HARVARD | BUSINESS | SCHOOL

Imperfect Information, Patent Publication, and the Market for Ideas

Deepak Hegde
Hong Luo

Working Paper

14-019

August 31, 2013

Copyright © 2013 by Deepak Hegde and Hong Luo

Working papers are in draft form. This working paper is distributed for purposes of comment and discussion only. It may not be reproduced without permission of the copyright holder. Copies of working papers are available from the author.

Imperfect Information, Patent Publication, and the Market for Ideas*

Deepak Hegde† Hong Luo‡

Abstract

We investigate the role of an important information-disclosure mechanism—patent publication—in the market for ideas. We do so by analyzing the effects of the American Inventors Protection Act (AIPA), which required, as of November 29, 2000, that U.S. patent applications be published 18 months after their filing rather than at the time of patent grant. We develop a theoretical framework that yields predictions about the effects of AIPA on the timing of licensing, and test the predictions using a sample of 339 licenses of biomedical inventions protected by patent applications filed between 1995 and 2005. We find that post-AIPA patent applications experience a sharp increase in the probability of licensing after 18-month publication, and, on average, are licensed about 8.5 months sooner than pre-AIPA patent applications. Thus, information disclosure through patent publications appears to facilitate transactions in the market for ideas and significantly accelerate the commercialization of inventions.

This Version: August 31, 2013
Initial Draft: July, 2012

*The authors are grateful to Luís Cabral, Jay Choi, Wesley Cohen, Nancy Gallini, Bronwyn Hall, David Hsu, Alfonso Gambardella, David Mowery, Bhaven Sampat, Tim Simcoe, Scott Stern, and seminar participants at New York University, Harvard Business School, Georgia Tech, University of California, Berkeley, the Erasmus School of Economics, the University of Munich, the NBER Summer Institute, the International Industrial Organization Conference, and the Academy of Management meetings for helpful comments. We also thank Hazel Pike and Laurel McMechan for their excellent research assistance. Hegde's research was funded by a 2013 Kauffman Junior Faculty Fellowship.

†New York University-Stern School of Business and USPTO; email: dhegde@stern.nyu.edu.

‡Harvard Business School; email: hluo@hbs.edu.

1 Introduction

Transactions in the market for ideas face many information-related frictions. Inventors have to credibly disclose their ideas' quality in negotiations with potential buyers and, at the same time, safeguard the idea from expropriation (Arrow (1962); Gallini and Wright (1990); Anton and Yao (1994, 2002); Arora, Fosfuri, and Gambardella (2001)). Both inventors and potential buyers face substantial search costs to identify each other (Hellmann (2007); Elfenbein (2007)). From the buyers' perspective, the value of an idea may not be clear until it is evaluated against competing ideas—information that is not always easily available. These frictions can stall the commercialization of ideas and cause substantial losses: For example, a single year's delay in licensing a patented invention in the biomedical industry can cost the inventor millions of dollars in forgone royalties and affect the marginal buyer's decision to commercialize the invention (Hegde (2013)).

How can inventors and buyers of ideas overcome these informational frictions? One option for inventors is to offer their ideas for sale after patents are granted. In a study of the timing of licensing transactions, using a sample of 198 technology licenses negotiated between 1990 and 1998, Gans, Hsu, and Stern (2008) find that the hazard rate of licensing increases by 70 percent following the allowance of patents to inventors. This finding offers direct evidence for the importance of patents in facilitating licensing transactions and suggests that delays in patent grant delay the commercialization of inventions. However, because, historically, U.S. patent applications were published at the time of patent grant, the study leaves open the question of whether the benefits of patents are due to the public disclosure of patented inventions or to the certification of inventors' property rights.

In this paper, we investigate whether the disclosure of inventions through the publication of patent applications distinctly facilitates transactions in the market for ideas. The enactment of the American Inventor's Protection Act of 1999 (AIPA) required all inventors filing for patents at the United States Patent and Trademark Office (USPTO) on or after November 29, 2000 to publish their applications 18 months after the filing date. Since patent applications take, on average, 40 months to be granted, we exploit AIPA's enactment as a quasi-natural experiment to isolate the effects of information disclosure from those of the clarification of patent rights on the timing of licensing.[1]

In theory, the public disclosure of inventions through patent applications can facilitate transactions by reducing information asymmetries between the inventor and potential licensees (about the quality of the invention and the potential scope of the inventor's property rights); by enabling better evaluation of inventions through comparing published applications (because patent applications protecting potential substitutes of an invention are also published after AIPA); and by reducing the search costs for inventors and potential licensees (since inventors and licensees often search databases of published patents to learn about licensing opportunities). Yet, despite the acknowledged salience of informational frictions in the market for ideas (at least since Arrow (1962)), there is little evidence on the effects of information-disclosure mechanisms on transactions in this market. Surprisingly, the lively debate about AIPA's disclosure provisions (e.g., Ragusa

[1] In addition to Gans, Hsu, and Stern (2008), a number of studies examine the stage (or timing) of the sale of ideas. See Allain, Henry, and Kyle (2012) for impacts of downstream market structure on the stage of licensing in the biotech industry; Jensen and Thursby (2001) on faculty's choice to disclose their inventions at the proof-of-concept versus the prototype stage, and its effects on licensing terms; and Luo (2012) on the relationship between the sale stage and the seller's observable experience in the market for original movie ideas. The present study is distinguished by its focus on the role of patent disclosure on the timing of licensing.

(1992); Modigliani *et al*. (1999); Johnson and Popp (2003)) has also not motivated empirical tests of the law's effects.

We address this gap by developing a simple theoretical framework to derive predictions about the inventor's licensing timing decision before and after AIPA. We model the timing decision as a function of the effects on inventors' profits of disclosure through the publication of the patent application, the clarification of property rights conveyed by patent allowance, and the expropriation risk during licensing negotiations. We then test the predictions using a sample of 339 licenses of biomedical inventions involving 661 U.S. patents (applications and granted patents) filed between 1995 and 2005.

The biomedical industry is an ideal context for our study because inventors of drugs and medical devices often lack downstream capabilities and license their inventions to specialist developers for further development and commercialization (according to Pharmaprojects, a leading drug-development database, 51 percent of the drugs launched between 1981 and 2008 were associated with at least one licensing agreement). Unlike in industries such as electronics and semiconductors, in which firms exchange stacks of patents in complex licensing negotiations, parties in the biomedical industry use relatively well defined patents that protect discrete inventions to facilitate licensing transactions (Cohen, Nelson, and Walsh (2000)). This, along with the fact that the revenue potential of biomedical products depends critically on the duration of patents that protect the products, highlights the importance of the licensing timing decisions we study.

Consistent with our predictions, we find that the likelihood of licensing in the window between 18-month publication and patent allowance more than doubles for post-AIPA patent applications, and that post-AIPA patent applications are about 18 percentage points less likely to wait until allowance to be licensed. In addition, for applications that wait until allowance to be licensed, licensing occurs much sooner after AIPA, suggesting that the 18-month publication of patent applications facilitates earlier search and evaluation. We interpret these results as providing evidence that patent publication, as a credible information-disclosure mechanism, facilitates licensing transactions by reducing information asymmetries between the licensing parties, as well as reducing their search costs and the costs of evaluating competing ideas. Overall, the net effect of 18-month publication is that post-AIPA patent applications, on average, are licensed 8.5 months earlier than pre-AIPA applications. The two mechanisms—licensing at an earlier event (post 18-month publication) and licensing sooner post patent allowance—contribute roughly equally to the reduction in the average licensing lag. The magnitude of the reduction is economically significant given the 20-year duration of U.S. patents and can translate into millions of dollars in profits and licensing revenues.

We also investigate differences in the treatment effect of AIPA on different types of inventions and inventors. The findings are broadly consistent with our theoretical predictions and strengthen our core result about the important facilitating role of patent publication. For example, we find that the overall effects of AIPA are stronger for U.S. patent applications that do not have equivalent foreign applications. This is because AIPA harmonized U.S. patent publication rules with those in the rest of the world: Before AIPA, U.S. patent applications with equivalent foreign applications were published in those foreign countries at 18 months from the application date of the first related application, regardless of where it was filed. Also, AIPA's effect on increasing the likelihood of licensing after the publication date is much more significant, both economically and statistically, for non-profit than for for-profit licensors. Non-profit licensors (pri-

marily universities and other medical research institutions) typically lack the resources to advertise their inventions and search for suitable licensees. Thus, patent publication plays a particularly important role in facilitating licensing transactions for these inventors.

We acknowledge that our analysis cannot estimate the overall effects of pre-grant publication on inventors' *ex ante* incentives for patenting and licensing because we cannot observe their decisions to forgo patenting and licensing.[2] Despite this limitation, we submit that our findings contribute to a better understanding of the effects of an important disclosure mechanism—patent publication—on licensing transactions. With the caveat that our understanding of the welfare effects of AIPA (and, thus, of patent publication) is incomplete, we conclude that, for inventors who decide to license, pre-grant publication directly facilitates transactions in the market for ideas.

The rest of the paper is organized as follows. Section 2 describes the institutional details and presents a theoretical framework for understanding the potential effects of AIPA on inventors' licensing timing decisions. Section 3 introduces the sample and describes the data. Section 4 presents our empirical analyses and results. Section 5 concludes.

2 Institutional details and the timing of licensing

2.1 The American Inventor's Protection Act (AIPA)

Patent systems have two main objectives: to encourage innovation by awarding inventors monopoly rights to their inventions (e.g., Gallini and Scotchmer (2001)); and to promote knowledge diffusion by publishing the technical knowledge behind the invention so that those skilled in the subject area can learn from and improve upon the invention (Kitch (1977); Denicolò and Franzoni (2004); Bessen (2005)). Prior to AIPA, all U.S. patents were published after their grant date; the technical knowledge represented in the patent application, the filing date of the patent application, and even the inventor's decision to seek a patent all remained secret until the patent was granted. In contrast, most countries in the developed world, including all European countries, Japan, and Australia, have required pre-grant publication at 18 months after the earliest filing date since long before AIPA was enacted.[3]

AIPA required the publication of all U.S. non-provisional utility patent applications filed on or after November 29, 2000 that are also filed in a foreign country requiring pre-grant publication. Consistent with the international rule, publication occurs 18 months from the earliest filing date of the patent application for which benefit is sought; this is called the "priority date." AIPA also granted provisional rights to the owner of the published application to pursue a reasonable royalty for the period between the publication date and

[2] A number of papers study the effect of Canada's 1989 Patent Act reform that switched from a confidential filing system with a first-to-invent priority rule to a pre-grant publication system with a first-to-file priority rule. Tepperman (2002) finds that after the reform, firms increased both their R&D investments and their patenting intensity. Putnam (1997), however, estimates that pre-patent publication is associated with a $479 decrease in the mean value of patents. These studies do not separate out the effects of pre-grant publication from the effects of switching to first-to-file from first-to-invent, which occurred simultaneously with the passage of Canada's Patent Act reform.

[3] For example, if a firm applies for a patent in the U.S. prior to filing for a patent in Japan, the publication in Japan will occur 18 months from its U.S. filing date.

the grant date of the patent (we later analyze the effects of provisional rights in detail).[4]

In order to balance concerns that mandatory disclosure might disadvantage small firms that prefer pre-grant secrecy (expressed by 25 Nobel Laureates in a letter to the U.S. Senate: see Modigliani et al. (1999)), AIPA also provided a way to avoid disclosing the invention 18 months after filing the application: Inventors can opt out of the 18-month publication requirement by filing, along with the patent application, a certification that the application has not been, and will not be, filed in any foreign country that requires pre-grant publication. However, in practice, this opt-out option is rarely used: Graham and Hegde (2013) analyze all post-AIPA patent applications filed before 2006 and report that only 7.5 percent of all U.S. patent applications, and less than four percent in the biomedical industry, opted out of 18-month disclosure.

Prior to AIPA, U.S. applications that were also filed in foreign countries were published 18 months after the priority date in those countries, and the applications were available to the public, even in the U.S. However, as AIPA proponents argued, several frictions increased the cost of obtaining this information (e.g., the applications were published in the official language of the foreign granting authority).[5] Hence, it is possible that AIPA also affects applications that would be filed—and, hence, disclosed—in foreign jurisdictions, but perhaps to a lesser extent. In our empirical analysis, we exploit this institutional feature to check whether the effects of AIPA are more pronounced for U.S. applications that do not have foreign counterparts than for those that do.

AIPA is considered one of the most important patent laws enacted in the last century, and its potential effects on innovation are widely debated (e.g., Ragusa (1992); Gallini (2002); and the 1999 letter to the U.S. Senate by 25 Nobel laureates to block mandatory 18-month publication, cited above). In theory, pre-grant publication of patent applications may encourage or deter patenting. For example, Aoki and Spiegel (2009) argue that pre-grant publication leads to fewer patent applications because greater technology spillover reduces the value of patenting for the inventor, even though a patented technology is likely to be commercialized sooner because rivals now have a stronger incentive to invest in R&D. However, when not considering the spillover effect, Aoki and Prusa (1996) show that pre-grant disclosure could increase firms' profits by enabling them to coordinate their R&D investments better—thus increasing their incentive to patent.

Despite the attention in policy circles and theoretical studies motivated by pre-grant publication, empirical studies of its potential effects have been scarce. Johnson and Popp (2003) use data on U.S. patents from the pre-AIPA period (1976-1996) to infer some of AIPA's effects. They suggest that major inventions are most likely to be affected by AIPA because they take longer to be examined; they also find evidence that the publication of a patent, more than other means, is the primary reason for the diffusion. Examining post-AIPA data, Graham and Hegde (2013) find that small inventors in the U.S. are particularly likely to prefer 18-month disclosure to secrecy for their most important inventions. They argue that the publication of patent applications allows small inventors to advertise their inventions and attract external investors and po-

[4]To be entitled to this reasonable royalty, the patent owner is required to provide proper notice to an alleged infringer, and the published claims have to be "substantially identical" to the claims in the granted patent. See Subtitle E under "American Inventors Protection Act of 1999 is Law" available at: http://www.uspto.gov/patents/law/aipa/summary.jsp.

