly specify the patent numbers that are licensed out. Since some firms are not publicly listed, many R&D alliance contracts do not disclose the involved patent numbers. When contracts listed patent application numbers, the USPTO website was searched to determine the corresponding patent numbers. Out of 1330 contracts signed between biotech and pharma firms, 104 contracts explicitly list the patents or patent application numbers for license.

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 and total milestones, plus upfront payment and royalties, if applicable. Since some firms choose to not disclose milestone payment in the contracts available from Recap, such missing information makes the ratio measure infeasible. The amount of upfront payment is defined as the net present value of innovation rent of the focal patent. Due to incentive misalignment concerns, a pharma firm tends not to pay a large amount of upfront payment, as cash payment to a biotech firm may be subject to misuse for other research projects within the biotech firm (Elfenbein & Lerner, 2003). This variable captures the valuation from a pharma firm and the bargaining power from a biotech firm in capturing its innovation value. To code upfront payment, the following steps were taken. When there is upfront payment and the amount is disclosed, this amount is logarithmically transformed. When there is no upfront payment, this variable is coded zero. For undisclosed upfront payment, it is coded as a 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 pharma 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 Higgins (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, the same coding scheme of Adegbesan and Higgins (2010) is utilized. The control right is coded from the perspective of the pharma firm. The author and a second coder separately coded the control rights and to discern which control right is won by the pharmaceutical firm. When disagreement occurs regarding which control right is won by the pharma firm, the two coders used the coding scheme to engage in a discussion until consensus is reached. The control right is a count variable of how many control rights are won by a pharma firm.

The independent variables of patent attributes are measured based on patent citations. Patented knowledge builds 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 with a 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 via the GOOGLE website. The patent citation data used patent novelty which measures the extent to which cited patents of a focal patent span technological fields. The wider the 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. This 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) use citations and other measures of patent quality for hypotheses testing 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 the estimated patent value that patent owners offer for sale is positively related to subsequent citations (cf. Hall et al, 2005). In assessing the value of a 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) propose 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. Stated differently, knowledge reuse, as measured by self-citations, helps new product development substantially. Also, a focal patent with high self-citations increases firm's exclusionary ability to appropriate innovation rent due to the consistent knowledge development path. This helps firmsto defend their intellectual property if patent litigation arises.

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).

$$\text{Generality or Generalizability}_i = 1 - \sum_j^{n_i} s_{ij}^2$$

“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 a R&D firm can increase the 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, the prior year's patent count is used. To address the skewness issue, I use the natural logarithm of patent count. Prior alliance with other pharmaceutical firms or biotech firms 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 in which the contract is signed. As an 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 patents. 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 the dependent variable as upfront payment to the R&D firm, I use ordinary linear regression with robust standard errors. Since the number of control rights (the

dependent variable) is count variable, Poisson regression is used instead of negative binomial to mitigate the overdispersion issue.

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 decreases from 104 to 98. On average, the number of control rights won by R&D firms is four, while the average amount of upfront payment from a client firm is \$116,746 U.S. dollars (4.76 exponentiated times 1000). There is a positive correlation between the patent stock of a R&D firm and upfront payment received, showing that patent stock increases bargaining power of R&D firms. Prior research empirically demonstrates that the number of patents that are filed or granted at USPTO is positively associated with the pre-money values of R&D firms (Lerner, 1994).

Table 3 presents the results of OLS regression with robust standard errors on upfront payment. Model 1-Model 9 test the effects of patent attributes on upfront payment received by R&D firms. Model 1 is the baseline model which includes only control variables. Model 2-Model 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 due to the insignificant coefficients. 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, patent generality. Model 7 tests the interaction effect of self-citations and patent originality, which is not significant. Model 9 tests the interaction effect of generality and novelty. It is not significant. Therefore, H5a and H6a are not supported.

Results of Poisson regression 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, we 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 a 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 negatively impacts the number of control rights won by R&D firms. So H1b is not supported. Model 3-Model 5 test the hypothesized positive 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	Std		Minimum	Maximum
		Mean	Dev		
Control rights	104	4.00	1.11	1	7
Upfront pay	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

	1	2	3	4	5	6	7	8	9
1. Control rights									
2. Upfront pay	0.06								
3. Self-citation	-0.098	-0.16							
4. Technological 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	

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

TABLE 3: OLS REGRESSION ON UPFRONT PAYMENT

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5
Prior alliances	0.309** (0.149)	0.323** (0.149)	0.339** (0.146)	0.228 (0.155)	0.310** (0.152)
Patent stock	-0.260 (0.458)	-0.243 (0.463)	-0.241 (0.456)	-0.130 (0.482)	-0.260 (0.462)
Backward citation	0.375 (0.285)	0.539 (0.361)	0.479* (0.284)	0.597** (0.290)	0.375 (0.288)
Year	included	included	included	included	included
Originality		-0.736 (1.034)			
Tech importance			-0.342 (0.291)		
Self citation				-0.394*** (0.147)	
Generality					0.0601 (1.244)
Constant	-340.1** (144.8)	-345.7** (146.9)	-240.1 (160.5)	-341.4** (143.6)	-340.2** (145.2)
Observations	97	97	97	97	97
R-squared	0.068	0.074	0.086	0.113	0.068

