Paper to be presented at the DRUID 2011

on

INNOVATION, STRATEGY, and STRUCTURE -
Organizations, Institutions, Systems and Regions
at
Copenhagen Business School, Denmark, June 15-17, 2011

Intellectual Property Protection and Technology Commercialization Strategy: Reconciling the Competing Effects on Licensing vs. Financing

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Abstract

The importance of intellectual property (IP) rights for innovating firms is well established. Separate streams of literature in ?markets for technology? and entrepreneurial finance have shown that obtaining IP rights facilitates both product licensing and third-party (especially venture-capital) fundraising, respectively. However, since raising third-party financing enables the firm to continue commercializing its innovation alone (and thereby put off sharing the rents with a licensee), the effect of IP rights on technology commercialization strategy is unclear. This paper presents an empirical analysis of the licensing decisions by 650 start-up biotech firms which shows that the hazard of licensing is positively correlated with the stock of filed patents but negatively correlated with the proportion of those patents that have issued. The results are robust to different methods of dating the patent filing, as well as to alternative weightings for the patent count. It suggests that while the obtaining the potential to receive patent rights facilitates licensing, obtaining the patent rights themselves may actually have a greater effect on the ability to raise third-party financing.

Jelcodes:O34,O32

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The importance of intellectual property (IP) rights for innovating firms is well established. Separate streams of literature in "markets for technology" and entrepreneurial finance have shown that obtaining IP rights facilitates both product licensing and third-party (especially venture-capital) fundraising, respectively. However, since raising third-party financing enables the firm to continue commercializing its innovation alone (and thereby put off sharing the rents with a licensee), the effect of IP rights on technology commercialization strategy is unclear. This paper presents an empirical analysis of the licensing decisions by 650 start-up biotech firms which shows that the hazard of licensing is positively correlated with the stock of filed patents but negatively correlated with the proportion of those patents that have issued. The results are robust to different methods of dating the patent filing, as well as to alternative weightings for the patent count. It suggests that while the obtaining the potential to receive patent rights facilitates licensing, obtaining the patent rights themselves may actually have a greater effect on the ability to raise third-party financing.

1. Introduction

The importance of intellectual property (IP) protection for innovating firms seeking to commercialize their technology is well established. The literature on markets for technology (Arora *et al.*, 2001; Gans *et al.*, 2008) has shown that stronger IP protection facilitates licensing, while recent research on entrepreneurial finance (Haeussler *et al.*, 2011; Hsu *et al.*, 2007; Mann *et al.*, 2007) demonstrates that obtaining IP rights is related with being better able to access funding on the capital markets. However, these two streams of literature present conflicting predictions on how stronger IP protection affects technology commercialization strategy. Since raising third-party financing enables a firm to continue commercializing its innovation alone (and thereby put off sharing the rents with a licensee), third-party financing and alliance financing might be considered as substitutes (Lerner *et al.*, 2003; Majewski, 1998; Ozmel *et al.*, 2009). Hence, it is not clear whether obtaining more IP rights will make a firm more likely to enter an alliance or to commercialize alone.

This paper reports the results of an empirical analysis of the licensing decisions of 650 start-up technology-based firms in the biopharmaceutical industry. The results show that the likelihood of entering into a commercialization alliance at a given point in time is positively correlated with the number of filed patents but negatively correlated with the proportion of those patents that have been granted. These results are robust to different methods of dating the patent filing, as well as to alternative weightings for the patent count.

This suggests that the *nature* of the IP rights (i.e., whether the patent application has been granted) has a significant effect on the relationship between IP protection and technology commercialization strategy. Consistent with the previous literature, *more* IP rights on an invention unambiguously increases the likelihood of (i.e., accelerates) an innovating firm entering into a commercialization alliance. However, *stronger* IP rights – that is, those which give a definite right to sue – can in fact lead to a delay in licensing.

The results suggest a way to reconcile the competing predictions in the literature. The effect can be explained by the differential ability of potential licensees and third-party financial investors to assess the significance of an invention and the strength of IP protection. An incumbent's

technological expertise, combined with the ability to examine patent applications closely during the due diligence process, gives it both the sophistication and the information to evaluate IP rights based on a patent application. By contrast, a third-party investor, especially one investing through the public market, generally lacks both the information and the sophistication to evaluate these for itself and hence it relies to a much greater extent on objective signals, such as the determination of the patent office to assess both the significance of an invention and the strength of IP protection. This in turn influences the innovating firm's trade-off between entering into a commercialization alliance into order to access the incumbent's complementary assets and waiting until a later stage of the commercialization process in order to capture a higher return from the innovation. By increasing the willingness of outside investors to finance independent development of the technology, patent issue strengthens the innovating firm's outside options and enables it to delay licensing until the optimal point.

The next section of this paper positions this paper in the context of the related literature. Section 3 discusses how stronger patent protection is likely to affect commercialization strategy, particularly in an environment when entering into an alliance with an incumbent product firm is generally the optimal strategy. Section 4 sets out the empirical analysis of the relationship between IP rights and the timing of licensing for a set of biotech firms entering into their first alliance with a pharmaceutical firm. Section 5 discusses the results and concludes.

2. Relationship to the prior literature

Teece (1986) first highlighted the relationship between IP protection – or appropriability more generally – and technology commercialization strategy, positing that if the 'appropriability regime' surrounding an innovation is stronger then the optimal strategy is to contract with an established firm to access the requisite complementary assets. Subsequent research has developed this proposition and tested it empirically, showing that the choice of commercialization mode depends on the nature of appropriability – whether it comes from formal patent rights or secrecy (Gans *et al.*, 2002; Gans *et al.*, 2003) – as well as the innovating firm's position with respect to the complementary assets (Arora *et al.*, 2006). Other research has shown that stronger appropriability also has a positive effect on whether an innovating is commercialized (Dechenaux *et al.*, 2008). However, this research typically conceives of the level

of IP protection as a factor pre-determined by environment, and relies on general measures, particularly those from the Yale and Carnegie Mellon surveys (Cohen *et al.*, 2000; Levin *et al.*, 1987), to measure the strength or IP protection or appropriability. By contrast, this paper looks at the IP rights relating to an individual specific innovation, so is able to be more precise about the strength of IP protection as well as to examine how the nature of those rights change over time.

While much of the prior empirical research using patents treated patent rights merely as a proxy for innovation or inventive activity (see Griliches, 1990, for a survey), recent literature has begun to analyze the effectiveness of patents as mechanisms for protecting the returns from innovation (Cohen *et al.*, 2000) and how the strength of patent protection affects technology commercialization strategy (Arora *et al.*, 2001; Arora *et al.*, 2004). Using a similar empirical approach to this paper, Gans, Hsu & Stern (2008) found that the likelihood (or hazard) of licensing an innovation increases dramatically after decision to grant the patent is notified, suggesting that clarifying the uncertainty around IP protection significantly increases the willingness of firms to transact over the technology. However, Gans, Hsu & Stern examined only on innovations for which a patent application had already been filed. By contrast this paper considers the incremental effect of both the lodging of the patent application and the grant.

