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Marketing University Inventions: The Role of Property Rights, Publications, and Patent Quality

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This paper examines the market for university technologies, and generates a number of stylized facts about the process whereby new inventions are matched with commercial buyers. In particular, I examine how the characteristics of new inventions (and their inventors) relate to the likelihood that property rights to the invention will be sold to an outside party. This setting is particularly appropriate for this investigation because the adverse selection problems that plague intellectual property markets populated by profit-maximizing buyers and sellers are greatly reduced. The analysis reveals that inventor experience with commercialization, inventor academic standing, and measures of patent importance are all positively correlated with the likelihood that buyers will be found for new university technologies. In this sample, new technologies are frequently sold to buyers prior to applying for and receiving property rights for them. The grant of a patent is associated with a statistically significant increase in the rate at which technologies are sold, but the submission of a patent application has no impact. I examine these stylized facts in the light of the literature on patent valuation, markets for intellectual property, and the diffusion of new technologies. The conclusion lays out a research agenda stemming from this descriptive work.

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1. Introduction

A longstanding theoretical literature examines the strategies inventors should pursue to maximize the quasi-rents of their innovations when they are unable to commercialize these inventions themselves (Arrow, 1962; Kamien and Tauman, 1986; Gallini and Wright, 1990, *inter alia*). Typically these strategies involve the design of disclosure strategies and licensing contracts, and vary significantly depending on the strength of intellectual property protection and other features of information transfer such as the presence (or absence) of important tacit information about the inventions. These theoretical models assume the existence of an identifiable set of prospective licensees for which the invention has a value in excess of the resources consumed by generating the contract. In so doing, these models abstract away from a critical step in the process of commercialization of new technologies—how inventors find potential licensees or, conversely, the process through which prospective licensees discover that new technologies may be of value to them. This paper focuses on a number of aspects of this process of matchmaking between inventions and buyers by studying the invention disclosure, patenting, and deal-making activity of faculty researchers and technology licensing officers at Harvard University.

The university licensing setting has distinct differences from the market for firm-generated inventions. Firms that sell inventions presumably have a single objective—profit maximization. A firm will only sell the rights to inventions, then, if its expected profit from doing so is greater than its expected profits from developing the technology in-house, including the cost of financing. Even though firms may have limited capabilities, and limited resources, new capabilities can be obtained at some price and new financing may be obtained if a technology is good enough (although there may be a number of attendant difficulties in doing so). As a result, the market for firm-generated inventions may suffer from adverse selection problems. Anecdotal evidence suggests that on-line intellectual property marketplaces suffered severely from adverse selection problems and generally reported trades in fewer than 1% of the technologies for sale (Elfenbein, 2003).

Universities, on the other hand have a dual set of objectives. The first is to get the inventions to into the marketplace (a commercialization objective).[1] The second is to generating return for the university (a financial objective). These two objectives are reflected in the mission statement of Harvard's Office of Technology and Trademark Licensing: "[The organization's mission is] to bring University-generated intellectual property into public use as rapidly as possible while protecting academic freedoms and generating a financial return to the University, inventors, and their departments."[2] The commercialization objective means that, although universities generally will not give them away, these new technologies are "priced to sell."[3] The university's ability to commercialize technologies themselves is limited, and thus there is little incentive for the university to withhold the most valuable technologies for its own use. Each technology that the university patents, then, is a realistic candidate for sale to outside parties.

This paper explores how characteristics of new inventions and their inventors influence the likelihood that the market for a new invention clears. In my analysis, a transaction is said to occur if the university agrees on an option or license agreement for the technology with a firm. If no contract is agreed upon for the rights to the technology, the market is thought to have failed.

Empirically, I identify a new invention from the "Reports of Invention" made by university faculty to the school's technology licensing office (TLO). Since I examine inventions that come from a single institution, I abstract away from issues concerning how the incentives provided by the university impact the quality and timing of invention reports, which Jensen et al. (2003) argue impact the performance of technology transfer activity.

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[1] In the long run, satisfying this objective may increase the willingness of the public sector to support university research.

[2] In interviews with the author, individual case managers confirmed that the commercialization objective was indeed a major influence on their deal-making activity. According to the case managers, prospective option or licensing agreements rarely break down over price.

[3] An interesting practical question is how the university licensing offices derive any bargaining power at all. This deserves further investigation.

Although this paper is essentially exploratory in nature, it draws motivation from a number of sources. These sources include theories of exchange, the literature on markets for intellectual property, and the literature on the diffusion of new technologies. In addition, I motivate the analysis by examining a common practical problem, the decision of a university technology licensing office to invest in patent expenses for a new faculty invention. The empirical analysis I perform yields a number of stylized facts. They include:

- A new invention's hazard rate of first sale reaches a peak roughly 12 months following its disclosure to the technology licensing office and falls steadily thereafter.
- Inventor experience with commercialization activity, as measured by prior invention reports and prior licenses or options, is associated with an increased likelihood that a new technology will be sold.
- Controlling for inventor commercialization experience, the inventor's academic standing, as measured by publications in the literature, is positively associated with the probability that a new invention can be sold.
- The majority of technologies are sold prior to the issuance of a patent. In a number of cases, deals for new technologies are agreed upon prior to submitting a patent application.
- The grant of a patent raises the likelihood of finding a buyer for that a technology that is still on the market. The submission of a patent application does not raise the likelihood that a patent will be sold.
- Measures of patent importance, such as citations relative to its technology-year cohort, number of claims granted, and time under review by the USPTO are positively related to the likelihood of selling the technology.
- The data suggest that the rates at which chemical, medical, and biological technologies are sold seems to be greater than the rates at which all other technologies are sold.

The remainder of this paper describes the motivation for this analysis, the generation of these stylized facts, and provides some discussion of these results in the context of several streams of related literature.

In particular, the plan of this paper is as follows. Section 2 reviews the relevant literature. Section 3 describes university technology licensing in practice and describes a common decision problem faced by technology licensing offices. Section 4 draws upon the prior two sections to motivate a set of empirical analyses. Section 5 presents an overview of the data and the data collection process. Section 6 presents the analysis, and section 7 concludes and lays out a research agenda stemming from these early findings.

2. Literature

When does trade occur?

Describing how and when trade occurs is a fundamental issue in economics. Until relatively recently, however, perspectives on this issue have been relatively simplistic. For example, the basic partial equilibrium theory of trade presented in introductory economics textbooks describes a marketplace in which prices adjust to equilibrate supply and demand. As long as some party values a product at a price that is greater its production cost, the producer will sell a unit of product to the buyer. General equilibrium notions describe a similar, if somewhat more nuanced, marketplace. When agents' initial endowments allow for Pareto-improving exchanges, these exchanges will occur although several different combinations of quantities and implied prices might result. These notions of trade and exchange make a number of extreme assumptions, including perfect information and unlimited divisibility of goods, and describe idealized rather than actual marketplaces (MasCollel et al., 1990).

Economists and other scholars have made significant progress in describing the dynamics of real marketplaces. Search costs (Diamond, 1987 and others), asymmetric information (Akerlof, 1970), intermediaries (Spulber, 1999, provides an excellent overview), and the role of economic and social institutions (e.g., Greif, 1993) are among the many important features of marketplaces that have attracted the attention of economists. A related literature examines bilateral bargaining under a number of different conditions, including costly bargaining and incomplete information. Each of these approaches to describing real marketplaces is of some potential value in describing markets for intellectual property and the imperfections in these markets. The distinct literature on markets for intellectual property, which draws upon some but not all of these insights is discussed below.

Exchange and intellectual property

When it comes to describing markets for technology and other forms of intellectual property, search costs, asymmetric information, and other transaction costs present severe challenges. Unlike the market for commodities or works of art, this is not a market in which unrestricted bargaining or mechanisms such as auctions can be used to quickly find a price that equilibrates supply and demand. Technological information cannot generally be consumed directly, but only has value in use. It may be highly idiosyncratic; as such there may be few (or no) potential entities for which the technology has any value. Moreover, new technology can be difficult to describe and even more difficult to investigate; this may generate a particularly severe problem in areas in which the science is immature. Zeckhauser (1996) and Arora et al. (2001) address these issues and describe a number of other reasons why selling intellectual property can be difficult.[4]

Pakes (1986) provides a clearer picture of the idiosyncratic nature of individual patents. By exploiting the various fees required in the UK, Germany, and France to keep a patent in force during its lifetime along with patent holders' decisions to pay these fees, Pakes estimates distribution functions of the value of holding a patent. Not surprisingly, these distributions are highly skewed. For example, roughly 2/3 of German patents are estimated to be less valuable than mean of the distribution, and the bottom 1/4 of German patents are estimated to be worth less than $2000 in 1986 dollars. While these

[4] Much of the discussion about the difficulty of trading intellectual property has focused on the strength of intellectual property rights. Arrow (1962) identified the fundamental problem of selling information, that it is impossible for a buyer to value it until they "have" it, and noted that intellectual property rights such as patents could enable potential traders to overcome this problem. An extensive theoretical literature investigates how to design technology licenses in the absence of complete property rights (in particular, see Anton and Yao, 1994 and Anton and Yao, 2002). In empirical work, Anand and Khanna (2000) find evidence that relationships between firms in facilitating technology transfer when property rights are incomplete. Branstetter, Foley, and Fisman (2003) investigate the impact of cross-country differences in the strength of intellectual property rights in facilitating international technology transfer.

estimates do not provide much guidance about the value of holding current patents in the US or in Europe, they do suggest that even modest transaction costs—like the costs of hiring lawyers to write a licensing contract or the value of the time required by two parties to negotiate terms—are likely to make it unprofitable to trade many patented technologies (see Figure 1).

Ex ante, i.e., before a new technology has been thoroughly investigated, experimented with, and adopted into the marketplace, it can be extraordinarily difficult for a potential buyer to place a value on it. This problem has been investigated extensively in the literature on the adoption or diffusion of new technologies in the marketplace, which has identified a number of factors that influence the speed at which new technologies are adopted. These include the relative advantage of the new technology, the compatibility of the new technology with existing complementary technologies, the complexity of the new technology, and the ease of experimentation with the new technology (Rogers, 1995). The literature is also replete with debate about whether and under what conditions "superior" technologies fail to be adopted. These discussions tend to focus on the presence and character of consumption externalities (e.g., David, 1985; Liebowitz and Margolis, 1990; Katz and Shapiro, 1986; Farrell and Saloner, 1986).

In summary, the literature identifies a number of reasons why no buyer might be found for a particular innovation even if it were to be sold at a very low (or zero) price. They are:

- Property rights for the technology are so weak that the technology is essentially given away once the potential buyer has a chance to inspect it, and the seller therefore has no incentive to provide information about it.
- Potential buyers are not aware of the new technology. Search costs to locate the technology are not incurred or search efforts are not effective (because of the stochastic nature of such a process).
- Potential buyers are aware of the new technology but are deterred from investigating it (due to its complexity) or experimenting with it (because this is too expensive).
- The value of the technology in use may not be high enough to warrant paying the mundane transaction costs (legal fees, negotiation effort) required to transfer it.

- No potential buyers may be able to internalize the network externalities that lock consumers into existing technologies.

Conversely, it is more likely that a buyer will be found for a new technology if it can be protected with intellectual property rights, if potential buyers are more likely to be aware of the new technology, if the technology is easier to investigate or experiment with, if the technology is of clear value in the production process or in the marketplace, and if there are no externalities that might thwart a buyers' ability to unseat the incumbent technology.

Commercializing university technologies

The conditions underpinning the exchange of intellectual property are of particular interest to the commercialization of technologies developed in universities and national laboratories. University involvement in commercializing intellectual property has grown steadily since the passage of the Bayh-Dole Act in 1980 (Association of University Technology Managers, 2002). This Act enabled universities to obtain sole ownership of the patent rights to technologies developed partially or wholly with public funds. Universities and national labs, however, rarely become directly involved in the commercialization process. Rather the dominant mode through which these entities have participated in commercialization is through licensing intellectual property rights to established firms, startups, and faculty-directed ventures.

