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HOW DOES OBTAINING INTELLECTUAL PROPERTY RIGHTS IMPACT TECHNOLOGY COMMERCIALIZATION STRATEGY FOR START-UP INNOVATORS?

RECONCILING THE EFFECTS ON LICENSING VS. FINANCING

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Abstract

How does obtaining intellectual property rights impact technology commercialization strategy for start-up innovators? Reconciling the effects on licensing vs. financing[+]

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The importance of intellectual property (IP) rights for commercializing innovation is well established. Moreover, separate streams of literature have shown a positive relationship between IP rights and both product licensing and third-party (especially VC) financing. However, since raising third-party finance enables an innovating firm to continue commercializing its innovation alone, it is not clear how obtaining IP rights will impact the choice between licensing product rights and continuing to commercialize the product alone. This paper attempts to reconcile these two alternative effects of obtaining IP rights and the implications for commercialization strategy. The paper empirically examines the relationship between the status of the primary patent covering an innovation and whether the innovating firm's licenses its innovation or raises external finance. The results show that while filing and allowance of the primary significantly increases the likelihood of raising finance at certain stages of the firm/product's development, and thereby enable the firm to delay licensing, obtaining patent rights has a much larger, positive effect on licensing. While it is not possible to identify the drivers of these different effects from the empirical analysis, the theory suggests that patent filing may act as a signal to financial investors that enable early-stage firms to raise finance, but ultimately they are most valuable as appropriability mechanisms for facilitating financing.

Keywords: intellectual property, licensing, financing, innovation, strategy

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1. Introduction

The benefits of obtaining intellectual property (IP) rights for firms seeking to commercialize an innovation are well established (Levin *et al.*, 1987; Dechenaux *et al.*, 2008; Webster *et al.*, 2011). Moreover, separate streams of literature have shown a positive relationship between obtaining IP rights and both product licensing and third-party financing. The literature on markets for technology (Arora *et al.*, 2001; Gans *et al.*, 2008) shows that stronger IP protection facilitates licensing. At the same time, research on entrepreneurial finance (Mann *et al.*, 2007; Haeussler *et al.*, 2011; Hsu *et al.*, 2011) has demonstrated that obtaining more IP rights is correlated with an increase in raising finance on the capital markets. However, if the complementary assets required to commercialize the innovation are substantial, commercializing alone requires that the innovating firm must either finance the development from internal resources or – as is usually the case with start-up innovators – raise funds from third-party sources.[1] Hence, product licensing and raising third-party finance may be considered substitutes and it is not clear how obtaining IP rights will impact the choice between licensing product rights and continuing to commercialize the product alone.

This paper attempts to reconcile these two simultaneous effects of obtaining IP rights on the choice of commercialization mode. The paper empirically examines the relationship between the status of the primary patent covering an innovation and the innovating firm's choice between product licensing and third-party financing. The results show that while filing and allowance of the primary significantly increases the likelihood of raising finance at certain stages of the firm/product's development, and thereby enable the firm to delay licensing, obtaining patent rights has a much larger, positive effect on licensing. While it is not possible to identify the drivers of these different effects from the empirical analysis, the theory suggests that patent filing may act as a signal to financial investors that enable early-stage firms to raise finance, but ultimately they are most valuable as appropriability mechanisms for facilitating financing.

The next section of this paper relates the contribution of this paper to the prior literature. Section 2 discusses how obtaining IP rights 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 2.2 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.

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[1] Third-party financing means that from sources other than the innovator's internal resources and a licensee/contracting partner, including private (such as venture capital) and public investors.

2. IP rights and the choice of commercialization mode

2.1. 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 papers have developed this proposition and tested it empirically, showing that the choice of commercialization mode depends on the source 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).

Some more recent literature has analyzed how obtaining patent rights affects the choice of commercialization mode. Gans, Hsu & Stern (2008) examined the impact on licensing. They argued that by clarifying the uncertainty around IP protection patent grant significantly increases the willingness of firms to transact over the technology, and found evidence that the likelihood (or hazard) of licensing an innovation increases dramatically after the decision to allow a patent is notified. However, Gans, Hsu & Stern examined the effect of patent grant on licensing only for inventions for which a patent application had already been filed, for which the patent was ultimately allowed, and which were eventually licensed. Moreover, relying on license contracts that had been publicly disclosed implicitly restricted their sample to publicly listed firms. By contrast this paper analyzes the effect of both patent filing and patent grant on both licensing and raising finance, and regardless of whether the patent was eventually granted or whether the product was ultimately licensed. It also includes firms that are public and private, so generalizes the analysis to a wider range of financial conditions.

Several recent papers have studied the relationship between obtaining 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 (2011) performed a similar study for semiconductor 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) examined the relationship between patenting and VC financing in the biopharmaceutical industry, finding that the size of patent application stock is positively related to obtaining VC financing, but that patent grant does not have

any effect on obtaining finance. However, all of these papers used firm-level counts of patent rights so were unable to distinguish the effect of obtaining patent rights from the creation or development of a product.

Another line of literature has examined the choice that technology-based firms make between alliance and other, third-party financing. Majewski (1998) looked at how financial risk affects the choice between using alliance financing and raising equity, and found that firms with higher asystematic risk 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). Lerner, Shane & Tsai (2003) examined the effect of equity-market cycles on the structure of alliance relationships, and found that when equity markets are tighter, the biotech firm is more likely to enter an alliance arrangement with a pharmaceutical firm. Ozmel, Robinson, & Stuart (2012) looked at the relationship at how prior alliance and VC-fundraising activity impacted and future activity, and found that higher prior alliance activity meant future alliances were more likely, but future VC activity less likely, while higher prior VC activity was correlated with both higher future alliance activity and higher future VC activity. 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.

2.2. Commercialization strategy

Teece (1986) framed commercialization strategy in terms of how an innovating firm accesses the complementary assets necessary to commercialize the innovation, and characterized commercialization strategy as a choice as between (1) contracting with a firm that holds the requisite complementary assets and (2) integrating downstream to commercialize the innovation alone. He emphasized the role that the innovating firm's position with respect to the complementary assets and the strength of the appropriability 'regime' surrounding the innovation play in determining the optimal strategic choice.

2.2.1. Impact of financial constraints

When the complementary assets necessary to commercialize an innovation are substantial, the innovator firm's access to the financial resources may significantly impact its commercialization strategy. Using the "property rights" framework developed by Grossman & Hart (1986) and Hart & Moore (1990), Aghion & Tirole (1994) analyzed the allocation of property rights over an innovation under development. Under this framework, optimal efficiency occurs when the rights are allocated

to the party (i.e., either the innovating firm or the "customer") whose effort has the greater relative impact on development of innovation. Aghion & Tirole (1994) showed, however, that if the innovating firm is financially constrained then the rights may be allocated to the customer even when it would be optimal (in terms of efficiency) for the innovating firm to hold the rights.

According to this view, loosening the financial constraint simply enables the innovating firm to pursue self-commercialization when it is optimal to do so. However, although some large firms may be able to fund commercialization from internal resources, for many firms – and especially for start-up firms – those financial resources are more likely to come from third-party sources, through either a loan or selling equity. Hence licensing and raising finance from external investors may be alternative ways by which the innovating firm can finance the development of the innovation in order to bring it to market, and commercialization strategy becomes a choice between partnering with – or "licensing" to – an incumbent firm and raising external finance.

Moreover, raising finance is not costless to the innovating firms. Outside investors will demand a share of equity in return, diluting the profits that the firm's founders are able to capture for themselves, and often some control over firm decisions, both of which may detrimentally affect the innovating firm's incentives to further invest in development. (This is especially true when the licensing agreement to which it is compared contains some provisions for sharing risk and reward, such as a royalty share or even profit sharing.) Meanwhile, using internal resources has an opportunity cost in terms of the return on alternative uses to which the funds might be put.[2]

Several recent papers have examined factors that determine the choice between licensing (a.k.a. partnering) and third-party financing. As mentioned above, Majewski (1998) found that firms with higher asystematic risk and greater volatility in stock prices are more likely to choose an alliance partner, while Lerner, Shane & Tsai (2003) found that when equity markets are tighter, a biotech firm is more likely to enter an alliance arrangement with a pharmaceutical firm – albeit on less favorable terms. Ozmel, Robinson, & Stuart (2012) found that higher prior alliance activity meant future alliances were more likely, but future VC activity less likely, while higher prior VC activity was correlated with both higher future alliance activity and higher future VC activity.

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[2] An innovating firm's ability to raise finance will be a function of both firm-specific attributes, such as the promise of the firm's product portfolio, and industry-level issues, such as the state of the financial markets and/or the willingness of financiers to invest.

Nevertheless, the relationship between licensing and raising finance is complex. If licensing and raising finance are substitutes then a firm which raises finance is less likely to license in immediate period following raising finance; conversely a firm which licenses a product in its portfolio is less likely to need finance in the immediate future. However this may not be true at all stages in a product and/or innovating firm's development. At early stage in a product's development, before product rights have been clarified, a licensor may be reluctant because it will be difficult to protect and appropriate its share of the value. Similarly, any potential licensee may be unwilling because it is not clear what rights it is receiving. Hence, raising finance may be the only option. In this context raising finance may complement licensing the product rights because it funds additional development and thereby increases possibility of subsequent licensing. At the same time, entering a license for one product may signal the value of the firm's whole portfolio to outside investors, which then increases the ability to raise finance. This is especially likely to be true at early stages in a firm's development when the value of the firm's underlying technological portfolio is unclear. Hence in this context licensing may be a complement to financing.

2.2.2. The temporal dimension

In the framework used by Teece (1986) and others, the innovating firm's commercialization strategy is a one-off choice between the licensing and self-commercialization (or raising finance). However, when the commercialization process is lengthy, the timing of licensing and or raising finance may have a critical impact on the commercialization success and/or the innovating firm's ability to capture value from the innovation. Hence in this context the innovating firm's commercialization strategy may be a choice of not only if but also when to license the innovation and/or raise finance.

Several recent papers have examined factors that influence the timing of licensing. As mentioned above, Gans, Hsu & Stern (2008) examined the impact of patent grant on licensing, and found evidence that the hazard of licensing increases significantly in the period soon after a patent is allowed. Allain et al. (2011) argued that the likelihood of licensing increases over time as information about the innovation is revealed, and found evidence that nevertheless an increase in the number of firms competing to license the innovation means the innovation was more likely to be licensed at an earlier stage. Luo (2011) examined a situation in which not only the availability of information but also appropriability increases over time and, using data from the movie industry, found that under this scenario both low-quality and high-quality writers wait to license their idea until it is more developed.