Several recent papers have studied the relationship between patent rights and the ability to raise finance. Mann & Sager (2007) looked at the relationship between patenting and the progress of software firms through the venture capital cycle, and found a strong relationship between a firm's patent stock and the likelihood of raising additional rounds of venture capital. Hsu & Ziedonis (2007) performed a similar study for semi-conductor firms and found a positive relationship between the number of patent applications and the ability to raise capital from venture capital firms. Finally, Haeussler, Harhoff, & Mueller (2011) have examined the relationship between patenting and VC financing in the biopharmaceutical industry, finding that while the size of patent application stock is positively related to obtaining VC financing, grants do not show any effect.

Although the positive relationship between patent protection and the hazard of third-party financing established in those papers gives a potential explanation for the negative relationship between patent issue and licensing observed in this paper, both Hsu & Ziedonis (2007) and

Haeussler, Harhoff, & Mueller (2011) found the positive relationship with patent application, rather with *issued* patents. Nevertheless, it may be the strength of the effect that determines the relative result. The results in this paper could be reconciled if the positive relationship with stock of patent applications were stronger for licensing than for third-party financing, but the inverse were true for the negative relationship with patent issue.

Another line of literature has directly examined the trade-off that technology-based firms make between alliance and other, third-party financing. Majewski (1998) found that firms with higher asystematic risk (i.e., higher volatility in the portion of firm returns that is uncorrelated with market movement) and greater volatility in stock prices are more likely to choose an alliance partner to fund their R&D program (as opposed to issuing stock or obtaining venture capital). Meanwhile, Lerner, Shane & Tsai (2003) looked at the effect of equity market financing cycles on the structure of alliance relationships, and found that when equity markets are tighter, the biotech firm obtains less favorable terms in an alliance arrangement with a pharmaceutical firm. This paper complements this literature by examining an alternative factor (i.e., level of IP protection) that may affect the trade-off between these alternative sources of finance.

3. Theoretical framework

The relationship between a stronger appropriability regime and technology commercialization is well established.[1] Under a stronger appropriability regime an innovator is better able to prevent imitation by a competitor and thereby capture a larger share of the returns to its innovation (Ceccagnoli, 2009). If the innovator requires complementary assets to bring a product to market, strong appropriability may give the innovator time to acquire those assets without threat of imitation (Teece, 1986). Alternatively, if it makes sense to license to an incumbent (rather than to commercialize alone) because the incumbents are much better positioned with respect to the complementary assets, being able to prevent imitation puts the innovating firm in a stronger

[1] Teece (1986) identified a range of mechanisms or "appropriability regimes" – including patents, secrecy, bundling with complementary assets, and the tacit nature of the knowledge itself – that enable firms to mitigate the risk of expropriation in the commercialization of technology.

position to negotiate better terms in a commercialization alliance with an incumbent (Arora *et al.*, 2006; Gans *et al.*, 2002; Gans *et al.*, 2003).

However, much of the literature implicitly assumes that the level of IP protection or appropriability of an innovation is an exogenously determined characteristic of the environment. But even in a strong appropriability regime, the level of appropriability increases over time as the innovator acquires IP rights on the innovation. Moreover, even when the situation dictates that partnering with an incumbent to commercialize the innovation is the optimal strategy, the level of appropriability affects the timing of entry into a commercialization alliance, as well as the choice of partner and the structure of the agreement.

3.1.The nature and strength of IP protection for technological innovation

In most cases, an innovator must take active steps to protect a technological innovation. For many technological innovations, and especially those in biotechnology and pharmaceuticals, the primary form of IP protection comes from patents.[2] A patent is a legal monopoly right, granted by a government authority, which gives the patentee a right to prevent others from making, using, or selling the invention covered by the patent.[3] However, the right to exclude only attaches once the patent has been granted by the appropriate authority (typically a patent office) and often the process of reviewing – or "prosecuting" – a patent takes several years. Moreover, the scope of the invention covered by the patent may change considerably during the review process.

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[2] In some cases firms are able to protect a technological innovation by keeping the key aspects of the innovation a secret, and relying on laws and internal organizational arrangements that protect trade secrets. This is especially likely to be the case when the key innovation is a new process that cannot be reverse engineered from observing the final product. However, it is much more difficult collaborate on commercializing innovations that are protected by trade secrets, and this limits their viability when incumbents are much better positioned with respect to any complementary assets necessary to commercialize the innovation.

[3] Copyright and trademark protection attach automatically (Merges *et al.*, 2006). However, a copyright only protects the expression of an idea, and not the idea itself, so only covers an invention to the extent that it is completely expressed in a medium. Meanwhile, a trademark protects the commercial value in a distinctive sign or indicator. Moreover, registering a copyright or trademark confers stronger rights.

Nevertheless, once a patent is granted the legal rights date back to when the first related application was filed (typically known the "priority" date).

Obtaining IP protection does not necessarily imply product-market exclusivity. The most common type of patent – a "utility" patent – only protects the technological aspects of the product that are "novel, useful, and non-obvious".[4] The appropriability of the final product depends on how well the patented aspects "map" onto the final product – in other words, how essential the patented aspects are for achieving the function that the final product performs.

An innovator can strengthen the appropriability of its product by protecting more than one aspect of its innovation, or by protecting variations or improvements – even those which are not part of the current product – to prevent others from inventing around (Shapiro, 2001). For instance, while the primary protection for a pharmaceutical product comes from a patent on the underlying chemical composition, a pharmaceutical firm can strengthen that protection by patenting the method by which the product is manufactured or the therapeutic use of the product. Moreover, it can attempt to forestall its rivals from circumventing the innovation by protecting similar chemical structures that have the same functional properties.

Nevertheless, even if the essential aspects of a product are covered by a set of patents, this does not guarantee appropriability. To prevent imitation, the patent holder must enforce its patent rights in court. Even if a patent purports to cover a particular aspect of the innovation, a court can invalidate the patent if the alleged infringer proves that the claimed invention is not novel, useful, and non-obvious. Alternatively the court may limit the patent's scope if it determines that the claimed invention was previously disclosed by the 'prior art'. Furthermore, enforcing a patent is an expensive exercise with considerable uncertainty, and the resources required to finance and conduct patent litigation may themselves be a barrier to appropriability, particularly for small firms (Lanjouw *et al.*, 2004b).

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[4] U.S. patent law distinguishes between "design", "plant", and "utility" patents, but by far the largest category of patents is utility patents. In order for a utility patent to be valid, an inventor must claim a concept, idea, or item that is useful, novel, and non-obvious. The invention can be a process, a machine, an article of manufacture, or a composition of matter (or an improvement of any of these items).

3.2.Intellectual property protection and licensing

These limitations aside, obtaining stronger IP protection provides at least three benefits for firms attempting to commercialize an innovation through a commercialization alliance.

3.2.1. Protecting against expropriation in pre-contractual negotiations

Revealing an innovation to a potential partner during pre-alliance negotiations exposes the innovating firm to the risk that its partner may expropriate the innovation and use it outside the alliance without paying proper compensation. Arrow (1962) highlighted the paradox that in order to assess the value of an innovation, the licensor needs to reveal information to a prospective licensee, but once the information is revealed a prospective licensee has no reason to pay for it.

