# The effect of patent protection on the timing of alliance entry

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This paper analyzes how a start-up biotech firm's patent rights affect if and when it enters into an alliance with a pharmaceutical firm. The existing literature presents conflicting predictions of how obtaining patent rights affects alliance entry. The literature on markets for technology argues that obtaining patents increases the firm's protection during pre-contractual negotiations, hence increasing the likelihood of alliance entry. However, research in finance suggests that obtaining patents also increases the ability to access outside funding, which in turn enables the firm to delay entry into an alliance with a pharmaceutical firm. Using a dataset comprising information on 650 U.S. biotech firms founded over the period 1976-2002, I estimate the effect of a firm's patent protection on the hazard of it entering into an alliance with a pharmaceutical firm. I find that while the likelihood of a firm entering into an alliance increases with the firm's patent filings, it decreases as those patents issue. This result is robust to different methods of dating the patent filing, as well as to weighting the patent count by both the number of forward citations and a more general index of patent quality. This suggests that, while filing patents over the technology enables the biotech firm to transact with a pharmaceutical firm, the issue of those patents increases the biotech firm's outside options and hence enables it to delay the timing of alliance entry until the optimal stage in the commercialization process.

Keywords: patents, intellectual property, alliances, biotechnology, R&D finance.



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## 1. Introduction

The importance of patent protection for profiting from innovation in the biopharmaceutical industry is well established. Evidence from the Carnegie-Mellon survey (Cohen, Nelson, & Walsh, 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. However, the effect of patent protection on the commercialization strategy of start-up biotech firms, and in particular the timing of alliance entry, is less clear.

The choice of timing for entering into an alliance is critical for the biotech firm to maximize the returns it captures from its innovation. Since an established pharmaceutical firm supplies the funding necessary to get the product to market, delaying alliance entry may mean the biotech firm runs out of cash to maintain development and thereby misses a potential market opportunity. Moreover, since the pharmaceutical firm can also offer expert advice on how to advance the product through development process, the sooner the biotech firm enters an alliance, the easier will be the path to market. Nevertheless, to induce the pharmaceutical firm to enter into the alliance, the biotech firm must give up a share of the expected returns from the innovation and compensate the pharmaceutical firm for the risk that the product will never get to market. If the biotech firm is better able (or more willing) to bear the technological risk, it may be able to capture a larger share of the returns by delaying alliance entry. Hence there are also advantages to waiting, and the timing of alliance entry involves a strategic trade-off between these offsetting factors.

The biotech firm's patent protection over its technology impacts the timing of entry into an alliance to commercialize that technology. On the one hand, pharmaceutical firms typically refuse to enter an alliance until the biotech firm

has established a "clean and unencumbered" patent position that will translate into exclusivity on the pharmaceutical product market. At the same time, since patent rights give the biotech firm protection against expropriation by the pharmaceutical firm during pre-contractual negotiations (Merges, 2005), obtaining patent protection may facilitate transacting (Gans, Hsu, & Stern, 2006) and hence potentially increase the likelihood that the firms will enter into an alliance. Nevertheless, patent rights also provide a positive signal of the technology's value to third parties, increasing the biotech firm's ability to raise funding from other financial investors (Hsu & Ziedonis, 2007; Mann & Sager, 2007), and hence reducing the urgency for the biotech firm to enter into an alliance with a pharmaceutical firm. Therefore, obtaining patent protection may at the same time both accelerate and delay the biotech firm's entry into an alliance.

In this paper I seek to distinguish between these two conflicting effects, taking advantage of the difference between filed and issued patents. I present an empirical analysis of the entry timing that draws on a unique dataset of patenting and licensing information from 650 start-up biotech firms founded in the United States between 1976 & 2002. The dataset combines information from the Recombinant Capital database and the NBER patent file (Hall, Jaffe, & Trajtenberg, 2001), as well as data from my own internet research. In order to measure the effect of the biotech firm's patent rights on entry into its first deal with a pharmaceutical firm, I estimate a proportional hazards model with time-varying covariates (Wooldridge, 2001). The results show that the likelihood of a start-up biotech firm entering into its first alliance at a particular point in time (i.e., the hazard rate) is positively correlated with the number of filed patents but negatively correlated with the proportion of those patents that have issued.[1] This result is robust to different methods of dating the patent filing, as well as to weighting the patent count by either the number of forward citations the patent receives within 5 years of issue or the more general patent quality index developed by Lanjouw & Schankerman (2004). When the analysis is limited to the subset of firms that entered into an alliance during the observation period, the

effect of patent issue on the hazard rate – although still negative – is not significant. Nevertheless, the effect of patent issue is significantly *more* negative for those firms that enter into a deal in the pre-clinical stages of commercialization.