[5]As noted by Ragusa (1992, p.174), "It is theoretically possible for a U.S. inventor to locate patent applications when they are published in another country and to obtain English language translations of such publications. This is not, however, a practical alternative for small businesses with limited resources to invest in the patent application process. When a U.S. company conducts a search in the USPTO, it is more difficult for the company to discover and understand foreign language prior art than a U.S. patent."

tential licensees. Consistent with their finding (in the population of all U.S. patent applications filed before 2006), we find that only two percent of the post-AIPA patents in our sample opted out of 18-month publication. Therefore, we, do not investigate the potential consequences of withholding 18-month publication after AIPA.

How does the pre-grant publication of patent applications affect inventors' decisions regarding when to license their inventions? The next section develops a simple theoretical framework, building on previous studies on patent disclosure, patent rights and licensing.

2.2 AIPA and the timing of licensing

In deciding when to license an invention, the seller (licensor) faces tradeoffs. Licensing early yields revenues for a longer period, which is important because of the fixed duration of patent exclusivity from the application date. However, frictions in the market for ideas—such as asymmetric information, expropriation risk, and search costs—might delay licensing. In their study, Gans, Hsu, and Stern (2008) point to a number of such frictions and articulate how obtaining formal patent rights might mitigate the frictions.[6] However, because their focus is on the patent-grant event under the pre-AIPA regime, they do not distinguish between the effects of patent publication and the clarification of patent rights. Yet both may distinctly affect licensing transactions.

Why patent publication matters

The publication of a patent application is important for several reasons. First, patent publication by the USPTO establishes an official record of invention disclosures and helps credibly reduce the information asymmetries between inventors and potential buyers. Asymmetries could arise from the inventor's superior knowledge about her invention, from the potential scope of her property rights, or even from the prior art related to her invention. Second, patent publication notifies potential licensees of the invention, reduces their search costs and, thus, broadens the possible set of cooperative opportunities. Before a patent application is published, the public is unaware of its existence. Many patentees—small patentees, in particular—emphasize the role of the USPTO's online database of patent applications in making potential licensees aware of their applications. Third, (earlier) publication of patent applications enables comparisons of the applications and their prior art, thus facilitating the evaluation of the idea against potential competing ideas. We emphasize that the above benefits of publishing patent applications through the patent office are difficult to reap through inventors' voluntary disclosures.

Why the clarification of patent rights matters

According to Gans, Hsu, and Stern (2008), inventors may have more knowledge than potential buyers about the likelihood of grant and the eventual scope of their patents' claims because inventors have repeated interactions with patent examiners during the course of patent prosecution. Hence, inventors with a higher likelihood of obtaining strong and broad patent rights may want to wait until their patent is granted before licensing. In addition, if an inventor has to engage in a costly search to locate the most suitable licensing

[6] As Gans, Hsu, and Stern (2008) point out, pure uncertainties should not result in licensing delays. Uncertainties can be priced in, while the productive efficiency implies that inventions should be licensed right away.

partner, the incentives to search may be sufficient only after a strong patent is granted, especially if the inventor fears substitution or imperfect imitation by rivals. Finally, if the inventor needs to engage in costly efforts to transfer tacit but hard-to-protect knowledge (which is necessary to make full use of the invention), her incentives to exert such effort may be sufficient only with the backing of secure property rights.

The following analysis incorporates the distinct benefits and costs of patent publication and grant and derives predictions regarding the effects of AIPA on an inventor's choice of when to license.

2.2.1 The setup

Figure 1 illustrates the sequence of events before and after AIPA. Let T_a, T_d, T_g, and T denote, respectively, the application date, the publication date, the date of patent grant, and the date of patent expiration. Before AIPA, $T_d = T_g$, and after AIPA, $T_d < T_g$.[7]

Figure 1 here

Let v be the per-period licensing revenue that the inventor expects from licensing the invention right after the application date; d the difference that the inventor expects in his per-period payoff once the patent application is published; and g the difference once the claims of the patent are clarified when the patent is granted. d and g could be positive or negative.

Let ρ be the probability that a potential licensee would obtain enough information to come up with a successful substitute for the invention during the negotiation process and before the application is published (the probability becomes 1 after publication). Δ is the corresponding loss to the inventor in per-period licensing revenues. For simplicity, assume that "inventing around" takes place immediately after the potential licensee gains enough knowledge.

For the sake of parsimony, we do not consider transaction costs, such as the time taken to negotiate with licensing partners. We also do not explicitly model the choice between licensing and other outside options. After laying out our key predictions, we discuss how these factors might influence the timing of licensing.

The licensor's timing decision before AIPA.

Given an invention, the inventor can either license the invention immediately after the application date or wait until the patent allowance date. The payoff from licensing right away is

$$U_a^{\text{before}} = (1-\rho)vT_g + \rho(v-\Delta)T_g + (v-\Delta)(T-T_g).$$

For periods before patent grant, with probability $1-\rho$, the inventor enjoys per-period revenue v; and with probability ρ, the revenue is offset by Δ because of "inventing around." After the patent grant date, the invention becomes public, and inventing around happens with probability 1.

The inventor's payoff from licensing after the patent grant date is

$$U_g^{\text{before}} = (v+d+g-\Delta)(T-T_g).$$

[7] It is possible for a patent to be allowed before the 18-month publication date. Because AIPA would have no effect in such a scenario, we consider the more interesting case here.

The inventor receives no revenue in the periods before patent grant; after grant, the per-period licensing revenue changes by $d+g$, the net effect from publication and the clarification of patent rights. Hence, the inventor licenses the invention immediately if and only if the net benefit from earning licensing revenues for T_g more periods, while risking information leakage through the negotiation process, is greater than the combined net effect from public disclosure and the clarification of patent rights for the rest of the patent protection period. In other words,

$$(v-\rho\Delta)T_g > (d+g)(T-T_g). \tag{1}$$

The licensor's timing decision after AIPA.

The inventor chooses among three alternative dates for licensing in the post-AIPA period; the payoffs of the three alternatives are, respectively,

$$U_a^{\text{after}} = (1-\rho)vT_d + \rho(v-\Delta)T_d + (v-\Delta)(T-T_d),$$

$$U_d^{\text{after}} = (v+d-\Delta)(T-T_d),$$

$$U_g^{\text{after}} = (v+d+g-\Delta)(T-T_g) - \Delta(T_g-T_d).$$

Note that the term $-\Delta(T_g-T_d)$ in U_g^{after} reflects that, once the patent application becomes public, inventing around would depress the inventor's revenues regardless of the licensing decision.

The inventor licenses immediately after application if neither the benefit from waiting for disclosure nor the benefit from waiting for the clarification of patent rights outweighs the benefits from obtaining a longer period of royalties while risking information leakage from the negotiation process; that is,

$$(v-\rho\Delta)T_d > d(T-T_d) \;\;\&\;\; vT_g - \rho\Delta T_d > (d+g)(T-T_g). \tag{2}$$

The inventor licenses after publication if the net benefit from disclosure is greater than the lost net profits of T_d period and if the marginal benefit from clarifying intellectual property (IP) rights is less than losing revenues for $T_g - T_d$ periods; that is,

$$(v-\rho\Delta)T_d < d(T-T_d) \;\;\&\;\; (v+d)(T_g-T_d) > g(T-T_g). \tag{3}$$

The inventor waits until patent grant if neither of the above two conditions is met.

2.2.2 Empirical implications

Figure 2 illustrates the timing of licensing after significant patent-related events, before and after AIPA, as a function of the effect of public disclosure, d, and the effect of clarifying the IP rights, g. Figure 2a shows that, before AIPA, inventors who would benefit substantially from the net sum of disclosure and clarification of property rights would delay licensing until the patent grant date—*i.e.*, when $(d+g) \geq \frac{vT_g - \rho\Delta T_g}{T-T_g}$.

Figure 2 here

The effects of AIPA are depicted in Figure 2b. First, the separation of the publication date from the grant date gives inventors more options. For inventions that would have been licensed immediately after the application date before AIPA, inventors who value public disclosure (*i.e.*, when $d \geq \frac{vT_d - \rho\Delta T_d}{T - T_d}$) can now wait until the publication date. For inventions that would have waited until the grant date before AIPA, inventors can now expedite licensing to the publication date if the benefits from the additional licensing revenues exceed those of clarifying their IP rights by waiting for the patent to be granted (*i.e.*, when $g \leq \frac{(d+v)(T_g - T_d)}{T - T_g}$).

Second, because AIPA requires earlier publication, some inventions that, before AIPA, would have been licensed after grant are now licensed either immediately after the application date or 18 months later, after publication of the patent application. Figure 2(b) shows that the line separating licensing before and after the patent grant date in the pre-AIPA era shifts rightward in the post-AIPA era. This is because AIPA expedites the public disclosure of information (and the corresponding risk of inventing around now occurs after T_d, instead of after T_g). Thus, relative to waiting until the allowance date, starting to negotiate earlier is associated with lower losses after AIPA. As a result, inventors are more likely to choose earlier licensing.

Considering the net of the above effects yields the following predictions. Our first set of predictions concerns the effect of AIPA on the likelihood of licensing after various patenting-related events.

Prediction 1 (likelihood of licensing after patenting-related events).

Other things being equal, after AIPA,
(a) the likelihood of licensing after the publication date (i.e., 18 months after the filing of an application) increases;
(b) the likelihood of licensing after the patent grant date decreases; and
(c) the likelihood of licensing after the application date decreases if losses due to information leakage during pre-publication negotiations are low (or when the patent grant date is close to the publication date).

Predictions 1(a) and 1(b) are evident from Figure 2b. However, incidences of licensing events immediately after the application date may increase or decrease after AIPA, depending on the relative number of inventions that are licensed later (*i.e.*, moving from the application date to the publication date) and those that are licensed earlier (*i.e.*, moving from the grant date to the application date). However, the dashed line $(d+g) = \frac{vT_g - \rho\Delta T_g}{T - T_g}$ is close to the solid line $(d+g) = \frac{vT_g - \rho\Delta T_d}{T - T_g}$ when the likelihood of information leakage during the negotiation process (ρ) is small, when the damage from inventing around (Δ) is minimal, or when the patent grant delay is close to the publication date (*i.e.*, when T_g is close to T_d). In those circumstances, the likelihood of licensing immediately after the application date would only decrease.

The magnitude of the changes anticipated by Prediction 1 depends on the distributions of d and g (and on the values of the other parameters). Here, we make only qualitative predictions and let the data help us infer whether d and g are, in fact, important. For example, if the value of d is mostly low (*i.e.*, public disclosure does not significantly benefit inventors), we will not observe an increase in the likelihood of licensing after the required 18-month disclosure post-AIPA.

The second "prediction" concerns the effect of AIPA on the average licensing lag. Because some inventions have been licensed earlier and others later since the implementation of AIPA, the overall effect of AIPA is theoretically indeterminate, and we treat it as an empirical question.

Prediction 2 (licensing delay).

Other things being equal, the average licensing delay may increase or decrease after AIPA.

In our model, licensing occurs as soon as key patenting-related events occur because we do not consider transaction costs, such as the time required by the licensees to evaluate patents and the time the parties take to search for each other and negotiate the terms of the contract. Adding such transaction costs would provide richer predictions, but would also overcomplicate the model. However, one potential effect of incorporating such transaction costs into the model is noteworthy: Publication at 18 months, in general, makes patent applications available earlier for evaluation by the public and potential licensees. Hence, conditional on licensing after the grant date, licensing occurs more quickly after AIPA than before because potential licensees have had the opportunity to evaluate the invention before its grant.

3 Sample and variables

3.1 Sample construction

Publicly traded U.S. companies are required by the Securities and Exchange Commission (SEC) to disclose material transactions, including license agreements, to the public. In addition, several state governments require privately-held companies with employee stock options to publish material transactions. Our sample of license agreements was drawn from these disclosures. We obtained the agreements from Deloitte Recap's RecapIP, which assembles all publicly-disclosed contractual agreements in the biomedical industry.[8] We supplemented RecapIP's data with our own search of the SEC's EDGAR filings database.

We finalized our sample after imposing the following criteria to ensure that the agreements represent key elements considered by our framework. First, we excluded contracts that involved collaborative research, manufacturing, marketing, supply, distribution, and other complex transactions because the timing of these arrangements may be dictated by considerations other than the state of the licensor's patent application.[9] Second, a license agreement between two parties might be followed by renegotiations and amendments to the original agreement. Because we are interested in the tradeoffs that the inventor faces at the initiation of the transaction, we discarded agreements that are amendments and revisions of original licenses. Third, we retained only those agreements that involve the licensing of at least one identifiable non-provisional U.S. patent application or granted patent, thus excluding contracts in which the identity of the patents was redacted.

[8] A number of studies have used Recap data, including Lerner and Malmendier (2010), Lerner and Merges (1998), Allain, Henry, and Kyle (2012), and Wakeman (2012). Lerner and Merges (1998) describe the database in detail.

[9] RecapIP has collected data on deals in the biomedical industry (primarily in the pharmaceuticals and biotechnology sectors) since 1973. There are 9,874 unique deals in the database. There are multiple types of deals; license (42%), research contracts (14%), development (11%), supply (11%), collaboration (10%), and acquisition (7%) are the most common types. A deal can also be recorded as more than one type. We include contracts that are identified by RecapIP as license only, which is about 23% of the deals.

Then we assembled information on the following three dates associated with each agreement.

(i) License agreement date: The licensing date is typically specified in the contracts as the "effective date"; it is the date from which the licensee is entitled to use the licensor's patents. We determined this date after reviewing each agreement.

(ii) Patent application date: We collected information on every U.S. patent (identified either by its application number or patent number) specified in each contract in our sample. We then matched the patents to the USPTO's database and identified the relevant dates associated with the patents. The patent application date typically refers to the filing date of the last application associated with a granted patent and is found on the cover page of granted U.S. patents. However, the first application date associated with a patent, the "priority date," may be different because applications can have "parents" in the form of related previous applications (that is, continuations, divisionals, or continuations-in-part—these parent applications are typically abandoned when related applications, or "children," are filed).[10] Since the priority date establishes the date from which the inventor's legal rights begin, and AIPA's provisions specify publication 18 months after the priority date, we use the priority date as the actual application date (and henceforth use the term "application date" to refer to the priority date, unless otherwise noted). About half of the sample agreements license more than one patent. In these cases, we use the application date of the earliest patent application in the license.