In theory, an innovator might be able to prevent a potential partner from using any information disclosed during discussions by making it agree contractually not use the information without permission. That is the purpose of a non-disclosure or confidentiality agreement. However, the difficulty in delineating what information is covered by such an agreement – for instance, distinguishing what is new information and what is already in the public domain – makes it difficult to write a 'complete' contract that protects against expropriation entirely (Williamson, 1991). Moreover, this uncertainty means that prospective partners often refuse to enter such agreement because of the risk that the innovating firm will use it stop the potential partner from subsequently bringing *any* related product to market, whether or not the product relied on the innovating firm's innovation. For these reasons an innovating firm often must reveal its innovation to a potential partner even before it can rely on contractual protection.

Merges (2005) describes how patent rights – or IP rights more generally – facilitate contracting by enabling information to be disclosed during pre-contractual negotiations. Contract law and associated legal doctrines (e.g., promissory estoppel and restitution) provide limited relief for any damage suffered due to information disclosure prior to a contract being signed. However, property rights are "good against the world", covering use of the property by any party, whether or not there is a relationship with the owner. Therefore obtaining stronger IP protection gives the innovating firm better protection in pre-contractual negotiations than it would have relying on contractual arrangements.

3.2.2. Mitigating contractual hazards within an alliance relationship

Even when an innovator has entered into a partnership with an incumbent, the nature and strength of appropriability may impact the value that an innovator can capture from the relationship.

In negotiating a long-lived, complicated partnership such as a commercialization alliance , it is impossible to foresee and contract on all possible contingencies. As a consequence, the innovator is exposed to the risk that an opportunistic partner may use an unforeseen – and non-contracted – contingency to skew the relationship to its advantage (Williamson, 1975, 1985). For instance, the partner may seek to exit the contract on dubious grounds in order to exploit a competing product developed with a third party.

Stronger patent protection helps the innovating firm to mitigate the risk of expropriation inside a contractual arrangement. To the extent that the partner's behavior infringes the terms of a patent but not of the contract, IP rights provide a remedy against a breach. Moreover, while the law of contract usually only allows a plaintiff to obtain damages for contract infringement, IP rights confer the right to stop – or "injunct" – an infringer from using an invention without authorization. Furthermore, patent rights provide more flexible and longer-lived legal actions than are traditionally available under contract (Merges, 2005).[5]

These additional remedies may either enable the innovating firm to obtain reparation in the event of expropriation, or prevent expropriation from happening in the first place. The right to control any use of the protected invention even after the contract terminates means its partner has less to

[5] Potentially the parties could prevent expropriation though hierarchical governance mechanisms (Williamson, 1991). By taking control of its partner (e.g., through an equity stake), the firm can prevent the partner from using the technology outside the alliance or, alternatively, can claim a share of the returns from its misappropriated technology as a return on equity. Oxley (1997) showed that strategic alliance partners choose more hierarchical alliances when appropriability hazards are higher. However, in alliances between a small technology-based firm and an established product firm, the relative firm sizes typically make it infeasible for the technology-based firm to obtain a sufficient ownership stake in its partner to exercise any control or capture the incremental returns the partner gains from using the technology outside the alliance.

gain from terminating the contract and hence less incentive to act opportunistically. Moreover, this right will strengthen its bargaining position in any renegotiation triggered by an unforeseen contingency.

3.2.3. Signaling value to prospective licensees and third parties

At the same time, regardless of the actual legal protection provided by a patent, patents may signal the value of the innovation to interested parties. Since it is impossible to completely determine the likelihood of commercial success for technological innovation, potential partners and financial investors must decide which projects to back under considerable uncertainty. Moreover, although they conduct due diligence before making an investment, they may not completely trust all the information they receive from the innovating firm because of the innovator's incentives to exaggerate in order to induce investment. In economic terms, they may suffer due both to incomplete information and to asymmetric information (vis-à-vis the innovating firm).

One way to mitigate the lack of information about the likelihood of success is to rely on variables that are positively correlated with success. As an independent assessment of the novelty, usefulness, and non-obviousness of an invention by the appropriate authority, or that the grant of a patent may be such a correlate. Meanwhile, to avoid relying completely on information from the innovating firm, they may instead use only information that is deemed to be credible. Due to the severe penalties from making misstatements, filing a patent application provides a way to credibly disclose information about an innovation, and more generally about the innovating firm's inventive activity (Long, 2002). Hence, patents may provide a reliable way for potential partners or investors to distinguish an innovating firm (Spence, 1973).

3.3.The effect of stronger IP protection on the timing of licensing

The timing of entry into a commercialization alliance is a critical determinant in how much value a firm can capture from its innovation (Lavie *et al.*, 2007). If the incumbent is in a better position to commercialize the innovation then – by definition – the innovator remains at a disadvantage as long as it attempts to commercialize the innovation alone. Moreover, if the innovating firm is financially constrained, by not entering an alliance at an early stage then it may run out of money

to finance further development or slow development to the extent that it misses a market opportunity.

Nevertheless, to induce the pharmaceutical firm to enter into the alliance, the innovating firm must give up a share of the expected returns from the innovation and compensate the partner for the risk that the product will never get to market. The risks of technological and commercial risks are likely to be resolved – or at least become clearer – over time, and if the innovating firm is better able to bear or to mitigate these risks then it may be able to capture larger returns by delaying licensing (Allain *et al.*, 2009). Hence there are also advantages to waiting.

The level of IP protection that an innovating firm has over its innovation has a significant impact on its decision whether to enter an alliance at a point in time. To begin with, the grant of a patent resolves uncertainty about the legal rights that attach to an innovation (Gans *et al.*, 2008) and the potential appropriability of the final product, it is likely to increase a potential partner's willingness to contract. Moreover, by giving the innovator protection against expropriation during pre-contractual negotiations, obtaining IP protection may facilitate the innovator in revealing its innovation to potential partners. Finally, since patent protection gives the innovating firm a mechanism to mitigate the risk of expropriation during a commercialization alliance, it encourages the innovating firm to enter the agreement. For these reasons, obtaining (stronger) patent protection is likely to accelerate entry into a commercialization alliance.

However, obtaining stronger patent protection may at the same time delay a tech firm entering into a commercialization alliance. As discussed above, patent rights may provide a positive signal of the technology's value to third parties. In particular, patent rights potentially signal the value of an innovation to venture capital firms and public equity investors (Haeussler *et al.*, 2011; Hsu *et al.*, 2007; Mann *et al.*, 2007).

Financial resources that pay for the additional research and development necessary to get a product to market are an essential ingredient into technology commercialization, and venture capital firms and public equity investors are a primary source of this funding. Therefore, obtaining stronger patent protection may increase the innovating firm's ability to raise funding from other financial investors, and reduce the urgency to enter into an alliance with a partner.