The results of this analysis indicate that patent filing and patent issue have very different implications for biotech commercialization strategy. Patent filing unambiguously increases the likelihood of the biotech firm entering into an alliance. This suggests that while filing a patent application gives the biotech and pharmaceutical firms the assurances necessary to transact over the technology, it does not significantly affect the biotech firm's other options, in particular its ability to raise money on financial markets. By contrast, as patents issue the likelihood of the biotech firm entering into an alliance decreases, thereby delaying the biotech firm's entry into an alliance. The most likely explanation for this result is that patent issue increases the willingness of outside investors to finance independent development of the technology, and thereby enables it to delay entry until the optimum stage in the commercialization process.

The next section of this paper presents a brief review of the prior, related literature. Section 3 discusses several different ways in which patent protection affects commercialization strategy. Section 4 sets out the empirical analysis of the relationship between a start-up biotech firm's patent protection and the timing of entry into its first alliance with an established pharmaceutical firm. Section 5 discusses the results and concludes.

## 2. Literature review

Much of the prior empirical research involving patents treats patent rights merely as a proxy for technology (i.e., patent stock) or innovation (i.e., as a flow); see, for instance, Hall, Jaffe, & Trajtenberg (2005). However, recent literature has focused on the role that patent rights themselves play in firm strategy. Gans, Hsu & Stern (2007) used a very similar empirical set-up to that used in this paper (i.e.,

estimating the hazard of a firm licensing its technology) to examine how patent issue affects transactions in the market for technology. They found that the likelihood of licensing a technology increases dramatically immediately after the patent issues (relative to the period shortly before), suggesting that patent issue significantly affects the willingness of firms to transact over the technology. However, in contrast to this paper, they only examined technologies which were already covered by a patent application and focused on what they identified as the primary patent protecting that technology. This paper looks more generally at the effect of patent protection on the timing of alliance entry, and aggregates across all assigned patents in the firm's portfolio.

Other researchers have studied the effect of obtaining patent rights on the ability to raise finance for firms in other industries. 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. However, neither paper distinguished the effect of higher patent stock from the effect of a stronger technological position (which is highly correlated with patent stock) so do not show how the patent rights *themselves* affect the ability to raise venture capital financing. Moreover, since alliance relationships are not a significant alternative source of finance in the software and semi-conductor industries, neither paper considers how patent rights affect the trade-off between obtaining financing through an alliance and either issuing stock or obtaining venture capital finance.

Another line of literature has directly examined the trade-off that biotech firms make between alliance financing and other sources. Majewski (1998) examined the effect of asymmetric information on this trade-off, and 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 the prior literature by examining how the level of the biotech firm's patent protection affects the trade-off between these alternative sources of finance.

## 3. Theoretical analysis

Obtaining patent protection provides at least three distinct benefits for biotech firms attempting to commercialize an innovation through an alliance:[2]

1. It provides the biotech firm with some protection against expropriation when revealing its technology to potential partners in pre-contractual negotiations.
2. It provides some assurance that the drug generated from the patented invention will have exclusivity on the pharmaceutical product market.
3. It signals the novelty and usefulness, and hence – in principle – the commercial value, of the underlying technology.

The following sections describe these benefits in more detail.

### 3.1.Protecting against expropriation by an alliance partner

Revealing its technology to another firm during the pre-alliance negotiations exposes the biotech firm to the risk that its partner may expropriate the invention and use it outside the alliance without paying proper compensation. In principle, the biotech firm could prevent expropriation by making its partner agree contractually not use the technology without permission. However, the amorphous nature of knowledge makes it difficult to delineate the biotech firm's invention from the pre-existing technology, so it is often difficult to write a 'complete' contract that protects the invention entirely (Williamson, 1991).

Moreover, a prospective partner may refuse to enter such agreement because of the risk that the biotech firm will use it stop the partner from subsequently bringing *any* related product to market, whether or not the product relied on the biotech firm's technology.[3] For these reasons a biotech firm often must reveal its innovation to a potential partner even before it can rely on contractual protection (Arrow, 1962).

Merges (2005) describes two important roles that patent protection – or property rights more generally – play in facilitating contracting. Firstly, patent rights protect sensitive information that needs to be disclosed during pre-contractual negotiations. Secondly, patent rights give the owner an alternative set of remedies against infringement that are both more flexible and longer lived than contractual remedies. Hence obtaining patent protection gives the biotech firm better protection over its technology from expropriation by an alliance partner.