Recently, the commercialization of university technologies has attracted significant attention. Jensen and Thursby (2001) discuss the results of a survey of university technology managers, which reports that most university-generated technologies are licensed at a very early stage. Typically these technologies require significant additional investment from their licensees and enter the marketplace years after the initial license. The early-stage nature of these technologies is likely to make them particularly difficult to value, heightening the technology's uncertainty relative to later-stage technologies. It is not surprising, then, that Sine et al. (2003) find that the status or prestige of a university enhances its ability to license a technology beyond what would be predicted by the school's past licensing performance.

Although the authors promote sociological explanations for these findings, they are also consistent with the notion that potential buyers (and their financiers) may pay significant attention to observable quality signals when uncertainty is high.

Lowe (2002) examines the role of inventor-founded firms in the commercialization of university inventions. The preponderance of inventor-founded firms may be a response to inventors' inability to find potential outside buyers for the technology, a response to the difficulty in transferring knowledge about the inventions across organizational boundaries, or a solution to incentive problems such as those described by Aghion and Tirole (1994). Mowery and Ziedonis (2001) present an associated finding in an examination of the geographic concentration of university license activity that is also consistent with the importance of inventor-founded firms

3. University technology licensing in practice

Timing of Invention, Patenting, and Licensing

Figure 2 presents a diagram of the timing of activity relating to the commercialization and intellectual property protection of university inventions. At t_0, the inventor reports the invention to the licensing office, which opens a case file for the invention. Following the report of invention the licensing office decides whether or not to apply for a patent for the new technology in conjunction with the inventor and legal counsel. If a decision is made to seek patent protection for the invention, a patent application is submitted at $t_{application}$ to the United States Patent and Trademark Office (USPTO). The initial filing may be a provisional application[5], and multiple patents may be filed on the invention. Patent protection may also be sought outside the United States, requiring the licensing office to file additional patent applications. For the present analysis, the date of the first application to the USPTO is the focus of my attention. The lag between when the USPTO receives the patent application and when the patent is granted can be substantial. Merges et. al. (1997) describes the process as on of iterative communication (and negotiation) between the patent office and the applicant and suggests that patents are typically granted between 2 and 3 years after the initial application. For Harvard University technology applications, the 25th and 75th percentile durations between application and patent grants are 2.2 and 4.3 years respectively. The date of grant is designated in the figure at t_{grant}. In subsequent analysis I define this as the first date at which any patent for the technology in question was granted, even if it does not correspond to the first patent application.

In principle, marketing activity of the licensing office can begin at the date at which the invention is reported. Licensees may be identified and license agreements may be signed in either of the intervals: $[t_0, t_{application})$, $[t_{application}, t_{grant})$, $[t_{grant}, \infty)$. In the data under analysis, 29.1% of technology sales occur before the first patent application, 59.1% occur after the patent application but before the patent grant, and 11.8% occur following the patent grant. When licenses alone are considered, these figures are 21.5%, 61.2%, and 17.3%, respectively.

The technology licensing offices' problem

The technology licensing office (TLO) must decide whether or not to patent each new technology reported by a faculty member. Unless the inventor has located a licensee for the technology these fees will be born by the university.[6] A stylized version of the TLO's decision problem can then be represented as follows:

$$\max_{k \in \{0,1\}} k[-P + \alpha(x_i)(P + V(x_i))]$$

[5] A provisional application established the priority of the patent with the patent office but does not contain all of the information that will ultimately be included in the patent application. It may be made with a reduced fee.

[6] Since the late 1980s, the TLO at Harvard has required licensees to bear all patent expenses for each licensed patent.

where P is the cost of patenting, $\alpha(\ )$ is the increased probability of licensing a technology if a patent application is filed, which depends on x_i, a vector of observable characteristics at t_0, $V(x_i)$ is value in excess of patent expenses that the university expects to receive from the license which is also a function of the t_0-observables, and k equals 1 if the TLO invests in patenting and 0 otherwise.

4. Motivating the empirical analysis

Motivation for the empirical analysis is drawn from the literature and from the TLO's problem. Two approaches are taken to investigating the TLOs problem. The first is to understand how the likelihood of finding a buyer for a given technology relates to t_0-observables (i.e., x_i). The present analysis will focus on broad categories describing the area of research of the inventor (chemical, bio-medical, and other), the source of funding for the technology, the experience of the inventor with technology transfer activities, and the academic reputation of the inventor. The second approach is to analyze the impact of intellectual property protection on the likelihood of finding a buyer. As discussed in the prior section, the IP status of each new technology falls into three broad categories, pre-application, pre-grant, and post-grant.[7]

A final set of analyses draws its motivation from the literature on the diffusion of new technologies. This analysis investigates how the characteristics of individual patents affect the likelihood that the technology will be matched with a buyer. Patent characteristic information is available only after a patent has been granted, and thus this analysis is restricted to a subset of the data. The objective of these analyses is to determine whether measures of patent quality and scope, such as citations to the

[7] To make the analysis tractable, I will assume that there is a stark contrast between these three categories. In reality, the IP status is likely to be more continuous in nature. In particular, after the a patent application is submitted, an iterative process akin to a dialogue between the applicant and the Patent Office occurs, gradually reducing the uncertainty about whether the patent will be granted and exactly what the scope of patent protection is.

patent and claims granted, and other patent characteristics are associated with higher or lower probabilities of being matched with corporate buyers.

5. Data

Harvard University's Office of Technology and Trademark Licensing (OTTL) and the Office of Technology Licensing and Industry Sponsored Research (OTL-ISR) at Harvard Medical School provided data on over 2000+ technologies invented by faculty between 1974 and March 2003. The technologies marketed by the OTTL and OTL-ISR included patents, copyrights, materials (typically biological products such as cell lines, monoclonal antibodies, or knockout mice), software, and very occasionally know-how. The majority of the OTTL and OTL-ISR marketing activity focused on patents. In order to control for technology type and to make use of accepted proxies for technology characteristics, this paper focuses on the patent subset of all technologies marketed by these organizations.

Table 1 provides summary statistics for the patent cases used in the analysis. Each case corresponds to a distinct report of an invention by a faculty inventor. Panel A presents a number of characteristics of the technology such as the year in which the licensing office opened its case file, the number of different patents the university applied for based on the technology, and the current status of these applications—i.e., whether they have been granted or are still pending. The number of issued and pending applications does not add up to the total number of patent applications because many patents applications have been abandoned and some patents have expired. The data about patenting strategy and its results is available for slightly over half of the sample; invention reports did not lead to patent applications for the remaining technologies. The number of observations in the sample is also skewed somewhat toward the later half of the period examined reflecting, perhaps, an increasing propensity of university scientists to seek patents and marketing support for their innovations over this time period. Fifty percent of the cases began in or after 1994, and 25 percent of the cases were opened in or after 1998.

Panel B presents data on the rates at which buyers were found for all technologies for which the licensing office opened a case file. At this panel shows, the likelihood that a new case file would result in a license differs only slightly across the different schools in the university.

Data about patent attributes came from two sources. The first is the NBER Patent Citation file. This file contains data on patents granted between 1963 and 1999—including the patent class and NBER defined category and subcategory; the number of citations by and to the patent; the number of claims granted for the patent; and measures of originality and generality (Hall et al., 2001). Data on patents granted after 1999 was downloaded directly from the website of the U.S. Patent and Trademark Office (USPTO).[8] On the USPTO's forms, several patent classes were typically listed. The author selected the first patent class, which was also identified in bold type, and used this data in subsequent analysis. Likewise, the author counted the number of citations to US patents and claims made on the patent form, attempting to use the same methodology as Hall et al. Panel C summarizes the characteristics of the patents involved in these licenses. Table A1 in the appendix presents the breakdown of the licensed patents in the groups defined by Hall et al (2001).

Panel D summarizes the sources of funding by school at the new case level. The large majority of federally funded technologies were developed with support from the National Institutes of Health (NIH). A substantial minority were developed with support from the National Science Foundation (NSF) and from various U.S. military agencies. About one-third of all investigated technologies involved no federal support whatsoever. I do not observe whether these technologies were developed with the use of university funds, private grants, or corporate grants.

Panel E summarizes the academic credentials of the investigated technologies' lead inventor. Publication and citation data are drawn from ISI Corporation's Science Citation Index. To simplify the data collection, only journal articles published after 1960 were included in the counts. Publication counts were weighted using two different mechanisms. The first weighting scheme assigned a score of 1 if the

[8] http://patft.uspto.gov/netahtml/srchnum.htm

author was the primary or last author and a score equal to one divided by the total number of authors otherwise. The second weighting scheme multiplied each publication (and "fractional" publication) by the ISI's journal impact factor measure. The publication records were identified for 458 of the 625 lead inventors.[9]

The publication data are presented at two time periods, mid-year 2003, when the data were collected, and at the time of the invention report. On average, inventors in the sample had 67 publications by mid-year 2003, and at the time of report, the inventor had 80 publications. The fact that the latter average is larger than the former indicates that more prolific inventors in terms of publications were also more prolific in terms of disclosed inventions (the second figure is invention-weighted). The distribution of publications for both measures is highly skewed toward the left (or lower numbers of publications). The weighted publication metrics, which hopefully represent more precise measures of inventors' academic standing display the same properties as the unweighted measures.

Panel F presents data on the commercialization experience of faculty members who reported patentable inventions. The average inventor in the sample disclosed 2.8 inventions (median 1, 75th percentile 3), and the average invention had been preceded by 4.7 inventions by the same faculty inventor. Similarly, the average inventor licensed or optioned 0.8 new technologies (median 0, 75th percentile 1), and the average invention was reported by an inventor who had already licensed or optioned 2.1 inventions. In cases of both invention disclosures and invention sales, a few dozen highly active inventors generate a skewed distribution.

Timing of invention reports and sales

[9] It was nearly impossible to identify the publication records of inventors whose names were very common. Rather than introduce a measurement error into the analysis, these inventors were dropped. A possible selection bias may result, as we were unable to identify the publication records of a substantial fraction of Asian and South Asian inventors.

The status of reported inventions and the timing of first sale is reported in Table 2. For the entire sample, 29.7% of all invention disclosures[10] have been matched with a buyer, compared with 35.0% and 35.5% of invention disclosures in the 1981-1990 and 1991-2000 time periods respectively. Restricting the sample only to invention disclosures that resulting in a patent application, yields sale rates of 49.3% for the whole sample and 67.6% and 53.5% for the periods 1981-1990 and 1991-2000, respectively. Further restricting the sample to disclosures resulting in granted patents, yields sale rates of 66.2%, 79.7%, and 66.7%. The major change between the decade 1981-1990 and 1991-2000 is the greater likelihood that a disclosure would result in a patent application in the latter period (62.3% vs. 49.3%). Table A2 in the Appendix analyzes the timing of first license (as opposed to first sale, which includes both licenses and options). When the analysis is restricted to licenses, the proportion of transactions taking place prior to patent submissions and patent grants fall by roughly 45% and 25% respectively, whereas the proportion of transactions occurring after the first patent for the technology is granted rises slightly. This is consistent with the fact that when parties buy and sell options on technology licenses, they do so early in the process, when uncertainty about the value of the technology (and its potential intellectual property protection) is high.

Modeling the hazard rate of first sale and first license

In the analysis section, the information about invention disclosure and sales are treated as survival-time data. Technologies enter observation on the date of the report of invention and exit observation as a failure on the date when the technology is sold or as censored observation if the last day of observation is reached and no agreement has been signed. The hazard rate of first sale as a function of time for all reported inventions—i.e., the likelihood that the technology will be sold at time t conditional on not having been sold until time t—is plotted in Figure 3. The hazard rate increases in the first year in which the technology is on the market and decreases rather rapidly thereafter (although the decrease not

[10] In the discussion below, I use the terms “report of invention “ and “invention disclosure” synonymously.

purely monotonic). By year 4, the hazard rate is roughly one-third of its average level between year 0 and year 2. While this hazard rate may be influenced by the effort put forth by the OTL case manager who markets the technology, it is consistent with the notion that some technologies are "hot" and are sold very rapidly after disclosure whereas the majority are not. The time dependence in the model also suggests that parametric models of hazard rates may be of value in the analysis below, since they make more efficient use of the time information in the data than semi-parametric techniques.