4. Empirical analysis

4.1.The empirical context

The empirical context for this study is the biopharmaceutical industry. In the life sciences the close relationship between a patentable invention – such as the composition of a chemical compound that has therapeutic effects – and the pharmaceutical product that comes out of that invention means that a patent potentially gives the holder strong and unambiguous rights to exclude others on the product market. Evidence from the Carnegie-Mellon survey (Cohen *et al.*, 2000) shows that – in contrast to most industries – patent rights provide the primary means for appropriating the returns to innovation in this industry. Moreover, using evidence from renewal fees, Schankerman (1998) shows that firms in this industry are willing to pay to maintain these patents for the full life of the patent.

4.2.Data sources

In order to analyze the effect of obtaining patent protection on the timing of licensing, I constructed a dataset of the patenting history of start-up biotech firms from their founding to their first alliance with a pharmaceutical firm. The dataset includes information on the year in which each biotech firm was founded, the date on which it signed its first alliance with a pharmaceutical firm (if appropriate), and the filing and issue dates of patents assigned to it over this period.

The data comes from several sources. The alliance data comes from the rDNA database compiled by Deloitte Recap ("Recap"), a San Francisco Bay Area-based consulting firm. The database contains records of all publicly announced deals in the biopharmaceutical industry from its inception in the 1970s through to the present day, as well as the actual contracts for those (approximately 50% of the total) which are filed with the U.S. Securities and Exchange Commission (SEC) under the 'materiality' requirement.[6] The patent data comes from the NBER

[6] The SEC filing rules require that publicly listed firms file anything that may be "material" to the firm's value. The Alliances database currently contains over 19,000 high-level summaries of biotech alliances signed since 1973.

patent file, compiled by Hall, Jaffe, and Trajtenberg (2001). This dataset contains information on all patents issued by the U.S. Patent & Trademark Office (USPTO) from 1963-2002, including (most usefully for this analysis) the name of the firm to which each patent is assigned.[7] I supplemented this with raw USPTO data (published on the Micropatent CD-ROMs) to obtain the exact application date listed on the patent and each patent's case history so that I could trace back to the date of first related patent application.

4.2.1. Construction of the dataset

I defined the set of firms for this analysis to be all "Biotech" firms contained in the Recap database.[8] I then used the Recap database to obtain the date of the biotech firm's first transaction with a pharmaceutical firm. In almost every case, firms that appear in the Recap database have at least one transaction.[9] However, these transactions include purely financial transactions, physical asset sales, and agreements with other biotech firms and with universities. Since I am focused on the relationship between the patent protection that the biotech firm has over its technology and alliances to commercialize that technology, not all of these transactions are relevant for this analysis. Instead, I restrict attention to transactions between a biotech and a pharmaceutical firm[10] that involved the transfer (either sale or license) of an intellectual property asset.[11]

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[7] The firm name is standardized across the many variations recorded by the PTO.

[8] Recap identifies each firm as "Biotech, "Device", or "Pharma". I rely on Recombinant Capital's classification of firms into biotech and pharma.

[9] In a few cases, Recap has created a record for a biotech firm in order to record their contact details, even though it has no record of any deals by that firm.

[10] I include all firms that Recap classifies as "Pharma" firm in the set of pharmaceutical firms. I also include any "Biotech" firm which (at the date of the alliance) is marketing pharmaceutical products.

[11] Recap classifies each transaction into a range of "types", for which it provides standard definitions. An individual agreement may fall into multiple categories. Using these definitions I determined that the following transaction types involve the transfer of an intellectual property asset: Co-Development, Co-Market, Co-Promotion, Collaboration, Development, License, Research, and Sublicense. Meanwhile, I excluded any transactions that were

I manually matched firm names in the Recap dataset to the corresponding assignee code in the NBER patent assignee file. If multiple permutations of the firm name appear in the assignee file, I used Google searches to determine which (if any) of the permutations are related to the firm in the Recap database and include multiple assignee codes where appropriate. If the firm name does not appear in the NBER assignee file, I searched the USPTO and Patent Genius (www.patentgenius.com) websites for the first US patent assigned to the firm, then searched for that patent in the NBER patent file to recover the firm's assignee code. If I could not find the assignee code I assumed that the firm had not been assigned any patents by December 31, 2002.

Finally I performed an internet search (using Google) for the firm's name and the word "founded" to find the year of founding. If I could not find the year of founding then I dropped the firm's record from the database.

Since the NBER patent file finishes in 2002, I restrict the sample to firms that were founded in or before 2002. Meanwhile, since the alliance-based model for commercialization was pioneered by Genentech, which was founded in 1976, I exclude all firms which were founded before that year. Table 1 describes the firms in the dataset, listing them by the year the firm was formed and indicating which firms entered into a deal with a pharmaceutical firm, and which were acquired before doing so.

Table 1: Number of firms that sign a deal with a pharmaceutical firm (by year formed)

Year of founding	Firms founded	Firms acquired before entering a pharma deal	Firms entering first pharma deal by 2002	Percentage of firms entering first pharma deal by 2002
1976-1980	26	2	19	73.1%
1981-1985	97	6	63	64.9%
1986-1990	126	12	91	72.2%
1991-1995	179	21	119	66.5%
1996-2000	181	27	68	37.6%
2001-2002	41	6	3	7.3%
	650	74	363	

categorized into the following types: Acquisition, Merger, Settlement, and In-licensed Products (i.e., where the biotech firm in-licenses products or technology from a pharmaceutical firm).

4.3.Econometric specification

The objective is to measure the effect of the firm's patent protection on the start-up biotech firm's entry into its first alliance to commercialize the technology. The simplest way to do this would be to estimate the effect of the firm's patent count on the time to its first alliance using an OLS specification. However, since the time to first alliance is only available for those firms that were observed entering into an alliance, this analysis would automatically exclude all firms that did not enter an alliance with a pharmaceutical firm during the observation period. Moreover, under this specification the firm's patent protection could only be represented by the patent count at the date the firm enters into the alliance, even though the most interesting aspect is how *changes* in the firm's patent protection over time affect the timing of licensing.

To overcome these limitations, I instead estimated a Cox proportional hazards model with time-varying covariates. Each firm enters the dataset on the first month of the year in which it was formed and exits either when it signs an alliance with a pharmaceutical firm or when it is acquired (so is no longer entering transactions under its own name). Since Recap reports the date of the alliance only to the nearest month, the time variable is the number of months since formation. The "hazard" is entering into an alliance with a pharmaceutical firm.

4.4.Explanatory variables

To proxy for the strength of patent protection over its technology, I use a count of the number of patent rights assigned to the biotech firm at each point in time.

4.4.1. Issued vs. filed patents

In order to receive a patent, a firm must first create the invention, reduce it to practice, describe the invention in a patent application, and then file the application with the patent office. The patent office then reviews the application, compares it against the prior art, determines whether the patent fits the requirements of being novel, useful, and non-obvious, and (if it meets these criteria) issues the patent.

The strictest definition of patent rights would only include issued patents counted from the issue date because it is only once the patent issues that the inventor (or the firm as assignee) has a

legally enforceable right to the claimed technology. However, the process of filing a patent application is a significant step, and the cost of doing so means that the firm must have a reasonable expectation that the patent will eventually issue. Moreover, once the patent issues, the legal rights date back to the date of the original application (often called the "priority" date). Hence, I use the number of patent rights counted from the filing date and refer to this as the "count of filed patents".