(iii) Patent allowance date: The USPTO informs applicants of the allowance of their patents on the "patent allowance date." The allowance date typically precedes the administrative patent grant date on the cover page of patents by three to four months.[11] Since the date on which the inventor is officially informed of the grant is more relevant for license negotiations, we use this date in our analysis rather than the administrative grant date, and we use the term grant date and allowance date synonymously (unless noted otherwise). For licenses with more than one patent, we use the date of the earliest allowance to characterize the agreement.

We excluded licenses with their earliest patents filed before June 8, 1995 because these patents enjoyed protection for 17 years from the patent grant date rather than 20 years from the application date. Including these licenses might conflate the effects of AIPA with the effects of this prior important patent law change. After these exclusions, we were left with a sample of 425 licenses, with the earliest patent application date being between 1995 and 2010.

3.2 Sample selection and potential biases

Because we have a longer time window to observe the licensing events for patent applications filed in the earlier years of our study, inventions that take longer to be licensed may be underrepresented during later years in a retrospective sample. This could lead us to incorrectly conclude that licensing occurs sooner in the post-AIPA years. We mitigate this truncation bias by considering a uniform 90-month window in which

[10] Hegde, Mowery, and Graham (2009) show that nearly a third of all U.S. patents issue from previous related non-provisional applications, and the priority date for these patents precedes their application date by nearly a year, on average.

[11] After receiving the notice of allowance, inventors can choose to have the patent granted by paying a stipulated fee, request modifications/revisions to the patent, or even abandon the application. The administrative grant date represents the date on which the inventors were officially issued the patent after paying the specified fees.

to observe the licensing event, starting with each license's earliest patent application date.[12] This excludes 86 licenses from our sample and makes 2005 the last patent application year for the patents in our sample (since we observe licensing events up to the end of May 2013).

Thus, our final sample consists of 339 patent licenses: The earliest patent in each agreement was licensed within 90 months from its application date, with the application dates ranging between June 8, 1995, and December 31, 2005. The 339 licenses in our sample collectively licensed out 661 U.S. patents (applications and granted patents). 48 of the licenses specified a single U.S. patent application and no granted patent (some of these applications were abandoned, and the rest were still pending examination as of May 2013). Of the 339 licenses, 266 had their first patent applications filed before AIPA took effect (before November 29, 2000), and the remaining 73 were filed after AIPA.

The licenses in our sample are not randomly drawn; they are among the contracts disclosed as material by one of the licensing parties likely to be a U.S. public firm. The probable consequence is that we have oversampled valuable inventions (relative to the firm's size). The advantage of this oversampling of valuable inventions is that the contracting parties are more likely to behave like the profit-maximizing agents considered in our theoretical framework. More importantly, it is hard to think of plausible reasons why AIPA might have influenced sample selection based on quality, and we confirm later that important characteristics of patents, including common measures for their value, do not differ significantly across our pre- and post-AIPA subsamples.

We retain only those agreements for which we have the text of the contracts (information on the identity of the licensed patents, disclosed in the text of the agreements, is essential for our analysis) and omit redacted agreements. According to Verrecchia and Weber (2006), to avoid adverse reactions from investors, firms redact information when they have suffered financial losses. But firms are also more likely to redact strategically important transactions to prevent scrutiny by competitors. We might need to worry about redaction if we had found that firms redact more after AIPA (to compensate for the public disclosure of patent applications), which might result in a different distribution of patent value and, hence, different timing strategies. However, the characteristics of pre-AIPA and post-AIPA patents do not vary significantly in our sample. In addition, we also confirm that the rate of redaction in contracts is not statistically different before and after AIPA.

Although we have a comparable time window in which to observe licenses of patents filed pre- and post-AIPA, our sample has substantially more licenses with pre-AIPA patents. The decline in licensing activity might be worrisome if the reasons for the decline biased our conclusions about licensing timing before and after AIPA. One such reason could be the reporting delay in disclosing material transactions. Our construction of a 90-month window within which to license does not directly address this delay because, conditional on licensing within this window, earlier-year licensing events still enjoy a longer time to be

[12] We chose a 90-month window since 80% of the licenses were negotiated within 90 months from the application date of their earliest patent in our sample. Choosing a shorter window (say, four or five years) would not leave us with a long enough period in which to observe the grant event for a substantial number of patent applications since patent applications take, on average, about four years to be granted; and, according to Gans, Hsu, and Stern (2008), the hazard of licensing in the pre-AIPA years increases by 70% on patent allowance. Choosing a longer window (say, eight or more years) requires us to consider only patent applications filed through December 31, 2005, which means dropping the limited number of post-AIPA observations that we have. Nevertheless, we experimented with both six-year and eight-year windows and found our results to be robust for each time window.

reported (and, hence, to be observable to us). However, according to Deloitte Recap, the primary provider of our data, material transactions are typically reported in the reporting period that immediately follows.[13] Therefore, reporting lags the actual transactions by a fiscal quarter at most, and reporting delay is unlikely to be the reason behind the decrease in observed patent licenses for the later years in our sample. Instead, according to Recap, the reason for the decrease in reported licensing activity for the later years is due to a sharp decline in initial public offerings (IPOs)—and, thus, a decline in publicly-listed firms reporting transactions—after the historic bubble in public markets between 1997 and 2000.[14]

Figure 3 here

Figure 3 reveals that the decline in licensed patents starts for patents filed in 1998 and is not coincident with the enactment of AIPA. Since the average patent is licensed about 40 months after application, the decline of applications after 1997 is consistent with the decline in licensing transactions after the public market bubble burst in mid-2000. The figure also breaks down trends in the frequency of licenses for the subsample of licenses with and without foreign equivalent patents. Recall that the subsample with foreign equivalent patents was subject to 18-month disclosure in foreign jurisdictions even before AIPA and, therefore, is less likely to be affected by AIPA. The fact that the frequency of licenses in both the subsamples declined after 1997 also suggests that the decline was due to changing macroeconomic factors and not to AIPA. Of course, one might argue that some financially constrained inventors were more likely to attempt licensing sooner after the financial collapse in 2000 and, thus, bias our estimates of AIPA. This effect, while unlikely (because the financial collapse also affected buyers, who may have been less willing to invest in early-stage inventions), should not be related to the primary effect of AIPA, which we expect to be concentrated after the 18-month publication date of patents.

Our analysis does not model the outside options of not patenting or not licensing. In theory, the effect of pre-grant disclosure required by AIPA on the incentives to patent and to license is ambiguous. On the one hand, pre-grant disclosure implies greater spillovers (hence a higher risk of inventing around), which may make opting out of patenting more attractive (see Aoki and Spiegel (2009)). Thus, one might worry that patents that value the benefits of 18-month publication are more likely to select into patenting and licensing post-AIPA. However, AIPA also provides inventors with an additional choice in terms of licensing timing that may make opting out less attractive (Aoki and Prusa (1996) make a similar prediction but through a different mechanism). Although we have not focused on this aspect of the law, it is important to emphasize that AIPA allows applicants the option of maintaining pre-grant secrecy. Thus, inventors have all of the pre-AIPA options available to them after AIPA, in addition to the 18-month publication option that we study. It is, therefore, unlikely that inventors have a greater incentive to opt out of patenting (or licensing) after AIPA. In fact, Graham and Hegde (2013) show that patenting did not drop after AIPA and that only a negligible fraction of the post-AIPA patent applications in the biomedical industry (less than four percent of

[13] This is consistent with the SEC's rule regarding the disclosure of material transactions. "The limited number of Form 8-K disclosure items permitted a public company to delay disclosure of many significant events until the due date for its next periodic report." The rules are available at http://www.sec.gov/rules/final/33-8400.htm.

[14] Note that the total number of licensing events increases continuously from the early 1990s until 2007, without an obvious discrete change in the rate of increase before and after 2000.

all applications) opted for pre-grant secrecy. This preference for pre-grant publication is also confirmed in our sample: None of the focal patents and only two percent of all the patent applications in our sample opted for pre-grant secrecy. Hence, it is unlikely that our results are biased by particular types of patents selecting into our post-AIPA sample. Still, we acknowledge that we do not directly observe inventors' decisions to select into, or out of, patenting (or licensing), and our results should be interpreted with this caveat.

3.3 Variables

Our main variables capture the timing of licensing with respect to the timing of three patenting-related events: patent application, patent disclosure at 18 months, and patent allowance. As mentioned before, for licenses with multiple patents, we consider the dates and characteristics associated with the earliest patent application in the license.[15] Accordingly, we construct a categorical variable indicating whether the licensing event occurs in one of the following three windows: (i) sooner than 18 months from the patent application date and before patent allowance; (ii) after 18 months since patent application and before patent allowance; and (iii) after patent allowance.[16,17] We view the inventor's choice among the three options for the timing of the license as a function of the patent disclosure regime (pre-AIPA or post-AIPA), the characteristics of the invention, and the characteristics of the licensing parties. In our sample, 23 percent of the license agreements were negotiated before 18 months from the first patent application and before patent allowance, 20.4 percent between 18 months and allowance, and the rest after allowance. The average difference between patent application and licensing is 39.4 months, and the average difference between patent allowance and licensing is 10.3 months.

Table 1 shows that pre-AIPA patents (application dates before November 29, 2000) and post-AIPA patents (application dates after November 29, 2000) differ significantly in the timing of their licensing. Post-AIPA patent licensing occurs 8.3 months sooner after the application date and 20.8 months sooner relative to patent allowance than pre-AIPA licensing, on average.

Table 1 here

We construct several control variables related to the characteristics of the licensed IP that may be correlated with the timing of patenting-related events and licensing. These include the number of patents specified in the license and variables that capture importance, originality, novelty, and breadth of the licensed patent (the measures are constructed as described in Hall, Jaffe, and Trajtenberg (2001)). These characteristics are based on the earliest-filed patent application in each license.

[15] It is possible for a patent application filed after the patent with the earliest application date in a license to be issued first. In such circumstances, which happen in about 10% of our sample cases, we use the earliest allowance date, not the date associated with the earliest application.

[16] We verified from the USPTO that disclosure for post-AIPA patents does, indeed, happen after 18 months from application date (the mode application to disclosure lag was 18.2 months, and mean application to disclosure lag was 19.1 months due to administrative delays associated with publishing the applications).

[17] Twenty percent of the 339 sample licenses were for patents issued within 18 months. These are classified as belonging to (i) or (iii), depending on whether the licensing event occurred before or after allowance. We later show that our results are robust to the exclusion of these licenses from our analyses.

Table 1 confirms that the characteristics of the patents (except for expected pendency) do not differ significantly in our pre- and post-AIPA subsamples, thus allaying concerns that the characteristics of the licensed patents changed after AIPA. Pendency is the time taken by the USPTO to examine and allow patent applications, and Hegde (2012) shows that average pendency increased from 19.2 months to 29.1 months at the USPTO between 1995 and 2005, largely due to increasing backlogs of unexamined applications at the office. Though unlikely to be related to the introduction of AIPA, increased pendency over time may increase the inventor's incentives to license earlier. Therefore, we control for "expected pendency" (defined as the average time that the USPTO takes to examine patents granted in the application year and technology class of the focal patent) while estimating the effect of AIPA on the timing of licensing. Table 1 suggests that the expected pendency in post-AIPA years is, on average, 5.7 months longer than in pre-AIPA years.[18] The chief merit of using expected pendency rather than actual pendency is that variation in the former is caused largely by vagaries in the resources available at the patent office for examination and is exogenous to the licensing and patent prosecution strategies associated with the focal patent applications. Actual pendency is likely to be endogenous to the timing of licensing because, for patents that are licensed before grant, applicants are likely to delay the patent examination process to ensure that the patent issues with the exact set of claims represented in the licensed application.

We also include controls for the technological class of the focal patent in each license to capture systematic differences in licensing strategies across the technological fields. Of the 291 licenses with granted patents (the USPTO assigns technological classes only to granted patents), 60.5 percent of the patents belong to the "Drugs" category, 19.2 percent to the "Surgery and Medical Instruments" category, 9.6 percent to the "Organic Compounds" category, and the rest to miscellaneous classes.

Next, we control for the observed characteristics of the licensing parties. This includes indicators for the licensor's organizational type (among the licensors, 41.9 percent are non-profit organizations such as universities, hospitals, and research institutes; 54.3 percent are corporations; and the rest are individuals), the licensing parties' experience levels, and the extent to which they deal with each other. We measure the licensor's experience as the number of deals (including licensing and other types of deals) the licensor has undertaken as a seller prior to the focal agreement; the licensee's experience as the number of deals the licensee has made as a buyer prior to the focal agreement; and the relational experience as the number of prior deals the licensor and the licensee have transacted before the focal agreement. Table 1 reveals that licensees are, on average, more experienced in the post-AIPA sample; this difference may reflect the relatively small number of repeat buyers (most of whom stay in the market throughout the sample period).

3.4 Descriptive evidence

Before testing the robustness of the patterns econometrically in the next section, we subject our sample to a visual examination guided by our predictions.

Prediction (1a) suggests that if patent publication matters, we should observe an increase in the likeli-

[18] These average pendency statistics represent the lag in months between the first application date of patent applications and patent allowance. Pendency, when calculated using patents' administrative grant date (in place of allowance date) is longer by four to six months.

hood of licensing after the publication date (18 months after the patent application date) for patent applications filed after AIPA came into force.

