Publications, Patents, and the Market for University Inventions

March 28, 2005

Daniel W. Elfenbein*

This paper takes as its unit of analysis the disclosure of an invention by a faculty member to the university technology transfer office and examines the factors that lead some inventions to be sold be matched with buyers while others are not. In particular, I analyze the degree to which inventors' academic publications, their experience with disclosure and licensing, and the patent status of the invention are correlated with the likelihood that the invention will be purchased by a commercial buyer and the deal terms that result. I find that an inventor's prior experience with and success in commercialization is positively correlated both with likelihood of finding a commercial buyer and with the levels of non-contingent payments in the resulting licenses. Controlling for prior experience, inventions made by inventors with more extensive publication records are more likely to find commercial buyers, and the publication records of these inventors are positively correlated with the resulting non-contingent payments but are uncorrelated with the contingent payment structure of the licensing contracts. Although the majority of inventions are licensed prior to patent awards, the receipt of a patent significantly increases the likelihood that the invention will be licensed. Inventor's publications and experience matter more in the absence of patent awards, and conversely patent awards are critical only when inventors' commercialization experience is limited. Overall, these findings paint a complex picture about the process whereby inventions are matched with buyers and the role that different types of information play in enabling potential buyers to form valuations of the given invention..

*University of California Berkeley
dan@elfenbein.net

The author is grateful to Harvard University's Office of Technology and Trademark Licensing and Harvard Medical School's Office of Technology Licensing and Industry Sponsored Research and Partners HeathCare Corporate Sponsored Research and Licensing Office for providing access to the data. Carliss Baldwin, Josh Lerner, Alfonso Gambardella and seminar participants at the Harvard University economics department, Harvard Business School, UC Berkeley, and Stanford provided valuable comments. The author would also like to thank Joyce Brinton, Kenneth Levin, and Stephen Atkinson for many hours of discussion and helpful comments. Ben Shultz provided outstanding research assistance.

1. Introduction

A number of information problems plague markets for intellectual property—asymmetric information, important tacit knowledge to be supplied by inventors, uncertainty about the future value of a technology, uncertainty about the scope of property rights, and others (Zeckhauser, 1996; Arora, Fosfori, and Gambardella, 2001; Gans, Hsu, and Stern, 2003). Some of these factors affect the ability of potential transaction partners to locate and contract with one another, some affect the design of the contracts they agree on, and some affect both. This paper chooses a setting—university-generated technologies—in which technologies are available for sale at an "embryonic"[1] stage and the uncertainty about the future value of a technology (to a particular firm) and the scope of the property rights around the technology is particularly severe. It examines the degree to which characteristics of university inventors, such as prior academic publications and commercialization experience, interact with certainty about property rights (or lack thereof) to enable these information problems to be overcome, leading to a sale of these embryonic technologies.

A growing literature examines the possibility that tradeoffs exist for academic scientists between engaging in commercialization activity and academic research (Agrawal and Henderson, 2002; Azoulay, Ding, and Stuart, 2004; Markiewicz and DeMinin, 2004; Mukherjee, Thursby, and Thursby, 2005; Stephan, Gurmu, Sumell, and Black, 2004, *inter alia*). While it is clear that a scientist's time is a scarce input in the production function that generates both of these economically desirable outputs, the empirical research has found little evidence that commercialization activity and scientific research are substitutes in the statistical sense; rather these outputs seem to be highly correlated even after controlling for a number of factors.[2] In other words, there seem to be spillovers from one domain to the other. This paper analyzes

[1] To my knowledge, the term embryonic technologies was first employed by Jensen and Thursby (2001).

[2] Unobservable individual heterogeneity, including unobservable movements of individuals down more or less promising research paths over time, the preponderance of biomedical research in "Pasteur's Quadrant", and the relationship between success, both commercial and academic, and the acquisition of resources (a "Matthew Effect") have each been hypothesized as potential explanations for this relationship.

a related issue: whether the *effectiveness* of commercialization activity (rather than the volume) jointly undertaken by an academic scientist and the university to whom the scientists' invention is assigned is impacted by the academic's scientific research, i.e., whether there is a spillover from academic reputation to the effectiveness of the TTO's licensing activity. In this regard, this paper complements the work on the impact of star scientists, whom Zucker, Darby, and Armstrong (1998) and Darby, Qiu, and Zucker (1999) show to be influential in generating a number of important economic outcomes.