### 3.2.Providing exclusivity on the final product market

For pharmaceutical firms attempting to commercialize a new product, obtaining market exclusivity is a primary objective. The enormous costs of taking a pharmaceutical product through clinical trials mean that the firm needs to earn economic rents from sale of the product just to break even. The grant of a patent gives the owner the right to prevent or exclude others from making, using, or selling the claimed invention.[4]

Obtaining a patent on a technological invention, however, does not translate directly into exclusivity on the final product market. The relationship between patent rights and product exclusivity depends on the validity of the patent, the ease of enforcing the patent on alleged infringers, how closely the claimed invention maps onto the final product, and (obversely) how difficult it is for rivals to invent around. In many industries the invention described in a patent bears only a loose relationship to the final product (or a component of that product), so patent rights provide only limited protection against expropriation. Instead

inventors must rely on a range of alternative appropriation mechanisms such as secrecy and lead time on competitors to capture the returns when commercializing an invention (Cohen et al., 2000; Levin, Klevorick, Nelson, & Winter, 1987; Teece, 1986). In the life sciences, by contrast, 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. Hence, patent rights provide one of the primary means for obtaining exclusivity in this industry (Cohen et al., 2000).

### 3.3. Signaling the potential value of the firm's underlying technology to financial investors

Regardless of the actual legal protection provided by patent rights, the issue of patent rights also provides a clear signal as to the novelty and usefulness – and hence, potentially, the underlying commercial value – of the firm's technology. While potential alliance partners (or acquirers) can examine the technology in detail during the due diligence process, market analysts and other financial investors only have access to limited publicly available information such annual reports, press releases, and scientific publications. Moreover, even if they were privy to the private information disclosed during due diligence, market analysts and pure financial investors are poorly placed to evaluate the novelty and usefulness of a particular invention as against other technology in the field. Hence, the independent assessment of the patent office on a clear – if arguably weak – standard of novelty, usefulness, and non-obviousness provides a demonstrable signal as to the technology's value.

## 4. Econometric analysis

The key finding from a set of interviews with biotech and pharmaceutical firm executives reported elsewhere (Wakeman, 2007) is that the primary effect of

obtaining patent protection on alliance strategy is likely to be on the "if and when" a biotech firm *enters* a technology commercialization alliance, as opposed to the details of the alliance structure. This section describes an empirical analysis designed to identify the relationship between the biotech firm's patent protection and the timing of alliance entry.

### 4.1.Data sources

In order to analyze the effect of obtaining patent protection on alliance entry, 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 three sources.

The data on the alliances (and the base set of the firms used in this analysis) comes from the database compiled by Recombinant Capital ("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.[5] The second source is the NBER patent file, compiled by Bronwyn Hall, Adam Jaffe, and Manuel 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.[6] I have supplemented this with the 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. This allows me to trace back to the date of first related patent application.

The third source is the Corp Tech database. Corp Tech compiles the results of a continuous census of all U.S. technology organizations, primarily for the purpose of generating mailing lists of technology companies for direct marketing firms. Most useful for this analysis, it also records the year in which the organization was founded.

### 4.2.Construction of the dataset

I defined the universe of firms for this analysis to be the set of "Biotech" firms contained in the Recap database.[7] 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.[8] 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[9] that involved the transfer (either sale or license) of an intellectual property asset.[10]

I used name matching to link each of the firms in the Recap dataset to its 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.

I then used name matching to match each firm to the corresponding record in the Corp Tech database. Where there was a match, I used the information on the year of founding recorded in the Corp Tech database. Otherwise I performed a Google search 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 | |

## 4.3.Empirical methodology

### 4.3.1. Econometric specification

My 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 alliance entry.

To overcome these limitations, I instead estimate a Cox proportional hazards model with time-varying covariates (Wooldridge, 2001). 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 variable: Strength of biotech firm's patent protection

To measure the strength of patent protection over its technology, I count 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,[11] 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 information on the Micropatent CDs. I use this date to create my 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.[12] 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 from the patent's case history[13] and use the original filing date to create a second measure of the filed patents.[14]

### 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 & Pakes, 1986), patent citations (Hall et al., 2005; Trajtenberg, 1990), claims (Tong & Frame, 1994), family size (Lanjouw, Pakes, & Putnam, 1998; Putnam, 1996),[15] forward patent citations, and whether the patent was litigated (Allison, Lemley, Moore, & Trunkey, 2004). However, Lanjouw & Schankerman (2004) 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 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, Narin, Scherer, & Vopel, 1999), the probability of litigation (Allison et al., 2004), the likelihood of opposition (Harhoff & Reitzig, 2004), and the market value of the firm (Hall et al., 2005).

### 4.4.4. Further 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.

#### *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.[16] 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,[17] 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.

#### *4.4.4.3. Assigned patents that are not related to the deal*

Thirdly, the patents assigned to the biotech firm may include patents that are not related to the technology in the alliance.[18] Since the analysis is focused on start-up firms, 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.

### 4.4.5. 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.[19]

**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".

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.

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 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).[20] 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 collinearity between the two variables at early stages of the firm's life.[21] 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.