6. Analysis

The analysis proceeds in three parts. The first set of analyses focuses on the relationship between t_0-observables on the likelihood of finding a buyer. The second set of analyses examines the impact of intellectual property protection on the likelihood of finding a buyer. The final set of analyses examines the relationship between patent characteristics and the likelihood of finding a buyer for the technology.

In each set of analyses a hazard rate model is used to examine multivariate relationships. In Tables 3 through 10 the event under study is the probability that a technology is licensed or optioned. To simplify the analysis, only the first incidence of a license or option is examined. Thereafter, the technology exits observation. This approach has the advantage of avoiding the double counting of technologies that are licensed non-exclusively but has the disadvantage of losing potentially valuable information about technologies that are first optioned and subsequently licensed. Estimating a hazard rate model has the additional advantage that it makes efficient use of the information contained in right-censored observations. A large number of technologies are still on the market—although no commercial partner has yet been found, one may be found in the future—and hence are right censored from the point of view of the analyst. For the sake of comparison, Tables A3 through A7 in the Appendix repeat the analysis considering licensing alone as the event of interest. In this analysis observations exit at the time of first license, and all option activity is ignored. Generally, the relationships found using licensing alone as the outcome of interest are stronger than those when licensing or options are studied.

The analysis below relies on three different hazard rate models. In all cases, I use the Cox proportional hazards model as a baseline for investigating the relationship between the sale of the technology and the independent variables. This model makes no assumption about the form of the underlying survival function and is therefore "memoryless" (Cox, 1972). Additionally, I parameterize the underlying survival function using a Weibull specification, which allows the hazard rate to change monotonically over time and a piecewise exponential specification, in which I allow the hazard rate to take on different (but constant) values in years 0 through 6 and then hold constant thereafter. These parametric approaches have the advantage of producing more efficient estimates when the analyst has information about the form of the hazard rate.

In all cases, the coefficient estimates that I report are the natural logarithms of the relative hazard rates associated with the independent variable of interest. These coefficients are directly comparable across specifications. In general, the three specifications produce similar results. In one case the Weibull model produces estimates that are significantly different from the estimates of the Cox and piecewise exponential models.

Observable characteristics at the time of invention disclosure

Table 3 presents the correlations between the likelihood that a given technology was licensed or optioned and several variables that measure the academic standing and commercialization experience of the inventor. The shaded column highlights the correlations between a binary variable equal to 1 if the technology has been licensed and 0 otherwise and the measures of academic standing and commercialization experience. Each measure of academic standing is positively correlated with the likelihood that a buyer is found for a new technology. The correlation of these variables with the probability of technology sale is moderately stronger when the inventor's cumulative publication records in 2003 are considered than for their publication records as of t_0. A possible reason for this is that the stock of publications monotonically increases with time, and the more time that has elapsed the more likely a buyer will be found. In each case the correlations are significant at the $p < 0.01$ level and in several cases they are significant at the $p < 0.001$ level.

The measures of inventor commercialization experience are also positively correlated with the likelihood of matching the technology with a buyer. Not surprisingly, the inventor's experience with consummating deals is more highly correlated with the probability of licensing (or optioning) a new technology than the inventor's experience with reporting new technologies to the OTL.

The non-shaded columns display the correlation coefficients between the measures of academic standing and commercialization experience. The measures of academic standing are highly correlated both with each other and with measures of commercialization experience. These correlations reflects the fact that, in this sample, prolific inventors are (relatively speaking) also prolific publishers.[11] However, in the present data set, both measures may be highly correlated with both the field of the inventor (which I can observe) and with the inventor's age and or tenure (which I cannot).

Table 4 presents the results of the hazard rate analysis of the inventor's academic standing and commercialization experience on the likelihood of finding a commercial buyer for a new technology. After controlling for the inventor's field of research,[12] a larger number of publications was associated with a significantly higher hazard rate of license or option (see columns 1, 2, 6 and 7). This suggests a stronger academic reputation may be a good predictor at t_0 of whether or not a technology can be licensed. Commercialization experience as measured by the cumulative number of prior inventions disclosed and by the cumulative number of prior inventions licensed or optioned is also associated with a significantly increased the hazard rate (see columns 3, 4, 8 and 9). This result is consistent with the idea

[11] Using a different sample of faculty inventors, Markiewicz and DiMinin (2003) observe a similar relationship between inventor patenting and publishing in universities. They investigate this relationship in greater detail.

[12] A handful of inventors, published in multiple fields, i.e. chemical physics or biophysics. Physical chemists were classified in the Chemistry category, and biophysicists were classified in Bio-Medical.

that inventors may learn about the marketplace as they gain more exposure to it and (1) either self-censor subsequent inventions, disclosing only the most promising ones to the TLO, or (2) generate inventions that are more likely to be desirable to industry. The results are also consistent with the explanation that some inventors have closer ties to industry (possibly through corporate sponsored research, consulting relationships, or involvement in startups) that lead both to more disclosures and more licenses. Future research will delve more deeply into this possibility and will attempt to distinguish it from the learning explanation.

Columns 5 and 10 examine the role of academic standing, controlling for commercialization experience. Although these measures are highly correlated in the data, inventors' publication records remain an important predictor of commercialization success even after controlling for commercialization experience; the null hypothesis is rejected in a 1-sided test at the $p < .05$ levels of significance. The relationship between publication record and the probability of sale is economically important as well. Controlling for the field of the inventor and the inventor's commercialization experience, improving the inventor's publication record by one standard deviation increases the relative hazard by 12%. When licenses alone are considered as the outcome of interest, the relationship between the probability of sale and publications are economically and statistically stronger.

The strength of the relationship between the hazard rate of sale and inventor's characteristics is not uniform across the three fields of research that I investigate. Table 5 investigates these differences. In particular, an equal increment of improvement in the publication record has roughly three times impact on the hazard rate of sale in the Other category as compared to in the field of Chemistry. An increment of improvement in the field of Chemistry has double the impact as it would in the Bio-Medical category. These differences may reflect fundamental differences in the markets for technologies produced in these areas. They may, however, reflect differences in the publication environments between these fields, e.g., there may be more medical journals than physics journals, and it may cost less to produce an additional increment of research in medicine than in physics. Commercialization experience, by contrast, seems to be more economically and statistically important in the Bio-Medical category than in the Chemistry or in the Other categories.

Next, the analysis of t_0-observables was expanded to include the source of funding of the reported inventions. In non-parametric tests (specifically a log-rank test of the equality of survivor functions), technologies that were generated wholly or partially with federal funds are associated with an increased likelihood of finding a commercial buyer ($p = 0.023$). Similarly, receiving funding from the National Institutes of Health ($p = 0.000$), the National Science Foundation ($p = 0.004$), and the Department of Energy ($p = 0.007$) were associated with higher rates of signing a license or option contract.[13]

Table 6 reports the results of the survival analysis, controlling for inventor characteristics. When the license or option outcome variable is examined, the estimated coefficient on a federal funding dummy variable is positive, but not statistically significant; when licensing alone is examined, the coefficient on the federal funding dummy is significantly greater than zero (see Table A4). When individual agency dummy variables are included in the model, coefficients on NIH, NSF, and DOE are each positive and significant. The different models produce point estimates of the increases in the hazard rates relative to technologies that were developed with no federal support between 54-62%, 46-48%, and 125-156% for the NIH, NSF and DOE respectively.

Patent status and timing

Trade in technological information is generally thought to be facilitated by stronger intellectual property rights (Gallini, 2002). *Ex ante,* i.e., prior to trade, strong property rights enable the seller of technological information to disclose more (or all) of the details about the technology in question without fear that technology will be expropriated or imitated by potential buyers. *Ex post,* i.e. after trade, strong

[13] The log rank test of equality survivor function compares technologies receiving federal funds with all others, technologies receiving NIH funds with all others (including funds from other federal sources), etc. In these tests, I do not control for other factors.

property rights enable the buyer of the technology to defend it against infringement by outside parties, thereby raising its value.

As discussed in Section 3, above, a technology disclosed by a university faculty member moves through three distinct stages with respect to patent protection. These are (1) pre-submission: $[t_0, t_{application})$, (2) post-submission / pre-grant: $[t_{application}, t_{grant})$, and (3) post-grant: $[t_{grant}, \infty)$. Theory suggests that from the seller's point of view, the risk of expropriation or imitation should decrease as the technology moves from stage (1) to (2), since submitting a patent application stakes an inventor's claim to the intellectual property in question (Besen and Raskind, 1994). Similarly, theory suggests that from the buyer's point of view, the uncertainty about the actual value of the patent declines from stage (2) to stage (3).[14,15] An increasing hazard rate from stage (1) to (3) would provide empirical support for these theoretical suggestions.

Table 7 presents a log-rank test of the equivalence of survivor functions across the three different states on two subsets of the data, the subset of all technologies for which patents were filed, and the subset of all technologies for which patents have been granted. This test compares the number of events in each state with the total time at risk in that state. In first subset—the all technologies for which a patent was submitted prior to March 15, 2003—the test provides strong support for the proposition that the hazard rate increases from state (2) to state (3), but no support for the proposition that the hazard rate increases from state (1) to (2). In the second subset—technologies for which patents were granted by March 15, 2003—there are no significant differences between the stages in the rate of licensing.

Table 8 attempts to examine the same question by employing hazard rate models with a limited set of additional control variables, examining only the subset of technologies for which patent

[14] In stage (2) there is uncertainty about whether the patent will be granted at all and about which of the patent application's claims will be granted.

[15] In reality, the drop in uncertainty between stages (2) and (3) is not likely to be a step function. As Merges et al. (1997) discuss, the patent application process frequently involves repeated communication between the applicant and the PTO over the course of several years. There is reason to think that uncertainty about the patent's likelihood of being granted and about its scope fall with each communication from the PTO.

applications were submitted. In the Cox and piecewise exponential specifications, the grant of a patent is significantly related to an increase in the hazard rate of sale. That this result does not hold for the Weibull specification is somewhat of a puzzle. In the Cox and piecewise exponential specifications, the coefficients on the submission dummy variable are negative and significant. This may result from the fact that a number of technologies have submission and sale dates that are very close together, suggesting that sale is driving submission in these cases, generating a bias in the estimations. When technologies for which sale is simultaneous to submission are excluded from the analysis, the coefficients on the estimated submission dummies are near zero. The analysis examining only license agreements corroborates these findings (see Table A6).

The evidence presented in Tables 7 and 8 does not support the hypothesis that property rights facilitate the sale of intellectual property by reducing the risk associated with disclosing information about unprotected technologies. This result may be particular to the setting of university inventions. First, university technologies are rarely developed behind a complete veil of secrecy. Through publications, conference presentations, and interactions with research colleagues, new inventions may already be partially in the public domain at the time they are disclosed to the TLO. Hence, limiting information disclosure prior to patent filing may have limited utility. If is the case, then moving from stage (1) to stage (2) might only have a limited impact on the ability of the TLO or the inventor to disclose information about the technology. Second, prior to filing the patent application with the USPTO, alternative steps may be taken to limit the hazards of providing information about new technologies to potential buyers in the absence of property rights. The most important among these is ability of the parties to sign confidentiality agreements. Even if the enforcement of such a provision is limited, it may enhance the confidence of the TLO and the inventor sufficiently to enhance their ability to provide information about the new technology to potential buyers. Additionally, the dual objectives of the TLO—commercialization as well as revenue generation—may lead it to disclose information about a not-yet-filed patent application that a purely profit-maximizing inventor would not. Reputation mechanisms and important tacit knowledge about the invention may provide further, and more general, reasons why so much deal-making activity occurs before property rights are applied for or received.

If property rights are not important factors in enabling the transmission of information about university-generated technologies, then the finding that the grant of a patent can be an important factor in enabling the sale of a new technology seems, on the surface, to be somewhat of a paradox. This paradox may be explained, however, as the reduction in uncertainty about the scope of the property rights that will be granted to the technology. The patent event, then, impacts the hazard rates as a reduction in uncertainty rather than as a mechanism for protecting the selling party from appropriation of the invention.