The insights from Teece (1986) and Aghion & Tirole (1994) also extend to this temporal framework. As complementary assets become more important, Teece (1986) implies that the optimal point of licensing shifts earlier. Moreover, as the greater relative impact of the firm's contributions shifts from the innovating to the customer/owner of the complementary assets, the property rights framework would imply that the innovating firm becomes more likely to license at an earlier stage. Nevertheless, as the innovating firm acquires the complementary assets then the optimal point of licensing shifts later. Meanwhile, Aghion & Tirole's model would imply that in a temporal framework, a financially constrained innovation is likely to license earlier. As an innovating firm progresses through the commercialization process, typically the financial resources required to progress become greater and hence a financial constraint is likely to become more binding over time. For instance in the pharmaceutical industry, at early stages development requires relatively cheap laboratory work, the commercializing firm must conductive extensive clinical trials involving large numbers of human volunteers. If a financially constrained innovating firm is not able to compensate the "customer" for its contribution, it is forced to transfer the rights to the customer earlier in the process, even when it would be optimal for the innovating firm to retain the rights until a later stage.

2.3. The effect of obtaining IP rights

Having sketched a framework that takes into account financial constraints and the temporal dimension, we now consider how obtaining IP rights impacts the choice between product licensing and raising third-party finance. The most obvious benefit of obtaining IP rights comes from ensuring that whoever owns the rights holder will be able to appropriate the returns from the final product, and thereby increasing the value of the innovation and the incentive to bring it to market. Secondly, by giving the innovator protection against expropriation during pre-contractual negotiations, obtaining stronger IP protection may facilitate the innovator in revealing its innovation to potential partners and thereby obtaining access to the complementary assets required to bring it to market. IP protection also gives the innovating firm a mechanism to mitigate the risk of expropriation during a commercialization alliance, and hence encourages the innovating firm to enter the agreement. Finally, obtaining patent IP rights may provide a credible signal to others of the existence and value of the innovating firm's underlying invention. We discuss each of these in turn.

2.3.1. Ensuring appropriability of the final product

An innovator's ability to capture value from innovation to a large extent depends on its ability to prevent rivals from imitating the innovation and diverting customers away. However, in the case of a technological innovation, the inventor(s) must take active steps to protect to apply for a patent and

the right to exclude and the scope of protection only attaches once the patent has been granted by the appropriate authority (i.e., the patent office).

Moreover, obtaining patent protection does not necessarily imply product-market exclusivity. Appropriability depends on how well the patented aspects "map" onto the final product – in other words, how essential are the patented aspects are for achieving the function that the final product performs. An innovator can strengthen the appropriability 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.

Furthermore, even if the essential aspects of a product are covered by a set of patents, the patent holder must enforce its patent rights to obtain a remedy. Even if a granted patent covers a rival product, a court can invalidate the patent if it deems the claimed invention is not novel, useful, or non-obvious.[3] 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.*, 2004).

2.3.2. 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) pointed out 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.

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 (2005). However, property rights are "good against the world", covering use of the property by any party, whether or not there is a relationship

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[3] 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).

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. [4]

2.3.3. Mitigating contractual hazards within a contractual relationship

Even after an innovator has entered into a partnership to develop an innovation, the nature and strength of appropriability may impact the value that it can capture from the partnership. Stronger IP protection helps the innovating firm to mitigate the risk of expropriation inside a contractual arrangement. IP rights may provide a remedy even when a partner's behavior does not strictly infringe the contractual terms. 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 gain from terminating the contract and hence less incentive to act opportunistically. Moreover, IP rights may strengthen the owner's bargaining position in any renegotiation.

2.3.4. Signaling value to prospective licensees and third parties

Regardless of the actual legal protection provided by a patent, patent rights may also be valuable in signaling the value of an innovation or the innovating firm's portfolio more generally to venture capital firms and public equity investors (Long, 2002). Since it is impossible to completely determine the likelihood of commercial success for technological innovation, potential partners and financial

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[4] In theory, an innovator should 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 (i.e., entering a non-disclosure or confidentiality agreement). However, the difficulty in delineating what is covered by such an agreement makes it difficult to write a 'complete' contract that protects against expropriation entirely and this uncertainty means that prospective partners often refuse to enter such an agreement because of the risk that the innovating firm will use it opportunistically (Williamson, 1991).

[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.

investors must decide which projects to back under considerable uncertainty. In economic terms, they may suffer due both to incomplete information and to asymmetric information (vis-à-vis the innovating firm). Moreover, although they conduct due diligence before making an investment, they may not be able to rely on all the information they receive from the innovating firm because of the innovator's incentives to exaggerate.

One way to mitigate the lack of information about the likelihood of success is to use observable variables that are positively correlated with success. A patent application indicates the existence of an invention – potentially patentable subject matter – and, although the application is not independently verified, the significant cost of filing a patent application[6] indicates the inventor has sufficient confidence in the invention to be worth the expense. Meanwhile, the grant of a patent indicates that an independent authority – the relevant patent office – has validated the novelty, usefulness, and non-obviousness of the invention. Hence, patent rights – both patent applications and granted patents – may provide a reliable way for potential partners or investors to evaluate an innovating firm (Spence, 1973).

2.4. Discriminating between IP mechanisms

The previous discussion outlined how the different mechanisms by which obtaining IP rights act may impact the likelihood of licensing vis-à-vis raising external finance. One way to discriminate between these mechanisms is use the status of the underlying patent (i.e., whether a patent has been filed and whether that patent has been granted).

A patent right depends on the existence of a patentable invention. However, at least until recent changes in US patent law, an inventor has up to one year from when the invention is first disclosed publicly or offered for sale to file a patent application with the United States Patent & Trademark Office (USPTO), meaning that there may be a significant time period between the first patent filing where no patent application exists.[7] Moreover, once the patent has been filed the inventor (or his/her assignee) must then "prosecute" the patent through the patenting process in order to obtain

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[6] By one estimate, obtaining a patent on a complex invention costs in the order of $15,000 in the US alone (Quinn, 2011).
[7] Osenga (2009) elucidates: "The law does permit some sort of period prior to the one year grace period clock beginning for testing and making changes to the invention to determine whether it works for its intended purpose. In the context of offers for sale, the Supreme Court has stated that the clock begins to run once the invention is "ready for patenting", whatever that means. Finally, if third parties are subject to confidentiality or non-disclosure agreements, this should keep the clock from running because these are not "public" disclosures."

the legal right to prevent others from using the invention. From patent filing to grant usually takes at least 2 years, and frequently takes considerably longer, especially if the inventor uses continuations and divisions to extend the process (see Graham *et al.*, 2004, for a discussion of this).

The properties of the IP "right" changes as it passes through these different stages. Prior to patent filing, typically there is limited public information about the invention and although it may potentially be patentable there are certainly no legal rights to exclude.

Filing a patent application often provides earliest verifiable information about the invention, and implies the inventor and/or her assignee considers it sufficiently valuable to warrant the time and expense of a patent application. Hence patent filings are likely to be useful as signals.[8] However, a patent application entails no legal rights so on its own provides no assurance about appropriability.

The grant of the patent – or specifically the decision by that appropriate patent office to allow the patent – resolves much of the uncertainty about appropriability. Gans, Hsu & Stern (2008) highlighted three distinct types of uncertainty that are resolved by the grant of a patent:[9]

1. Patent grant uncertainty: whether the patent will actually be granted;
2. Patent scope uncertainty: the scope of the patent rights ultimately allowed and the claims that are (potentially) enforceable through litigation;
3. Patent pendency uncertainty: when the owner will actually be able to enforce its rights.

Therefore patent status may provide a way to discriminate between the different mechanisms discussed above. Changes that occur upon patent filing are more likely to be driven by the signaling value of patents. Meanwhile, changes that occur on patent grant are more likely to be driven an increase in appropriability.

2.5. The impact of obtaining IP rights on commercialization strategy

The mechanisms discussed above impact the likelihood of licensing and raising finance in different ways. By strengthening the appropriability of the final product, obtaining IP rights increases the potential value of the innovation and makes it more attractive to both potential licensees and

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[8] Both Haeussler, Harhoff & Mueller (2011) and Hsu & Ziedonis (2011) rely on patent filings (or in the latter case issued patent dated from filing) to analyze the signaling properties of patents.
[9] They also identified two types of uncertainty that remain unresolved even after the grant of a patent:
1. Patent enforcement uncertainty: whether a court will uphold the claims on the granted patent; and
2. Uncertainty over market value.

investors. It also strengthens the bargaining position of the innovating firm (and its owners), enabling it to drive a harder bargain, but – particularly in industries where the requisite complementary assets are significant – it does not change the need either to license the innovation to an established firm or to raise finance in order to continue with commercialization. Hence by strengthening appropriability of the final product obtaining IP rights is likely to increase the likelihood of both licensing and raising financing.

However, these different participants may seek different levels of certainty as to appropriability of the innovation. Because a licensee will usually be the one bringing the product to market, it may want certainty that it will be able to appropriate the innovation on the final product market. By contrast, since a purely financial investor will frequently exit earlier, it may be comfortable to trade on uncertain rights as long as there is sufficient probability of IP protection eventually. Moreover, since potential licensees are typically focused on only one or few inventions in the portfolio, they may seek clarity that the IP rights demarcate the invention not only from third party inventions but also from other inventions in the innovating firm's portfolio.

The benefits of IP protection for pre-contractual negotiations will also apply to both licensing and raising finance. Both potential licensees and potential investors will seek details about the innovation in order to be able to evaluate its potential success. However, since potential licensees are typically focused on only one or few inventions, while potential investors are evaluating the whole firm, licensees are likely to obtain more information about specific inventions and so IP protection may be more valuable in protecting against licensees. Similarly, the benefits of IP protection during a relationship will be more valuable against licensees than against investors because licensees are more likely to have access to the knowledge necessary to replicate the invention, while investors often remain at arm's length over decisions about progression any individual product.

On the flipside, while IP rights may signal value to both potential licensees and outside investors, they are likely to be more useful to outside investors because those investors are less likely to have the specific knowledge necessary to evaluate the invention themselves. Moreover, because they are evaluating the whole firm, rather than a specific invention, they will be able to conduct less detailed due diligence on any given product. Hence external signals will be more valuable in verify any claims the innovating firm makes about an invention.

Based on the preceding discussion I posit two hypotheses for how obtaining patent rights will impact the choice of commercialization mode:

Hypothesis 1: (a) Filing a patent application will increase the likelihood of both licensing product rights and raising finance. (b) The effect of filing a patent application will be greater on raising external finance (vs. licensing product).

Hypothesis 2: (a) Patent grant will increase the likelihood of both licensing product rights and raising finance. (b) The effect of filing a patent application will be greater on licensing product rights (vs. raising external finance).