Nevertheless, since the NBER patent data files only contain information on issued patents, it is important to emphasize that this count only includes patents that eventually issue. Moreover, since the most up-to-date version of the NBER patent file only contains information on patents issued prior to 31 December 2002,[12] the count only includes patents which issue prior to that date. Meanwhile, in order to include some information about the status of these patents, I also include a second variable that reflects the share of the patent applications that have issued at a particular point in time.

4.4.2. Application date

Each patent document lists a patent application date, which I extracted from the raw USPTO information available on the Micropatent CDs. I use this date to create the first measure of the count of filed patents. However, patents often go through multiple iterations, including divisions into multiple applications and continuations (or continuations-in-part), before issue.[13] Hence the application date listed on the issued patent is not necessarily the date on which the firm filed the first relevant application or from which it claims priority over the claimed invention. Hence, for a sample of the patents in the database I extracted the date of the first related patent application

[12] The original NBER patent files are available at the NBER website (http://www.nber.org/patents/) but the most up-to-date data is available at Bronwyn Hall's website (http://elsa.berkeley.edu/~bhhall/bhdata.html).

[13] See Graham & Mowery (2004) for a detailed description of this practice and its role in the patent strategy of software firms.

from the patent's case history[14] and use the original filing date to create a second measure of the filed patents.[15]

4.4.3. Patent counts

Since patent rights vary widely in quality, a simple patent count is a very imperfect measure of the level of a firm's patent protection. In the past two decades patent researchers have tried various indicators to proxy for patent quality, including the patent renewals (Schankerman *et al.*, 1986), patent citations (Hall *et al.*, 2005; Trajtenberg, 1990), claims (Tong *et al.*, 1994), family size (Lanjouw *et al.*, 1998; Putnam, 1996),[16] forward patent citations, and whether the patent was litigated (Allison *et al.*, 2004). However, Lanjouw & Schankerman (2004a) pointed out that, while any of these indictors may be correlated with patent quality, if they are also correlated with unobserved variables that are not associated with quality but are correlated with the dependent variable then using these indicators as proxies for quality can be problematic. To correct for this concern in a study of research productivity, they constructed a composite index from the

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[14] I extracted the patent case history for all firms in the dataset. If the patent case history filed in the patent document is empty I interpreted this to mean that there are no other relevant patent applications, so the application date listed on the issued patent is the original filing date. For the remainder, I used a Stata program to parse the case history text into words that look like part of a date, reassembled these to create a list of dates contained in the case history, selected the first application date in time if there was more than one date, and then doubled-checked this date against the text in the patent's case history. However, since Stata SE only handles 244 characters of text, if the case history was longer this method did not produce a complete list of dates. This was the case for 1768 (or 15%) of the 12174 patents assigned to the firms in the dataset. The only way to extract the date of the first application for these patents would be to search each patent record individually on the PTO website, which would be a very time-intensive process. Instead, I left the original application date missing. However, this meant that I was able to the count the filed patents from the original application date only in those cases when I knew the original application date for all patents in the firm's portfolio.

[15] The resulting count of filed patents includes both pending patents (i.e., patents that had been filed but not yet issued) and issued patents. However, I exclude expired patents (i.e., patents more than 17 years after their issue date or 20 years after their application date, depending on the date) from both counts.

[16] Measured by the number of international applications lodged for the patent.

common factor in a factor model of four of these indicators (claims, family size, backward and forward citations):

$$patent\ quality = \beta_1 \cdot claims + \beta_2 \cdot family\ size + \beta_3 \cdot backward\ cites + \beta_4 \cdot forward\ cites$$

4.4.3.1. Weighting by Lanjouw-Schankerman quality measure

I weight each patent by the Lanjouw & Schankerman quality measure in order to adjust for patent quality in this analysis. Lanjouw & Schankerman distinguished between 7 technological classes, including biotechnology and pharmaceuticals, and for each class produced a different set of weights for the indicators. In combining the various factors, I use the coefficients that Lanjouw & Schankerman estimated for the biotechnology industry, namely 0.72 for claims, 0.128 for backward citations, and 0.139 for forward citations. Since I do not have information on the fourth variable (family size) I am unable to include it in the calculation of the index. However, according to Lanjouw & Schankerman's calculations, the contribution of this indicator to the quality measure in biotechnology (0.013) is minor and hence its omission is unlikely to significantly affect the results.

4.4.3.2. Weighting by number of "forward" citations

As an alternative, I weight the patent count by the number of "forward" citations – that is, the citations from subsequent patents. The number of forward citations is the most popular indicator of patent quality used in the patent literature. Moreover, this indicator has been shown to proxy for the patent's social value (Trajtenberg, 1990), its private value (Harhoff *et al.*, 1999), the probability of litigation (Allison *et al.*, 2004), the likelihood of opposition (Harhoff *et al.*, 2004), and the market value of the firm (Hall *et al.*, 2005).

4.4.4. Limitations of the patent count measure

Nevertheless, these patent counts, based on issued patents recorded in the NBER patent file, are only approximate measures of all the relevant patent rights held by the biotech firm at a particular point in time, or the patent protection a firm has on technology.

4.4.4.1.Patents that are filed but never issue

Firstly, these measures omit patent applications that were filed but never issued. The USPTO only started publishing the patent applications themselves on 15 March 2001 (i.e., for patents that were pending on that date), which is right at the end of the observation period for this analysis.[17] Moreover, even for the short period in which this information is available, to my knowledge this data is not available in an easily analyzable format. Therefore it is not possible to capture fully the patent applications that the firm had pending or issued at a particular point in time.

4.4.4.2.Licensed patents

Secondly, in many cases, the biotech firm does not own (i.e., have assigned to it) all the relevant patents rights covering its technology. If the technology was spun out of a university, the patent rights relating to the technology are likely to be licensed from the university to the start-up firm. Even if the technology was developed in-house, another firm may have patents that relate to the technology. Hence, the biotech firm must usually in-license to those patent rights in order to achieve a clean and unencumbered IP position and so its portfolio will include some licensed patents.

The NBER patent file does not include any information about patent licenses. Moreover, to my knowledge there is no comprehensive dataset of patents licensed to biotech firms,[18] so it is not possible to include the licensed patents in this analysis. The count of assigned patents is, therefore, the best available measure of the patent protection covering the firm's technology.

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[17] In fact, the USPTO only publishes patent applications after an 18-month lag from their filing date.

[18] There is no general obligation on either the licensee or licensor to disclose a licensing arrangement. In some cases, these patent licenses are disclosed to the SEC under the materiality requirement and hence available on EDGAR (http://sec.gov/edgar.shtml) or databases such as Recap that collect information from EDGAR. In other cases, these licenses are included in datasets of university licensing collected by other researchers (see, e.g., Lowe *et al.*, 2006).