Figure 4 here

Figure 4 examines the density distribution of licensing lags in months (*i.e.*, between the licensing date and the earliest patent application date) for the patent applications before and after AIPA. For patents filed before AIPA, the density of the licensing lag displays a bump shortly following the application date, hits a slight "trough" after about 20 months from application, and then picks up before dropping off about five years after the application date. In contrast, for patent applications after AIPA, licensing appears to be concentrated around three periods: (i) the months immediately after the application date; (ii) shortly after the 18-month publication date; and (iii) 50 months after the application date. The "bump" in the concentration of licenses shortly after the 18-month publication date is unique to the post-AIPA subsample and provides the first suggestive evidence that public disclosure facilitates licensing transactions. Table 2 confirms the substantial increase in the fraction of licenses that occur between 18 months after application and patent allowance after AIPA (37 percent) relative to pre-AIPA patents (15.8 percent).

Table 2 here

Figure 5 here

Prediction (1b) states that the likelihood of licensing after patent allowance is expected to decrease after AIPA. Figure 5 plots the density distribution of the difference between the licensing date and the earliest patent allowance date (in months). In the figure, the mass of licenses to the left of zero indicates licenses signed prior to patent allowance, and the mass to the right of zero are licenses signed after allowance. The distribution of licenses for patents filed pre-AIPA is similar to the one presented in Figure 2 of Gans, Hsu, and Stern (2008), showing a significant increase in the density of licenses after patent allowance.[19]

A couple of aspects stand out when comparing the timing density distributions of pre- and post-AIPA patent licenses. First, a larger fraction of licenses are signed before patent allowance post-AIPA. This is consistent with our prediction that AIPA's 18-month disclosure requirement is instrumental in shifting the licensing date from the patent allowance date to either the patent publication date or the application date. Table 2 confirms that, before AIPA, a majority—62 percent—of inventions are not licensed until patent allowance; for post-AIPA inventions, this proportion drops to 37 percent.

Second, since the implementation of AIPA, for inventors who wait until after patent grant to license their inventions, the timing of licensing appears to be concentrated closer to the allowance date. This effect is likely because the required 18-month disclosure allows potential licensees to access, learn about, and

[19]There are, however, some differences between our sample and the one used in Gans, Hsu, and Stern (2008). Their data on 198 licenses are spread across four different industries, while our 339 licenses are all in the biomedical industry. The (mean) patent allowance lag and patent application-to-licensing lag are, respectively, 38 and 48 months in Gans, Hsu, and Stern (2008). They are, respectively, 32 and 39 months in our study for the comparable pre-AIPA period.

perform due-diligence regarding the invention and its potential value earlier in the patent application review process; thus, licensing occurs sooner after the legal rights of the inventor are certified by patent allowance.

Figure 6 plots the cumulative distributions of licensing lags for pre-AIPA and post-AIPA patent applications, confirming a systematic increase in the cumulative probability of licensing around and immediately following 18-month publication for post-AIPA patents (Kolmogorov-Smirnov tests confirm that the pre-AIPA and post-AIPA distributions are statistically different from each other at $p < 0.05$).

Figure 6 here

The above patterns in the sample suggest that pre-grant patent publication facilitates licensing, both before and after patent allowance. Still, the patterns could be driven by other factors that may have changed over the study period in ways that increased the benefits of earlier licensing. In particular, expected patent pendency (the time required to examine and grant patent applications) increased by nearly six months for post-AIPA patent applications. This could be an important confounding factor because, given a fixed patent term (20 years), longer grant delay (T_g) implies more periods of lost revenues and, thus, incentives to license sooner. In the following sections, we estimate the effects of AIPA on the timing of licensing after controlling for changes in expected pendency and other factors that might influence the timing of licensing.

4 Regression results

4.1 Baseline results

4.1.1 Effects of AIPA on the likelihood of licensing after patenting-related events

We are interested in isolating the effects of patent publication (required by AIPA) on the timing of licensing, separate from the effects of patent allowance. Hence, in the multivariate regressions below, we control for several variables that commonly influence the timing of licensing and patenting-related events. The conditional probability of licensing in each of the three licensing windows (before 18 months from the patent application date; between 18 months after application and patent allowance; and after patent allowance) can be estimated by the following multinomial logit (MNL) model. We set the third option (license after allowance) as the baseline outcome. The conditional likelihood of observing outcome $j \in \{1,2\}$ is given by

$$\Pr(Y_i = j|X_i) = \frac{\exp(\alpha_j \text{PostAIPA}_i + X_i\beta_j)}{1+\sum_{h=1}^{2}\exp(\alpha_h \text{PostAIPA}_i + X_i\beta_h)},$$

where PostAIPA_i is a dummy variable that indicates whether the earliest patent application in the license i is filed after AIPA; X_i are control variables including characteristics of the patent, licensing parties, and technology class; and α_j and β_j, $j \in \{1,2\}$ are coefficients of the independent variables associated with the j^{th} outcome.

Since the MNL parameter estimates are hard to interpret, we report the relative risk ratios (RRR) corresponding to the MNL estimates. A greater-than-one (less-than-one) ratio corresponds to a positive (negative)

effect of a unit increase in the independent variable on the risk of choosing the outcome category relative to the baseline outcome.

Table 3 here

Table 3 reports the MNL estimates of the risk of licensing in the three licensing windows as a function of the licensing regime (post-AIPA patent application). Column (1) shows that, after AIPA, the unconditional risk ratio of licensing within 18 months of filing a patent application is nearly twice that of licensing in the same period before AIPA; and the risk ratio of licensing between 18 months and allowance is nearly four times that of licensing in the same period before AIPA (relative to the baseline risk of licensing after patent allowance). Column (2) shows that, after controlling for the number of patents specified in the license and the contracting parties' experience, the estimated effects of AIPA on inventors' choice of earlier licensing windows are marginally stronger. Column (3) adds more patent-level variables, including measures of patent quality (number of claims, number of forward citations, patent originality, and backward citations to scientific prior art), patent technology class, and expected pendency, as control variables.

Using the full set of controls reduces the number of licenses (observations) in our estimating sample to 291 because 48 of the agreements licensed patent applications that were either pending grant or abandoned by the end of 2012. Thus, we do not have information about their characteristics (such as claims, citations, or technology class). Since post-AIPA patent applications are more likely to be licensed before allowance, omitting the licenses of applications that were not granted is likely to underestimate the positive effect of AIPA on licensing in the earlier windows. Despite this, Column (3) shows that post-AIPA patents have a 3.8 times greater risk ratio of licensing between 18 months and patent grant than pre-AIPA patents (significant at $p < 0.01$). The estimates show that post-AIPA patents are not more likely to be licensed sooner than 18 months after application.

What effect does AIPA have on the probability of licensing after grant? Given that the estimated risk of licensing immediately after patent application is not significantly different for post-AIPA patents, the increase in licensing after 18 months should be accompanied by a corresponding drop in the probability of licensing after allowance. A linear probability model (see Column 1 of Table 4) confirms that, conditional on licensing, post-AIPA patents are 18 percentage points less likely to be licensed after allowance, controlling for the characteristics of the licensing parties and licensed patent.

These results are qualitatively consistent with Predictions (1a) and (1b), and the large magnitudes of the estimated effects of AIPA suggest that public disclosure benefits a substantial proportion of inventions (*i.e.*, d is sufficiently high for these inventions). The fact that the likelihood of licensing does not change much immediately after application post-AIPA suggests that, on average, concerns about information leakage are high enough to shift licensing for some inventions from post-allowance to immediately post-application (*i.e.*, negating Prediction (1c)), possibly counterbalancing some inventions that moved from licensing immediately after application to licensing after the required 18-month disclosure.[20]

[20]Two of our control variables—the number of patents in a license and the expected examination pendency— significantly affect the timing of licensing, but both appear to affect the choice between licensing after patent grant and licensing immediately after application. Inventions associated with patent applicants that face longer pendencies are more likely to be licensed immediately on

Table 4 here

4.1.2 Effects of AIPA on licensing delay

Our second prediction is that the effect of AIPA on the overall licensing lag is indeterminate and depends on the net effect of inventors who postpone licensing (from application date to publication date) and those who expedite licensing (from patent allowance to either publication or application date). Our findings show that the probability of licensing after the 18-month publication increased after AIPA, while the likelihood of licensing immediately after application was largely unchanged, suggesting that overall licensing delays were reduced by pre-grant patent publication. We next estimate the magnitude of this reduction in licensing delays after AIPA.

Column (2) of Table 4 reports Tobit estimates for licensing lags, which are censored below at zero. The estimates suggest that, on average, the licensing lag is shorter for post-AIPA patent applications by 8.5 months, after controlling for other patent and licensing party characteristics. As suggested before, this acceleration in licensing stems from two distinct effects of disclosure. First, as the previous section showed, after AIPA, licensing is substantially more likely to occur before patent allowance, thereby reducing licensing lags. Second, conditional on licensing after allowance, licensing also occurs more quickly (Column (3) of Table 4 suggests that post-allowance licensing happens 11.7 months closer to the allowance date for post-AIPA patent applications). This latter finding, also evident from Figure 5, suggests that pre-grant publication facilitates the dissemination of information about the patent to potential licensees such that they can be licensed soon after allowance. Our back-of-the-envelope calculation suggests that these two channels contribute roughly equally to the decrease in the average licensing lag.[21]

4.2 Heterogenous effects of AIPA

Although our empirical tests lack a control group of patent applications that are not affected by AIPA, the 18-month publication date mandated by the law was a non-event for pre-AIPA patent applications. Hence, the sharp increase in the likelihood of licensing shortly after the 18-month publication date is unlikely to be caused by factors other than patent publication. Still, we explore the effects of AIPA in different subsamples, which, we believe, have different characteristics pertaining to the parameters that influence inventors' trade-offs regarding the timing of licensing as captured by our theoretical framework. If the observed differences across the subsamples are consistent with our expectations, the findings should strengthen our interpretation that the estimated effects of AIPA are due to patent publication.

application, and applicants with several (future) patent applications appear to delay licensing until the allowance of their earliest patent.

[21] First, 37% of post-AIPA patents are licensed after issue. With an average decrease of 11.7 months, this post-allowance effect contributes to reducing overall licensing lags by about four months. Second, compared to pre-AIPA, licensing is more likely to happen sooner—*i.e.*, shortly after 18-month publication and before allowance. With the pre-AIPA difference in the conditional licensing lag of about 22 months, this latter mechanism also contributes about four months to the overall reduction in licensing lags.

4.2.1 Patents with and without foreign-patent counterparts

As explained in Section 2, prior to AIPA, U.S. applications that were also filed in a foreign country were already published 18 months after the earliest filing date (priority date) in those countries. Therefore, we expect that U.S. patent applications with corresponding foreign applications would be less likely influenced by pre-grant publication in the U.S. after AIPA. Since publication in a foreign jurisdiction does not have the same effect as publication by the USPTO (our potential set of licensees—primarily U.S. corporations—are more likely to search for, and be aware of, patents disclosed by the U.S. patent office), we expect AIPA to affect patents with foreign counterparts, but not as strongly as it affects those without foreign equivalents.

Table 5 here

Table 5 reports MNL estimates of the effects of AIPA on the choice of licensing window for the subsamples of patents with and without foreign equivalents. As we expected, the effects of AIPA are substantially stronger (in predicting licensing after the 18-month publication date) for the subsample of U.S. patents *without* foreign counterparts.

Appendix Table A1 (Columns 1 and 2) shows that, after AIPA, U.S. patents without foreign equivalents are 23 percent less likely to wait until patent allowance before they are licensed, and the law change appears to have no significant effect on the likelihood of post-allowance licensing for U.S. patents with foreign counterparts. Likewise, Appendix Table A2 (Columns 1 and 2) shows that licensing lags are, on average, 8.2 months shorter for U.S. patents without foreign equivalents after AIPA, but not significantly changed for post-AIPA applications with foreign equivalents.

4.2.2 For-profit versus non-profit licensors

We compare the estimated effects of AIPA on patents licensed out by non-profit organizations versus for-profit corporations. In our sample, 41.9 percent of the licensors are non-profit organizations (such as universities, hospitals, and research institutes), and the rest are for-profit entities (54.3 percent corporations and 3.8 percent individuals). Non-profit organizations are different from for-profit organizations in a number of aspects: They typically have fewer resources with which to advertise and search for potential licensees, and they may also be less concerned about information leakage. Therefore, we expect that the effect of AIPA on increasing the likelihood of licensing after publication is greater for non-profit than for for-profit licensors because, for example, publication would bring the former greater benefits through reducing search costs for potential licensees. At the same time, we also expect that the likelihood of licensing immediately after application is more likely to decrease for non-profit licensors because, according to Prediction (1c), when concerns for information leakage are small, the likelihood of licensing immediately after application will decrease.

Table 6 here

Table 6 reports MNL estimates predicting licensing timing for the subsamples of non-profit and for-profit licensors. As we expected, after AIPA, non-profits are significantly more likely to license after the 18-month

publication date, while corporate licensors are not. For non-profit organizations, post-AIPA patents are less likely to be licensed immediately after application, although this effect is not statistically significant (at p < 0.05). Still, the contrast in the estimated signs of this variable for non-profit and for-profit licensors is consistent with our supposition that non-profit organizations care less about information leakage.

Appendix Table A1 (Columns 3 and 4) shows that, after AIPA, U.S. patents belonging to non-profit licensors are 26 percent less likely to wait until patent allowance to be licensed, while the law change has no significant impact on the likelihood of post-allowance licensing for corporate licensors. Appendix Table A2 (Columns 3 and 4) shows that licensing lags are, on average, 8.5 months shorter after AIPA for non-profit licensors ($p < 0.1$) and 8.06 months shorter for corporate licensors, though the latter estimate is only marginally significant ($p = 0.11$). These results suggest that pre-grant publication affects corporate licensors primarily through facilitating quicker evaluation and negotiations after patent allowance.

One might argue that these results duplicate our previous findings on the differences between AIPA's effects on patents with and without foreign equivalents, if non-profit licensors are also significantly less likely to pursue equivalent foreign protection. But 43 percent of the patents belonging to non-profits (and 50 percent of the patents belonging to for-profits) pursued foreign protection, making it unlikely that the differences reported in Sections 4.2.1 and here are driven by the same underlying variation.