**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.

### 4.5.Results

Table 4 presents the results of the base-line 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 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.[22]

**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 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.

**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 | | | |
| | | (0.303) | | | |
| Stage of commercialization at signing = Phase II[2] (dummy) | | -0.674 | -0.580 | | |
| | | (0.260)*** | (0.188)*** | | |
| Stage of commercialization at signing = Phase III[2] (dummy) | | -0.491 | | -0.548 | -0.935 |
| | | (0.389) | | (0.173)*** | (0.279)*** |
| 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.[23] 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 alliance entry 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.

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 patent rights facilitate transactions, as well as with more general notions in Teece (1986) and Cohen et al. (2000) about the importance of patent rights for appropriating returns in this industry. Nevertheless, 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 last variable is omitted from this analysis, it is not possible to draw any definite conclusions from this result about the effect of patent rights *per se*.

The finding that the hazard rate decreases with the share of patents that have issued is more interesting, and potentially more substantial. This finding suggests that patent filing and patent issue impact the biotech firm's strategy in different ways – patent filing makes the firm more likely to enter into a deal, while patent issue decreases it. It also provides a way to reconcile the conflicting predictions in section 2. That section argued that, since patent rights mitigate the biotech firm's risk of expropriation and increase the chance of achieving market exclusivity for the final product, obtaining patent rights increases the likelihood that the firm will

enter an alliance. However, since obtaining patent rights signals the value of the firm's underlying technology to financial investors, making them more willing to finance independent development by the biotech firm, it may reduce the biotech firm's urgency of entering into an alliance.

The result that patent filing increases the likelihood of entering into an alliance suggests that patent filing enables the firms to transact. Hence filing a patent must be sufficient to provide the biotech firm with some assurance against expropriation and to reassure a prospective partner that the product will have some exclusivity on the market. However, the result that the hazard rate decreases as those patents issue suggests that the biotech firm does not acquire the ability to delay alliance entry until patent issue. Therefore it appears that outside investors are unwilling to finance the biotech firm to develop the technology alone until they see issued patents.

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. A pharmaceutical 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 for itself whether the patent is likely to be issued. Hence pharmaceutical firms are willing to enter into alliances and invest in the technology at earlier stages in the commercialization process. By contrast, purely 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 than filed patents.

Nevertheless, this interpretation is subject to several caveats. Firstly, I assume that the reason a biotech firm is more likely to delay alliance entry after patent issue is

because it is better able to raise finance from outside investors (i.e., other than from pharmaceutical firms). However, I have not tested this assumption directly. Although such a test is beyond the scope of this paper, it would be helpful to clarify what is causing the reduction in the hazard rate. It may be possible to test this relationship by regressing the biotech firm's financing history on its patenting history in a manner similar to Mann & Sager (2007).

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. We know that 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, 2007) – 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 firm's intellectual property protection.

Furthermore, the primary of the technology commercialization alliance in commercialization strategy is unique to the biopharmaceutical industry. Start-up firms in the software or semiconductor industries are more likely to commercialize their technology alone (i.e., partnering only with purely financial investors) or alternatively to sell out entirely to an established 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 intellectual property protection.

In conclusion, this paper has shown that patent filing and patent issue have opposite effects on the timing of alliance entry: while filing patents increases the likelihood of alliance entry (and so brings forward the date of entry), the issue of those patents decreases it (i.e., delays entry). I attribute this result to the different types of assurances that intellectual property protection provides to pharmaceutical 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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[1] Since the NBER file only includes information on issued patents, the count of filed patents that the firm had at any point in time only includes patents that were eventually issued.

[2] I define *stronger* patent rights over a technology to mean that there are patent rights covering the technology, as against the situation when the same technology is not protected by patents, or when the technology is covered by more patents, as against the situation when it is protected by fewer patents. By contrast, other researchers and commentators often refer to stronger patent rights when the whole regime of patent protection is stronger (e.g., when the definition of 'patentable subject matter' is extended).

[3] The interviews, discussed in Wakeman (2007), revealed that this is a reason why pharmaceutical firms will not sign a non-disclosure agreement, at least until they are convinced that the technology is novel and interesting.

[4] Patent law distinguishes between "design", "plant", and "utility" patents, but by far the largest category of patents – and the category into which most biotech innovations fall – 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).

[5] 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.

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

[7] Recap identifies each firm as "Biotech, "Device", or "Pharma", although for a number of firms the firm type is not identified. I rely on Recombinant Capital's classification of firms into biotech and pharma. I define a mature biotech firm as a firm that has done at least 10 alliances and has done more alliances as a licensee than as a licensor. Under these criteria, Genentech and Amgen switched from being a start-up technology firm to an established product firm in 1995, and Genzyme in 1996.

[8] 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.

[9] 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.

[10] 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 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).

[11] 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).

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

[13] 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.

[14] 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.

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

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

[17] 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 & Ziedonis, 2006).

[18] 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 (2006) 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.

[19] 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.

[20] 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.

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

[22] 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.

[23] 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.