3. Empirical analysis

3.1. The empirical context

To analyze the effect of obtaining IP protection on the choice of commercialization mode, I have constructed a dataset that contains complete product licensing, financing, and patenting history for 90 of the largest firms in the biopharmaceutical industry.[10] The biopharmaceutical industry is an especially appropriate setting for this study because the close relationship between a patentable invention (such as the composition of a chemical compound) and the resulting pharmaceutical product means that a patent right 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. Similarly, using evidence from renewal fees, Schankerman (1998) shows that firms in this industry firms value patents enough that they are willing to pay to maintain these patents for the full life of the patent. Therefore the level of patent protection may be considered a sufficient statistic for the level of IP protection more generally.

Moreover, in this industry start-up firms use a combination of raising finance on the external capital markets in order to fund self-commercialization and licensing the product rights to an established firm in order to bring an innovation to market.

3.2. Data sources

The data comes from several sources. The primary source is the RecapRx database, produced by Deloitte Recap ("Recap"), a San Francisco Bay Area-based consulting firm. This database contains the clinical development and licensing history by clinical indication of all products that at some point in

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[10] The biopharmaceutical industry is the industry that applies biological methods to research and develop pharmaceutical products.

their history belonged to one of the 146 largest biopharmaceutical firms. The data is organized by 'product-indication', meaning a specific indication developed for a given pharmaceutical product, and the full database contains information on approximately 2350 'product indications'.[11] Hereafter, unless otherwise noted, I refer to a product indication as a "product".

The RecapRx database also contains links to the press releases, reports of any clinical trials (from clinicaltrials.gov), and detailed individual records of the licensing transactions contained in Recap's rDNA database.[12] I used this information to trace the ownership of the territorial rights (i.e., the right to sell the product in a given territory) through all transfers to construct a complete history of which firm owned product rights to which territory at each point in time for each product.

I also used Recap's rDNA database to obtain information on all financing rounds for those firms for which it is available. Deloitte Recap collects the information on all financing rounds (including pre-IPO VC round, the IPO itself, and post-IPO secondary offerings) from SEC filings by all firms that filed to go public.[13]

Using the IMS Lifecycle R&D Focus database I obtained information on the primary US patent covering each product. To identify the primary patent covering the product I matched the names of the products in the RecapRx database to the same products in the R&D Focus database. The R&D Focus database contains information on the country, number, year, and type (composition of matter, method of use, etc.) for both the primary priority application and (if it exists) the primary issued patent for most products in the database.[14] If the issued patent is a US patent then I was able to read the patent information directly off the R&D Focus record. If not, I used the patent equivalents file compiled by Dietmar Harhoff[15] or alternatively the Derwent Innovations Index to identify the US equivalent (i.e., the US patent deriving from the same priority patent application as

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[11] Because of missing data for other variables, I am only able to analyze the commercialization of 330 product-indications developed by 90 of these firms.

[12] The complete rDNA database contains records of all publicly announced transactions in the biopharmaceutical industry from its inception in the 1970s through to the present day (currently over 35,000). Moreover, Recap has also collected the actual contracts that filed by the firms with the U.S. Securities and Exchange Commission (SEC) under the SEC's 'materiality' requirement (which is for approximately 40% of the total). However the data for this analysis relies just on the basic information on the transaction, which is available for all publicly announced transactions, whether or not the firm when public.

[13] This means that this information is available even if the firm subsequently withdrew its IPO and never went public.

[14] In some cases the IMS R&D Focus lists multiple primary patents (up to 4) for a single product, meaning that multiple aspects of the product (the composition of matter, the method of use, etc.) were protected. In this case I used the information for the primary patent with the earliest priority date, and if multiple patents claim the same priority date then the first patent that is allowed.

[15] See http://www.en.inno-tec.bwl.uni-muenchen.de/research/proj/patent-cit-project/index.html.

the listed patent). I then searched the USPTO's public PAIR (Patent Application Information Retrieval) database for each US patent number to obtain the date on which the patent was allowed (i.e., the date on which the USPTO mailed the "Notice of Allowance") and the priority date (i.e., either the patent's filing date if the patent was issued directly from the original application, or the filing date of the first parent application or the foreign priority application if the patent claims priority from a prior application). If I was not able to find a USPTO equivalent patent, I assumed that the patent had been filed but has not yet been issued in the US. In that case I used the date of the foreign patent application listed on the R&D Focus record as the priority date.

I used these and other databases to extract information necessary to build a number of control variables (described below). In particular, I used the NBER patent dataset to obtain the full portfolio of (issued) patents assigned to the firm by the U.S. Patent & Trademark Office (USPTO), originally compiled by Hall, Jaffe, and Trajtenberg (2001)and subsequently updated by numerous contributors for all patents until 2006.[16] To obtain the priority date for the NBER patents, I used information from PATSTAT and Micropatent.

3.3. Econometric approach

The objective of the empirical analysis is to estimate the effect of obtaining IP rights on an innovating firm's choice of commercialization mode. Following the framework in Teece (1986), in the baseline analysis I examine the effect of obtaining patent rights on the likelihood of licensing product rights at a given point in time relative to the counterfactual of retaining those rights inhouse.

$$Pr(licensing) = I(patent\ status)_{it} + X_{it} + e$$

where X_{it} is a vector of control variables.

The dependent variable for this analysis is an indicator of whether the firm licensed the rights to market the product in the US in the given month,[17] and the two primary explanatory variables [$I(patent\ status)_{it}$] are indicators of:

1. Whether the primary patent claims priority from a date before the given month; and
2. Whether the USPTO had mailed the "Notice of Allowance" for the patent before the given month.[18]

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[16] See https://sites.google.com/site/patentdataproject/Home.
[17] The variable is coded as one if the firm entered a licensing transaction in the month and zero otherwise.

Since the licensing analysis is focused on whether the biotech firm licenses rights to the specific product, I construct the dataset as a panel of monthly observations for each product owned by a biotech firm in the analysis. Since a firm can only license a product if it owns the rights, a product enters the dataset on the date on which the firm obtains the rights to the product, either the estimated date of invention or the date on which the firm obtains the rights from another firm (by licensing, acquisition, etc.), and exits the dataset on the date when the firm loses the rights, either by transferring them to another firm (through outlicensing, acquisition, or reversion to an earlier owner) or when the product is terminated.[19]

As discussed above, in an industry such as the biopharmaceutical industry, where complementary assets are important and the innovating firms are financially constrained, if the innovating firm does not license the rights then it will be obliged to raise finance on the external capital markets. Therefore I simultaneously estimate the effect of obtaining patent rights on the likelihood of raising finance:

$$\Pr(\text{financing}) = I(\text{patent status})_{it} + X_{it} + e$$

The dependent variable for this analysis is an indicator of whether the firm entered into a financing transaction (i.e., an agreement to sell a share of the firm's equity in exchange for a cash payment) in the given month,[20] and the primary explanatory variables are the same indicators as described above.

Since raising external finance is a firm-level decision the natural unit of analysis is the firm, and so in the first instance I structure the dataset as a panel of monthly observations for each firm and use aggregate measures of the firm's patents. However, this means that I have to disregard the detailed

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[18] Each variable is coded one if the patent claims priority/has been allowed before the given month and zero otherwise.

[19] There is no authoritative source for the date on which a product was invented or discovered. Instead, I estimate an "invention" date using information in the product history of each product contained in the R&D Focus and RecapRx records. Under patent law, the inventor (or his/her assignee) must file for a patent within a year of invention/discovery and priority starts from the date of filing. Therefore for all products for which I have determined the priority date, I assume that the patent was filed on the last day of that period (this is consistent with standard practice) and therefore I estimate that invention date is 365 days before the priority date. In some cases the product record actually lists the "discovery" – or invention – date. If not, I use the mean time from discovery to priority filing, or to entering preclinical trials, in the complete data to estimate the invention date for the remaining observations where this information is missing. Then, to prevent patent filing being collinear with product age (i.e., time since invention), I add to the invention date a random variable that is normally distributed with mean of zero and standard deviation of 3 months.

[20] As above, the variable is coded as one if the firm entered a financing transaction in the month and zero otherwise. However, if the firm raised finance as part of a licensing transaction then the transaction is coded only as a licensing transaction.

product-level information, including the status of the primary patent on a specific product. Therefore, as an alternative I structure the dataset as a panel of monthly observations for each product (as in the licensing analysis). Since a firm may raise finance at any point after founding, I allow each product enters the financing analysis starting from the beginning of the year in which the firm was founded until either the end of the observation period (December 2006) or when the firm is acquired or goes bankrupt,[21] and include an additional variable to indicate whether the firm actually had rights to the product.

To ensure that each firm is weighted equally, I weight each product-level observation by the inverse of the number of products that firm each firm owns. This implicitly assumes that the firm is raising finance to spread across all of its products equally.[22]

In the baseline analyses I estimate the effect of patent rights on licensing using first a logit model and then a Cox proportional hazard-rate model. The dataset used for the analysis is the same in both cases – that is, a panel of monthly observations with time-varying covariates. The advantage of the Cox hazard-rate model is that values of the different variables are compared relative to an underlying "baseline" hazard at the same point in time. In the hazard-rate analysis of licensing, I set the analysis time to product age (i.e., t=0 at the date of invention) while in the financing analysis I set analysis time equal to firm age.[23] By contrast, in the logit analysis the values of the different variables are compared relative to the average of all observations across time. Hence, to control for time-varying effects – and make the results from the different model specifications more comparable – I include product age (and product age squared) in the licensing analysis and firm age (and firm age squared) in the financing analysis.

3.4. Identification strategy

To identify the effect of obtaining IP rights on an innovating firm's choice of commercialization mode, it is necessary to account for other factors that may explain the observed relationship.

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[21] While it is natural that a product exits from the dataset once the firm has entered a product licensing agreement, entering into a financing agreement does not preclude entering into a subsequent financing agreement. Hence, I allow a product/firm to remain in the dataset after a financing event (i.e., in the hazard-rate model I allow for multiple failures).

[22] As an alternative I also conducted the analysis including only the data on the product owned by the biotech that is most advanced in the commercialization process (which I call the "lead product"). However, this analysis does not produce any significant results.

[23] As a robustness check, I have also estimated the licensing model with analysis time as firm age and the financing model with analysis time as product age. This does not make any qualitative changes to the results.

3.4.1. Correlation between licensing and financing events

The first potential identification concern arises because licensing and raising finance are correlated. As discussed above, at some times raising external finance may substitute for the need to license (and vice versa), while at other times (e.g., early in the firm and/or product's development) they may instead be complementary. As prior literature has shown, obtaining IP rights is likely to impact both the likelihood of licensing product rights and the likelihood of raising external finance. Hence, the baseline regressions described by (1) and (2) – which implicitly assume that these two events are uncorrelated – are likely to underestimate the effect of obtaining IP rights on licensing/raising finance when these licensing and raising finance are substitutes, and overestimate it when they are complementary.