Finally, the analysis performed above ignores a few key factors. I do not include any information about the level of development of the technology in question. Implicitly, the analysis assumes that the technology is "fixed" following disclosure. This is clearly an extreme assumption. If more information becomes available about the invention, through increased experimentation or the development of complementary inventions, then the uncertainty around the technology would generally fall. If anything, this would produce an increase in the ability of the technology to be licensed over time and would bias the coefficient on submission toward overestimating the effect. Second, I examine only the signing of a contract for an option to the technology or a license. The price negotiated between the parties—a major consideration of the TLO— is ignored. Firms, for example, may be willing to pay reduced fees to option a technology in the period prior to the submission and / or grant of the patent. Further research will examine this issue.

Impact of NBER measures of patent quality, originality, and generality

A longstanding literature has proposed and validated a number of measures of patent quality and patent scope (Hall et al., 2001). This section tests whether these measures have explanatory power in modeling the hazard rates of licensing or optioning new inventions. Unfortunately, these measures are available only for granted patents (and some measures which rely on citations to the patent are not yet available as not enough time has elapsed to generate accurate measures). Therefore, I proceed with the analysis using only the subset of inventions that were granted patents.

Table 9 examines the correlations between the likelihood that a technology has been sold, the time of invention disclosure, and five patent characteristics. More citations (relative to an individual patent's technology category and cohort), more claims, and a longer lag between patent submission and grant,[16] are all positively correlated with the likelihood that a technology was sold. This is far from a surprise; we would expect more valuable technologies to be licensed. The NBER's measures of originality and generality, which are based on the citations by and citations to the patent in question, respectively, are not statistically related to the likelihood of sale.

Table 10 presents the estimates of the hazard rate models and corroborates the findings of Table 9. Columns 1 though 5 and 7 through 11 test different patent characteristics individually using Cox and Weibull specifications, respectively. This analysis controls for technology groupings based on the NBER-defined technology category and subcategory of the patent. Columns 6 and 12 test the three measures of patent importance simultaneously. Based on the estimates in column 12, the relative hazard rate of a patent that is cited twice as much as other patents (relative to its time-industry cohort) is 5% greater than a patent cited an average number of times. Likewise, increasing the number of claims by one standard deviation (a total of 20 claims) raises the relative hazard rate by 12%. When licensing alone is examined the relationship between citations received and claims granted and the relative hazard rate increases in both magnitude and significance (see Table A7). The relationship between the hazard rate and evaluation time at the USPTO weakens, but remains significant, and the relationship of originality and generality to the hazard rate remains insignificant.

[16] Johnson and Popp (2003) demonstrate that major inventions take a longer time to go through the evaluation process at the USPTO.

7. Discussion

Stylized Facts

The setting examined in this paper provides a focus on certain aspects of the markets for intellectual property. The fact that universities rarely enter the market to commercialize faculty inventions directly—coupled with the dual mission of university TLOs—means that adverse selection issues generate much less severe market imperfections in this setting than they do when both buyers and sellers of intellectual property are solely driven by profit-maximization. In the absence of adverse selection, I am able to provide some empirical analysis of the characteristics of inventors, inventions, and intellectual property protection that lead to market transactions for early-stage technologies. The principle findings of this analysis are:

- Inventor experience with placing new technologies on the marketplace improves the inventor's likelihood of finding a commercial partner for subsequent inventions. The more commercial partners have been found for inventor's prior technologies, the more likely subsequent inventions will be placed with a corporate partner. These findings are consistent with a number of hypotheses. First is the hypothesis that inventors learn about what is valuable to firms and what is not through their experience in assisting the TLO with trying to locate new buyers for their inventions. Second is the possibility that prior commercialization experience reflects the possession by the inventor of valuable ties to industry (either through consulting relationships or corporate sponsored research). Third, it is possible that firms can observe an inventor's prior deal-making activity and use this information to infer something about the quality of subsequent invention. Future research will attempt to distinguish between these potential explanations.
- An inventor's academic standing, as measured by publication record, has a positive influence on the TLO's likelihood of finding a buyer for a new technology. These findings are consistent with a handful of other empirical papers that document the importance of reputation and publications in commercial outcomes. Sine et al. (2003) find that university status explains a portion of the increased

productivity of university technology licensing offices above what one would predict based upon their prior productivity. Darby, Liu, and Zucker (1999) find that ties to star scientists, reflected in publications, significantly enhance biotechnology firms' market values. These findings are consistent with a number of explanations, which are discussed in the next subsection.

- A majority of inventions in this data set are licensed prior to the receipt of patents. Applying for a patent does not enhance the ability of the TLO to sell a disclosed invention. It seems that in the case of university inventions, the risk of appropriation of new technologies by potential buyers is limited by factors other than formal property rights. These factors may include confidentiality agreements, tacit information about the technologies, and reputation. If a firm 'steals' a technology from a university inventor, the communication between university TLO may make it very difficult for the firm to acquire a university technology at any price in the future.
- Receiving a patent grant does increase the likelihood of finding a buyer for a new technology. The actual patent grant may dramatically reduce the uncertainty about the value of the technology as it defines the scope of the patent in legal terms.
- Patents that are more important are more likely to be licensed or optioned. This finding is highly consistent with that licensing a new technology entails some fixed transaction costs. Only technologies that are likely to have value in excess of the resources that the transaction consumes will be licensed.

Two additional findings, which are unrelated to any theoretical literature, are also noteworthy:

- A new invention's hazard rate of first sale reaches a peak roughly 12 months following its disclosure to the technology licensing office and falls steadily thereafter. Whether this reflects the marketing efforts of the TLO or some other deeper phenomenon about the process of marketing idiosyncratic goods deserves further investigation.
- The rates at which chemical, medical, and biological technologies are sold seems to be greater than the rates at which all other technologies are sold. Whether this reflects something particular to the

institution under study or something that reflects differences in the strength of intellectual property and/or downstream markets also deserves further investigation.

Research Agenda

For TLOs and for scholars who study exchange in these complex markets, the link between inventors' publication records and the likelihood of finding commercial partners is one of the most interesting of the stylized facts presented above. Unfortunately, theory presents us with a number of potential explanations, all of which are consistent with the data as presented above. A major focus of ongoing research is to distinguish between these potential explanations in order to understand better the mechanism through which an inventor's publication record improves the likelihood of finding a licensing firm to commercialize the research. Among the potential explanations for this relationship are theories from the economics, finance, and sociology literature:

1. *Publications reduce search costs.* The greater the stock of an inventor's publications, the more likely buyers are to be aware of the inventor's lab.
2. *Publications are a signal of quality.* A strong publication record may also be a proxy for quality for an invention's quality. Assuming commercialization were the scientist's objective, if publication were more costly for low-quality scientists than for high-quality scientists, then publishing would fit into standard signaling models in economics. Moreover, when information asymmetries associated with financing high technology ventures are introduced, it may be the case that financiers may demand that the firms they back do business with highly reputable scientists (as this scientific reputation provides them with an "independent" signal of the innovation's quality).
3. *Publications are a proxy for status.* A strong publication record may also be an indicator of an inventor's status, which Podolny (1993, 1994) distinguishes from pure notions quality and suggests may be important factors influencing economic exchange in the presence of complexity and/or uncertainty.

4. *Publications provide complementary goods to innovations in question.* These complementary goods make experimenting with and understanding applications for new innovations less costly.
5. *Publications reflect the size of an inventor's lab, and potentially the size of his or her professional network.* Akin to the search cost argument above, this explanation suggests that for a certain segment of scientists who are familiar with the inventor's research search costs are low. This also suggests that licensees are much more likely to be known to the inventor prior to disclosure than otherwise. Alternatively this mechanism could operate through an effect such as that described by Greif (1994).

The potentially complex relationship between an inventor's academic reputation and the marketing of university inventions does not readily yield itself to a horserace between each of the potential explanations above. Moreover, these explanations are not mutually exclusive. Rather each must be investigated in turn, and may require different data to be tested. Investigating explanations (1) – (3) will involve examining cross-field differences in the relationship between publications and commercialization, examining payment terms for the licensed technologies, and the difference in the rate at which new innovations are licensed to small vs. large firms. Increasing value of publication record in crowded fields is supportive of explanation (1). Conditional on being sold, greater payments (or a greater use of non-contingent payments) is supportive of explanations (2) and (3). Likewise, examining the split of licensed inventions by type of licensing firm can shed some light on the relative strength of (2) and (3).

Examining (4) will involve dividing inventors' publications into two groups: related publications and unrelated publications. I propose doing this investigation for a sample of authors' publications, using a content analysis of publication abstract with information about the invention disclosure. Examining (5) will involve examining the co-author list of publishing inventors. Larger labs should have a larger number of unique co-authors. Network measures may also be used to examine a scientist's position within a system of local, national and international researchers and innovators.

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Figure 1. Estimated Distribution of Value of German Patents in 1986 dollars