The second major issue analyzed in this paper is the role that intellectual property protection plays in facilitating the transfer of university-generated technologies. A longstanding theoretical literature emphasizes the role that intellectual property rights play in facilitating trade in the market for ideas, principally through protecting inventors from expropriation (Arrow, 1962; Gallini and Wright, 1990), and stronger IP protection has been shown to increase the flow of technology across national borders (Branstetter, Fisman, and Foley, 2003). On the other hand, as Anton and Yao (1994) and Arora (1995) hypothesize, under a number of conditions, securing formal property rights in advance may not be required for trade in intellectual property. Support for these hypotheses can be found in the university context, where Elfenbein (2004) shows that a majority of university technologies developed at Harvard University are licensed prior to the grant of patents and many are licensed prior to the submission of a patent application; similarly, and in the context of inter-firm licensing, where Gans, Hsu, and Stern (2003) find that nearly 50% of all licenses take place prior to the grant of a patent. Nonetheless, while patents might not be absolute requisites for licensing university inventions, they may have a positive impact on the university's ability to find a buyer for the technology. Gans, Hsu, and Stern (2003) suggest that the resolution of uncertainty about the scope of the patent rights is the critical factor, while Hellman (2005) postulates that patents' offer important incentives to scientists (and disincentives to firms) to engage in search activities that would lead inventions to be matched with buyers. This paper addresses the impact of receiving a patent on university's ability to license and the prices received for resulting licenses. For university technology licensing offices, patenting can represent a significant expense, so much so that several technology transfer offices will not proceed with incurring patent expenses unless partners have already been identified (Siegel, Waldman, and Link, 2003; Owen-Smith and Powell, 2003).

This paper takes as its unit of analysis the disclosure of an invention by a university scientist to the university's technology transfer office. The paper seeks to assess the degree to which inventors' publication records, disclosure and commercialization experience, and the patent status of the invention affect the likelihood that the invention will be matched with a commercial buyer. In the 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 disclosure from the "Reports of Invention" made by university faculty to the school's technology licensing office (TTO). 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, Thursby, and Thursby (2003) argue impact the performance of technology transfer activity.[3]

A key distinction between the inter-firm market for inventions and the university licensing setting enables me to assume that each invention disclosure by university faculty is truly a candidate for sale. A firm selling an invention presumably has a single objective—profit maximization. A firm will only sell the rights to an invention, 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 rarely commercialize new technologies themselves; incentives and capabilities to do so are both limited. Thus there is little incentive for the university to withhold the most valuable technologies for internal development. Each technology that the university patents, then, is a realistic candidate for sale to outside parties.

This paper builds on Elfenbein (2004) which develops a number of stylized facts about the commercialization process, including observations that (a) the majority of licensed inventions are licensed prior to the receipt of a patent and a significant fraction are licensed before the submission of a patent application, (b) the hazard rate of sale of a new disclosure peaks at about 12 months and declines rapidly thereafter, (c) measures of patent importance—such as citations relative to a technology-year cohort, number of claims granted, and time under review by the USPTO—are all positively related to the hazard rate of sale, (d) significant differences exist between the rates at which chemical, medical/biological, and other inventions are licensed, and (e) significant differences exist between the rates at which inventions developed as the byproduct of research funded by different federal institutions, such as the NSF, NIH, DOD, and others are commercialized. This paper focuses on a subset of issues addressed in Elfenbein (2004) regarding the importance of inventor characteristics and patenting to commercialization outcomes, and yields the following results:

- Measures of prior commercialization experience—both prior disclosures and prior licenses or options—are positively correlated with the hazard rate of sale.
- Measures of the inventor's academic publication record—both on an absolute basis and relative to the cohort of other Harvard University scientist-inventors in their particular field—are positively correlated with the hazard rate of sale. Controlling for prior experience, field, and inventor fixed effects, inventors' publication records remain positively and significantly correlated with the hazard rate of sale.

[3] I do account for key policy changes likely to affect the quality of disclosures at this institution.

- The hazard rate of sale increases significantly following the award of a patent for the licensed technology.
- Prior to the receipt of the patent, measures of the inventor's publication records are positively and statistically related to the hazard rate of sale. After the receipt of the patent, stronger publication records are not associated with higher hazard rates of sale.
- For inventions made by faculty who have not yet had commercial success (i.e., disclosed an invention that was subsequently licensed), the hazard rate of sale increases dramatically after the receipt of a patent. For inventions made by faculty who have had prior commercial success, receiving a patent is not associated with a higher hazard rate of sale.
- When technologies are licensed, measures of the inventor's academic publication record are positively and statistically correlated with upfront payments negotiated by the university for the licensed technology, controlling for a number of other factors. Measures of the inventor's academic publication record are weakly correlated with the use of equity as a compensation for the technology but are *not* correlated with other contingent types of compensation such as royalties or milestones.
- Technologies licensed post-patent do not receive statistically greater non-contingent fees than technologies licensed prior to the receipt of a patent.