4.2.3 Patents with a high versus low a number of references to scientific prior art

We compare the estimated effects of AIPA across subsamples of patents that cite a high versus a relatively low number of scientific papers. The assumption behind this distinction is that patents that cite a larger number of scientific papers are more likely to be associated with inventions that are already publicly disclosed (before the application date). Hence, the potential loss from information leakage enters the licensor's payoff from licensing in the same fashion (as $-\Delta T$), regardless of the licensing timing or the patent regime, and, therefore, they cancel each other out. Correspondingly, in Figure 2(b), the terms related to information leakage reduce to zero, and the lines separating "application" and "grant" overlap. As a result, the likelihood of licensing immediately after application date decreases after AIPA.[22] Therefore, we expect that AIPA is more likely to decrease the likelihood of licensing immediately after the application date for patents that cite a relatively high number of scientific papers than for patents that cite a relatively low number of scientific papers.

Table 7 here

We choose the sample mean of 5.8 references to non-patent (scientific) prior art to divide the sample into subsamples with a below-average number of scientific references (119 licenses) and an above-average number of scientific references (172 licenses). Table 7 reports MNL estimates predicting licensing timing separately for the two subsamples. Consistent with our expectation, after AIPA, patents with a high proportion of references to scientific papers are less likely to be licensed immediately after application; and,

[22] Note that this reasoning is not exactly the same as in Prediction (1c) since the inventors can still care about information leakage, but AIPA does not affect this aspect of the tradeoffs.

in sharp contrast, patents with below-average references to scientific papers appear to be substantially more likely to be licensed immediately after patent application.

Appendix Table A1 (Columns 5 and 6) shows that, after AIPA, patents with a below-average number of scientific references are 35 percent less likely to wait for patent allowance to be licensed, while the corresponding estimated effect of 16 percent is not statistically significant at conventional levels for patents with a high number of references to scientific papers. The estimated shorter licensing delay for the latter sample (10.3 months) is statistically significant, but not so for the sample with a low number of scientific references (see Columns 5 and 6 of Appendix Table A2).

The patents in our subsample of non-profit licensors contain 6.7 references to scientific articles, on average, compared to 5.2 references in the for-profit licensors' subsample. However, we obtain the subsample estimates of this section after controlling for the organizational type of the licensors, and it is unlikely that they simply duplicate the findings reported in Section 4.2.2.

We acknowledge that our comparisons of AIPA's effects in the different subsamples are imperfect and open to alternative interpretations. In particular, corporate licensors differ from non-profit licensors in several aspects, and the number of patent references to scientific prior art could be a primary indicator of the "basicness" of the inventions. Nonetheless, taken together, the results of our investigation of the heterogeneous effects of AIPA are consistent with our expectations based on the theoretical framework presented in Section 2. Furthermore, the results strengthen the interpretation of our main results as revealing the substantial benefits of patent publication in facilitating licensing.

4.3 Robustness checks

4.3.1 Patent allowance within 18 months from filing

Twenty percent of all licenses in our sample and 23.4 percent of the 291 patent licenses granted by the end of 2012 were allowed within 18 months of the patents' application date. These patents, which enjoyed a relatively short period of examination, are infrequent in the post-AIPA subsample (less than ten percent of the post-AIPA patent applications that are granted), and we might worry that they bias our estimates of AIPA's effects. Therefore, we re-estimate our main regressions after excluding the 68 licenses with patents that were allowed within 18 months of application. The corresponding estimates, reported in Table A3 of the Appendix, confirm the robustness of the full-sample estimates presented in Tables 3 and 4.

4.3.2 The hazard of licensing

We also estimate the effect of AIPA on licensing delay with a Cox proportional hazard rate model. Let λ be the hazard rate of licensing changing from 0 to 1 (*i.e.*, the instantaneous probability of licensing at t conditional on not being licensed until t).

$$\lambda(t|X_i) = \lambda_0(t)\exp(\alpha \text{PostAIPA}_i + \beta X_i + \varepsilon_i \geq 0).$$

The coefficient α is the estimated effect of AIPA on the hazard rate of licensing. Appendix Table A4 reports the estimated coefficients from the Cox proportional hazard rate model and reveals that the hazard rate of licensing is 67-percent higher for post-AIPA patent applications.

4.3.3 Provisional rights

As mentioned in Section 2, AIPA also granted provisional rights to inventors such that they could collect royalties for the period between patent publication and patent grant from infringers (contingent on the patent issuing with claims comparable to the ones in the published application). Before AIPA, inventors could collect royalties from alleged infringers only from the date of patent allowance. Hence, one might argue that rather than patent publication, the allocation of provisional rights was responsible for expedited licensing. Our baseline and heterogeneous-effects results suggest that our core findings are due to patent publication. In addition, provisional rights are closely tied to disclosure: Without credible proof of disclosure (which patent publication establishes), it would be hard to establish willful infringement and, thus, claim provision rights.

Nevertheless, we attempt to understand the effect of provisional rights on the timing of licensing by adding enforcement to our theoretical framework (see Appendix A1). We find that conditional on 18-month publication, the legal right to recoup royalties from publication date does not affect the timing of licensing. This is because, in each regime, enforcement affects the payoffs from licensing in the same way for all timing options; thus, the effects cancel each other out. Of course, this is not to say that provisional rights do not matter. In fact, our interviews with inventors suggest that provisional rights are an important reason for publishing applications before patent allowance even if they can opt out. Therefore, we infer that provisional rights compensate inventors for the potential negative spillovers and leakage associated with early publication. However, the expected changes in licensing timing are due to the effects of publication and not to provisional rights.

4.3.4 Changes in FDA approval times

Finally, changes in FDA approval times could affect the timing of licensing. In particular, longer approval times might encourage earlier transactions because the effective time during which the developers can recoup their R&D investments is shorter. According to Recap Development, the difference between the FDA application date and the approval date was 18 months before and 13 months after AIPA ($p < 0.01$).[23] Thus, the change in FDA approval times is unlikely to drive earlier licensing in the post-AIPA period and might even downwardly bias our estimate of AIPA's effects in accelerating licensing.

5 Concluding thoughts

The market for ideas improves the innovation process by promoting the division of labor between upstream inventors and downstream developers. Frictions such as asymmetric information and search costs may

[23] Recap Development data cover the clinical trial and approval data for all projects of top 200 biotechnology firms. There have been 318 biomedical drugs approved between 1990 and 2011.

hinder the smooth functioning of the market and delay, or even block, mutually profitable transactions between buyers and sellers. In this paper, we study the effects of an important disclosure mechanism, the publication of patent applications, on mitigating these frictions and, thus, facilitating transactions in the market for ideas. In particular, we employ an important policy change (AIPA) that required U.S. patent applications filed beginning on November 29, 2000 to be published 18 months after the application date. AIPA established a separation between two events that were coincident before the law: the disclosure of technical information embedded in patent applications and the certification of property rights associated with patent allowance. Our theoretical framework develops predictions about the effects of AIPA on the timing of licensing, and we test the predictions with data in the biomedical industry.

Consistent with our predictions, we find that post-AIPA patent applications are more likely to be licensed after the 18-month publication (and before patent allowance) than pre-AIPA patent applications, and that post-AIPA patent applications are, on average, 18 percentage points less likely to wait until patent allowance to be licensed. In addition to expediting licensing to an earlier milestone (*i.e.*, the publication event), pre-grant publication also seems to facilitate quicker evaluation and negotiations and, therefore, results in licensing sooner, even if the parties decide to transact after the patent is allowed. Overall, after controlling for changes in the time taken by the USPTO to examine patents and other observable characteristics of the licensing parties and patents, we find that post-AIPA patents, on average, are licensed 8.5 months earlier than pre-AIPA inventions. This shortening of the licensing lag is economically significant, given the 20-year duration of U.S. patents, and can translate to millions of dollars in profits and licensing revenues.[24]

Our findings provide evidence that disclosure through patent publication facilitates transactions in the market for ideas, potentially through reducing frictions such as information asymmetries, search costs and costs of evaluating competing ideas. Our results also confirm the conclusion in Gans, Hsu, and Stern (2008) that the clarification of property rights plays a critical role in facilitating licensing, as well. In particular, Figure 5 suggests that once transaction costs (such as evaluation time) are partially removed post-AIPA because of pre-grant publication, the patent allowance event has an even stronger impact on the likelihood of licensing.

Our results on patent publication raise the natural question: Why don't inventors voluntarily disclose their ideas? We believe that the effects of disclosure of inventions obtained through patent publication is distinct from voluntary disclosure in several aspects: The USPTO's requirements for patent applications establish a uniform and credible standard for the disclosure of inventions, which, in turn, facilitates easy search and "comparison shopping" of ideas; patent publication simultaneously reveals the technical details of inventions and the potential scope of the inventors' property rights; and licensors and licensees are known to search databases of patent applications for potential licensing opportunities, and patent databases are among the largest repositories of inventions. These unique benefits of patent publication by patent offices are hard to convey through inventors' voluntary disclosures.

Our study has several limitations. Although it appears unlikely that particular types of patents selected into (or out of) licensing after AIPA, we have not analyzed the overall effects of pre-grant publication on

[24]Our findings also contrast with those in a recent working paper by de Rassenfosse, Palangkaraya, and Webster (2013), who find no difference in the probability of licensing for inventions covered by pending Australian patent applications and those without patent applications and interpret this as the absence of a disclosure effect.

inventors' *ex ante* incentives for patenting and licensing. Our analysis also falls short of pinpointing the exact mechanisms (and their relative importance) through which patent disclosure facilitates licensing (e.g., through reducing information asymmetry or search costs). The exact channels through which informational frictions impede transactions are important to understand and, when addressed, could help us obtain a more complete picture of how information disclosure increases the efficiency of the market for ideas.

References

ALLAIN, M.-L., E. HENRY, AND M. KYLE (2012): "Inefficiencies in the Sale of Ideas: Theory and Empirics," CEPR Discussion Paper No. DP8206.

ANTON, J. J., AND D. A. YAO (1994): "Expropriation and Inventions: Appropriable Rents in the Absence of Property Rights," *The American Economic Review*, 84(1), 190–209.

——— (2002): "The Sale of Ideas: Strategic Disclosure, Property Rights, and Contracting," *Review of Economic Studies*, 69, 513–31.

——— (2003): "Patents, Invalidity, and the Strategic Transmission of Enabling Information," *Journal of Economics and Management Strategy*, 23, 151–178.

AOKI, R., AND T. PRUSA (1996): "Product Development and the Timing of Information Disclosure under U.S. and Japanese Patent Systems," *Journal of the Japanese and International Economies*, 10, 233–249.

AOKI, R., AND Y. SPIEGEL (2009): "Pre-grant Patent Pulication and Cumulative Innovations," *International Journal of Industrial Organization*, 27, 333–345.

ARORA, A. (1995): "Licensing Tacit Knowledge: Intellectual Property Rights And The Market For Know-How," *Economics of Innovation and New Technology*, 4, 41–60.

ARORA, A., A. FOSFURI, AND A. GAMBARDELLA (2001): *Markets for Technology: The Economics of Innovation and Corporate Strategy*. MIT Press, Cambridge, Mass.

ARROW, K. (1962): "Economic Welfare and the Allocation of Resources for Invention," in *The Rate and Direction of Inventive Activity: Economic and Social Factors*, ed. by R. Nelson. Princeton University Press.

BESSEN, J. E. (2005): "Patents and the Diffusion of Technical Information," *Economics Letters*, 86, 121–28.

BLOCH, F., AND P. MARKOWITZ (1996): "Optimal Disclosure Delay in Multistage R&D Competition," *International Journal of Industrial Organization*, 14, 159–179.

COHEN, W. M., R. R. NELSON, AND J. P. WALSH (2000): "Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)," National Bureau of Economic Research Working Paper, Working Paper Series 7552.

DE RASSENFOSSE, G., A. PALANGKARAYA, AND E. WEBSTER (2013): "Do Patents Shield Disclosure or Assure Exclusivity When Transacting Technology?," Intellectual Property Research Institute of Australia Working Paper No. 1/13.

DECHENAUX, E., M. THURSBY, AND J. THURSBY (2009): "Shirking, Sharing Risk and Shelving: The Role of University License Contracts," *International Journal of Industrial Organization*, 27, 80–91.

DENICOLÒ, V., AND L. FRANZONI (2004): "The Contract Theory of Patents," *International Review of Law and Economics*, 23, 365–380.

ELFENBEIN, D. W. (2007): "Publications, Patents, and the Market for University Inventions," *Journal of Economic Behavior & Organization*, 63(4), 688–715.

GALLINI, N. T. (2002): "The Economics of Patents: Lessons from Recent U.S. Patent Reform," *Journal of Economic Perspectives*, 16, 131–154.

GALLINI, N. T., AND S. SCOTCHMER (2001): "Intellectual Property: When is it the Best Incentive System?," in *Innovation Policy and the Economy*, ed. by A. Jaffee, L. J., and S. Stern, vol. 2, p. 5177. MIT Press, Boston, Massachusetts.

GALLINI, N. T., AND B. D. WRIGHT (1990): "Technology Transfer under Asymmetric Information," *RAND Journal of Economic*, 21(1), 147–160.

GANS, J. S., D. H. HSU, AND S. STERN (2002): "When Does Start-Up Innovation Spur the Gale of Creative Destruction?," *RAND Journal of Economics*, 33(4), 571–586.

——— (2008): "The Impact of Uncertain Intellectual Property Rights on the Market for Ideas: Evidence from Patent Grant Delays," *Management Science*, 54, 982–997.

GANS, J. S., AND S. STERN (2010a): "Is There a Market for Ideas?," *Industrial and Corporate Change*, 19(3), 805–837.

——— (2010b): "When do Patents Encourage Disclosure," working paper.

GILBERT, R. J., AND D. M. G. NEWBERY (1982): "Preemptive Patenting and the Persistence of Monopoly," *American Economics Review*, 72, 514–526.

GLAZER, A. (1985): "The Advantages of Being First," *American Economic Review*, 75, 473–480.

GRAHAM, S., AND D. HEGDE (2013): "Which Inventors Value Secrecy in Patenting? Evidence from the American Inventor's Protection Act of 1999," NYU-Stern School of Business Working Paper.

HALL, B., A. JAFFE, AND M. TRAJTENBERG (2001): "The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools," NBER Working Paper 8498.