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

TABLE 3: OLS REGRESSION ON UPFRONT PAYMENT (CONTINUED)

VARIABLES	Model 6	Model 7	Model 8	Model 9
Year	included	included	included	included
Prior alliance	0.0119 (0.0238)	0.0116 (0.0241)	0.0128 (0.0243)	0.0132 (0.0240)
Patent stock	0.0709* (0.0370)	0.0720* (0.0386)	0.0680* (0.0355)	0.0678* (0.0353)
Backward citation	-0.0781** (0.0328)	-0.0796** (0.0326)	-0.0883*** (0.0312)	-0.0902*** (0.0319)
Self citation	-0.0107 (0.0303)	-0.00827 (0.0282)		
Originality	0.138* (0.0802)	0.135 (0.0855)	0.154* (0.0805)	0.155* (0.0798)
Self-citation×Originality		-00180 (0.115)		
Generality			-0.0737 (0.0979)	-0.0733 (0.0983)
Generality×Originality				0.0720 (0.261)
Constant	-21.07 (14.82)	-20.67 (14.44)	-20.53 (14.77)	-20.79 (14.69)
Observations	97	97	97	97

TABLE 4: POISSON REGRESSION ON CONTROL RIGHTS

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5
Year	included	included	included	included	included
Prior alliance	0.0161 (0.0223)	0.0139 (0.0242)	0.0152 (0.0226)	0.0139 (0.0222)	0.0157 (0.0223)
Patent stock	0.0695* (0.0365)	0.0674* (0.0355)	0.0690* (0.0365)	0.0735* (0.0377)	0.0699* (0.0367)
Backward citation	-0.0530** (0.0263)	-0.0845*** (0.0310)	-0.0564** (0.0268)	-0.0464* (0.0274)	-0.0535** (0.0264)
Originality		0.141* (0.0803)			
Tech importance			0.0108 (0.0255)		
Self citation				-0.0118 (0.0286)	
Generality					-0.0392 (0.100)
Constant	-22.86 (15.08)	-21.20 (15.04)	-25.99 (16.11)	-22.77 (14.86)	-22.63 (14.93)
Observations	103	103	103	103	103

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

TABLE 4: POISSON REGRESSION ON CONTROL RIGHTS (CONTINUED)

VARIABLES	(1) Model 6	(2) Model 7	(3) Model 8	(4) Model 9
Year	included	Included	included	included
Prior alliance	0.0119 (0.0238)	0.0116 (0.0241)	0.0128 (0.0243)	0.0132 (0.0240)
Patent stock	0.0709* (0.0370)	0.0720* (0.0386)	0.0680* (0.0355)	0.0678* (0.0353)
Backward citation	-0.0781** (0.0328)	-0.0796** (0.0326)	-0.0883*** (0.0312)	-0.0902*** (0.0319)
Self citation	-0.0107 (0.0303)	-0.00827 (0.0282)		
Originality	0.138* (0.0802)	0.135 (0.0855)	0.154* (0.0805)	0.155* (0.0798)
Self-citation×Originality		-0.0180 (0.115)		
Generality			-0.0737 (0.0979)	-0.0733 (0.0983)
Generality×Originality				0.0720 (0.261)
Constant	-21.07 (14.82)	-20.67 (14.44)	-20.53 (14.77)	-20.79 (14.69)
Observations	103	103	103	103

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

DISCUSSION

This study investigates the signaling role of patent attributes and how patent novelty, technological importance, and patent generalizability impact the upfront payment and the allocation of control rights to biotech firm. This study is 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 measurements 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 positing that signals can be complementary and substituting in highly information asymmetric R&D alliance context. 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 substitute for other signals. In studying the signaling effect of lockup period, Arthurs and colleagues (2008) demonstrate that a longer lockup period that shareholders agree to hold shares of initial public firms substitute signals of venture capital and prestigious investment bank backup. Drawing on signaling theory, I argue that while patent novelty, technological importance, and patent generalizability signal the quality of underlying knowledge, signals of patent novelty and technological importance reinforce each other. Biotech firms with patents that are novel and technologically important gain higher upfront payment and a large share of control rights. Further, patent novelty and patent generalizability negatively interact each other, reducing the upfront payment from pharma firms and the share of control rights for biotech firms.

Second, this study focuses on the measurement branch of Transaction Cost Economics (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 capture a large share of innovation rent through high up-front payment and more 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 on allocation of control rights primarily focuses on bargaining power of one or two transaction parties at the firm level. Pharma firms with abundant financial resources and complementary capabilities are portrayed as dominant players in capturing an unfair amount of control rights (e.g. Adegbesan & Higgins, 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). This study makes a small step in pointing out that at the alliance governance stage biotech firms also play strategically in securing innovation rents.

Managerial Implications

This study also offers practical significance for managers and firms. Managers should pay close attention to patent characteristics when engaged in crafting alliance contract. On the part of small and young firms focusing on the upper stream of the value chain, taking advantage of patents demonstrating high novelty and technological importance helps small firms to gain the negotiation leverage and to capture a large share for their innovation output. In terms of strategizing, licensee firms may avoid patent with high generality, as it could incur high cost of protecting the intellectual property and capturing the economic rent from it. At the same time, firms must make a tradeoff when multiple patent attributes, positive and negative, are present.

Limitations and Future Research

This study has some limitations and 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.

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