A related issue is that licensing to different territories may also be correlated. Typically they are highly complementary: a firm will license rights to multiple territories in the one agreement or in a set of agreements signed around the same time. However, in some cases, they may substitute for one another: specifically, a firm may license rights to one territory in order to finance the commercialization of the product in another territory. Although IP rights obtained in one territory (particularly the US) do not give rights in other territories, they may be indicative of the IP rights obtained in other territories. Moreover, they may still have the same signaling benefits.

Although it is beyond the scope of this paper to directly examine the relationship between licensing and financing in detail,

Figure 1 presents some suggestive evidence about the correlation between these two events. Specifically, it contains two charts showing the coefficients from a series of regressions where the dependent variable is whether the biotech firm licensed/raised finance in a given month and the primary explanatory variable is an indicator of whether the firm raised finance/licensed product rights within the past n months (where n ranges from 1 to 12 along the X axis).[24] Each chart shows the results with and without controls (the latter is shown with a dotted line). Panel A shows that the hazard of licensing is lowest in the period immediately following raising a round of finance but rises back toward zero over the next 12 months. This is consistent with the argument that firms that raise finance have less need to license (i.e., they are substitutes). Meanwhile, Panel B shows that the hazard of raising finance is negative immediately following a licensing transaction but rises quickly and by the third month after licensing is back above zero. This pattern makes sense if one considers

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[24] The first variable indicates licensing/financing in the past 1 month, the second in the past 2 months, etc.

that licensing one product may have positive spillovers on the ability to raise finance for the firms residual products or the residual territories to the licensed product (i.e., licensing is to some extent complementary to raising finance).

I take account of the possible correlation between these different events in the estimation. In the first instance I estimate a multinomial logit model, where the alternative outcomes are:

1. the firm licensed the rights to market the product in the US in the given month;
2. the firm licensed the rights to a major territory other than the US (specifically Japan, German, France, and UK);
3. the firm entered into a financing transaction (i.e., to sell a share of the firm's equity in exchange for a cash payment) in the given month; and
4. the firm did none of the above.

However, as I argue above, the advantage of the hazard-rate model is that is that values of the different variables are compared relative to an underlying "baseline" hazard at the same point in time. Therefore, as an alternative I estimate a competing risks model, where in the licensing analysis outcomes (2) and (3) above are competing events, and in the financing analysis outcomes (1) and (2) are competing events. The competing risks analysis uses the method in Fine & Gray (1999), which takes accounts for the effect that the other event occurring has on the sub-hazard of the focal event.[25]

3.4.2. Omitted variables

A second potential identification concern is that both filing and/or grant of a patent and the decision to license and/or raise finance may be driven a variable that is omitted from the analysis. Since the analysis is limited to products for which it was possible to identify a patent application, the filing decision itself is clearly exogenous. Nevertheless, the timing of filing or patent allowance may still be endogenous.

The ideal way to deal with this concern would be to find a natural experiment in which the patent filing and/or grant was perturbed by an exogenous event. Unfortunately I am not able to identify such an event. Instead, I take a number of steps that attempt to (at least partially) mitigate this concern.

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[25] I estimate the competing risk analysis using stcrreg command in version 12 of Stata.

Gans, Hsu & Stern (2008) assumed that a patent's time in prosecution (i.e., patent grant) was exogenous to licensing decision, but were concerned that both might be driven by some unobserved heterogeneity (e.g., some feature of the underlying technology) that is associated with the timing of both patent allowance and licensing. Using the approach developed by Abbring & van den Berg (2003), to control for any unobserved heterogeneity that may drive both variables they included a measure of the patent allowance lag. I follow this approach; specifically, in the licensing analysis I include a measure of the time from invention to allowance while in the financing analysis I include measures of the time from firm founding to invention and from firm founding to allowance.[26] Since the date of invention is estimated based on the patent filing date, there should be no relationship between the time to licensing and the invention-to-patent-filing lag.

In addition, to control for any other unobserved factors that might vary systematically with the underlying technology, I include dummies for technological field, using the 22 technological fields identified in RecapRx.

Another factor that may drive both patent filing/allowance and the decision to license/raise finance is the quality of the product. One aspect of quality that might potentially affect both variables is evidence of clinical viability. For instance, an innovating firm may be more likely to prosecute a patent, as well as more likely to seek licensing and/or financing opportunities, on receiving positive clinical evidence. To account for this I include dummies for the product's stage of development in the given month (preclinical, phase 1, phase 2, phase 3, US NDA/BLA filed, and approved by the FDA). Moreover, to capture the effect of new information, I include an additional indicator that captures whether the product has entered a new stage of clinical development since the patent was filed.[27]

Another aspect of product quality that may drive both patenting and licensing/financing is technological quality. It is very difficult to measure technological quality of a product at a given point

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[26] A significant number of the primary patents are still pending at the end of the observation period (December 2006). To avoid having to drop these observations, in those cases I calculate the patent allowance lag assuming the patent allowance date was January 2007 and then include a dummy variable to indicate that the allowance date was imputed. For consistency, I use this procedure even if the patents were subsequently allowed after December 2006.
[27] Since the primary patent is usually filed within a year of discovery, it is unlikely that the product will have entered clinical trials before this happens.

time, but using citations to the primary patent I am able to obtain an 'ex post' measure. I include the log value of this variable.[28]

The propensity to prosecute the patent and to license/raise finance may also be driven by firm-level variables. For instance, more experienced firms may be quicker at prosecuting patents and better at entering into licensing or financing agreements. Conversely more experienced firms may able to manage the process better in order to obtain advantages from delaying both patent grant and licensing/raising finance. I use two variables to measure a firm's experience: its age (i.e., years since founding)[29] and a count of the products in the firm's portfolio (calculated from the full set of product data in RecapRx database).

More specifically, the firm's prior licensing experience and prior financing experience may affect the likelihood of licensing/raising finance, and may also affect the timing of patent prosecution. Therefore I include the logged value of both the count of the firm's prior alliances (including technology licensing agreements) and the count of the firm's prior financing rounds.

The firm's prior patenting experience and/or its technological capabilities may also affect both its patent prosecution and decision to license. To account for these issues I include (1) a count of all US patents assigned to the biotech firm that claimed priority before the given date; and (2) the proportion of those filed patents that had been allowed. These are constructed using the NBER patent database (Hall *et al.*, 2001), supplemented with data from the PATSTAT and Micropatent datasets.[30]

Table 1 presents some descriptive statistics and Table 2 shows the correlation matrix for the variables used in the analysis. Figure 2 shows the estimated probability of licensing product rights and raising finance given the firm's age. It shows that firms raise finance early in their lifespan, predominantly in the first 5-10 years, and tails of sharply. The likelihood of licensing increases over time, peaking at around 10 years of age but stays high for much longer.

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[28] The availability of this information depends on knowing the number of the US patent that was eventually granted.
[29] To allow for non-linear effect of firm age, I also include the squared value.
[30] A limitation of using the NBER patent database to measure a firm's portfolio is that it contains information only on US patents that were eventually granted. It also only includes patents that were assigned – as opposed to licensed – to the firm. Since firms in the biopharmaceutical industry frequently rely on patents licensed from universities or other firms this is a significant limitation. Nevertheless, presuming there is no systematic bias across firms in licensed vs. assigned, this variable nevertheless may be a useful proxy for the overall size of the firm's patent portfolio.

4. Results

Table 3 presents the baseline results on product licensing and raising finance – shown in Panel A and Panel B (respectively). The results from the baseline regressions in columns (1)-(6) show no significant relationship between licensing the product rights and either patent filing or patent allowance. Moreover, to the extent any relationship between licensing and patent allowance exists, it is consistently negatively, contrary both to theory and the finding by Gans, Hsu & Stern (2008). A similar pattern occurs in the results from the multinomial regressions in columns (7)-(9). However, in the regressions estimated using the competing-risk model, shown in columns (10)-(12), the coefficients on both patent filing and patent allowance are positive and highly significant.

Panel B presents the results from similar sets of regressions of whether the firm entered into a financing transaction on measures of patent status and whether the firm owned rights to the underlying product. Since ownership of a patentable product and filing the priority application are highly correlated, it is not possible to estimate the coefficients on both (or all three) of these indicators in the same regression. Moreover the results of regressions that include both ownership of a patentable product and allowance show a very similar pattern to regressions including patent filing and allowance so I report on the latter here.

The results of the baseline regressions in columns (1)-(8) show a positive and significant relationship between raising external finance and all three indicators when estimated individually, and the effect of patent filing (or alternatively ownership of a patentable product) dominates the effect of patent allowance when they are estimated together. This may be because in the univariate regressions patent allowance proxies for the effect of adding an additional product (or patent application) to the firm's portfolio, but does not have a separate effect of its own.

The same pattern holds in the regressions estimated using the multinomial logit model that considers licensing events as an outcome. However, in the regressions that consider licensing as a competing risk, the positive effects of product ownership and patent filing disappear (in fact, the coefficient on product ownership becomes negative). At the same time, the effect of patent allowance becomes positive and significant, even in the present of patent filing.[31]

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[31] I also estimated a similar set of regressions at the firm level, using only one observation from each firm per month and using aggregate measures of the status of the primary patents (specifically, the number of patentable products, primary patents claiming priority, and primary patents allowed). I estimated these regressions using the four alternative models described above. The baseline regressions show a negative relationship in the univariate regressions of raising finance on each of the three counts, but the effects

Table 4 shows the results of regressions that attempt to account for alternative explanations for the relationships observed in the regressions estimated using the competing-risks model – particularly the results shown in Column (12) of Table 3A and Column (16) of Table 3B. As above, Panel A shows the results from the licensing analysis and Panel B the results from the financing analysis. The results in Panel A show that the positive relationship between patent filing and licensing is robust to adding a number of different controls. Moreover, the size of the coefficient decreases only slightly – from 2.229 to 1.766 – in the fully specified regression. The coefficient of 1.766 on patent filing corresponds to a sub-hazard ratio of 5.85 – that is, patent filing increasing the likelihood of licensing the product by 485%. At the same time, the coefficient on patent allowance increases dramatically when I account for the patent allowance lag. The coefficient of 1.488 on patent allowance in the fully specified regression corresponds to a sub-hazard ratio of 4.42, meaning patent allowance increases the likelihood of licensing by 342%.

Meanwhile, the results in Panel B show that the positive relationship between patent allowance and entering into a finance relationship is robust to controlling for a range of alternative explanations. The coefficient on patent allowance of 1.153 in the fully specified regression corresponds to a sub-hazard ratio of 1.15 – that is, patent allowance increases the likelihood of raising finance by 15%. By contrast, there does not appear to be a consistent relationship between patent filing and raising finance. The coefficient becomes negative when the product-level controls are included and positive when the firm-level controls are added, but is not significant in the fully specified regression.