HEGDE, D. (2012): "Funding and Performance at the U.S. Patent and Trademark Office," *Nature Biotechnology*, 30.

——— (2013): "Tacit Knowledge and the Structure of License Contracts: Evidence from the Biomedical Industry," (forthcoming) Journal of Economics and Management Strategy, Latest version: http://ssrn.com/abstract=1807128.

HEGDE, D., D. MOWERY, AND S. GRAHAM (2009): "Pioneering Inventors or Thicket-builders: Which Firms Use Continuations in Patenting?," *Management Science*, 55, 1214–1226.

HELLMANN, T. (2007): "The Role of Patents for Bridging the Science to Market Gap," *Journal of Economic Behavior & Organization*, 63, 624–657.

HELLMANN, T., AND E. PEROTTI (2011): "Circulation of Ideas: Firms versus Markets," *Management Science*, 57, 1813–1826.

JENSEN, R. A., AND M. C. THURSBY (2001): "Proofs and Prototypes for Sale: The Licensing of University Inventions," *American Economic Review*, 91, 240–259.

JOHNSON, D., AND D. POPP (2003): "Forced out of the Closet: the Impact of the American Inventor's Protection Act on the Timing of Patent Disclosure," *Rand Journal of Economics*, 34, 96–112.

KITCH, E. (1977): "The Nature and Functions of the Patent System," *The Journal of Law and Economics*, 20, 265–290.

LERNER, J., AND U. MALMENDIER (2010): "Contractibility and the Design of Research Agreements," *American Economic Review*, 100, 214–246.

LERNER, J., AND R. P. MERGES (1998): "The Control of Strategic Alliances: An Empirical Analysis of Biotechnology Collaborations," *Journal of Industrial Organization*, 46(2), 125–156.

LUO, H. (2012): "When to Sell Your Idea: Theory and Evidence from the Movie Industry," Harvard Business School Working Paper 12-039.

MODIGLIANI, F. (1999): "An Open Letter to the U.S. Senate," available at http://www.eagleforum.org/patent/nobel_letter.html.

PUTNAM, J. (1997): "The Value of International Patent Rights," Mimeo, Charles River Associates.

RAGUSA, P. A. (1992): "Eighteen Months to Publication: Should the United States Join Europe and Japan by Promptly Publishing Patent Applications?," *The George Washington Journal of International Law and Economics*, 26, 143–180.

ROBINSON, W. T. (1990): "Product Innovation and Start-Up Business Market Share Performance," *Management Science*, 36, 1279–1289.

SCHMALENSEE, R. (1978): "Entry Deterrence in the Ready-to Eat Breakfast Cereal Industry," *Bell Journal of Economics*, 9, 305–327.

TEECE, D. J. (1986): "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy," *Research Policy*, 15(6), 285–305.

TEPPERMAN, A. (2002): "Do Priority and Disclosure Rules Matter? Canadian Evidence from the 1989 Patent Reforms," Mimeo, Charles River Associates.

VERRECCHIA, R. E., AND J. WEBER (2006): "Redacted Disclosure," *Journal of Accounting Research*, 44, 791–814.

WAKEMAN, S. (2012): "How does Obtaning Intellectual Property Rights Impact Technology Commercialization Strategy for Start-up Innovators? Reconciling the Effects on Licensing and Financing," Working paper.

Appendix

A1. Incorporating Enforcement into the Theoretical Framework

This section incorporates the effects of enforcement of inventors' rights into our theoretical framework, with the goal of understanding how the granting of provisional rights (which coincided with the 18-month publication rule implemented by AIPA) might affect the timing of licensing. Before AIPA, the inventors' right to recoup royalties from infringers started from the grant date of their patents, while after AIPA, pre-grant publication allows inventors to demand royalties from infringers from the 18-month publication date of their patents (so long as the granted patent application substantially resembles the published application). Recall that "inventing around" reduces inventors' revenues by Δ. Suppose, now, that with probability γ, the inventor recovers the loss through enforcement. Thus, we can write the inventor's payoffs from licensing after our focal events before and after AIPA as follows. Notice that adding the effects of enforcement essentially reduces the magnitude of Δ to $(1-\gamma)\Delta$ in all the terms associated with the payoffs for periods after the grant date pre-AIPA and after the publication date post-AIPA.

Before AIPA, the inventor's payoffs are:

$$U_a^{\text{before}} = (1-\rho)vT_g + \rho(v-\Delta)T_g + (v-(1-\gamma)\Delta)(T-T_g).$$

$$U_g^{\text{before}} = (v+d+g-(1-\gamma)\Delta)(T-T_g).$$

The inventor licenses after the grant date if and only if

$$(v-\rho\Delta)T_g > (d+g)(T-T_g).$$

After AIPA, the inventor's payoffs are:

$$U_a^{\text{after}} = (1-\rho)vT_d + \rho(v-\Delta)T_d + (v-(1-\gamma)\Delta)(T-T_d),$$

$$U_d^{\text{after}} = (v + d - (1-\gamma)\Delta)(T - T_d),$$

$$U_g^{\text{after}} = (v + d + g - (1-\gamma)\Delta)(T - T_g) - (1-\gamma)\Delta(T_g - T_d).$$

The inventor licenses after application if and only if

$$(v - \rho\Delta)T_d > d(T - T_d) \;\; \& \;\; vT_g - \rho\Delta T_d > (d+g)(T - T_g).$$

and licenses after publication if and only if

$$(v - \rho\Delta)T_d < d(T - T_d) \;\; \& \;\; (v+d)(T_g - T_d) > g(T - T_g).$$

It turns out that the conditions under which the inventor chooses the timing of licensing (both before and after AIPA) are the same as the conditions derived without considering the effects of enforcement. In fact, the enforcement-related terms do not show up in these conditions because for any patent regime, enforcement enters the inventor's payoffs in the same way, regardless of the licensing timing, and cancels out when the inventor makes the timing decision. This suggests that, given publication (i.e., if the inventor does not opt out of pre-grant publication), changing the right to recoup the royalty to the publication date does not change the timing of licensing. In other words, all expected changes in the timing of licensing are due to the change in the pre-grant publication rule.

Figures and Tables

Figure 1: Patenting events before and after AIPA

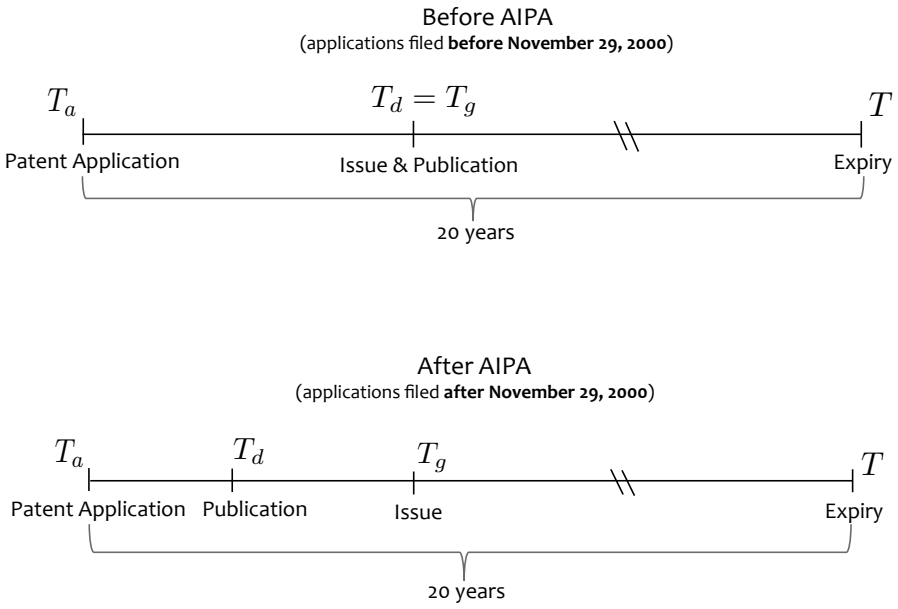
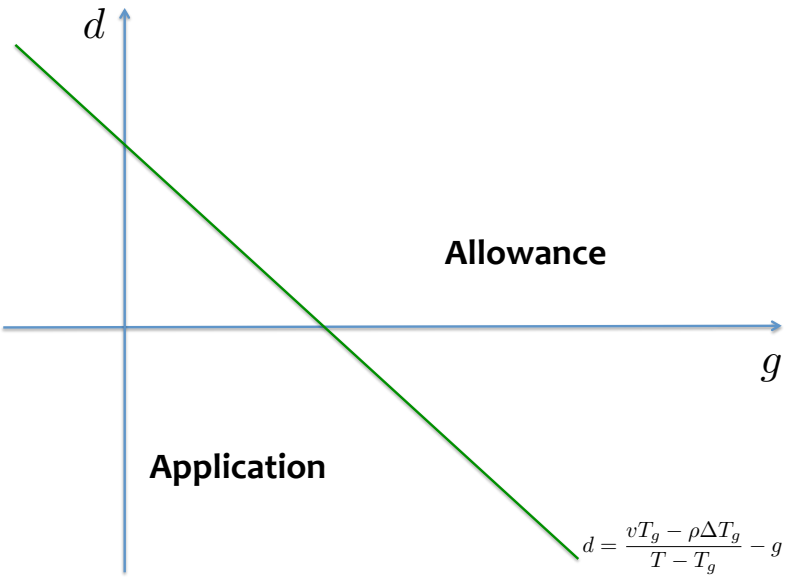


Figure 2: Timing of licensing before and after AIPA

(a) Before AIPA



(b) After AIPA

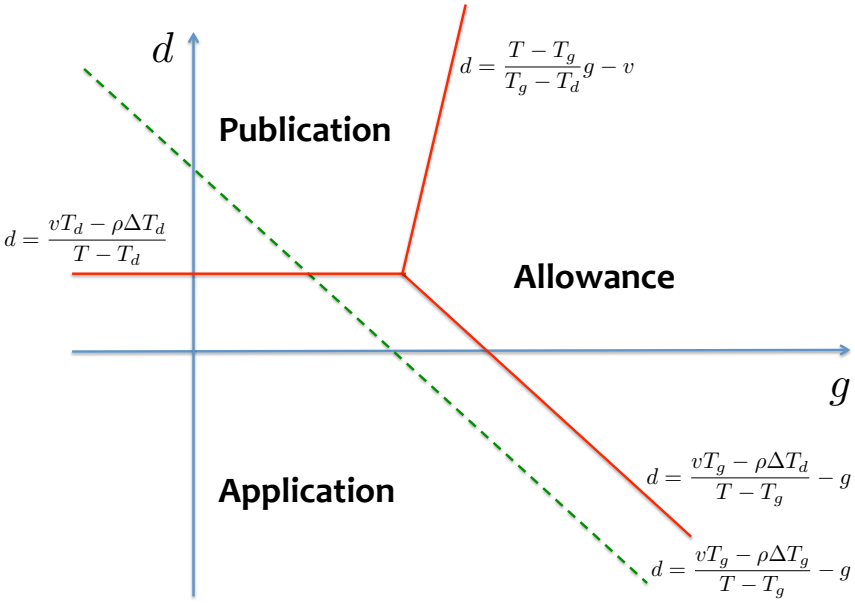
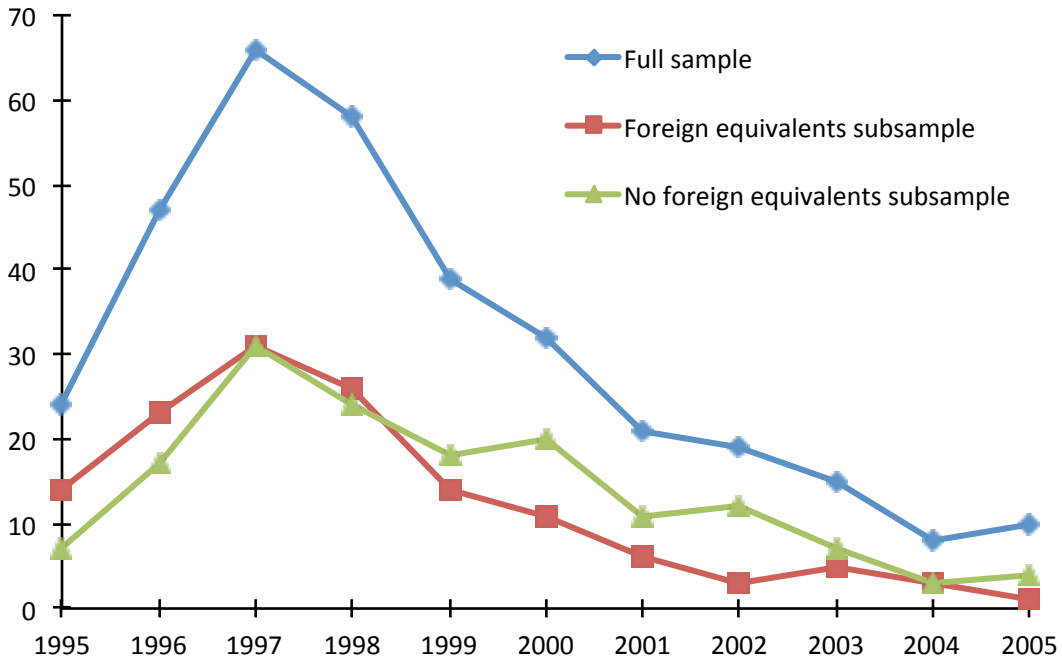
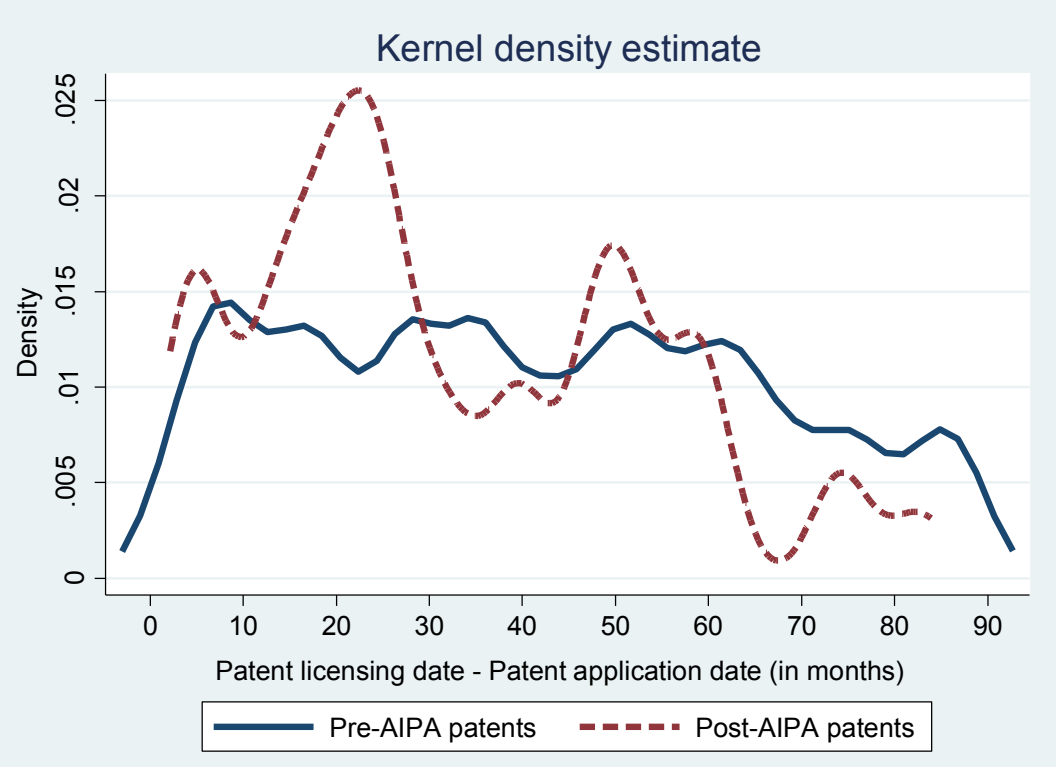