Overall, these findings paint a complex picture about the process whereby inventions are matched with buyers and the role that different types of information play in enabling potential buyers to form valuations of the given invention (and in enabling the university to appropriate this value). While some support can be drawn for the idea that publications reduce search costs for firms (or attract attention from them to the workings of an inventor's lab), the evidence is largely consistent with the idea that information used by firms to estimate the value of and uncertainty surrounding individual inventions is most critical in generating commercial transactions.

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 presents an overview of the data and the data collection process. Section 5 presents the analysis, and section 6 concludes and discusses the 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, Whinston, and Green, 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 (e.g., Rubinstein, 1982; Binmore, 1987). 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 identify 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, Fosfori, and Gambardella (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 estimates do not provide much guidance about the value of holding current patents in the US or in

[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.

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.

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 new technology's relative advantage, its the compatibility with existing complementary technologies, its complexity, and the ease with which it may be experimented (Rogers, 1995).[5]

In summary, the literature identifies two major categories of factors that affect the likelihood of exchange of intellectual property: (1) "upstream" conditions underpinning the search environment, namely ability of parties to locate one another and to form the impression that explore an agreement would be worthwhile and (2) and "downstream" conditions that enable the parties to assess the value of the technology, particularly on the buyers' side, once search has been completed. Factors that facilitate disclosure of information about the technology from the buying party to potential sellers, such as property rights or complementary tacit knowledge, may affect the effectiveness of both upstream and downstream activities.

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. Mowery, Nelson, Sampat, and Ziedonis (2004) provide an in-depth examination of patterns of patenting and licensing at Stanford, Columbia, and the University of California and their changes. Additional, these authors find evidence that technology transfer offices' capabilities develop with experience over time. 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. Jensen and Thursby (2001) and Dechenaux, Goldfarb, Shane, and Thursby (2003)[6] examine the role that contractual incentives, uncertainty, and appropriability play in determining whether and when licensed university inventions will be brought to market.

The role of start-ups, particularly those founded by academic inventors, in commercializing university generated technology has also been investigated. 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). Similarly, Chukumba and Jensen (2005) examine the relative impact of the university's cost of searching for

[5] 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).

[6] These authors also use the phrase "hazard rate of first sale." In their case, this means end-product sales of technology on the marketplace, as opposed to the first license or option event of the technology.

established partners and the 'local' costs of establishing start-ups in determining whether university inventions are commercialized by new firms or established ones. Comparing geographic distribution of university license activity compared to patent citation activity, Mowery and Ziedonis (2001) demonstrate that exclusively licensed technologies are more likely to be located near universities than non-exclusive licenses, which in turn are more geographically concentrated than patent citations. Although their inference does not directly relate to start-up activity it is consistent with both the prevalence of start-ups to commercialize certain types of technologies and the importance of post-license faculty inputs into the commercialization process.

The fact that university technologies are licensed at such an early-stage makes them difficult to value, particularly with respect to later-stage technologies. Given the uncertain, early-stage nature of university technologies, it is not surprising 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. Thursby and Thursby (2003) review a number of studies that address the importance of faculty involvement in locating licensees for particular technologies and for developing them post license; additionally, they show that from a firm's perspective, university licensing is related to personal contact between the firm's R&D personnel and university scientists. These papers that relate licensing outcomes to academic prestige and faculty characteristics are the most closely related to the current study.

3. University technology licensing in practice

Timing of invention, patenting, and licensing

Figure 1 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[7], 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. Table 1 breaks down the timing of sale for technologies in this data set.

The technology transfer offices' problem: investing in patents

The technology transfer office (TTO) must decide whether or not to patent each new technology reported by a faculty member. In some cases, the inventor has already located a licensee who will pay for the patent expenses of the technology. Otherwise, these fees will be born by the university.[8] For university TTOs, patenting can represent a significant expense, so much so that several TTOs will not proceed with incurring patent expenses unless partners have already been identified (Siegel, Waldman, and Link, 2003; Owen-Smith and Powell, 2003). A stylized version of the TTO's decision problem can then be represented as follows:

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

where P is the cost of patenting, $\alpha(\ )$ is the increased probability of licensing a technology if a patent application is granted multiplied by the likelihood of grant, 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. 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

[7] 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.