4.4.4.3.Assigned patents that are not related to the licensed technology

Thirdly, the patents assigned to the biotech firm may include patents that are not related to the technology in the alliance.[19] Since the analysis is focused on start-up firms prior to their first deal, the firms in this analysis are unlikely to hold patents over more than one, unrelated technologies so this may not be a big concern. Nevertheless, potentially this may be a limitation of the measures used.

4.5.Descriptive statistics & pairwise correlations

Table 2 presents some descriptive statistics for the set of firms used in this analysis. There are 650 firms in the dataset, 363 (or 56%) of which enter into a deal with a pharmaceutical firm to commercialize their technology at some stage during the period of observation (i.e., 1976-2002). Those 363 firms take on average 5.2 years from founding to their first alliance with a pharmaceutical firm, although this ranges from 3 months to over 20 years. 316 firms make an IPO during the observation period and 120 are acquired.[20]

On average it takes around 3.3 years for a firm to file its first patent (measured from the date of the first related patent application) and 6.6 years before its first patent is issued. By the time they sign their first deal with a pharmaceutical firm, the biotech firms have on average 3.6 filed patents (out of those which eventually issue) and have been issued with 1.3 patents. Each of those patents receives on average 4.9 citations within 5 years of being issued and has a Lanjouw-Schankerman quality measure of 10.9.

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[19] The only way to ensure that only relevant patents were counted would be to check each patent individually against the alliance document. For instance, Gans, Hsu, & Stern (2008) searched for a match between the key words in the patent and the alliance to establish a relationship. However, since there over 1300 potentially relevant patents, this would involve substantial work.

[20] The number of firms making an IPO or being acquired shown in Table 2 includes firms that do so *after* entering their first deal with a pharmaceutical firm. By contrast, Table 1 shows that 74 firms are acquired *before* they enter into an alliance with a pharmaceutical firm.

The low number of patent rights at the time it enters a deal is noteworthy. In part, this reflects the early stage that these firms are in their development. However, since the firms may also have licensed patents or may have patent applications that never issue (neither of which is accounted for in this analysis), this number does not necessarily represent the extent of their patent portfolio.

Table 2: Descriptive statistics

Variable	*N*	*mean*	*s.d*	*min*	*max*
Year of founding	650	1991.75	6.28	1976	2002
Firm has a pharma deal during period 1976-2002 (dummy)	650	0.56	0.50	0	1
Years to pharma firm deal[1]	363	5.21	3.75	0.25	20.50
Years to IPO[1]	316	6.16	3.74	0.50	21.08
Years to acquisition[1]	120	10.39	5.24	0.33	21.83
Years to first patent filed (measure #1)[2,3]	465	4.05	3.95	0	22.17
Years to first patent filed (measure #2)[2,4,5]	454	3.34	3.90	0	22.17
Years to first patent filed (measure #2)[2,4,6]	170	3.94	4.71	0	22.17
Years to first patent issued[2]	465	6.57	4.26	0	24.77
Firm has patent rights at time of pharma deal (dummy)	363	0.54	0.50	0	1
Number of patents at time of first pharma deal[1]	363	1.30	3.79	0	41
Number of patents at time of first pharma deal weighted by number of forward citations[1,7]	363	6.37	25.55	0	265
Number of patents at time of first pharma deal weighted by Lanjouw-Schankerman quality measure[1,7,8]	363	14.25	54.26	0	782.55
Number of filed patents at time of first pharma deal (measure #1)[1,3]	363	3.69	7.56	0	57
Number of filed patents at time of first pharma deal (measure #2)[1,4]	141	1.80	5.28	0	48
Stage of commercialization of alliance product at time of signing[9]	241	2.08	1.68	1	8

Notes:
1. For firms that actually sign a deal, receive an issued patent, make an IPO, or get acquired (respectively).
2. For all firms that have patent rights, whether or not they are observed entering a deal with a pharma firm.
3. Counting patent rights from application date listed on the patent that issues.
4. Counting patent rights from first related patent application (from patent case history).
5. Includes any firms for which the original patent filing date was available for at least one patent.
6. Includes only firms for which the original patent filing date was available for all patents.
7. Counting forward citations from only those patents that issue within 5 years of the original patent.
8. Based on weighted sum of forward citations, backward citations, and claims, as described in Lanjouw & Schankerman (2004).
9. Based on 8-stage scale coded by Recap where 1="Discovery" & 8="Approved".

Table 3: Correlations between explanatory variables

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1)	Number of issued patents	1.000									
(2)	Number of filed patents (measure #1)[1]	0.960	1.000								
(3)	Number of filed patents (measure #2)[2]	0.826	0.984	1.000							
(4)	Number of filed patents not yet issued (measure #1)[1]	0.629	0.821	0.728	1.000						
(5)	Number of filed patents not yet issued (measure #2)[2]	0.273	0.729	0.782	0.961	1.000					
(6)	Share of filed patents that have issued (measure #1)[1]	0.349	0.308	0.396	0.144	0.034	1.000				
(7)	Share of filed patents that have issued (measure #2)[2]	0.546	0.426	0.370	0.054	0.025	0.951	1.000			
(8)	Number of issued patents at time of first pharma deal[3]	0.055	0.046	0.415	0.015	0.235	0.165	0.184	1.000		
(9)	Number of filed patents at time of first pharma deal (measure #1)[1,3]	0.062	0.073	0.554	0.077	0.509	0.131	0.148	0.831	1.000	
(10)	Number of filed patents at time of first pharma deal (measure #2)[2,3]	0.404	0.565	0.594	0.517	0.541	0.191	0.152	0.653	0.990	1.000

Notes:
1. Counting patent rights from application date listed on the patent that issues.
2. Counting patent rights from first related patent application (from patent case history).
3. For firms that actually sign a deal.

Table 3 presents pairwise correlations between the explanatory variables used in the analysis. As expected, there is a very high correlation between the two measures of the count of filed patents (0.984). There is also a very high correlation between the number of issued patents and number of filed patents counted from the filing date listed on the issued patent (0.960).[21] The correlation between these two variables is significantly lower at the time of the deal (0.831), indicating that the high correlation is likely due to multicollinearity between the two variables at early stages of the firm's life.[22] The correlation between these variables is also lower (0.826) when number of filed patents is counted from the filing date on the first related patent application.

4.6.Results

Table 4 presents the results of the baseline hazard-rate analysis. The dependent variable is the 'hazard' of the biotech firm entering into its first deal with a pharmaceutical firm. The explanatory variables used in this analysis are the logged count of filed patents, an indicator variable for whether the firm had filed a patent, and the share of filed patents that had issued.

Panel A shows the results of an analysis using the number of filed patents counted from the filing date listed on the issued patent. The results in Column (1) show that the likelihood of the firm entering a deal with a pharmaceutical firm is positively correlated with the count of filed patents. Column (2) shows that this effect is not explained entirely to filing the first patent – the hazard rate increases with subsequent increases in the count of filed patents. Meanwhile, Column (3) shows that the likelihood of entering into an alliance decreases as these patents issue. Column (4) shows that both effects persist when year fixed effects are added.