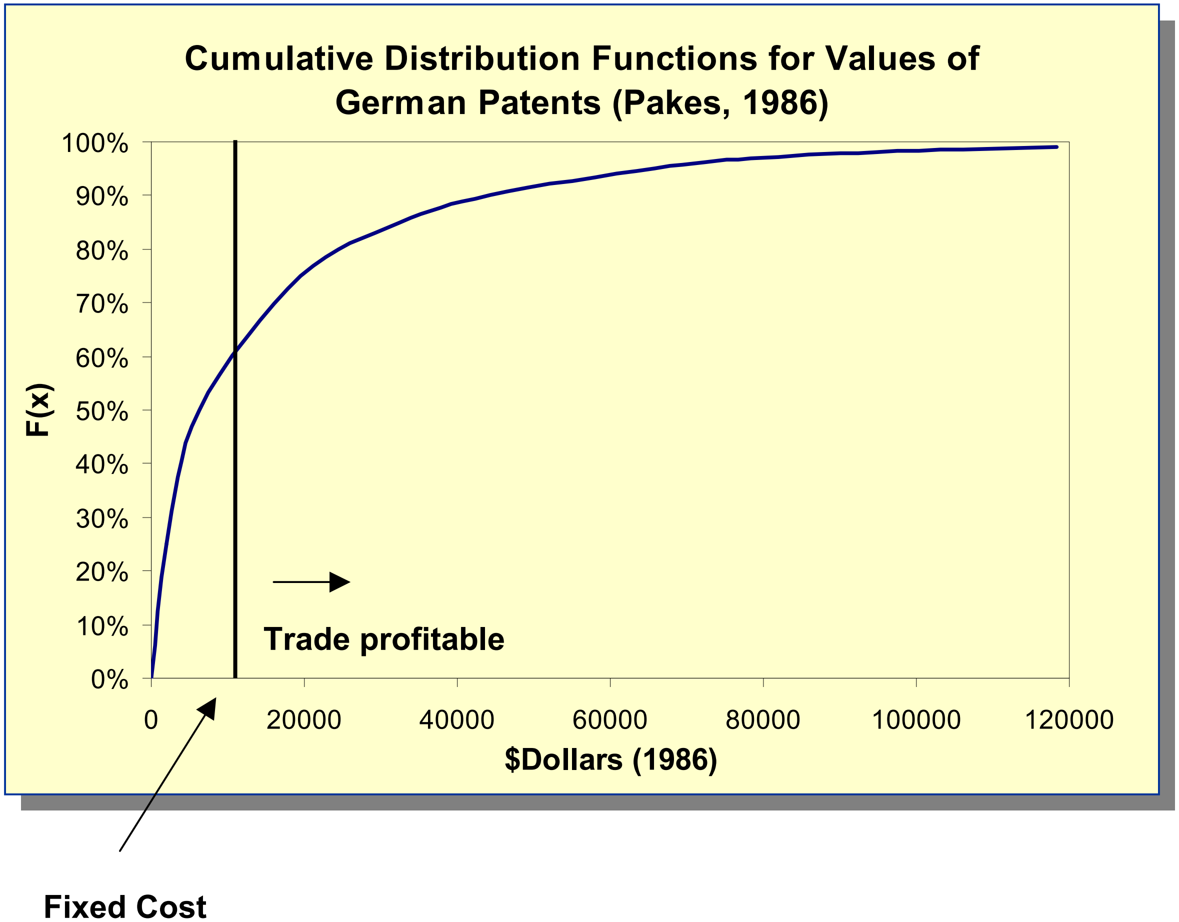


Figure 2. Timing of invention, patenting, and licensing

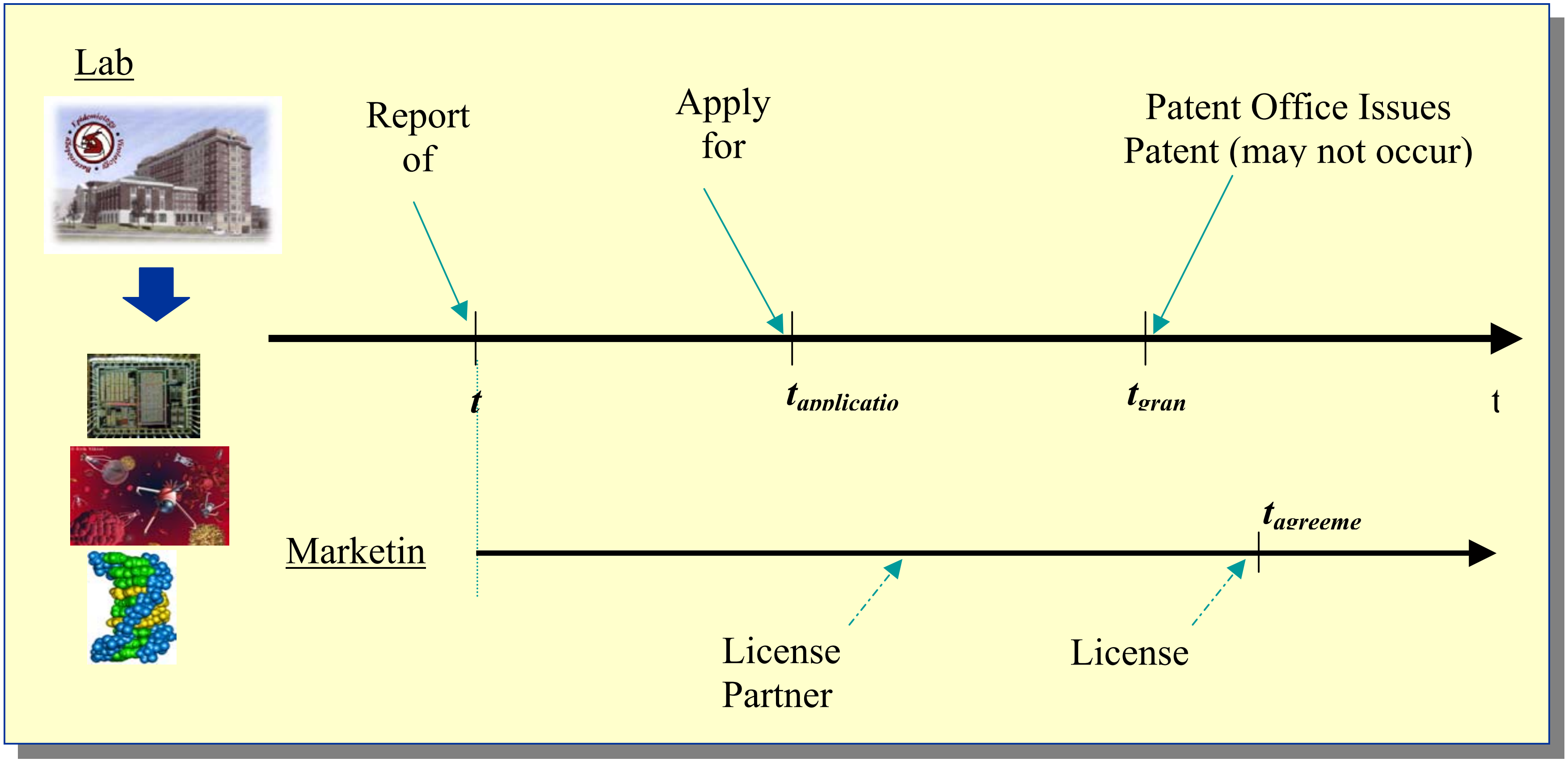
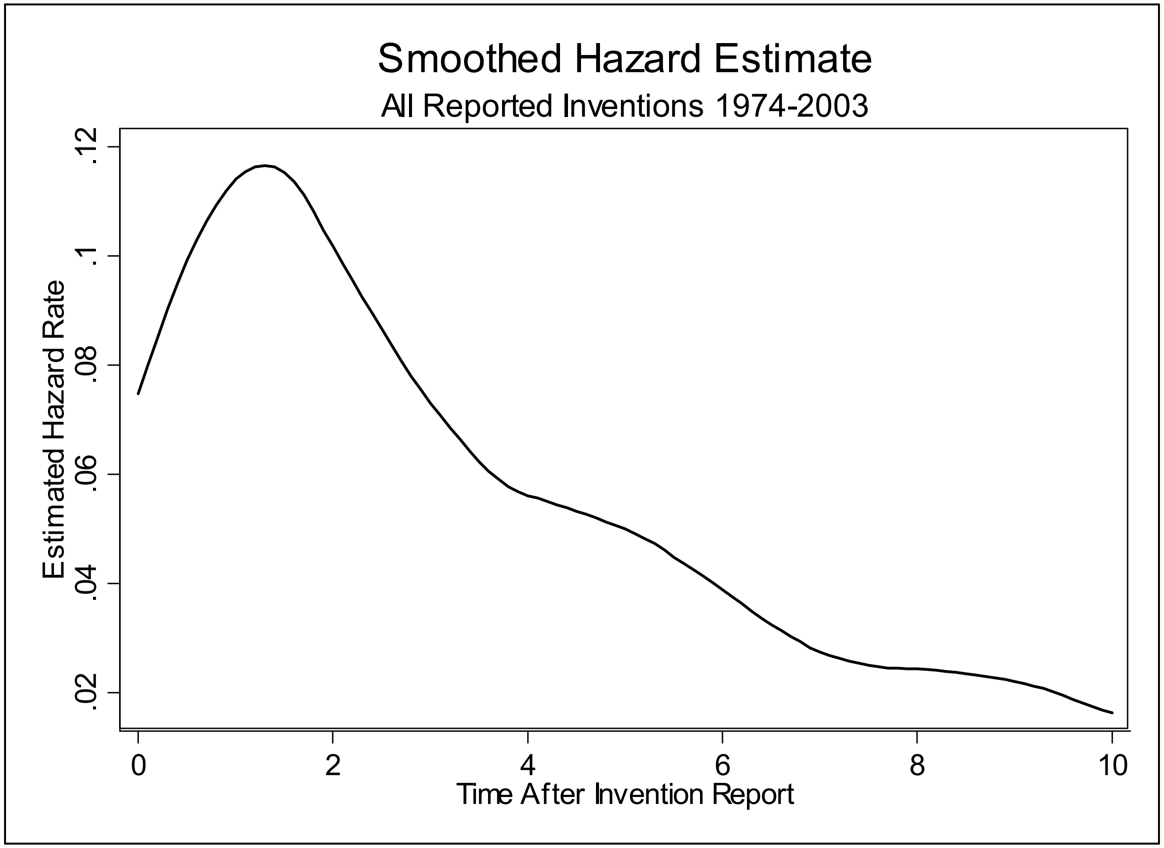


Figure 3. Hazard rate of first sale following invention disclosure.



Note: Estimates based on submitted invention disclosures.

Table 1. Summary statistics for reported inventions. The sample consists of 1703 reports of invention by Harvard University faculty between 1974 and March 2003. Each reported invention was classified as patentable. Observations are summarized by the time and patent status of the disclosed inventions, the fraction that have been licensed or optioned by the lead faculty of the inventor, the characteristics of the invention's patents if one or more has been received, the sources of funding that generated the invention, the publication credentials of the lead inventor where available, and the commercialization experience of the inventor at Harvard University.

Panel A. Technology Characteristics

	Obs.	*Mean*	*Std. Dev.*	*Min*	*Max*
Year Case Initiated	1703	1992.9	7.0	1974	2003
Number of Patent Applications	1023	2.14	1.78	1	25
Number of Patents Issued	1023	.58	1.05	0	13
Number of Patents Pending	1023	.53	.87	0	8

Panel B. Licenses & Options by Lead Faculty

	Exclusive License	*Nonexclusive License*	*Option*	*License or Option*
All Patents	17.7%	6.8%	13.8%	30.1%
Medical School (HMS)	17.4%	9.5%	9.9%	28.1%
Faculty of Arts and Sciences (FAS)	19.1%	6.1%	15.2%	32.0%
School of Public Health (HSPH)	14.3%	4.9%	18.8%	32.1%
Other[a]	13.9%	2.5%	11.4%	19.0%

Panel C. Patent Characteristics

	Obs.	*Mean*	*Std. Dev.*	*Min*	*Max*
Claims	445	19.44	20.09	1	235
Citations Received	445	8.84	16.26	0	171
Normalized Citation Score	351	1.33	2.13	0	22.94
Original[b]	260	.377	0.293	0	0.938
General[c]	229	.382	0.283	0	0.852

Panel D. Sources of Funding

	National Institutes of Health	*National Sci Foundation*	*U.S. Military*	*Department of Energy*	*Other Federal*	*Non-Federal*
All	702	104	69	30	99	453
HMS	425	5	12	22	35	222
FAS	133	99	62	8	42	128
HSPH	128	—	1	—	19	65
Other	16	—	—	—	2	33

Panel E. Lead Inventor Academic Credentials

	Obs	*Mean*	*Std. Dev.*	*Min*	*Max*
Journal Publications July 2003	458	66.69	81.928	0	601
Journal Publications July 2003 weighted by number of authors	458	20.33	25.77	0	200.36
Journal Publications July 2003 weighted by journal impact factor	458	460.81	637.92	0	4298.65
Journal Publications July 2003 weighted by journal impact factor and # of authors	458	130.80	183.89	0	1213.20
Year of First Publication	458	1981	10.8	1960	2003
Year of Last Publication	458	1999	7.2	1960	2003
Journal Publications at t_0	1442	79.91	108.46	0	601
Journal Publications at t_0 weighted by number of authors	1442	26.30	35.98	0	189.36
Journal Publications at t_0 weighted by journal impact factor	1442	564.04	759.6	0	4298.65
Journal Publications at t_0 weighted by journal impact factor and number of authors	1442	169.96	221.54	0	1213.20

Panel F. Lead Inventor Commercialization Track Record

	Obs	*Mean*	*Std. Dev.*	*Min*	*Max*
Total Invention Disclosures	625	2.78	4.87	1	72
Total Licenses & Options	625	0.84	2.34	0	32
Invention Disclosures at t_0	1705	4.65	8.88	0	71
Licenses & Options at t_0	1705	2.13	4.42	0	32

[a]Other lead faculty include the Graduate School of Design, the Graduate School of Education, the Harvard School of Dental Medicine, the Harvard Business School, and a category called "other".

[b]NBER-defined measures based on the patterns of citations made by the patent in question. A patent that cites a higher fraction of patents in other patent classes scores higher on this measure.

[c]NBER-defined measures based on the patterns of citations to the patent in question. A patent that cites cited by other patent classes more frequently scores higher on this measure.

Table 2. Breakdown of technology disclosures according to timing of first sale. The sample consists of 1703 reports of invention by Harvard University faculty between 1974 and March 2003. Each invention disclosure was classified as patentable. Invention records that had timing inconsistent with Figure 2 were dropped; these inventions were typically bundled or had been contracted on prior to their invention. Observations are summarized by the time and patent status of the reported inventions, and the fraction that have been licensed or optioned by the lead faculty of the inventor.