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

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 toward the later half of the period examined, reflecting 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. In 1998, the university formalized its policy regarding reporting of faculty inventions, making them an "obligation" for faculty members (previously this had not been specified as an obligation—one could simply not report an invention if one so desired). Therefore, I employ controls for the post-1998 time period in the survival time models below.

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.

Panel C 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 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 invention's 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 should represent more precise measures of inventors' academic standing display the same properties as the unweighted measures.

In addition to the raw publication scores, an attempt was made to create a measure of relative publication status that accounted for some of the major drivers of heterogeneity across individuals and years. Each measure of publications prior to year t was regressed against a fourth order polynomial of the year t using the entire set of Harvard inventors in the same research field over the entire period. The residual for each inventor, i, at time t, was then calculated. This residual measures the difference of the inventor's publication record from the average of his cohort at time t. Summary statistics for the two principle residuals used in the analysis below calculated at time t_0 are reported in panel D. The residual

[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.

measures also display some skewness, but much less than the absolute measures of inventor publication activity.

Panel E 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.

Panel F presents data on the payment structure of exclusive and non-exclusive licenses resulting from the OTT's commercialization activity for which payment terms were available. The average upfront payment, in 1996 dollars, was $26,388 thousand across 340 licenses in the sample. Of these 340, 12% had no upfront payments whatsoever. The average royalty in the sample was 3.1%, and nearly 18% of the licenses had royalty rates of 0. Equity was employed in 13% of the license contracts, while milestone payments and maintenance fees were scheduled in 26% and 36% of the contracts, respectively.

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 (i.e. a license or option contract is executed) or as a 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 2. 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 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 OTT 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. For this reason, time-to-license controls are included in regressions of payment terms. 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.

5. Analysis

The analysis proceeds in three parts. The first set of analyses focuses on the relationship between inventor characteristics 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 IP protection and inventor characteristics on the payment terms of license contracts.

In each set of analyses a hazard rate model is used to examine multivariate relationships. In Tables 3 through 8 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 not 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. In unreported regressions, I repeat the analysis considering licensing alone as the event of interest. In this analysis observations exit at the time of first license, exclusive or non-exclusive, 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 two different hazard rate models. 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 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 reported in the tables are the natural logarithms of the relative hazard rates associated with the independent variable of interest; statistical tests represent differences of these coefficients from zero. These coefficients are directly comparable across specifications. In general, the Cox and piecewise exponential specifications produce similar results.

Inventor experience, publications, and the hazard rate of sale

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 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 OTT.

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 reflect the fact that, in this sample, prolific inventors are (relatively speaking) also prolific publishers.[10] However, in the present data set, both measures may be highly correlated with both the field of the inventor (which I observe) and with the inventor's age and or tenure (which I do not).

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. Controls are employed for the inventor's field of research,[11] the year of the invention report, and an indicator variable for inventions made following a policy change that formalized invention reporting as a faculty obligation. The results show that a larger number of publications is associated with a significantly higher hazard rate of license or option (see columns 1, 2, 5 through 8). They are robust to the inclusion of a number of controls including the inventor's prior commercialization experience (column 5) and inventor fixed effects (columns 6 and 8). This suggests a stronger academic reputation may be a good predictor at t_0 of whether or not a technology can be licensed.

[10] 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.

[11] 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.

Columns 3 and 4 investigate commercialization experience individually. Both a dummy variable indicating whether the inventor has made five or more disclosures at t_0 and the cumulative number of inventions disclosed prior to t_0 are associated with significantly increased hazard rates. In unreported regressions, the cumulative number of prior licenses is also found to be associated with a significant increase in the hazard rate. These results is consistent with the idea 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 TTO, 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.

Patent status and the hazard rate of sale

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 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 (A) pre-submission: $[t_0, t_{application})$, (B) 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 (A) to (B), 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 (B) to stage (C).[12,13] An increasing hazard rate from stage (A) to (C) would provide empirical support for these theoretical suggestions.