Table 5 presents the results of competing-risks regressions with the primary explanatory variables interacted with a series of indicators that represent distinguishing characteristics of the firm or product – in particular, the firm's prior clinical development and marketing experience,[32] the state of the financial markets (i.e., whether the financing window is open),[33] whether the firm is publicly listed, whether the product is the lead product in the firm's portfolio, the technological quality of the product (measured in terms of citations to the primary patent), whether the product is targeted at cancer (the most prevalent therapeutic area), whether the technological capabilities of the firm (measured in terms of stock of assigned patents), and whether the patent on the product was

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disappear in the competing-risks model. The results are slightly weaker using the logged value of these variables (only the relationship with patent allowance is significant), but the coefficients have the same signs.

[32] I do not directly observe whether a firm is developing or marketing a product in the given month, but do observe whether the firm has held rights to develop (at or above Phase II) or market the product and so use these as proxies for development or marketing capabilities.

[33] I determine whether the financing market window is "open" by estimating the overall hazard of financing (i.e., across all firms in the dataset) from complete set of financing transactions from rDNA's Financings dataset, and let the window be open when the hazard of financing is above the mean.

granted during the observation period. This analysis highlights how the effect of obtaining patent rights varies with the different characteristics of the firms and/or products

Panel A shows the results for the licensing analysis and Panel B shows the results for the financing analysis. In general, the coefficients on patent status are relatively consistent throughout the dataset. The interactions show that the effect of patent filing on licensing is higher when the firm has more clinical development experience and the effect of patent allowance on licensing is slightly higher when the product is the lead product in the portfolio. Otherwise the effects are very similar across the different subsamples

Panel B shows that the effect of patent status on raising financing varies much more across the dataset. The effect of patent allowance on raising finance is much stronger for firms without clinical allowance; for firms with clinical experience the effect is close to zero. However, it is weaker for the lead product in the firm's portfolio (as opposed to later products in the pipeline), perhaps because when the firm is in an early stage the investors study the firm and its product more closely so do not rely on the patent allowance as a signal of quality. Meanwhile, we observe that patent filing can have a significant effect on raising finance for firms that are still private (as opposed to those that are publicly listed). When the firm is publicly listed there is typically a much greater amount of information about the firm and its products available so investors do not need to rely on patent filing as a signal. Patent filing also has a significant effect on financing for products whose patents had been allowed by then end of the observation period.

Interestingly patent filing has a significantly stronger effect on licensing for the lower-quality products (measured by citations to the primary patent). This is puzzling because we would expect that higher quality products would be more likely to provoke a financing arrangement. However, it may be because these are likely to be more recent products, and suggest that patent filings may be becoming more important as a signal to external investors over time.

5. Discussion & Conclusion

Taken together, these results show that obtaining patent rights on a product – both filing the patent application on the primary product and allowance of that patent – have a much larger effect on whether the firm licenses that product than on whether it raises finance. However, this result only becomes apparent after we account for the (presumably, negative) correlation between licensing and raising finance; in the baseline effects neither the effect of filing the patent application nor allowance of that application is significant.

On its face, patent filing appears to have a positive effect on raising finance, but this result is much weaker when we account for the simultaneous effect of patent filing on licensing and becomes isolated only to specific cases (e.g., for private firms). Meanwhile, the effect of patent allowance by contrast is much stronger after we account for the competing risk, and especially for firms without clinical experience.

It appears that the immediate effect of patent filing is to increase the probability of raising finance and cancels out the positive effect on licensing that we might expect to observe. However, this enables the firm to develop the product and increases the likelihood that the firm will license the product over the longer term. Therefore, once we take into account the effect of obtaining patent right on financing, the overall effect of obtaining patent rights on licensing is positive.

In the baseline regressions, patent allowance does not appear to be related to either licensing or raising finance, but is positive and significant under a range of specifications estimated using the competing-risks model. Part of this appears to be explained by adding the control variables, and particularly the patent allowance lag. In a series of fully specified regressions estimated using the standard Cox hazard-rate model (not reported here), I find that the negative coefficient on patent allowance lag disappears and is much larger after I account for the patent allowance lag (although it is still not significant). This suggests that products that spend longer in the patent prosecution phase are also more likely to be licensed, and may be because firms put initiate more patent office actions – and hence extend the prosecution process – for those products that have a higher probability of licensing (which presumably are the higher quality products). Moreover, once we take this into account, patent allowance has a positive effect on both licensing and financing but neither is strong enough to be significant; it is only after we adjust for the simultaneous effect that the effect becomes clear.

The positive relationship between patent allowance and licensing is consistent with the main result in Gans, Hsu & Stern (2008). It is puzzling that this relationship does not show up in the baseline analysis, given the strong result produced by Gans, Hsu & Stern (2008). However, as mentioned earlier, Gans, Hsu & Stern analyzed a selected sample of products which depended on the existence of a licensing contract – and the actual contract being publicly available (and contained in the SDC database), which implicitly means that these firms were publicly listed. As a result the firms in that sample were presumably more developed and likely less financially constrained, so the licensing decision could turn on other, non-financial issues (such as the appropriability of the underlying innovation). Hence, the result in Gans, Hsu & Stern (2008), although true for the subsample they

analyzed, may overstate the baseline effect of patent allowance on licensing for firms that are financially constrained.

The positive relationship between filing the primary patent application and raising finance that I find in the baseline analyses is consistent with the result in Haeussler, Harhoff & Mueller (2011), who found a positive relationship between patent application stock and raising the first round of finance. Although the general relationship disappears when I take into account the competing effect of patent filing on licensing, it persists for the set of (early-stage) private firms similar to those that Haeussler, Harhoff & Mueller were studying.

Taken together these results provide insight into how obtaining patent rights affects commercialization strategy. Early in the firm's development, the primary value of filing a patent application appears to come from signaling the existence of a product to external investors in order to raise finance. This is consistent with the literature starting with Long (2002) that emphasizes the role of patents as signals, and especially that which applies this to the financing context (Haeussler *et al.*, 2011; Hsu *et al.*, 2011). It is also consistent with the conclusion by Greenberg (2011) that patent filings are more important for earlier stage firms. However, overall the main effect of obtaining patent rights – both filing the initial patent application and grant of the patent – is to facilitate licensing the product to a firm that has the commercialization rights. Although patent allowance has a significant effect on the likelihood of raising financing, the effect on licensing is economically much greater. This is most likely because it increases appropriability of the innovation so both gives potential licensees confidence about its ability to capture value from the final product and facilitates the licensor disclosing its invention in pre-contractual negotiations.

That said, this interpretation is subject to several caveats. Firstly, the finding – and the interpretation given to it – about the differential role of filed and granted 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 – than firms in those other industries. Hence, while outside investors and pharmaceutical firms may be heavily influenced by 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 and/or technology portfolio.

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.

6. Tables & Figures

Figure 1: Relationship between licensing/financing hazard and recent financing/licensing activity

Panel A: Coefficients of Cox hazard model of licensing on whether raised finance in prior 1-12 months
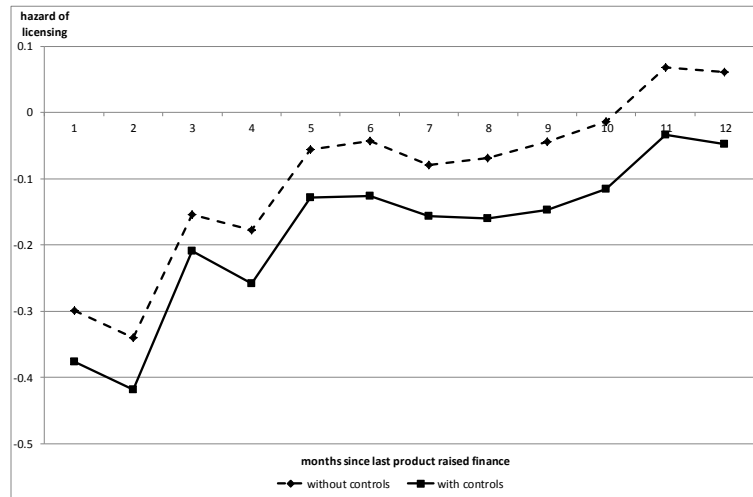
Panel B: Coefficients of Cox hazard model of raising finance on whether licensed in prior 1-12 months
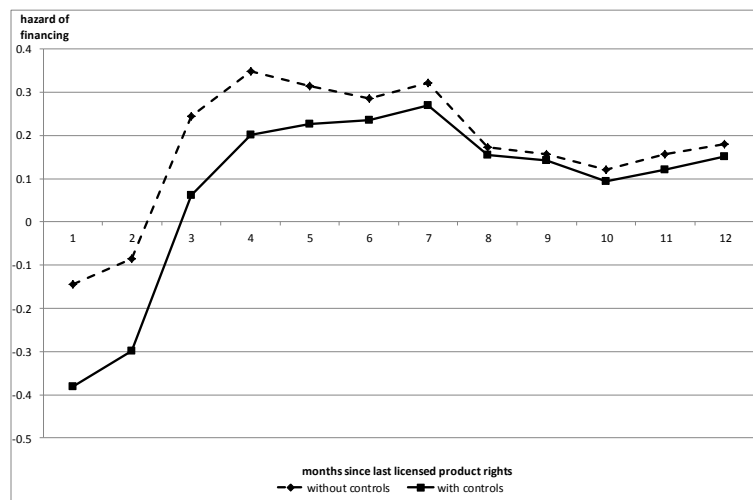
Table 1: Descriptive statistics