Figure 3: Number of licenses by the (first) application year of the licensed patents



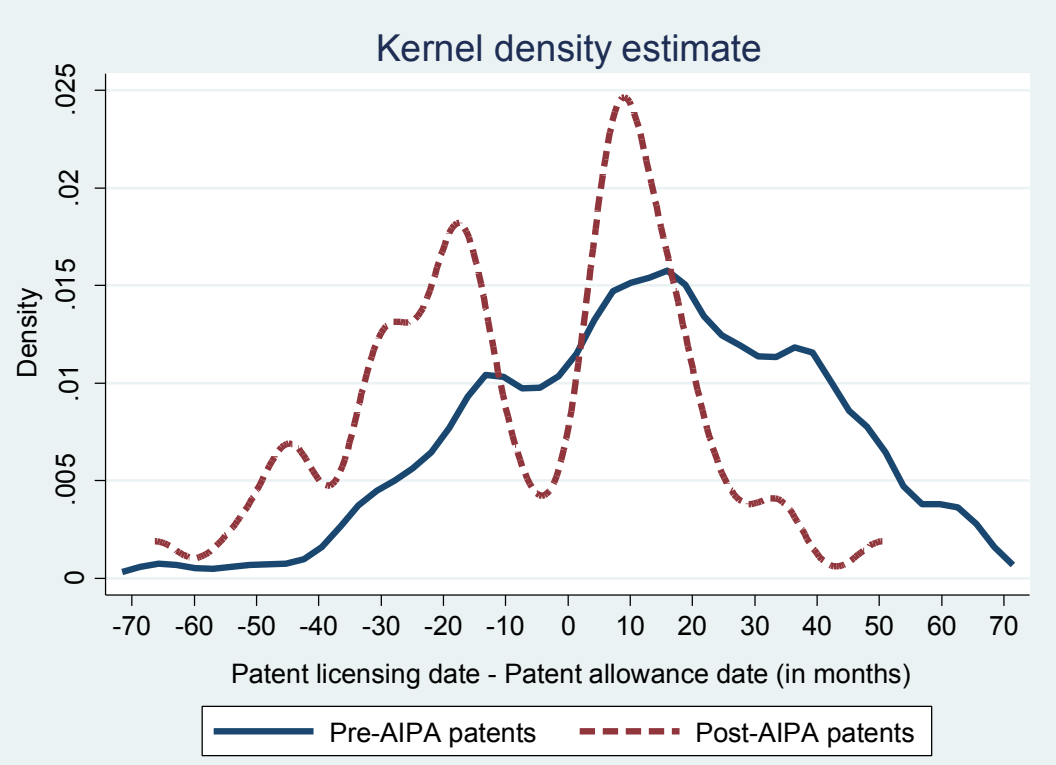
The full sample consists of 339 sample licenses that licensed patents with application dates between June 8, 1995 and December 31, 2005. The figure shows the number of licenses by the first application year of the licensed patents. The figure also shows the number of U.S. patents with foreign equivalents (137 licenses) and those without foreign equivalents (154 licenses). The latter information is available only for licenses associated with granted patents (291 licenses).

Figure 4: Distribution of difference between license date and patent application date



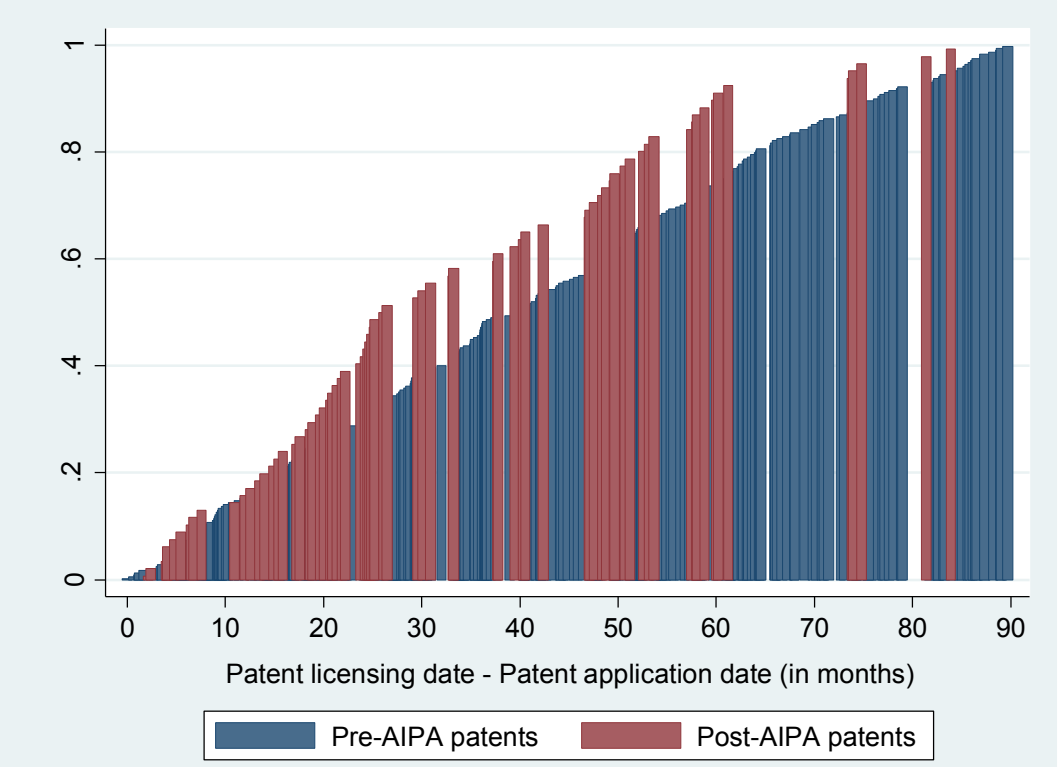
The figure shows kernel density estimates of the distribution of licensing lags (patent license date−patent application date) in months for pre-AIPA and post-AIPA patent applications. The horizontal timeline is measured in months; zero means that licensing happened in the same month in which the patent was applied for.

Figure 5: Distribution of difference between license date and patent allowance date



The figure shows kernel density estimates of the distribution of the difference between the license date and the patent allowance date (in months) for pre-AIPA and post-AIPA patents. The mass of data to the left of zero represents licenses that were transacted prior to patent allowance, whereas the mass of data to the right of zero represents licenses that occurred after patent allowance.

Figure 6: Cumulative distribution of difference between license date and application date



The figure shows the cumulative distribution of patent licensing lags (patent license date−patent application date) for pre-AIPA and post-AIPA patents. It shows a systematic shift to earlier licensing—i.e., a shorter licensing delay.

Table 1: Sample summary statistics

Variable	Mean	Before AIPA	After AIPA	Difference	p-value
Timing measures					
Patent application to license in months	39.35	41.14	32.85	-8.29*	0.01
Patent allowance to license in months	10.33	14.26	-6.53	-20.79**	0.00
Patent characteristics					
Number of patents	1.95	1.88	2.19	0.31	0.19
Patent claims	23.35	22.83	25.62	2.79	0.41
Patent citations	2.93	3.03	2.53	-0.50	0.61
Patent originality	0.39	0.38	0.43	0.04	0.33
References to non-patent prior art	5.79	5.71	6.11	0.40	0.48
Expected pendency in months	30.9	29.82	35.55	5.73**	0.00
Party characteristics					
Number of prior licensee deals	16.68	13.88	26.89	13.01*	0.03
Number of prior licensor deals	10.03	9.71	11.18	1.47	0.47
Number of prior joint deals	0.19	0.19	0.21	0.02	0.85

Table 2: The probability of licensing in different time windows before and after AIPA

Patent Regime	N. of Licenses	License before 18m	License b/w 18 mos. & patent grant	License after patent grant
Before AIPA	266	22.2%	15.8%	62.0%
After AIPA	73	26.0%	37.0%	37.0%

The table reports the percentage of licenses that occur after the three key patenting-related events (application date, 18-month publication date, and patent allowance date) for pre-AIPA and post-AIPA patents.

Table 3: Multinomial Logit (MNL) estimates for the choice of license timing window

Column #	(1)		(2)		(3)	
Sample	All licenses (applications & granted patents)		All licenses (applications & granted patents)		Patent licenses (patents granted by Dec-2012)	
D.V. = Licensing window	Before 18 months	B/w 18 mos. & allowance	Before 18 months	B/w 18 mos. & allowance	Before 18 months	B/w 18 mos. & allowance
Post-AIPA patent application	1.97*	3.93**	2.44*	4.57**	1.23	3.78**
	[0.66]	[1.27]	[0.88]	[1.57]	[0.53]	[1.58]
No. of patents in license			0.42**	0.93	0.50**	1.05
			[0.10]	[0.08]	[0.12]	[0.07]
No. of prior joint deals			1.55+	1.37+	1.48	1.33
			[0.38]	[0.23]	[0.36]	[0.24]
No. of prior licensee deals			1	1	1	1
			[0.00]	[0.00]	[0.00]	[0.00]
No. of prior licensor deals			0.99	1.01	0.98	0.99
			[0.01]	[0.01]	[0.02]	[0.01]
Patent claims					1	1
					[0.01]	[0.01]
Patent citations					1.03	1.02
					[0.02]	[0.03]
Patent originality					1.5	1.48
					[0.92]	[0.96]
Refs to non-patent prior art					0.97	0.99
					[0.05]	[0.05]
Log expected pendency					6.66*	1.96
					[6.38]	[2.24]
Licensor type dummies	N		Y		Y	
Technology class dummies	N		N		Y	
Observations	339		339		291	
Model chi-square	18.08		1633.10		2409.68	
Log-likelihood	-324.46		-296.48		-224.45	

The table presents MNL estimates for the probability of licensing in each of the three mutually exclusive categories: (i) before 18 months from (the first) patent application; (ii) between 18 months and allowance; and (iii) after patent allowance, the omitted base category. Coefficient estimates are reported as Relative Risk Ratios, with reference to the base category. Robust S.E. in brackets; ** $p < 0.01$, * $p < 0.05$, + $p < 0.10$.

Table 4: Estimates of license timing before and after AIPA

Column #—Model	(1)—OLS	(2)—Tobit	(3)—Tobit
Sample	All patent licenses	All patent licenses	Patents licensed *after* allowance
D.V.	Pr of license after patent allowance	Patent application to license lag	Patent allowance to license lag
Post AIPA patent	-0.18*	-8.56*	-11.69**
	[0.08]	[3.50]	[3.53]
No. of patents in license	0.02	2.35**	2.36**
	[0.02]	[0.85]	[0.70]
No. of prior joint deals	-0.07*	-5.28**	-4.94*
	[0.03]	[1.04]	[2.42]
No. of prior licensee deals	0	0.04	0.02
	[0.00]	[0.03]	[0.02]
No. of prior licensor deals	0	0.17	0.12
	[0.00]	[0.12]	[0.13]
Patent claims	0	0.02	-0.08
	[0.00]	[0.05]	[0.06]
Patent citations	0	-0.37**	-0.30+
	[0.00]	[0.13]	[0.16]
Patent originality	-0.07	-1.51	-8.94+
	[0.10]	[4.85]	[4.58]
Refs to non-patent prior-art	0	0.71+	0.25
	[0.01]	[0.41]	[0.36]
Log expected pendency	-0.25	-10.22	-14.77+
	[0.17]	[7.63]	[7.49]
Constant	1.44	58.67	71.05
Licensor type dummies	Y	Y	Y
Technology class dummies	Y	Y	Y
Observations	291	291	192
Log-likelihood	-179.94	-1309.69	-822.36
Adjusted R-square	0.05	0.02	0.02

Column (1) presents Linear Probability Model estimates of the relationship between the probability of licensing after patent allowance and AIPA and other control variables. Column (2) presents Tobit estimates of the relationship between patent application-to-license lag (in months) and explanatory variables for the full sample. Column (3) presents Tobit estimates of the relationship between patent allowance-to-license lag (in months) and explanatory variables for the subsample of patents licensed after allowance. Robust S.E. are reported in the brackets. ** $p < 0.01$, * $p < 0.05$, + $p < 0.10$.