Table 5 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. To avoid confounding the impact of the selection of technologies to patent with the impact of moving through the patent process itself, I limit the analysis to all technologies for which a patent was submitted prior to March 15, 2003. The log rank test provides strong support for the proposition that the hazard rate increases from stage (B) to stage (C), but no support for the proposition that the hazard rate increases from state (A) to (B). These changes are corroborated in unreported regression models that employ additional control variables. Together with the observation that a significant fraction of technologies are licensed prior to seeking any intellectual property protection, these results provide little support for the hypothesis that patents are facilitating information disclosure.[14] On the other hand, these results are quite consistent with the hypothesis that the receipt of a patent is an important event in reducing the uncertainty surrounding the value of the potential license.

---

[12] 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.

[13] 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.

[14] 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. 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.

Table 6 further examines the situations in which patents impact hazard rates of sale and the degree to which inventor reputation and experience may provide collateral for uncertainty about the scope of the property rights. When invention disclosures by all faculty members are included in the regressions, the hazard rate increases significantly (by 70% or more) following the grant of a patent. Inventors' academic standing is associated with an increase in the hazard rate of sale (see column 2). When separately estimating the impact of academic standing pre- and post-patent, however, it becomes clear that the main impact of academic standing occurs in the pre-patent stage (see columns 3 and 4). Once the patent has been received, academic standing does not matter much. Columns 5 and 6 show the impact of patent grants controlling for measures of inventor experience and field; receiving patents continue to improve the hazard rates in these specifications. Columns 7 and 8 split out inventions made by inventors who have found a commercial buyer for a prior technology and those who have not. Interestingly, receiving a patent nearly doubles the hazard rate of sale for inventions coming from inexperienced inventors, whereas the impact of receiving a patent for inventions coming from experienced inventors is minimal. It seems that potential buyers view external signals such as the receipt of a patent and an inventor's prior commercialization success as equally valuable in generating assessments about the potential value of a technology.

Inventor characteristics, patent status, and payment terms of negotiated licenses

To examine whether inventor characteristics and patent status affect prospective licensees' valuations as well as search activity, I analyze the degree to which these factors impact the upfront payments of licensed technologies in 1996 dollars. A number of control variables are employed in this analysis. Category variables control for the technology's primary application, be it diagnostics, research products, therapeutics / vaccines, process technologies, or other product technologies (mainly medical instruments or non-medical products). A second dummy variable is used for technologies with secondary applications in one or more of these categories. Additional controls include the year of the license[15], a dummy variable indicating whether the license was exclusive, a dummy variable indicating whether the license bundled multiple disclosures, and the length of time between the disclosure and the execution of the license. The regressions use a tobit specification is employed to adjust for fact that upfront fees cannot be less than 0.

Table 7 presents the results of this analysis. Exclusive licenses generate significantly higher upfront fees. Category variables representing the potential technology applications are jointly significant, with therapeutic and vaccine applications generating the highest upfront payments. Columns 1 through 4 examine all licenses, while columns 5 and 6 attempts to further restrict sources of unobserved heterogeneity by focusing the analysis on licenses to inventions made by medical and biological scientists. In columns 2 through 6, a measure of the inventor's publication record at time of disclosure is included in the regression. In each case the coefficient on the publication measure is positive and statistically significant; a one-standard deviation increase in this measure increases point estimates of the upfront fee by $5,000 - $10,000 depending on the specification. In column 6, additional controls for inventor experience and the square of inventor experience are included. The more disclosures an inventor has made the higher the upfront fees, although the rate diminishes and peaks near 10 disclosures. Columns 3, 5, and 6 also employ dummy variables for licenses executed after patents had been granted for the technologies in question. The coefficients on these dummy variables are positive and economically significant ($10,000 to $15,000), but not statistically so. It is important to note that the timing of the license is unlikely to be exogenous. Technologies assessed to be of high value are likely to be licensed early on, even if there is significant uncertainty regarding this valuation, all the more so because upfront fees can be traded off against contingent ones. Therefore, the estimated impact of patent status on upfront fees is likely to be biased downward.