Group		Variable	Definition	N	all observations Mean	Std. Dev.	Min	Max	financing analysis N=311889 Mean	Std. Dev.	licensing analysis N=88483 Mean	Std. Dev.
	(0)	Date		480497	Nov-95	2608.64	1-Feb-76	1-Dec-06	Sep-95	2601.92	Feb-99	1940.47
Dependent variables	(1)	Licensed rights in US (d)	Dummy=1 if firm licensed rights to product in US in month	480497	0.00	0.03	0	1	0.00	0.04	0.00	0.06
	(2)	Licensed rights outside US (d)	Dummy=1 if firm licensed rights to product outside US in month	480497	0.00	0.02	0	1	0.00	0.03	0.00	0.05
	(3)	Entered financing transaction (d)	Dummy=1 if firm entered financing transaction in month	480497	0.05	0.22	-1	1	0.05	0.22	0.04	0.23
Measure of IP status	(4)	Owns patentable product (d)	Dummy=1 if firm owns US rights to patentable product	480497	0.36	0.48	0	1	0.34	0.47	0.99	0.11
	(5)	Primary patent claiming priority (d)	Dummy=1 if priority application on primary patent has been filed	311889	0.30	0.46	0	1	0.30	0.46	0.91	0.28
	(6)	Primary patent allowed (d)	Dummy=1 if Primary patent been allowed	311889	0.17	0.38	0	1	0.17	0.38	0.49	0.50
Patent-level variables	(7)	Firm founding to invention (years)	Years from firm founding to invention	311889	8.47	6.76	0	28.75	8.47	6.76	6.00	5.84
	(8)	Firm founding to priority filing (years)	Years from firm founding to Primary patent filing	311889	9.36	6.92	0	30.00	9.36	6.92	6.89	6.00
	(9)	Firm founding to allowance (years)	Years from firm founding to patent allowance	311889	15.48	8.20	0	31.00	15.48	8.20	12.76	7.64
	(10)	Product invention to priority filing (years)	Years from product invention to Primary patent filing	311889	1.07	0.48	0	7.17	1.07	0.48	1.10	0.59
	(11)	Product invention to allowance (years)	Years from product invention to patent allowance	311889	7.59	5.97	0	40.16	7.59	5.97	7.48	5.78
	(12)	Patent allowance not observed (d)	Dummy=1 if patent allowance not observed	311889	0.35	0.48	0	1	0.35	0.48	0.25	0.43
Product-level variables	(13)	Product age (years)	Product age (years)	443192	4.62	6.38	0	47.42	5.61	6.88	7.98	6.24
	(14)	Product in phase 1 (d)	Dummy=1 if product is at least in phase 1 clinical trials	480497	0.18	0.38	0	1	0.24	0.43	0.37	0.48
	(15)	Product in phase 2 (d)	Dummy=1 if product is at least in phase 2 clinical trials	480497	0.09	0.29	0	1	0.13	0.34	0.18	0.38
	(16)	Product in phase 3 (d)	Dummy=1 if product is at least in phase 3 clinical trials	480497	0.04	0.20	0	1	0.06	0.23	0.07	0.26
	(17)	Product NDA/BLA filed (d)	Dummy=1 if product NDA/BLA filed has been filed	480497	0.01	0.09	0	1	0.01	0.11	0.01	0.11
	(18)	Change in product stage since filing (d)	Dummy=1 if change in product stage since filing	311889	0.16	0.37	0	1	0.16	0.37	0.36	0.48
	(19)	# Citations to primary patent (log)	No. of citations to primary patent (log)	480497	2.72	0.86	0	6.18	2.72	1.07	2.81	1.25
	(20)	Citations to primary patent not observed (d)	Dummy=1 if citations to primary patent not observed	480497	0.62	0.49	0	1	0.41	0.49	0.29	0.46
Firm-level variables	(21)	Firm age (years)	Firm age (years)	480497	10.23	7.05	0	30	10.27	7.00	12.39	6.70
	(22)	# Products owned (log)	No. of products to which firm owns US rights (log)	480497	0.89	1.25	0	4.04	0.84	1.21	2.22	0.84
	(23)	# Prior alliances (log)	No. of prior alliances (log)	480497	2.76	1.39	0	5.93	2.76	1.38	3.08	1.22
	(24)	# Prior financing rounds (log)	No. of prior financing rounds raised (log)	480497	1.83	0.87	0	3.37	1.84	0.87	2.12	0.72
	(25)	# Assigned US patents claiming priority (log)	No. of US patents assigned to firm claiming priority by date (log)	480497	2.94	2.06	0	6.81	2.91	2.05	3.21	1.97
	(26)	Prop. assigned US patents allowed	Prop. of US patents assigned to firm that have been allowed	480497	0.42	0.38	0	1	0.43	0.38	0.54	0.38
Firm-level indicators	(27)	Has phase 2+ clinical experience (d)	Dummy=1 if firm has phase 2+ clinical experience	480497	0.54	0.50	0	1	0.54	0.50	0.70	0.46
	(28)	Has marketing experience (d)	Dummy=1 if firm has marketing experience	480497	0.25	0.44	0	1	0.26	0.44	0.29	0.45
	(29)	Financing window open (d)	Dummy=1 if financing window open	480497	0.48	0.50	0	1	0.48	0.50	0.49	0.50
	(30)	Firm publicly listed (d)	Dummy=1 if firm is publicly listed	480497	0.72	0.45	0	1	0.72	0.45	0.81	0.39
	(31)	Lead product (d)	Dummy=1 if product is most advanced in firm portfolio	480497	0.04	0.19	0	1	0.04	0.19	0.11	0.32
	(32)	High citations to patent (d)	Dummy=1 if citations to primary patent above median	183431	0.50	0.50	0	1	0.50	0.50	0.54	0.50
	(33)	Targeted at cancer (d)	Dummy=1 if product is targeted at cancer	480497	0.41	0.49	0	1	0.44	0.50	0.42	0.49
	(34)	High patent stock (d)	Dummy=1 if assigned US patents above median	480497	0.49	0.50	0	1	0.49	0.50	0.53	0.50

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Notes: This table shows the descriptive statistics for the product-level patent variables created using the IMS R&D Focus dataset, the product-level, and the firm-level variables. Columns (1)-(5) show the number of observations, mean, standard deviation, minimum, and maximum for the complete set of monthly observations in the

dataset. Columns (6) & (7) and (8) & (9) show the mean and standard deviation for the observations used in the financing analysis (all observations with no missing data) and licensing analysis (observations with no missing data where a biotech firm owned US rights). As described in the text, the dataset for the financing analysis contains duplicate observations for each firm corresponding to the number of products that each firm owned. In the analysis each observation is weighted by the inverse of the number of products that firm owns so that each firm is weighted equally.

Table 2: Correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)
(1)	1.00																																	
(2)	0.00	1.00																																
(3)	-0.25	-0.22	1.00																															
(4)	0.01	0.00	-0.01	1.00																														
(5)	0.01	0.01	-0.02	0.38	1.00																													
(6)	0.00	-0.01	-0.02	0.11	0.30	1.00																												
(7)	-0.01	-0.01	-0.07	0.08	-0.05	-0.14	1.00																											
(8)	-0.02	-0.01	-0.07	0.07	-0.07	-0.16	0.99	1.00																										
(9)	0.00	0.02	-0.06	0.02	-0.05	-0.49	0.70	0.71	1.00																									
(10)	-0.01	0.00	0.01	0.02	-0.14	-0.05	-0.08	0.02	-0.02	1.00																								
(11)	0.02	0.03	0.00	-0.04	0.02	-0.49	-0.21	-0.20	0.50	0.06	1.00																							
(12)	0.02	0.01	-0.01	0.03	-0.05	-0.56	0.12	0.12	0.57	-0.04	0.64	1.00																						
(13)	0.01	0.01	-0.03	-0.03	0.29	0.44	-0.34	-0.37	-0.28	-0.02	0.18	-0.12	1.00																					
(14)	0.02	0.01	-0.03	-0.04	0.17	0.26	-0.06	-0.06	-0.03	-0.03	0.00	-0.05	0.26	1.00																				
(15)	0.02	0.01	-0.02	-0.05	0.10	0.16	-0.05	-0.05	-0.01	-0.03	0.05	0.02	0.29	0.33	1.00																			
(16)	0.02	0.01	-0.02	-0.06	0.04	0.06	-0.04	-0.05	0.00	0.01	0.07	0.05	0.22	0.22	0.36	1.00																		
(17)	0.01	0.01	-0.01	0.00	0.03	0.05	-0.02	-0.02	-0.01	0.01	0.02	0.01	0.12	0.11	0.12	0.33	1.00																	
(18)	0.02	0.01	-0.03	-0.05	0.18	0.26	-0.08	-0.09	-0.04	-0.06	0.03	-0.02	0.31	0.79	0.47	0.28	0.14	1.00																
(19)	0.00	0.01	-0.02	0.01	0.05	0.18	-0.08	-0.08	-0.12	-0.01	-0.04	-0.04	0.22	0.02	0.00	0.03	0.03	0.02	1.00															
(20)	0.01	0.01	-0.01	0.04	-0.05	-0.52	0.16	0.16	0.54	-0.03	0.56	0.89	-0.11	-0.04	0.00	0.05	0.01	-0.03	-0.04	1.00														
(21)	0.00	0.00	-0.10	0.03	0.18	0.21	0.72	0.71	0.55	-0.07	-0.09	0.02	0.30	0.21	0.19	0.12	0.07	0.22	0.08	0.04	1.00													
(22)	0.00	0.01	-0.08	0.10	0.08	0.03	0.56	0.55	0.47	-0.07	0.00	0.07	0.05	0.04	0.06	0.02	0.04	0.02	0.16	0.09	0.60	1.00												
(23)	0.00	0.01	-0.07	0.05	0.17	0.15	0.55	0.55	0.43	-0.06	-0.07	0.02	0.21	0.22	0.16	0.08	0.06	0.21	0.04	0.05	0.77	0.63	1.00											
(24)	0.01	0.01	-0.02	0.03	0.21	0.20	0.27	0.27	0.19	-0.03	-0.08	-0.03	0.31	0.21	0.17	0.10	0.05	0.26	0.01	-0.01	0.57	0.31	0.69	1.00										
(25)	0.00	0.01	-0.07	0.05	0.12	0.09	0.49	0.49	0.38	-0.03	-0.06	0.02	0.10	0.14	0.09	0.06	0.04	0.13	0.14	0.05	0.60	0.65	0.60	0.39	1.00									
(26)	0.00	0.00	-0.08	0.00	0.12	0.24	0.41	0.40	0.24	-0.02	-0.15	0.00	0.27	0.26	0.20	0.12	0.05	0.26	0.02	0.03	0.66	0.33	0.54	0.49	0.65	1.00								
(27)	0.01	-0.01	-0.07	0.04	0.19	0.22	0.34	0.33	0.23	-0.07	-0.06	0.03	0.30	0.25	0.28	0.17	0.07	0.28	-0.01	0.04	0.59	0.40	0.58	0.59	0.38	0.48	1.00							
(28)	0.00	0.01	-0.10	0.00	0.07	0.06	0.42	0.41	0.36	-0.07	0.03	0.06	0.18	0.14	0.14	0.13	0.08	0.11	0.16	0.07	0.57	0.60	0.51	0.24	0.55	0.42	0.40	1.00						
(29)	0.01	0.01	0.03	0.01	0.03	0.04	0.02	0.02	0.01	-0.01	-0.01	0.02	0.03	0.01	0.02	0.00	0.00	0.00	0.04	0.02	0.04	0.02	0.04	0.04	0.03	0.02	0.04	0.03	1.00					
(30)	0.01	0.01	-0.07	0.05	0.16	0.12	0.33	0.33	0.28	-0.11	-0.03	0.01	0.14	0.22	0.15	0.10	0.04	0.22	0.02	0.01	0.51	0.32	0.62	0.65	0.35	0.40	0.53	0.28	0.01	1.00				
(31)	0.02	0.00	0.01	0.04	0.02	-0.01	-0.19	-0.19	-0.14	0.04	0.04	0.02	0.03	0.13	0.20	0.32	0.25	0.15	0.02	0.00	-0.17	-0.23	-0.18	-0.17	-0.15	-0.11	-0.13	-0.12	-0.01	-0.14	1.00			
(32)	0.00	0.02	-0.01	0.09	0.07	0.17	-0.08	-0.07	-0.14	0.05	0.05	-0.01	0.26	-0.05	-0.02	0.01	0.02	-0.01	0.78	.	0.08	0.18	0.02	0.04	0.13	0.03	0.02	0.12	-0.01	-0.02	0.01	1.00		
(33)	0.01	0.00	-0.01	-0.06	-0.03	-0.02	0.11	0.11	0.04	0.03	-0.02	0.03	-0.03	0.08	0.03	-0.06	-0.04	0.07	0.00	-0.03	0.11	-0.07	0.05	0.06	-0.08	0.02	0.02	-0.05	0.05	0.01	-0.03	-0.02	1.00	
(34)	0.01	0.01	-0.06	0.01	0.07	0.07	0.36	0.36	0.27	-0.05	-0.05	0.03	0.06	0.14	0.10	0.07	0.05	0.11	0.19	0.05	0.43	0.52	0.42	0.32	0.83	0.50	0.31	0.47	0.04	0.27	-0.12	0.19	-0.07	1.00

Notes: This table shows the pairwise correlations for the product-level variables used in the licensing analysis. The row and column numbers correspond to the variables described in Table 1.