Panel B shows the results using the alternative measure of the number of filed patents; that is, counting the number of filed patents from the application date of the first related patent

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[21] The first measure of filed patents counts the number of patents from the filing date listed on the patent that issued. The second measure of filed patents counts from the filing date of the first related patent application listed in the patent's case history.

[22] In just under than half of the observations, both variables are zero.

application cited in the patent's case history. The results of this analysis show an even stronger positive effect of the number of filed patents on the hazard rate and a similar negative effect of the share of patents that have issued. However, the effect of the indicator variable is not significant.[23]

Table 5 presents the results of the same analysis as in Panel A of Table 4 but with the patent counts weighted by, first, the Lanjouw-Schankerman quality measure (Panel A) and then by the number of forward citations that the patent receives within 5 years (Panel B). The positive effect of filed patents and the negative effect of the issued share are slightly weaker in both cases but still significant. The effect of the indicator variable is insignificant in both cases.

Table 6 shows the results of the analysis repeated on just the subset of those firms observed entering into a deal. This analysis includes dummies for the stage of commercialization of the product at the time of signing, and interaction effects with the two primary explanatory variables. Column (1) shows that the effect of filed patent rights on the hazard rate is the same as in the previous results, but the effect of the share of patents that have issued, although negative, is not significant. These effects persist when the stage dummies and interactions are added in columns (2) to (5). The weaker effect might be due to either the reduction in sample size or the fact that all comparisons are now against firms that eventually sign an alliance.

[23] Since the count of filed patents by this measure begins from the priority date, it is arguably a more accurate measure of the number of filed patents that the firm had at that particular point in time. However, because the time from filing to issue includes continuations and divisions, the share of the patents that have issued may to some extent reflect the tendency to pursue continuations.

Table 4: Effect of biotech firm's patent rights on hazard of first pharma deal (base-line analysis)

Dependent variable: Hazard of first pharma deal

	(1)	(2)	(3)	(4)
Panel A: Counting filed patents from date on issued patent				
Number of filed patents (log)	0.302	0.182	0.240	0.242
	(0.051)***	(0.079)**	(0.081)***	(0.081)***
Biotech has any filed patents (dummy)		0.354	0.459	0.444
		(0.167)**	(0.168)***	(0.169)***
Share of filed patents that have issued			-0.755	-0.813
			(0.237)***	(0.242)***
Year fixed effects	N	N	N	Y
Observations (year-month)	51980	51980	51980	51980
Psuedo R^2	0.01	0.01	0.01	0.02
X^2	31.39	35.81	46.94	74.40
Number of firms	650	650	650	650
Number of firms entering deal	364	364	364	364
Panel B: Counting filed patents from first related patent application				
Number of filed patents (log)	0.491	0.662	0.706	0.620
	(0.121)***	(0.224)***	(0.221)***	(0.221)***
Biotech has any filed patents (dummy)		-0.308	-0.154	-0.206
		(0.351)	(0.350)	(0.353)
Share of filed patents that have issued			-0.685	-0.748
			(0.356)*	(0.360)**
Year fixed effects	N	N	N	Y
Observations (year-month)	27637	27637	27637	27637
Psuedo R^2	0.01	0.01	0.01	0.04
X^2	14.52	15.29	19.29	62.18
Number of firms	355	355	355	355
Number of firms entering deal	142	142	142	142

*Standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%*

Notes:
1. Counting patent rights from application date listed on the patent that issues.
2. Counting patent rights from first related patent application (from patent case history).

Table 5: Effect of biotech firm's patent rights on hazard of first pharma deal (using weighted counts)

Dependent variable: Hazard of first pharma deal

	(1)	(2)	(3)	(4)
Panel A: Patents weighted by Lanjouw-Schankerman quality measure[1,2]				
Number of filed patents (log)[3]	0.122	0.055	0.120	0.146
	(0.028)***	(0.073)	(0.074)	(0.073)**
Biotech has any filed patents (dummy)		0.296	0.281	0.281
		(0.292)	(0.288)	(0.284)
Share of filed patents that have issued			-0.052	-0.060
			(0.017)***	(0.017)***
Year fixed effects	N	N	N	Y
Observations	51980	51980	51980	51980
Psuedo R^2	0.00	0.00	0.01	0.02
X^2	18.19	19.20	31.43	67.92
Number of firms	650	650	650	650
Number of firms entering deal	364	364	364	364
Panel B: Patents weighted by number of forward citations[2]				
Number of filed patents (log)[3]	0.188	0.117	0.173	0.183
	(0.034)***	(0.058)**	(0.063)***	(0.063)***
Biotech has any filed patents (dummy)		0.293	0.265	0.262
		(0.190)	(0.191)	(0.190)
Share of filed patents that have issued			-0.097	-0.114
			(0.047)**	(0.049)**
Year fixed effects	N	N	N	Y
Observations	51980	51980	51980	51980
Psuedo R^2	0.01	0.01	0.01	0.02
X^2	28.40	30.72	36.08	67.42
Number of firms	650	650	650	650
Number of firms entering deal	364	364	364	364

*Standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%*

Notes:

1. Based on weighted sum of forward citations, backward citations, and claims, as described in Lanjouw & Schankerman (2004).
2. Count of forward citations includes only citations from patents that issue within 5 years of the original patent.
3. Counting patent rights from application date listed on the patent that issues.

Table 6: Interactions between patent rights and stage of commercialization of biotech's first pharma deal

Dependent variable: Hazard of first pharma deal

	(1)	(2)	(3)	(4)	(5)
Number of filed patents (log)[1]	0.374	0.407	0.404	0.398	0.387
	(0.077)***	(0.077)***	(0.077)***	(0.076)***	(0.085)***
Share of filed patents that have issued[1]	-0.021	-0.025	-0.031	-0.027	-0.387
	(0.288)	(0.288)	(0.284)	(0.285)	(0.343)
Stage of commercialization at signing = Lead Molecule[2] (dummy)		0.160	0.046		
		(0.185)	(0.157)		
Stage of commercialization at signing = Preclinical[2] (dummy)		-0.136			
		(0.238)			
Stage of commercialization at signing = Phase I[2] (dummy)		-0.437	-0.580	-0.548	-0.935
		(0.303)	(0.188)***	(0.173)***	(0.279)***
Stage of commercialization at signing = Phase II[2] (dummy)		-0.674			
		(0.260)***			
Stage of commercialization at signing = Phase III[2] (dummy)		-0.491			
		(0.389)			
Stage of comm. at signing = BLA/NDA Filed[2] (dummy)		-1.038			
		(1.007)			
Stage of commercialization at signing = Approved[2] (dummy)		-0.123	-0.123		
		(0.458)	(0.458)		
(Stage = Phase I - Approved)[2] x (Number of filed patents, log)[1]					0.052
					(0.188)
(Stage = Phase I - Approved)[2] x (Share of filed patents that issued)[1]					1.659
					(0.636)***
Observations	14003	14003	14003	14003	14003
Psuedo R^2	0.01	0.02	0.02	0.02	0.02
X^2	25.41	39.38	37.50	36.60	45.42
Number of firms	241	241	241	241	241
Number of firms entering deal	241	241	241	241	241

*Standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%*

Notes:
1. Counting patent rights from application date listed on the patent that issues.
2. Based on stage of commercialization of the alliance product at time the deal is signed.