		Status			
		Not sold	***Sold…***		
Year of disclosure Status of technology	All		*... before first submission*	*... before first grant*	*... after first grant*
1974-2003					
No patent application	733	697 *95.1%*	36 *4.9%*		
Patent application abandoned	197	144 *43.1%*	19 *9.6%*	34 *17.3%*	
Patent pending	290	177 *61.0%*	28 *9.7%*	85 *39.3%*	
Patent granted	438	148 *33.8%*	60 *13.7%*	172 *39.3%*	58 *13.5%*
All disclosures	1658	1166 *70.3%*	143 *8.6%*	291 *17.6%*	58 *3.5%*
1981-1990					
No patent application	216	209 *96.8%*	7 *3.2%*		
Patent application abandoned	59	38 *64.4%*	5 *8.5%*	16 *27.1%*	
Patent pending	3	0 *0.0%*	1 *33.3%*	2 *66.7%*	
Patent granted	148	30 *20.3%*	18 *12.2%*	70 *47.3%*	30 *20.3%*
All disclosures	426	277 *65.0%*	31 *7.3%*	88 *20.7%*	30 *7.0%*
1991-2000					
No patent application	274	258 *94.2%*	16 *5.8%*		
Patent application abandoned	119	89 *74.8%*	13 *10.9%*	16 *13.4%*	
Patent pending	104	45 *43.3%*	13 *12.5%*	46 *44.2%*	
Patent granted	231	77 *33.3%*	42 *18.2%*	93 *40.3%*	19 *8.2%*
All disclosures	727	469 *64.5%*	84 *11.6%*	155 *21.3%*	19 *2.6%*

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Table 3. Correlation of licensing/optioning, publication, and commercialization experience variables, for all reported inventions. The sample consists of 1703 invention disclosures by Harvard University Faculty between 1974 and March 2003. Inventors' publication records are drawn from the ISI Web of Science's Science Citation Index between January 1960 and July 2003 only. The journal impact factor was used to weight the importance of each publication and was drawn from the ISI Web of Science in July 2003. The Licensed or Optioned variable is coded as 1 if the technology resulted in a license or an option and 0 otherwise. For each pair of variables, correlation coefficients are listed above, and p-values are listed below.

	Licensed or Optioned	A. Date	B. Pubs 7/03	C. Pubs 7/03 JW	D. Pubs 7/03 AW	E. Pubs 7/03 JW AW	F. Pubs t_0	G. Pubs t_0 JW	H. Pubs t_0 AW	I. Pubs t_0 JW AW	J. Inv. lic/opt t_0	K. Inv. Discl. t_0	L. Inv. lic/opt 703
A. Date of Technology Disclosure	-.0137	1.0000											
	.5814												
B. Publications as of July 2003	.0964	.0473	1.0000										
	.0003	.0785											
C. Publications July 2003 weighted by journal	.1211	.0509	.8843	1.0000									
impact factor	.0000	.0579	.0000										
D. Publications July 2003 weighted by number of	.0831	.0273	.9728	.8216	1.0000								
authors	.0020	.3093	.0000	.0000									
E. Publications July 2003 weighted by journal	.1129	.0337	.8881	.9738	.8712	1.0000							
impact factor and # of authors	.0000	.2099	.0000	.0000	.0000								
F. Publications at t_0	.0748	.2822	.8871	.7752	.8764	.7858	1.0000						
	.0053	.0000	.0000	.0000	.0000	.0000							
G. Publications at t_0 weighted by number of authors	.0720	.2436	.8764	.7269	.9116	.7756	.9746	1.0000					
	.0074	.0000	.0000	.0000	.0000	.0000	.0000						
H. Publications at t_0 weighted by journal impact	.0858	.2852	.7688	.8763	.7162	.8504	.8802	.8098	1.0000				
factor	.0014	.0000	.0000	.0000	.0000	.0000	.0000	.0000					
I. Publications at t_0 weighted by journal impact	.0862	.2656	.7953	.8712	.7807	.8888	.8965	.8673	.9762	1.0000			
factor and number of authors	.0013	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000				
J. Invention Disclosures at t_0	.0777	.3018	.6036	.5300	.5838	.5383	.7374	.7052	.6597	.6704	1.0000		
	.0018	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000			
K. Licenses & Options at t_0	.0931	.2757	.5315	.4846	.5139	.4932	.6721	.6406	.6202	.6296	.9614	1.0000	
	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000		
L. Total Invention Disclosures	.0943	.2891	.6059	.5311	.5834	.5375	.7321	.6986	.6516	.6609	.9876	.9522	1.0000
	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	
M. Total Licenses & Options	.2196	.2505	.5461	.4988	.5245	.5049	.6711	.6390	.6161	.6247	.9390	.9696	.9556
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Table 4. Hazard rate analysis of the influence of inventor academic standing and commercialization experience on probability of licensing or optioning a new technology. The sample consists of 1703 invention disclosures by Harvard University faculty between 1974 and March 2003. The observation exits the sample at the date of the first license or option as a failure or on the last day of observation as a censored observation. Inventors' publications records are drawn from the ISI Web of Science's Science Citation Index and consists of each inventor's publication record between January 1960 and July 2003. The journal impact factor was used to weight the importance of each publication; it was drawn from the ISI Web of Science in July 2003. The field of the inventor was determined by examining the inventor's faculty affiliation and publication record. In the Weibull specification, the time parameter is estimated to be between 0.45 and 0.60. The piecewise exponential specification allows the baseline hazard rate to vary discretely in years 0 through 6, and constrains it to remain constant thereafter. The displayed coefficients are the natural logs of the estimated relative hazards. The null hypothesis is that these displayed coefficients equal zero. Standard errors are in brackets.

Specification:	Cox	Cox	Cox	Cox	Cox	Weibull	Weibull	Weibull	Piecewise expo-nential	Piecewise expo-nential
Column:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Academic Standing:										
Publications at 07/03 weighted by journal impact factor[a]	***.168									
	[.047]									
Publications at t_0 weighted by journal impact factor[a]		***.236			*.140	***.303		**.180	***.244	*.145
		[.062]			[.084]	[.062]		[.084]	[.062]	[.084]
Commercialization Experience:										
Invention Disclosures at t_0			***.020		*.013		***.026	**0.016		*.013
			[.005]		[.007]		[.005]	[.007]		[.007]
Licenses & Options at t_0				***.040						
				[.010]						
Field										
Chemistry	omitted	omitted	omitted	omitted	omitted	omitted	omitted		omitted	omitted
Medical / Biological	–.183	*–.241	–.117	–.135	–.143	**–.285	–.132	–.160	*–.243	*–.142
	[.136]	[.130]	[.140]	[.136]	[.144]	[.129]	[.140]	[.128]	[.130]	[.145]
Other	**–.732	***–.805	**–.700	***–.713	**–.713	***–.862	***–.738	***–.746	***–.801	**–.705
	[.287]	[.281]	[.278]	[.275]	[.287]	[.280]	[.278]	[.288]	[.281]	[.288]
Observations	1358	1358	1382	1382	1358	1358	1382	1358	1356	1356
Log Likelihood	–2659.1	–2658.7	–2722.3	–2721.1	–2657.1	–1469.3	–1500.3	–1466.6	–1410.0	–1408.3
LR χ^2 statistic	30.5	31.4	30.1	32.4	34.7	44.5	43.3	49.9	546.5	550.0

[a]Coefficients and standard errors in this row are multiplied by 1000.

*** = significant at $p \leq 0.01$; ** = significant at $p \leq 0.05$; * = significant at $p \leq 0.1$ (two sided test)

Table 5. Hazard rate analysis of the influence of inventor academic standing and commercialization experience on probability of licensing or optioning a new technology, by field of the inventor. The sample consists of 1703 invention disclosures by Harvard University faculty between 1974 and March 2003. The observation exits the sample at the date of the first license or option as a failure or on the last day of observation as a censored observation. Inventors' publications records are drawn from the ISI Web of Science's Science Citation Index and consists of each inventor's publication record between January 1960 and July 2003. The journal impact factor was used to weight the importance of each publication; it was drawn from the ISI Web of Science in July 2003. The field of the inventor was determined by examining the inventor's faculty affiliation and publication record. In the Weibull specification, the time parameter is estimated to be between 0.45 and 0.60. The piecewise exponential specification allows the baseline hazard rate to vary discretely in years 0 through 6, and constrains it to remain constant thereafter. The displayed coefficients are the natural logs of the estimated relative hazards. The null hypothesis is that these displayed coefficients equal zero. Standard errors are in brackets.

Specification:	Cox	Cox	Cox	Cox	Cox	Cox	Cox	Cox	Cox
Subset:	Chemistry	Medical / Biological	Other	Chemistry	Medical / Biological	Other	Chemistry	Medical / Biological	Other
Column:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Academic Standing:									
Publications at t_0 weighted by journal impact factor[a]	***.419 [.124]	**.170 [.077]	***1.453 [.567]				.501 [.323]	.082 [.087]	***1.499 [.584]
Commercialization Experience:									
Invention Disclosures at t_0				***.019 [.006]	***.029 [.010]	.014 [.188]	-.005 [.016]	**.025 [.012]	-.084 [.218]
Observations	228	1025	105	245	1028	109	228	1025	105
Log Likelihood	-411.3	-1911.6	-68.1	-440.9	-1931.0	-75.4	-411.2	-1909.5	-68.0
LR χ^2 statistic	11.0	4.4	4.7	8.6	7.1	.0	11.1	8.5	4.8

Specification:	Weibull	Weibull	Weibull	Weibull	Weibull	Weibull	Weibull	Weibull	Weibull
Subset:	Chemistry	Medical / Biological	Other	Chemistry	Medical / Biological	Other	Chemistry	Medical / Biological	Other
Column:	(1a)	(2a)	(3a)	(4a)	(5a)	(6a)	(7a)	(8a)	(9a)
Academic Standing:									
Publications at t_0 weighted by journal impact factor[a]	***.561 [.124]	***.224 [.076]	***1.648 [.586]				**.681 [.321]	.105 [.086]	***1.675 [.597]
Commercialization Experience:									
Invention Disclosures at t_0				***.026 [.006]	***.038 [.010]	.043 [.182]	-.007 [.164]	***.033 [.012]	-.053 [.209]
Observations	228	1025	105	245	1028	109	228	1025	105
Log Likelihood	-269.8	-1121.5	-70.8	-290.3	-1128.6	-77.4	-269.7	-1117.9	-70.8
LR χ^2 statistic	19.3	7.6	5.5	15.1	12.5	.1	19.42	14.7	5.6

[a]Coefficients and standard errors in this column are multiplied by 10^3.
*** = significant at $p \leq 0.01$; ** = significant at $p \leq 0.05$; * = significant at $p \leq 0.1$ (two sided test); standard errors in brackets

Table 6. Hazard rate analysis of the funding source on the probability of licensing or optioning a new technology. The sample consists of 1703 invention disclosures by Harvard University faculty between 1974 and March 2003. The observation exits the sample at the date of the first license or option as a failure or on the last day of observation as a censored observation. Inventors' publications records are drawn from the ISI Web of Science's Science Citation Index and consists of each inventor's publication record between January 1960 and July 2003. The journal impact factor was used to weight the importance of each publication; it was drawn from the ISI Web of Science in July 2003. The field of the inventor was determined by examining the inventor's faculty affiliation and publication record. In the Weibull specification, the time parameter is estimated to be between 0.45 and 0.60. The piecewise exponential specification allows the baseline hazard rate to vary discretely in years 0 through 6, and constrains it to remain constant thereafter. The displayed coefficients are the natural logs of the estimated relative hazards. The null hypothesis is that these displayed coefficients equal zero. Standard errors are in brackets.