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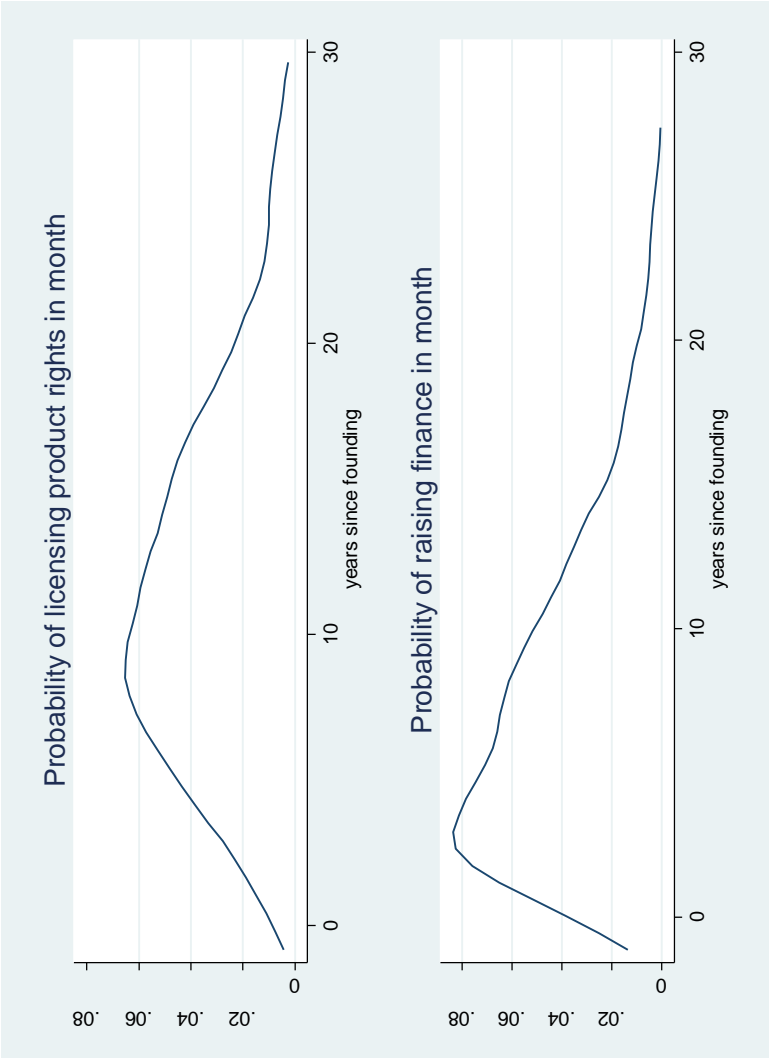**Figure 2: Probability of licensing product rights vs. raising finance by firm age**

Probability of licensing product rights in month

Probability of raising finance in month

Table 3: Baseline analysis

Panel A: Licensing

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dependent variable:				*Licensed rights in US (d)*								
Model specification:	logit			Multinomial logit			Cox proportional hazard-rate			Competing risks		
Primary patent claiming priority (d)	0.148		0.153	0.741		0.758	0.614		0.641	2.413***		2.229***
	(0.114)		(0.114)	(0.584)		(0.585)	(0.782)		(0.779)	(0.502)		(0.525)
Primary patent allowed (d)		-0.0921	-0.0945		-0.225	-0.231		-0.273	-0.275		0.789***	0.635**
		(0.107)	(0.107)		(0.251)	(0.248)		(0.236)	(0.235)		(0.252)	(0.250)
Product age (years)	-0.0321**	-0.0160	-0.0234	0.0784*	0.120**	0.0984**						
	(0.0157)	(0.0181)	(0.0190)	(0.0427)	(0.0492)	(0.0497)						
Product age squared (years)	0.0005647	0.000144	0.000358	-0.00198	-0.00311*	-0.00247						
	(0.000610)	(0.000648)	(0.000666)	(0.00149)	(0.00168)	(0.00165)						
Constant	-2.821***	-2.722***	-2.826***	-6.700***	-6.107***	-6.714***						
	(0.148)	(0.118)	(0.147)	(0.597)	(0.240)	(0.600)						
# firm-product-indication-months	88483	88483	88483	88483	88483	88483	88483	88483	88483	88483	88483	88483
# firm-product-indications	1046	1046	1046	1046	1046	1046	1046	1046	1046	1046	1046	1046
# firms	89	89	89	89	89	89	89	89	89	89	89	89
# events	330	330	330	330	330	330	330	330	330	330	330	330
# competing events	0	0	0	4390	4390	4390	0	0	0	4390	4390	4390
Log likelihood	-18401	-18401	-18398	-20360	-20358	-20352	-1901	-1899	-1899	-2411	-2419	-2397

Robust standard errors, clustered by firm, in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: This table shows the results of a series of regressions of whether the biotech firm licensed the US product rights in a given month on indicators of the patent status. The primary explanatory variables are indicators of whether the priority application for the primary patent on the product had been filed and whether the primary patent had been allowed by the USPTO. The results in columns (1)-(3) are estimated using a logit model while the results in columns (7)-(9) are estimated using a Cox proportional hazard-rate model. These regressions implicitly assume that licensing in the US is uncorrelated with any other event. The regressions in columns (7)-(12) take into account any possible correlation between licensing in the US, licensing outside the US, and raising finance. The results in columns (4)-(6) are estimated using a multinomial logit model where the dependent variable reflects which (if any) of these events occurred in the month. (Only the coefficients for the firm licensing rights in the US are reported.) The results in columns (10)-(12) are estimated using a competing-risks model where the focal event is licensing in the US and the competing risk is licensing the rights to market the product outside the US or entering a financing transaction. The baseline in the Cox and competing-risk models is an underlying "hazard" that depends on product age. To account for such time-varying effects in the logit and multinomial logit specifications I include product age and its square term.

Panel B: Raising finance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Dependent variable:								*Entered financing transaction (d)*								
Model specification:	logit				Multinomial logit				Cox hazard-rate				Competing risks			
Owns patentable product (d)	0.364***				0.221**				0.202**				-0.170*			
	(0.0902)				(0.0939)				(0.0822)				(0.0884)			
Primary patent claiming priority (d)		0.431***		0.410***		0.294***		0.276***		0.267***		0.239***		-0.00927		-0.126
		(0.0897)		(0.0875)		(0.0920)		(0.0853)		(0.0834)		(0.0835)		(0.0954)		(0.106)
Primary patent allowed (d)			0.385***	0.0465			0.269**	0.0387			0.262**	0.0632			0.184	0.283*
			(0.117)	(0.105)			(0.133)	(0.126)			(0.117)	(0.115)			(0.138)	(0.150)
Firm age (years)	-0.117***	-0.120***	-0.114**	-0.120***	-0.115**	-0.117***	-0.114**	-0.117***								
	(0.0452)	(0.0446)	(0.0457)	(0.0446)	(0.0454)	(0.0450)	(0.0461)	(0.0450)								
Firm age squared (years)	0.000662	0.000712	0.000609	0.000708	0.000400	0.000434	0.000372	0.000431								
	(0.00249)	(0.00247)	(0.00249)	(0.00248)	(0.00255)	(0.00254)	(0.00257)	(0.00255)								
Constant	-2.248***	-2.228***	-2.216***	-2.227***	-2.246***	-2.235***	-2.227***	-2.234***								
	(0.155)	(0.148)	(0.144)	(0.147)	(0.156)	(0.150)	(0.147)	(0.149)								
# firm-product-indication-months	311889	311889	311889	311889	311889	311889	311889	311889	311889	311889	311889	311889	311889	311889	311889	311889
# firm-product-indications	47985	47985	47985	47985	17233	17233	17233	17233	47985	47985	47985	47985	17233	17233	17233	17233
# firms	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
# events	512354	512354	512354	512354	15282	15282	15282	15282	512354	512354	512354	512354	15282	15282	15282	15282
# competing events					649	649	649	649					649	649	649	649
Log likelihood	-2.113e+06	-2.112e+06	-2.115e+06	-2.112e+06	-2.186e+06	-2.191e+06	-2.204e+06	-2.191e+06	-5.484e+06	-5.483e+06	-5.484e+06	-5.483e+06	-86028	-86055	-86041	-86033

Robust standard errors, clustered by firm, in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: This table shows the results of a series of regressions of whether the biotech firm entered into a financial transaction in a given month on indicators of the patent status. The primary explanatory variables are indicators of whether the firm owned a patentable product (i.e., the product had been invented and the firm owned the rights), whether the priority application for the primary patent on the product had been filed, and whether the primary patent had been allowed by the USPTO. The results in columns (1)-(4) are estimated using a logit model while the results in columns (9)-(12) are estimated using a Cox proportional hazard-rate model. These specifications implicitly assume that raising finance is uncorrelated with any other event. These regressions in columns (5)-(8) & (13)-(16) take into account any possible correlation between licensing in the US, licensing outside the US, and raising finance. The results in columns (5)-(8) are estimated using a multinomial logit model where the dependent variable reflects which (if any) of these events occurred in the month. (Only the coefficients for the outcome where the firm entered a financing transaction are reported.) The results in columns (13)-(16) are estimated using a competing-risks model where the focal event is entering a financing transaction and the competing risk is licensing the rights to market the product inside or outside the US. The Cox and competing-risk models are estimated relative to a baseline "hazard" that depends on firm age. To account for such time-varying effects in the logit and multinomial logit specifications I include firm age and its square term.