Table 5: Multinomial Logit estimates for the choice of license timing window: U.S. patents with foreign equivalents and U.S. patents without foreign equivalents

Column #	(1)		(2)	
Sample	US patents *with* foreign equivalents		US patents *without* foreign equivalents	
D.V. = Licensing window	Before 18 months	B/w 18 mos. & allowance	Before 18 months	B/w 18 mos. & allowance
Post-AIPA patent	1.01	3.37	1.24	5.35**
	[0.98]	[2.55]	[0.71]	[3.20]
No. of patents in license	0.18**	0.65+	0.72	1.1
	[0.07]	[0.16]	[0.16]	[0.08]
No. of prior joint deals	2.99**	1.91**	1.01	0.89
	[1.09]	[0.38]	[0.42]	[0.32]
No. of prior licensee deals	0.99	1	1	0.99
	[0.02]	[0.01]	[0.00]	[0.01]
No. of prior licensor deals	1.03	1.01	0.98	1
	[0.04]	[0.03]	[0.02]	[0.02]
Patent claims	1.02	1.02	0.99	0.99
	[0.02]	[0.01]	[0.01]	[0.02]
Patent citations	1.03	1.04+	1.04	0.85
	[0.03]	[0.02]	[0.03]	[0.08]
Patent originality	0.7	2.2	1.57	1.24
	[0.80]	[2.33]	[1.43]	[1.10]
Refs to non-patent prior art	0.91	0.85	1.02	1.16+
	[0.09]	[0.09]	[0.08]	[0.10]
Log expected pendency	0.11	0.82	16.44*	1.12
	[0.26]	[1.52]	[20.23]	[1.71]
Licensor type dummies	Y		Y	
Technology class dummies	Y		Y	
Observations	137		154	
Model chi-square	2830.7		531.92	
Log-likelihood	-81.85		-119.43	

The table presents MNL estimates for the probability of licensing in each of the three mutually exclusive categories: (i) before 18 months from (the first) patent application; (ii) between 18 months and allowance; and (iii) after patent allowance, the omitted base category. Coefficient estimates are reported as Relative Risk Ratios, with reference to the base category. Robust S.E. in brackets; ** $p < 0.01$, * $p < 0.05$, + $p < 0.10$.

Table 6: Multinomial Logit estimates for the choice of license timing window: for-profit licensors and non-profit licensors

Column #	(1)		(2)	
Sample	For-profit licensors		Non-profit licensors	
D.V. = Licensing window	Before 18 months	B/w 18 mos. & allowance	Before 18 months	B/w 18 mos. & allowance
Post-AIPA patent	1.43	1.23	0.71	7.59**
	[0.81]	[0.70]	[0.50]	[5.51]
No. of patents in license	0.52+	1.05	0.36**	0.98
	[0.20]	[0.08]	[0.13]	[0.12]
No. of prior joint deals	1.49	1.60*	1.74	0.64
	[0.55]	[0.31]	[0.73]	[0.36]
No. of prior licensee deals	1	1	0.99	0.97
	[0.00]	[0.00]	[0.02]	[0.03]
No. of prior licensor deals	1.01	0.92*	0.97	1
	[0.03]	[0.03]	[0.02]	[0.02]
Patent claims	0.99	0.99	1	1
	[0.01]	[0.01]	[0.01]	[0.01]
Patent citations	0.96	0.95	1.19*	1.15+
	[0.05]	[0.05]	[0.09]	[0.08]
Patent originality	2.28	1.24	1.79	1.84
	[2.00]	[1.29]	[1.75]	[1.99]
Refs to non-patent prior art	0.99	1.03	0.92	0.89
	[0.08]	[0.07]	[0.07]	[0.09]
Log expected pendency	5.76	172.81**	9.16	0.15
	[7.87]	[292.97]	[17.33]	[0.30]
Licensor type dummies	N		N	
Technology class dummies	Y		Y	
Observations	176		115	
Model chi-square	1400.17		188.28	
Log-likelihood	-112.79		-94.14	

The table presents MNL estimates for the probability of licensing in each of the three mutually exclusive categories: (i) before 18 months from (the first) patent application; (ii) between 18 months and allowance; and (iii) after patent allowance, the omitted base category. Coefficient estimates are reported as Relative Risk Ratios, with reference to the base category. Robust S.E. in brackets; ** $p < 0.01$, * $p < 0.05$, + $p < 0.10$.

Table 7: Multinomial Logit estimates for the choice of license timing window: patents with below-average number of references to non-patent prior art and patents with above-average number of references to non-patent prior art

Column #	(1)		(2)	
Sample	Below-average no. of science references		Above-average no. of science references	
D.V. = Licensing window	Before 18 months	B/w 18 mos. & allowance	Before 18 months	B/w 18 mos. & allowance
Post-AIPA patent	7.46*	3.96	0.61	4.25**
	[6.25]	[4.76]	[0.41]	[2.21]
No. of patents in license	0.51+	0.71	0.43**	1.11
	[0.20]	[0.16]	[0.14]	[0.09]
No. of prior joint deals	0.67	0.00**	1.71+	1.42*
	[0.39]	[0.00]	[0.51]	[0.23]
No. of prior licensee deals	1	1.01	1	1
	[0.01]	[0.01]	[0.00]	[0.00]
No. of prior licensor deals	1	0.91+	0.98	1
	[0.03]	[0.05]	[0.02]	[0.02]
Patent claims	1.02	1	0.99	1
	[0.02]	[0.02]	[0.01]	[0.01]
Patent citations	0.96	1.12	1.03	0.89
	[0.05]	[0.09]	[0.04]	[0.07]
Patent originality	1.2	6.86	2.87	1.06
	[1.16]	[10.21]	[2.89]	[0.85]
Log expected pendency	0.69	220.89+	131.19**	6.33
	[0.98]	[663.17]	[199.92]	[9.08]
Licensor type dummies	Y		Y	
Technology class dummies	Y		Y	
Observations	119		172	
Model chi-square	3565.08		2025.76	
Log-likelihood	-71.56		-125.86	

The table presents MNL estimates for the probability of licensing in each of the three mutually exclusive categories: (i) before 18 months from (the first) patent application; (ii) between 18 months and allowance; and (iii) after patent allowance, the omitted base category. Coefficient estimates are reported as Relative Risk Ratios, with reference to the base category. Robust S.E. in brackets; ** $p < 0.01$, * $p < 0.05$, + $p < 0.10$.

Supplementary Results Appendix

Table A1: OLS estimates of probability of waiting until patent allowance before and after AIPA for various subsamples

Column #	(1)	(2)	(3)	(4)	(5)	(6)
Sample	US patents with foreign equivalents	US patents without foreign equivalents	For-profit licensors	Non-profit licensors	Below-average no. of science references	Above-average no. of science references
D.V.	Pr. of license after patent allowance					
Post AIPA patent	-0.08	-0.23*	-0.08	-0.26+	-0.35**	-0.16
	[0.11]	[0.11]	[0.10]	[0.14]	[0.13]	[0.10]
No. of patents in license	0.09**	0.01	0.02	0.03	0.06**	0
	[0.03]	[0.02]	[0.02]	[0.04]	[0.02]	[0.02]
No. of prior joint deals	-0.11**	0.01	-0.08*	-0.04	0.04	-0.08**
	[0.03]	[0.07]	[0.03]	[0.08]	[0.06]	[0.03]
No. of prior licensee deals	0	0	0	0	0	0
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
No. of prior licensor deals	0	0	0	0	0	0
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Patent claims	0	0	0	0	0	0
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Patent citations	0	0	0	-0.01**	0	0
	[0.00]	[0.01]	[0.00]	[0.00]	[0.00]	[0.01]
Patent originality	-0.03	-0.05	-0.06	-0.11	-0.11	-0.07
	[0.14]	[0.16]	[0.12]	[0.18]	[0.15]	[0.14]
Refs to non-patent prior art	0.02	-0.01	0	0.02		
	[0.01]	[0.01]	[0.01]	[0.02]		
Log expected pendency	0.17	-0.27	-0.54**	0.03	-0.1	-0.57*
	[0.29]	[0.25]	[0.20]	[0.33]	[0.21]	[0.24]
Constant	0.27	1.52	2.37	0.67	1.46	2.12
Licensor type dummies	Y	Y	N	N	Y	Y
Technology class dummies	Y	Y	Y	Y	Y	Y
Observations	137	154	176	115	119	172
Adjusted R-square	0.26	0.12	0.13	0.12	0.24	0.13

Table A2: Tobit estimates of licensing delay (from patent application date) for various subsamples

Column #	(1)	(2)	(3)	(4)	(5)	(6)
Sample	US patents with foreign equivalents	US patents without foreign equivalents	For-profit licensors	Non-profit licensors	Below-average no. of science references	Above-average no. of science references
D.V.	Patent application to license lag (in months)					
Post AIPA patent	-6.95	-8.23+	-8.06	-8.51+	-9.2	-10.30**
	[6.25]	[4.47]	[5.01]	[4.61]	[6.55]	[3.86]
No. of patents in license	6.99**	1.54*	2.83**	1.81	3.36*	2.00*
	[1.32]	[0.75]	[0.95]	[1.52]	[1.34]	[0.94]
No. of prior joint deals	-8.53**	-2.23	-5.26**	-7.08*	0.64	-6.38**
	[1.17]	[2.33]	[1.23]	[3.41]	[3.04]	[1.13]
No. of prior licensee deals	0.12**	0.03	0.04	0.15	-0.01	0.07**
	[0.04]	[0.03]	[0.03]	[0.25]	[0.06]	[0.03]
No. of prior licensor deals	-0.05	0.13	0.29	0.17	0.1	0.14
	[0.19]	[0.14]	[0.23]	[0.14]	[0.22]	[0.14]
Patent claims	-0.17+	0.07	-0.01	0.07	-0.13	0.03
	[0.09]	[0.08]	[0.06]	[0.10]	[0.12]	[0.06]
Patent citations	-0.29*	-0.41	-0.22	-0.49*	-0.04	-0.32
	[0.12]	[0.29]	[0.20]	[0.22]	[0.19]	[0.20]
Patent originality	-0.47	0.99	-3.03	2.46	-7.62	4.48
	[6.78]	[6.76]	[6.19]	[7.87]	[7.87]	[6.43]
Refs to non-patent prior-art	0.62	0.15	0.58	0.76		
	[0.57]	[0.59]	[0.50]	[0.68]		
Log expected pendency	15.74	-16.74+	-12.94	-5.25	-2.35	-15.84+
	[13.22]	[8.70]	[10.27]	[11.67]	[12.07]	[9.44]
Constant	-29.5	81.59	77.45	39.75	28.41	88.47
Licensor type dummies	Y	Y	N	N	Y	Y
Technology class dummies	Y	Y	Y	Y	Y	Y
Observations	137	154	176	115	119	172
Log-likelihood	-604.64	-691.56	-790.82	-515.05	-529.37	-771.51
Adjusted R-square	0.04	0.02	0.02	0.02	0.02	0.02

Table A3: Regression estimates of license timing for subsample of patents that are issued more than 18 months from application date

Column #—Model	(1)—MNL		(2)—OLS	(3)—Tobit
Sample	Patents with pendency > 18 months			
D.V.	Before 18 months	B/w 18 mos. & allowance	Pr. of license after patent allowance	Application-to-license lag
Post AIPA patent	1.36	3.84**	-0.20*	-9.28*
	[0.65]	[1.81]	[0.09]	[3.66]
No. of patents in license	0.49**	1.09	0.01	2.05+
	[0.13]	[0.09]	[0.02]	[1.05]
No. of prior joint deals	1.54+	1.34+	-0.07*	-5.33**
	[0.39]	[0.23]	[0.03]	[1.03]
No. of prior licensee deals	1	1	0	0.05+
	[0.00]	[0.00]	[0.00]	[0.03]
No. of prior licensor deals	0.99	0.99	0	0.09
	[0.02]	[0.01]	[0.00]	[0.13]
Patent claims	0.99	1	0	0.03
	[0.01]	[0.01]	[0.00]	[0.05]
Patent citations	1.03	1.01	0	-0.37**
	[0.03]	[0.03]	[0.00]	[0.13]
Patent originality	1.22	1.32	-0.05	4.22
	[0.85]	[0.90]	[0.12]	[5.26]
Refs to non-patent prior-art	0.95	0.97	0.01	0.75
	[0.06]	[0.06]	[0.01]	[0.48]
Log expected pendency	1.93	0.59	-0.02	-5.8
	[2.41]	[0.79]	[0.23]	[9.33]
Constant	0.32	1.93	0.5	44.62
Licensor type dummies	Y		Y	Y
Technology class dummies	Y		Y	Y
Observations	223		223	223
Model chi-square	2617.74		293.52	
Log-likelihood	-190.55		-146.76	-999.46

Table A4: Cox hazard estimates for licensing delay

Column #	(1)	(2)
Sample	All patent licenses	Patents licensed after issue
D.V.	Patent-application-to-license lag (in months)	
Post AIPA patent	1.67**	1.73*
	[0.26]	[0.39]
No. of patents in license	0.90*	0.90*
	[0.04]	[0.04]
No. of prior joint deals	1.36**	1.39*
	[0.09]	[0.22]
No. of prior licensee deals	1.00+	1
	[0.00]	[0.00]
No. of prior licensor deals	0.99	0.99
	[0.01]	[0.01]
Patent claims	1	1
	[0.00]	[0.00]
Patent citations	1.02**	1.02**
	[0.01]	[0.01]
Patent originality	1.06	1.03
	[0.26]	[0.33]
Refs to non-patent prior-art	0.97+	0.97
	[0.02]	[0.03]
Log expected pendency	1.59	0.87
	[0.55]	[0.45]
Licensor type dummies	Y	Y
Technology class dummies	Y	Y
Observations	291	192
Model chi-square	89.12	50.96
Log-likelihood	-1334.36	-808.22

The table presents estimates of the Cox proportional hazard rate model, where the dependent variable is the license event (or, implicitly, the licensing lag from patent application in months). Robust Standard errors are reported in the brackets; ** $p < 0.01$, * $p < 0.05$, + $p < 0.10$.