Specification:	Cox	Cox	Cox	Cox	Weibull	Weibull	Piecewise Exponential	Piecewise Exponential
Column:	(1)	(2)	(3)	(4)	(5)	(6)	(5)	(6)
Source of Funding:								
Federal Funding	.134 [.115]		.099 [.117]					
NIH		***.462 [.121]		***.435 [.122]	***.513 [.121]	***.485 [.122]	***.463 [.121]	***.438 [.122]
NSF		***.550 [.203]		*.383 [.215]	***.590 [.202]	*.397 [.214]	***.542 [.203]	*.369 [.214]
Military		.263 [.271]		.300 [.280]	.291 [.271]	.329 [.280]	.261 [.271]	.293 [.280]
Energy		***.800 [.305]		***.819 [.307]	***.916 [.305]	***.949 [.307]	***.806 [.305]	***.826 [.307]
Other		–.154 [.453]		–.559 [.583]	–.149 [.452]	–.538 [.582]	–.155 [.453]	–.560 [.582]
Academic Standing:								
Publications at t_0 weighted by journal impact factor[a]			.103 [.085]	.109 [.085]		*.144 [.086]		.111 [.086]
Commercialization Experience:								
Invention Disclosures at t_0			**.014 [.007]	*.013 [.007]		**.016 [.007]		*.014 [.007]
Field								
Chemistry	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
Medical / Biological	**–.272 [.124]	*–.248 [.144]	–.119 [.146]	–.120 [.159]	**–.304 [.142]	–.134 [.124]	*–.256 [.143]	–.134 [.124]
Other	***–.868 [.266]	***–.745 [.226]	**–.666 [.289]	*–.529 [.292]	***–.826 [.269]	*–.554 [.292]	***–.754 [.269]	*–.554 [.292]
Observations	1208	1208	1186	1186	1208	1186	1208	1186
Log Likelihood	–2569.7	–2560.1	–2506.7	–2497.8	–1391.1	–1353.6	–1330.5	–1301.0
LR χ^2 statistic	15.1	34.4	30.5	48.1	42.5	64.8	504.7	505.0

[a]Coefficients and standard errors in this row are multiplied by 1000.
*** = significant at $p \leq 0.01$; ** = significant at $p \leq 0.05$; * = significant at $p \leq 0.1$ (two sided test)

Table 7. Log-rank test of the equality of survivor functions of technologies by status of IP protection. The sample consists of 668 invention disclosures by Harvard University faculty between 1974 and March 2003 for which patents applications were submitted. The observation enters observation on the date of the invention report and exits the sample at the date of the first license or option (as a failure) or on the last day of observation (as a censored observation).

	All Submissions		All Granted Patents	
Timing relative to Patent Milestones:	Events Observed	Events Expected	Events Observed	Events Expected
Prior to first submission	93	82.74	41	39.11
After first submission before first grant	220	245.67	113	113.21
After first grant	42	26.59	39	40.67
All	355	355.00	205	205.0
$\chi^2_{(2)}$		***16.5		.44

*** = significant at $p \leq 0.001$

Table 8. Hazard rate model incorporating differences in the status of IP protection. The sample consists of 668 inventions reported by Harvard University faculty between 1974 and March 2003 for which patent applications were submitted. The observation enters observation on the date of invention disclosure and exits the sample at the date of the first license or option (as a failure) or on the last day of observation (as a censored observation). Technologies sold immediately upon disclosure are eliminated from the analysis below. The field of the inventor was determined by examining the inventor's faculty affiliation and publication record. In the Weibull specification, the time parameter is estimated to be between 0.45 and 0.60. The piecewise exponential specification allows the baseline hazard rate to vary discretely in years 0 through 6, and constrains it to remain constant thereafter. The displayed coefficients are the natural logarithms of the estimated relative hazards. The null hypothesis is that these displayed coefficients equal zero. Standard errors are in brackets.

Specification:	Cox	Cox	Cox	Weibull	Weibull	Piecewise Exp.	Cox
Subset:	All Submissions	All Submissions	Excluding "Simultaneous" Submissions & Sales	All Submissions	Excluding "Simultaneous" Submissions & Sales	All Submissions	Excluding "Simultaneous" Submissions & Sales
Column:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Patent Status:							
Not yet submitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
First patent application submitted	**–.380 [.162]	**–.414 [.164]	.056 [.202]	–.139 [.169]	**.542 [.211]	***–.479 [.146]	.032 [.182]
First patent granted	***.765 [.226]	***.817 [.228]	***.782 [.230]	–.177 [.186]	–.102 [.190]	***.820 [.226]	***.782 [.228]
Commercialization Experience:							
Invention Disclosures at t_0		***.018 [.005]	***.016 [.006]	***.021 [.005]	***.019 [.006]	***.020 [.005]	***.017 [.006]
Field							
Chemistry	omitted	omitted	omitted	omitted	omitted	omitted	omitted
Medical / Biological	**–.329 [.130]	–.131 [.148]	*–.281 [.153]	–.165 [.149]	**–.312 [.154]	–.132 [.148]	*–.281 [.154]
Other	**–.719 [.311]	–.471 [.322]	–.426 [.323]	–.378 [.323]	–.325 [.323]	–.469 [.322]	–.416 [.323]
Observations	1380 (668 subjects)	1380 (668 subjects)	1327 (621 subjects)	1380 (668 subjects)	1327 (621 subjects)	3237 (668 subjects)	3177 (621 subjects)
Log Likelihood	–1929.7	–1924.5	–1630.1	–983.7	–838.1	–931.2	–792.3
LR χ^2 statistic	23.4	33.8	29.3	25.4	33.0	341.9	258.0

*** = significant at $p \leq 0.01$; ** = significant at $p \leq 0.05$; * = significant at $p \leq 0.1$ (two sided test)

Table 9. Correlation of technology sale, timing, and patent characteristics. The sample consists of 442 invention disclosures by Harvard University Faculty between 1974 and March 2003 that received patents. The Licensed or Optioned variable is coded as 1 if the technology resulted in a license or an option and is coded as zero otherwise. For each pair of variables (row-column), correlation coefficients are listed above, and p-values are listed below.

	Licensed or Optioned	Date of Technology Disclosure	Normalized Citations	Time Between Patent Filing and Patent Grant	Claims Granted by USPTO	Originality	Generality
Date of Technology Disclosure	-.0133 .5833	1.0000					
Normalized Citations	.1455 .0070	.1046 .0001	1.0000				
Time Between Patent Filing and Patent Grant	.2039 .0000	.0940 .0001	.0022 .9360	1.0000			
Claims Granted by USPTO	.0937 .0514	.2903 .0000	.2177 .0000	.0808 .0011	1.0000		
Originality	.0670 .2874	.1502 .0000	.1962 .0000	.0475 .1468	.2997 .0000	1.0000	
Generality	.0372 .5802	–.0650 .0523	.2639 .0000	–.0596 .0785	–.0355 .2897	.0350 .3679	1.0000

Table 10. Hazard rate model of the impact of patent characteristics on likelihood of finding a buyer, granted patents only. The sample consists of 442 invention disclosures by Harvard University faculty between 1974 and March 2003 for which patents have been received. The observation exits the sample at the date of the first license or option (as a failure) or on the last day of observation (as a censored observation). In the Weibull specification, the time parameter is estimated to be between 0.45 and 0.60. The displayed coefficients are the natural logarithms of the estimated relative hazards. The null hypothesis is that these displayed coefficients equal zero. Standard errors are in brackets.

Specification:	Cox	Cox	Cox	Cox	Cox	Cox	Weibull	Weibull	Weibull	Weibull	Weibull	Weibull
Column:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Patent Characteristics												
Normalized Citations	*.040					.032	**.057					**.048
Received	[.024]					[.025]	[.023]					[.024]
Time Between Patent Filing		***.402				***.314		***.473				***.397
and Patent Grant[a]		[.091]				[.023]		[.090]				[.109]
Claims Granted			***.007			*.005			***.009			**.006
			[.002]			[.003]			[.023]			[.003]
Originality				.332						.462		
				[.300]						[.296]		
Generality					.263						.277	
					[.314]						[.316]	
Patent Category												
Chemicals	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
Drugs	–.147	–.202	–.171	–.023	–.242	–.222	–.238	*–.326	–.288	–.118	–.354	–.340
	[.193]	[.174]	[.172]	[.214]	[.224]	[.196]	[.194]	[.174]	[.173]	[.216]	[.224]	[.198]
Biotechnology	–.067	–.191	–.115	–.056	–.273	–.119	–.140	*–.285	*–.287	–.119	–.371	*–.206
	[.176]	[.157]	[.157]	[.228]	[.228]	[.197]	[.177]	[.157]	[.157]	[.226]	[.228]	[.179]
Others	***–.794	**–.616	***–.792	***–.810	***–1.04	***–.755	***–.824	***–.661	***–.868	***–1.31	***–1.16	***–.793
	[.289]	[.246]	[.246]	[.302]	[.356]	[.291]	[.289]	[.247]	[.246]	[.223]	[.223]	[.291]
Observations	304	387	390	221	197	303	304	387	390	221	197	303
Log Likelihood	–1030.9	–1321.4	–1335.2	–720.5	–619.1	–1022.0	–543.4	–663.3	–675.0	–395.4	–354.2	–531.4
LR χ^2 statistic	12.3	28.5	17.0	10.3	10.5	27.8	15.8	36.8	23.5	11.7	11.5	37.9

*** = significant at $p \leq 0.01$; ** = significant at $p \leq 0.05$; * = significant at $p \leq 0.1$ (two sided test)

Appendix:

Table A1. Categories and subcategories for issued patents using the Hall et al. classification scheme (Patents Granted Only)

Patent Category	Frequency	Patent Sub-Category	Frequency
Chemicals (1)	125	Agr., Food, Textiles (11)	1
		Coating (12)	13
		Gas (13)	2
		Organic Compounds (14)	45
		Resins (15)	34
		Miscellaneous (19)	30
Computers & Communications (2)	16	Communications (21)	2
		Computer HW & SW (22)	8
		Computer Peripherals (23)	4
		Information Storage (24)	2
Drugs & Medical (3)	272	Drugs (31)	110
		Surgery & Medical Instruments (32)	13
		Biotechnology (33)	149
Electric & Electrical (4)	21	Electrical Devices (41)	1
		Electrical Lighting (42)	1
		Measuring & Testing (43)	7
		Nuclear & X-Rays (44)	5
		Power Systems (45)	3
		Semiconductor Devices (46)	4
Mechanical (5)	4	Materials Processing (51)	1
		Optics (54)	3
Other (6)	4	Miscellaneous (69)	4
Total	**442**		**442**

Table A2. Breakdown of technology disclosures according to timing of first license. The sample consists of 1703 reports of invention by Harvard University faculty between 1974 and March 2003. Each invention disclosure was classified as patentable. Invention records that had timing inconsistent with Figure 2 were dropped; these inventions were typically bundled or had been contracted on prior to their invention. Observations are summarized by the time and patent status of the reported inventions, and the fraction that have been licensed or optioned by the lead faculty of the inventor.

		Status			
		Not sold		***Sold…***	
Year of disclosure Status of technology	All		*... before first submission*	*... before first grant*	*... after first grant*
1974-2003					
No patent application	719	708 *98.5%*	11 *1.5%*		
Patent application abandoned	196	163 *83.2%*	9 *4.6%*	24 *12.2%*	
Patent pending	285	200 *70.2%*	21 *7.4%*	64 *22.5%*	
Patent granted	431	202 *46.9%*	21 *4.9%*	131 *30.4%*	62 *14.4%*
All disclosures	1631	1273 *78.1%*	77 *4.7%*	219 *13.4%*	62 *3.8%*
1981-1990					
No patent application	216	213 *98.6%*	3 *1.4%*		
Patent application abandoned	59	45 *76.3%*	3 *5.1%*	11 *18.6%*	
Patent pending	3	0 *0.0%*	1 *33.3%*	2 *66.7%*	
Patent granted	148	30 *20.3%*	13 *8.8%*	50 *33.8%*	33 *22.3%*
All disclosures	423	307 *72.6%*	31 *4.7%*	63 *14.9%*	33 *7.8%*
1991-2000					
No patent application	274	268 *97.8%*	6 *2.2%*		
Patent application abandoned	119	101 *85.6%*	6 *5.1%*	11 *9.3%*	
Patent pending	104	52 *50.0%*	11 *10.6%*	41 *39.4%*	
Patent granted	231	114 *49.4%*	23 *10.0%*	73 *31.6%*	21 *9.1%*
All disclosures	727	535 *73.6%*	46 *6.3%*	125 *17.2%*	21 *2.9%*

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Table A3. Hazard rate analysis of the influence of inventor reputation and commercialization experience on probability of licensing a new technology. The sample consists of 1703 invention disclosures by Harvard University faculty between 1974 and March 2003. The observation exits the sample at the date of the first license or option as a failure or on the last day of observation as a censored observation. Inventors' publications records are drawn from the ISI Web of Science's Science Citation Index and consists of each inventor's publication record between January 1960 and July 2003. The journal impact factor was used to weight the importance of each publication; it was drawn from the ISI Web of Science in July 2003. The field of the inventor was determined by examining the inventor's faculty affiliation and publication record. In the Weibull specification, the time parameter is estimated to be between 0.45 and 0.60. The piecewise exponential specification allows the baseline hazard rate to vary discretely in years 0 through 6, and constrains it to remain constant thereafter. The displayed coefficients are the natural logs of the estimated relative hazards. The null hypothesis is that these displayed coefficients equal zero. Standard errors are in brackets.