Table 4: Results from competing-risks analysis with controls

Panel A: licensing

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:			*Licensed rights in US (d)*			
Model specification:			*Competing risk*			
Primary patent claiming priority (d)	2.229***	2.127***	2.216***	2.035***	2.098***	1.766***
	(0.525)	(0.555)	(0.538)	(0.545)	(0.508)	(0.576)
Primary patent allowed (d)	0.635**	1.932***	0.715***	0.893***	0.376	1.488***
	(0.250)	(0.385)	(0.250)	(0.235)	(0.230)	(0.357)
Product invention to allowance (years)		0.0754***				0.106***
		(0.0226)				(0.0295)
Patent allowance not observed (d)		0.972**				1.020*
		(0.398)				(0.615)
Technological field dummies			Y			Y
Product at least Phase 1 (d)				0.683**		0.651**
				(0.323)		(0.298)
Product at least Phase 2 (d)				0.583***		0.480**
				(0.211)		(0.198)
Product at least Phase 3 (d)				0.780***		0.864***
				(0.207)		(0.194)
Product NDA/BLA filed (d)				0.142		-0.0798
				(0.398)		(0.401)
Change in product stage since filing (d)				0.0510		-0.0848
				(0.324)		(0.286)
# Citations to primary patent				0.115		0.0722
				(0.0930)		(0.0836)
Citations to primary patent not observed (d)				0.838***		-0.567
				(0.226)		(0.471)
Firm age (years)					0.346***	0.359***
					(0.0972)	(0.107)
Firm age squared (years)					-0.0111***	-0.0117***
					(0.00327)	(0.00377)
# Products owned (log)					0.283	0.245
					(0.235)	(0.265)
# Prior alliances (log)					0.0301	0.139
					(0.131)	(0.139)
# Prior financing rounds (log)					-0.451**	-0.557**
					(0.220)	(0.233)
# Assigned US patents claiming priority (log)					-0.0901	-0.117
					(0.0917)	(0.0997)
Prop. assigned US patents allowed					0.614	0.747
					(0.529)	(0.513)
# firm-product-indication-months	88483	88483	88483	88483	88483	88483
# firm-product-indications	5512	5512	5512	5512	5512	5512
# firms	89	89	89	89	89	89
# events	330	330	330	330	330	330
# competing events	4390	4390	4390	4390	4390	4390
Log likelihood	-2397	-2340	-2372	-2312	-2344	-2220

Robust standard errors, clustered by firm, in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: This table shows the results of a series of regressions of whether the biotech firm licensed the US product rights in a given month on indicators of the patent status with a series of controls added. The results are estimated using a competing-risks model where the focal event is licensing in the US and the competing risk is licensing the rights to market the product outside the US or entering a financing transaction. Column (1) repeats the results of the regression from Table 3A, Column (12). Column (2) adds measures of the patent allowance lag, Column (3) adds 22 technology field dummies, Column (4) adds measures of product quality, Column (5) adds measures of firm quality, and Column (6) includes all variables together.

Panel B: Raising finance

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:			*Entered financing transaction (d)*			
Model specification:			*Competing risk*			
Primary patent claiming priority (d)	-0.126	-0.133	-0.0567	-0.238**	0.139**	0.118
	(0.106)	(0.0957)	(0.105)	(0.112)	(0.0686)	(0.0881)
Primary patent allowed (d)	0.283*	0.193*	0.197**	0.179*	0.162*	0.143*
	(0.150)	(0.102)	(0.0908)	(0.104)	(0.0882)	(0.0858)
Firm founding to priority filing (years)		0.00595*				0.0101***
		(0.00319)				(0.00240)
Product invention to allowance (years)		-0.0156*				0.00288
		(0.00864)				(0.00508)
Patent allowance not observed (d)		0.113				0.175***
		(0.0974)				(0.0577)
Technological field dummies			Y			Y
Product age (years)				0.0436***		0.0138
				(0.0152)		(0.00997)
Product age squared (years)				-0.000974**		-7.66e-05
				(0.000497)		(0.000449)
Product at least Phase 1 (d)				-0.0763		-0.0319
				(0.0884)		(0.0589)
Product at least Phase 2 (d)				-0.0472		-0.0628
				(0.111)		(0.0793)
Product at least Phase 3 (d)				-0.0326		-0.0144
				(0.108)		(0.0848)
Product NDA/BLA filed (d)				-0.315		-0.282
				(0.195)		(0.217)
Change in product stage since filing (d)				0.208		0.138
				(0.174)		(0.120)
# Citations to primary patent				-0.0476**		-0.0152
				(0.0212)		(0.0183)
Citations to primary patent not observed (d)				-0.00799		-0.191***
				(0.0794)		(0.0500)
# Products owned (log)					-0.143***	-0.128***
					(0.0352)	(0.0376)
# Prior alliances (log)					0.280**	0.290**
					(0.125)	(0.133)
# Prior financing rounds (log)					1.099***	1.140***
					(0.237)	(0.233)
# Assigned US patents claiming priority (log)					0.0287	0.0197
					(0.0368)	(0.0374)
Prop. assigned US patents allowed					-0.710***	-0.687***
					(0.255)	(0.249)
# firm-product-indication-months	311889	311889	311889	311889	311889	311889
# firm-product-indications	17233	17233	17233	17233	17233	17233
# firms	90	90	90	90	90	90
# events	15282	15282	15282	15282	15282	15282
# competing events	649	649	649	649	649	649
Log likelihood	-86033	-86000	-85834	-85936	-83838	-83781

*Robust standard errors, clustered by firm, in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

Notes: This table shows the results of a series of regressions of whether the biotech firm licensed the US product rights in a given month on indicators of the patent status with a series of controls added. The results are estimated using a competing-risks model where the focal event is licensing in the US and the competing risk is licensing the rights to market the product outside the US or entering a financing transaction. Column (1) repeats the results of the regression from Table 3B, Column (16). Column (2) adds measures of the patent allowance lag, Column (3) adds 22 technology field dummies, Column (4) adds measures of product quality, Column (5) adds measures of firm quality, and Column (6) includes all variables together.

Table 5: Results from competing-risks analysis with interactions

Panel A: Licensing analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variable:					Licensed rights in US (d)					
Model specification:					Competing risk					
Subsample dummy:		Firm has Phase 2 clinical experience	Firm has marketing experience	Financing window open	Firm publicly listed	Lead product in firm portfolio	High citations to patent	Targeted at cancer	High patent stock	Patent allowance not observed
Primary patent claiming priority (d)	1.766***	1.212*	1.767***	1.679***	1.346*	1.761***	2.894***	1.697***	1.670***	2.197**
	(0.576)	(0.635)	(0.581)	(0.582)	(0.733)	(0.579)	(0.824)	(0.579)	(0.596)	(0.897)
Primary patent allowed (d)	1.488***	1.840***	1.460***	1.725***	1.960***	1.415***	1.662***	1.669***	1.570***	1.455***
	(0.357)	(0.618)	(0.407)	(0.397)	(0.722)	(0.359)	(0.489)	(0.388)	(0.477)	(0.366)
Subsample dummy										
X Priority patent filed (d)		1.194**	0.0844	0.169	0.608	-0.0373	-0.889	0.129	0.229	-0.649
		(0.511)	(0.535)	(0.295)	(0.631)	(0.204)	(0.552)	(0.286)	(0.458)	(1.426)
Subsample dummy										
X Priority patent allowed		-0.426	0.140	-0.438	-0.524	0.471*	0.703	-0.379	-0.154	0
		(0.552)	(0.553)	(0.446)	(0.699)	(0.261)	(0.624)	(0.361)	(0.431)	(0)
Patent allowance lag	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Technological field dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Product-level variables	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm-level variables	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
# firm-product-indication-months	88483	88483	88483	88483	88483	88483	62537	88483	88483	88483
# firm-product-indications	5512	5512	5512	5512	5512	5512	3836	5512	5512	5512
# firms	89	89	89	89	89	89	75	89	89	89
# events	330	330	330	330	330	330	202	330	330	330
# competing events	4390	4390	4390	4390	4390	4390	3141	4390	4390	4390
Log likelihood	-2220	-2204	-2219	-2218	-2217	-2218	-1247	-2218	-2219	-2219

*Robust standard errors, clustered by firm, in parentheses; *** p<0.01, ** p<0.05, * p<0.1*

Panel B: Financing analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variable:	Entered financing transaction (d)									
Model specification:					Competing risk					
Subsample dummy:		Firm has Phase 2 clinical experience	Firm has marketing experience	Financing window open	Firm publicly listed	Lead product in firm portfolio	High citations to patent	Targeted at cancer	High patent stock	Patent allowance not observed
Primary patent claiming priority (d)	0.118	0.0752	0.125	-0.0368	0.398***	0.135	0.363***	0.0422	0.152	0.215***
	(0.0881)	(0.102)	(0.0910)	(0.0980)	(0.137)	(0.0886)	(0.104)	(0.0888)	(0.0943)	(0.0756)
Primary patent allowed (d)	0.143*	0.392***	0.175*	0.196	0.157	0.169*	0.0297	0.0959	0.139	0.0265
	(0.0858)	(0.145)	(0.0924)	(0.154)	(0.184)	(0.0872)	(0.146)	(0.0861)	(0.144)	(0.132)
Subsample dummy		0.0605	-0.415*	0.276*	-0.456**	-0.0885	-0.333***	0.226**	-0.109	-0.275
X Priority patent filed (d)		(0.135)	(0.251)	(0.161)	(0.200)	(0.0732)	(0.103)	(0.109)	(0.159)	(0.187)
Subsample dummy		-0.351*	-0.0518	-0.0739	0.0533	-0.337**	0.195	0.179	0.0222	0
X Priority patent allowed		(0.193)	(0.231)	(0.179)	(0.230)	(0.144)	(0.183)	(0.130)	(0.163)	(0)
Patent allowance lag	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Technological field dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Product-level variables	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm-level variables	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
# firm-product-indication-months	311889	311889	311889	311889	311889	311889	183431	311889	311889	311889
# firm-product-indications	17233	17233	17233	17233	17233	17233	10082	17233	17233	17233
# firms	90	90	90	90	90	90	77	90	90	90
# events	15282	15282	15282	15282	15282	15282	8911	15282	15282	15282
# competing events	649	649	649	649	649	649	396	649	649	649
Log likelihood	-83781	-83772	-83752	-83765	-83753	-83773	-46070	-83755	-83779	-83771

Robust standard errors, clustered by firm, in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Notes: This table shows the results of the fully specified competing-risks regressions (presented in the last column of Table 4) with the primary explanatory variables interacted with indicators of firm/product characteristics. The first two variables in the regression reflect the main effects of the two main explanatory variables and the second two variables reflect the effects of explanatory variables interacted with the dummy variable listed in the header. The regressions include the full set of control variables set out in Table 4.

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