Column (2) shows the analysis with dummies added for the eight stages of commercialization of the biotech's product at the time it enters the alliance. The omitted variable is the dummy for the "Discovery" stage. Columns (3) and (4) show the same analysis but with the stage variable grouped into four and two categories respectively.[24] Columns (2) to (4) show that, in general, the further along the commercialization process that the product is at the time the biotech firm enters into its first deal, the lower the hazard rate; that is, the longer it takes the biotech firm to sign its first deal with a pharmaceutical firm.

More interesting is the relationship between the effects of filed patents and the clinical-stage dummy on the hazard rate, shown in Column (5). We would expect that the effect of patents on licensing to be weaker at later stages in the commercialization process. This is because once a product reaches clinical trials the primary patent rights on the invention have long since been filed, so a marginal increase in the number of patent rights will not greatly affect the risk of expropriation. At the same time, since the technological risk has largely been resolved, financial investors will be more interested in signals of the product's likely progress through clinical trials and will not put as much value on patent rights. Filing additional patent applications may enhance market exclusivity if they 'tighten the net' around the technology or extend the length of patent protection if the new patents claim an improvement over the original one. However, by entering into the alliance before these additional patent applications are filed, the pharmaceutical firm can get directly involved in patent prosecution process and hence increase the likelihood of that happening. Hence, overall we would expect the effect of patent filing on the hazard rate to be lower for deals signed once the product has reached the clinical stage – that is, we would expect the interaction effect between the number of patent rights and the clinical-stage dummy to be negative. Similarly we would expect the effect of patent issue to be less negative (or more positive) – that is, the interaction effect with the clinical-stage dummy would be positive.

[24] In Column (3) the four categories are Discovery, Lead Molecule or Preclinical, Phase I to BLA/NDA filing, and Approved. In Column (4) the categories are Discovery to Preclinical and Phase I to Approved. The omitted variable is Column (3) is the dummy for the "Discovery" stage and in Column (4) is the dummy for Discovery to Preclinical.

The interaction effect between the number of filed patents and the clinical-stage dummy shown in column (5) is not significant. However, the interaction effect between the clinical-stage dummy and the share of issued patents is positive and significant, as predicted. This means that the share of patents that have issued is significantly more positive at the clinical stages. Obversely, the share of patents that have issued is significantly more negative at the pre-clinical stages.

5. Discussion

The result that, in general, the possession of more filed patents is correlated with a greater likelihood of the firm entering a technology commercialization deal is consistent with the Merges (2005) hypothesis that IP rights facilitate transacting, and adds a temporal perspective to the more general notions in Teece (1986) and Arora *et al.* (2001) that stronger IP protection means an innovating firm is more likely to license its innovation to an owner of the complementary assets. However, since both the number of filed patents and the likelihood of entering into a deal are correlated with improvements in the underlying technology, and the strength of the underlying technology is omitted from this analysis, it is not possible to draw any definite conclusions from this result about whether it is improvements in IP protection per se or in the technology itself that is drives the changes in commercialization strategy.

The additional finding that the hazard of licensing *decreases* with the share of patents that have issued is less intuitive, and potentially more significant. It suggests that the *nature* of the IP rights moderates the relationship between IP protection and technology commercialization strategy. While *more* IP rights on an invention may unambiguously increase the likelihood of licensing, *stronger* IP rights – that is, those which give a definite right to sue – can in fact delay licensing.

Taken together, these findings suggest a way to reconcile the conflicting predictions raised in the prior literature and developed in section 3 about the effect of patent rights – or IP protection more generally – on licensing vs. third-party financing. Filing an additional patent application appears to have the effect – predicted in the prior literature – of mitigating the innovating firm's risk of expropriation and alleviating the partner's concerns about market exclusivity for the final product. Filing an additional patent application may also strengthen the innovating firm's

position in obtaining outside financing, but that effect appears to be dominated by the effect on the relationship with an alliance partner. However, the effect of patent issue on licensing is not so clear. The empirical analysis does not provide the evidence to be certain, but patent issue may have a stronger effect on the relationship with outside investors than with alliance partners, and hence may reduce the innovating firm's urgency of entering into an alliance.

This interpretation accords with what we know about the different capabilities of pharmaceutical firms (on the one hand) and purely financial investors (on the other) with respect to the financing of technology commercialization. An incumbent product firm's technological expertise, combined with the ability to examine the patent filings closely during the due diligence process, means that it has both the sophistication and the information to judge the significance of an invention and the strength of IP protection based on a simple application. By contrast, outside financial investors, especially public equity investors, generally lack the information and the sophistication to evaluate the value of an invention for themselves. Hence, they rely to a much greater extent on objective signals such as the determination of the patent office, and so place much greater weight on issued patents.

Nevertheless, this interpretation is subject to several caveats. Firstly, I attribute the decrease in the hazard of licensing after a patent issues to the effect on the firm's ability to raise finance from third-party investors but I do not test this assumption directly. In ongoing work I combine the licensing data with third-party financing data (from the Recap and VentureXpert), which enables me to examine the competing effects of patent rights on licensing and third-party financing directly. Preliminary results show – consistent with Hsu & Ziedonis (2008) and Haessler et al. (2011) – that an increase in patent application stock increases the hazard of financing, while patent issue has a negative effect. Nevertheless, the effect of patent applications and patent issue on licensing is more positive and more negative, which is consistent with this explanation.

Secondly, the finding – and the interpretation that I given to it – about the differential role of filed and issued patents is likely to be industry-specific. While patent rights are generally considered a fairly effective means of protecting intellectual property in the biopharmaceutical industry, they are a less effective mechanism in other technology-based industries such as software and semiconductors (Cohen *et al.*, 2000). We also know that firms in the

biopharmaceutical industry typically have fewer patents (Mann *et al.*, 2007), and these patents are more likely to be taken at their face value – that is, other firms are more likely to accept them as valid without the holder establishing in a court (Lemley, 2008) – than firms in those other industries. Hence, while pharmaceutical firms and outside investors may be willing to transact with biotech firms upon patent filing and patent issue (respectively), their counterparts in other industries may require other assurances about the start-up technology-based firm's IP protection.

Furthermore, the primary role of the alliance with an incumbent product firm in commercialization strategy is somewhat unique to the biopharmaceutical industry. Start-up firms in the software or semiconductor industries are more likely to commercialize their technology alone – albeit with the assistance of other financial investors – or alternatively to sell out entirely to an incumbent firm. Hence, although firms in these other industries do enter into alliances, the timing of the alliance may not be such a critical issue and may also be less dependent on the level of IP protection.

In conclusion, this paper has shown that the nature of IP rights appears to have a significant effect on the timing of licensing: while filing a patent increases the likelihood of licensing (and so accelerates licensing), the issue of that patent appears to decrease it (i.e., delays licensing). It attributes this result to the different types of assurances that IP protection provides to incumbent product firms (on the one hand) and purely financial investors (on the other) before they are willing to transact with a biotech firm.

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