Specification:	Cox	Cox	Cox	Cox	Cox	Weibull	Weibull	Weibull	Piecewise expo-nential	Piecewise expo-nential
Column:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Academic Standing:										
Publications at 07/03 weighted by number of authors[a]	***.224									
	[.052]									
Publications at t_0 weighted by journal impact factor[a]		***.307			**.230	***.374		***.271	***.315	***.236
		[.069]			[.092]	[.068]		[.092]	[.069]	[.092]
Commercialization Experience:										
Invention Disclosures at t_0			***.021		.010		***.027	*.013		.010
			[.006]		[.008]		[.005]	[.007]		[.007]
Licenses & Options at t_0				***.040						
				[.011]						
Field										
Chemistry	omitted	omitted	omitted	omitted	omitted	omitted	omitted		omitted	omitted
Medical / Biological	***–.433	***–.519	***–.423	***–.470	***–.442	***–.561	***–.439	***–.459	***–.522	***–.444
	[.148]	[.140]	[.149]	[.144]	[.155]	[.140]	[.150]	[.155]	[.140]	[.155]
Other	***–.882	***–.995	***–.925	***–.971	***–.923	***–1.043	***–.960	***–.953	***–.998	***–.926
	[.327]	[.320]	[.312]	[.309]	[.326]	[.319]	[.312]	[.325]	[.319]	[.326]
Observations	1392	1392	1416	1416	1392	1392	1416	1392	1390	1390
Log Likelihood	–2659.1	–2059.5	–2124.7	–2125.1	–2058.6	–1178.6	–1214.0	–1177.1	–1132.0	–1131.2
LR χ^2 statistic	48.2	48.5	41.5	40.6	50.3	61.9	53.9	64.9	363.1	364.9

[a]Coefficients and standard errors in this row are multiplied by 1000.

*** = significant at $p \leq 0.01$; ** = significant at $p \leq 0.05$; * = significant at $p \leq 0.1$ (two sided test)

Table A4. Hazard rate analysis of the funding source on the probability of licensing of optioning a new technology. The sample consists of 1703 invention disclosures by Harvard University faculty between 1974 and March 2003. The observation exits the sample at the date of the first license or option as a failure or on the last day of observation as a censored observation. Inventors' publications records are drawn from the ISI Web of Science's Science Citation Index and consists of each inventor's publication record between January 1960 and July 2003. The journal impact factor was used to weight the importance of each publication; it was drawn from the ISI Web of Science in July 2003. The field of the inventor was determined by examining the inventor's faculty affiliation and publication record. In the Weibull specification, the time parameter is estimated to be between 0.45 and 0.60. The piecewise exponential specification allows the baseline hazard rate to vary discretely in years 0 through 6, and constrains it to remain constant thereafter. The displayed coefficients are the natural logs of the estimated relative hazards. The null hypothesis is that these displayed coefficients equal zero. Standard errors are in brackets.

Specification:	Cox	Cox	Cox	Cox	Weibull	Weibull	Piecewise Exponential	Piecewise Exponential
Column:	(1)	(2)	(3)	(4)	(5)	(6)	(5)	(6)
Source of Funding:								
Federal Funding	**.338 [.136]		**.312 [.138]					
NIH		***.749 [.144]		***.727 [.145]	***.781 [.144]	***.761 [.146]	***.746 [.144]	***.726 [.145]
NSF		***.828 [.223]		***.663 [.236]	***.868 [.221]	***.683 [.236]	***.815 [.222]	***.648 [.236]
Military		.263 [.322]		.287 [.337]	.300 [.322]	.327 [.338]	.260 [.322]	.282 [.337]
Energy		***1.02 [.339]		***1.09 [.341]	***1.11 [.339]	***1.21 [.342]	***1.03 [.339]	***1.10 [.342]
Other		.035 [.507]		–.518 [.713]	.032 [.506]	–.504 [.712]	.032 [.507]	–.520 [.713]
Academic Standing:								
Publications at t_0 weighted by journal impact factor[a]			**.214 [.093]	**.223 [.093]		***.264 [.094]		**.229 [.093]
Commercialization Experience:								
Invention Disclosures at t_0			.010 [.007]	.009 [.008]		.012 [.007]		.010 [.008]
Field								
Chemistry	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
Medical / Biological	***–.574 [.134]	***–.583 [.156]	***–.406 [.156]	***–.438 [.170]	***–.624 [.153]	***–.442 [.169]	***–.593 [.155]	***–.442 [.170]
Other	***–1.16 [.311]	***–1.01 [.314]	***–.937 [.337]	**–.743 [.341]	***–1.07 [.315]	**–.752 [.343]	***–1.02 [.314]	**–.749 [.342]
Observations	1240	1240	1218	1218	1240	1218	1240	1218
Log Likelihood	–2010.0	–1995.0	–1946.1	–1932.2	–1121.5	–1081.9	–1074.4	–1041.8
LR χ^2 statistic	32.8	62.8	52.7	80.6	70.1	96.0	349.8	355.3

[a]Coefficients and standard errors in this row are multiplied by 1000.
*** = significant at $p \leq 0.01$; ** = significant at $p \leq 0.05$; * = significant at $p \leq 0.1$ (two sided test)

Table A5. Log-rank test of the equality of survivor functions of technologies by status of IP protection. The sample consists of 668 invention disclosures by Harvard University faculty between 1974 and March 2003 for which patents applications were submitted. The observation enters observation on the date of the invention report and exits the sample at the date of the first license or option (as a failure) or on the last day of observation (as a censored observation).

	All Submissions		All Granted Patents	
Timing relative to Patent Milestones:	Events Observed	Events Expected	Events Observed	Events Expected
Prior to first submission	49	48.05	21	21.38
After first submission before first grant	175	193.12	97	95.92
After first grant	47	29.84	42	42.71
All	271	271.00	160	160.00
$\chi^2_{(2)}$		***16.1		.06

*** = significant at $p \leq 0.001$

Table A6. Hazard rate model incorporating differences in the status of IP protection on likelihood of finding a licensee. The sample consists of 668 inventions reported by Harvard University faculty between 1974 and March 2003 for which patent applications were submitted. The observation enters observation on the date of invention disclosure and exits the sample at the date of the first license or option (as a failure) or on the last day of observation (as a censored observation). Technologies sold immediately upon disclosure are eliminated from the analysis below. The field of the inventor was determined by examining the inventor's faculty affiliation and publication record. In the Weibull specification, the time parameter is estimated to be between 0.45 and 0.60. The piecewise exponential specification allows the baseline hazard rate to vary discretely in years 0 through 6, and constrains it to remain constant thereafter. The displayed coefficients are the natural logarithms of the estimated relative hazards. The null hypothesis is that these displayed coefficients equal zero. Standard errors are in brackets.

Specification:	Cox	Cox	Cox	Weibull	Weibull	Piecewise Exp.	Cox
Subset:	All Submissions	All Submissions	Excluding "Simultaneous" Submissions & Sales	All Submissions	Excluding "Simultaneous" Submissions & Sales	All Submissions	Excluding "Simultaneous" Submissions & Sales
Column:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Patent Status:							
Not yet submitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
First patent application submitted	–.272 [.198]	–.322 [.164]	.068 [.232]	.073 [.211]	**.546 [.245]	–.245 [.182]	.085 [.211]
First patent granted	***.799 [.230]	***.856 [.232]	***.776 [.230]	.020 [.187]	.091 [.190]	***.827 [.228]	***.811 [.229]
Commercialization Experience:							
Invention Disclosures at t_0		***.020 [.006]	***.016 [.006]	***.022 [.006]	***.023 [.006]	***.020 [.006]	***.022 [.006]
Field							
Chemistry	omitted	omitted	omitted	omitted	omitted	omitted	omitted
Medical / Biological	***–.670 [.141]	***–.467 [.148]	***–.725 [.146]	***–.509 [.149]	**–.549 [.164]	***–.465 [.159]	***–.514 [.163]
Other	***–1.12 [.373]	**–.861 [.384]	***–1.06 [.374]	**–.757 [.384]	*–.682 [.386]	**–.851 [.384]	**–.851 [.239]
Observations	1497 (685 subjects)	1497 (685 subjects)	1472 (664 subjects)	1497 (685 subjects)	1497 (664 subjects)	3761 (685 subjects)	3735 (664 subjects)
Log Likelihood	–1516.4	–1511.0	–1385.9	–821.3	–750.9	–781.0	–716.5
LR χ^2 statistic	37.4	48.0	38.3	40.5	49.7	251.0	217.9

*** = significant at p ≤ 0.01; ** = significant at p ≤ 0.05; * = significant at p ≤ 0.1 (two sided test)

Table A7. Hazard rate model of the impact of patent characteristics on likelihood of finding a licensee, granted patents only. The sample consists of 442 invention disclosures by Harvard University faculty between 1974 and March 2003 for which patents have been received. The observation exits the sample at the date of the first license or option (as a failure) or on the last day of observation (as a censored observation). In the Weibull specification, the time parameter is estimated to be between 0.45 and 0.60. The displayed coefficients are the natural logarithms of the estimated relative hazards. The null hypothesis is that these displayed coefficients equal zero. Standard errors are in brackets.

Specification:	Cox	Cox	Cox	Cox	Cox	Cox	Weibull	Weibull	Weibull	Weibull	Weibull	Weibull
Column:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Patent Characteristics												
Normalized Citations	***.073					**.058	***.087					***.073
Received	[.023]					[.025]	[.022]					[.024]
Time Between Patent Filing		***.347				**.248		***.398				**.280
and Patent Grant[a]		[.103]				[.121]		[.101]				[.119]
Claims Granted			***.011			***.009			***.009			***.010
			[.002]			[.003]			[.023]			[.003]
Originality				.107						.184		
				[.313]						[.310]		
Generality					–.274						–.244	
					[.344]						[.345]	
Patent Category												
Chemicals	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
Drugs	–.049	–.181	–.194	–.205	–.344	–.147	–.125	–.275	–.293	–.275	*–.425	–.232
	[.192]	[.191]	[.191]	[.224]	[.239]	[.213]	[.208]	[.191]	[.191]	[.225]	[.239]	[.212]
Biotechnology	.103	–.078	.019	–.081	–.261	.068	.044	–.152	–.037	–.125	–.349	.006
	[.191]	[.172]	[.171]	[.239]	[.240]	[.193]	[.192]	[.172]	[.171]	[.239]	[.241]	[.194]
Others	*–.567	*–.471	**–.671	**–.729	**–.848	*–.562	*–.569	*–.501	***–.727	**–.738	***–.893	*–.582
	[.312]	[.274]	[.272]	[.326]	[.375]	[.314]	[.312]	[.274]	[.272]	[.325]	[.374]	[.315]
Observations	318	402	405	232	204	317	318	402	405	232	204	317
Log Likelihood	–911.2	–1127.1	–1132.3	–656.7	–570.3	–901.9	–490.8	–590.8	–591.8	–336.4	–326.4	–479.5
LR χ^2 statistic	12.8	16.2	20.8	6.1	7.3	29.8	16.7	20.5	26.5	6.7	8.0	37.9

*** = significant at p ≤ 0.01; ** = significant at p ≤ 0.05; * = significant at p ≤ 0.1 (two sided test)