15 In unreported regressions year dummies rather than a year trend were employed. The main results are unchanged.

As the discussion above suggests, upfront fees are not the only measures of the value of the technology appropriated by the university. Royalties, equity arrangements, and milestones are payments that are contingent on the performance of the technology that may also provide significant returns to the university. Maintenance fees are payments that are due from the licensee that must be paid on a yearly basis for a licensee to continue to hold the license and are therefore contingent on the licensee's subjective assessment of the patent's value. Table 8 examines each of these payment terms together in a seemingly unrelated regression (SUR). The SUR has the advantage of allowing error terms to be correlated across observations for a given contract; e.g. the structure of the errors calculated allow for a positive shock, perhaps related to unobserved quality, to enter into each of separate regression equations, making some use of the relationship between the contract terms. In columns 1a through 1e, I perform the SUR on the independent variables examined in Table 7. In columns 2a through 2e, I include the relevant additional contact terms, i.e., royalties, equity, milestones, and maintenance fees in the upfront fee equation, upfront fees, equity, milestones, and maintenance fees in the royalty equation, etc. Although the impact of each contract term on the other would be more accurately modeled as a system of simultaneous equations, such estimations require additional exogenous factors to separately identify each equation. These factors are absent in this setting. Thus columns 2a through 2e should be thought of as a first-order, but incomplete, correction for the tradeoffs that exist between payment terms.

The results of the SUR are consistent across both specifications. The coefficients on inventors' publication records are positive and statistically significant in the regressions of upfront fees, positive and weakly significant for equity grants, and statistically insignificant for royalty rates, the use of milestones, and the use of maintenance fees. Similarly, inventors' prior experience is positively correlated only with the upfront payments. While the coefficients on patent grants are positive in the upfront fee equation and negative in the royalty rate equation, they do not reach statistical significance at conventional levels.

6. Discussion

This paper examines the degree to which inventor publications, experience with the commercialization process, and intellectual property interact to facilitate the sale to industry of university generated technologies, which are typically made available for license at very early stages. In particular, the following empirical regularities are observed.

- Measures of prior commercialization experience—both prior disclosures and prior licenses or options—are positively correlated with the hazard rate of sale.
- Measures of the inventor's academic publication record—both on an absolute basis and relative to the cohort of other Harvard University scientist-inventors in their particular field—are positively correlated with the hazard rate of sale. Controlling for prior experience, field, and inventor fixed effects, inventors' publication records remain positively and significantly correlated with the hazard rate of sale.
- The hazard rate of sale increases significantly following the award of a patent for the licensed technology.
- Prior to the receipt of the patent, measures of the inventor's publication records are positively and statistically related to the hazard rate of sale. After the receipt of the patent, stronger publication records are not associated with higher hazard rates of sale.
- For inventions made by faculty who have not yet had commercial success (i.e., disclosed an invention that was subsequently licensed), the hazard rate of sale increases dramatically after the receipt of a patent. For inventions made by faculty who have had prior commercial success, receiving a patent is not associated with a higher hazard rate of sale.
- When technologies are licensed, measures of the inventor's academic publication record are positively and statistically correlated with upfront payments negotiated by the university for the licensed technology, controlling for a number of other factors. Measures of the inventor's

academic publication record are weakly correlated with the use of equity as a compensation for the technology but are *not* correlated with other contingent types of compensation such as royalties or milestones.

- Technologies licensed post-patent do not receive statistically greater non-contingent fees than technologies licensed prior to the receipt of a patent.

The literature highlights two categories of conditions that must be met in order for trade in intellectual property to occur. First, the selling party must be able to locate a buying party for whom the technology has some potential value and convince them to investigate it. Second, the buying party must assess that the technology has an expected value (adjusting, perhaps, for risk aversion) that exceeds the transaction costs of licensing the technology, its patent costs, fees required to license it, and other opportunity costs. While industry may be more likely to pay attention to inventions coming out of prolific (famous) inventors' labs, the evidence of the interaction between patents and publications and on the impact of inventor academic status on payments suggests that inventors' academic profiles may play a particularly important role in generating positive expectations of the value of new technologies (or reducing the uncertainty surrounding these valuations). Moreover, the importance of applying for and receiving a patent to the marketing of early-stage university technologies seems not to operate through protecting the university from expropriation, but rather seems to be a strategy that is likely to reduce uncertainty about the value of the technology. This is especially important when the technology is developed by an inventor who is relatively unknown or who has few prior innovative successes to point to. It seems quite plausible that in the absence of strong signals of a technology's worth, i.e. conditions of extreme uncertainty, that potential buyers will use objective signals of the inventor's quality as an input into the calculation of a prospective technology's potential value. This result is not dissimilar to the one found by Podolny (1994).

While these factors are undoubtedly important, this paper abstracts away from a number of additional considerations that may be correlated with inventors' academic output but which may explain the correlation between academic output and successful commercialization of disclosed technologies. First is the possibility that past corporate sponsored research may generate current publications and licensable technologies for a given inventor. Second is the possibility that prolific academics may be able to raise funds to form start-ups that license and commercialize technologies developed in their own labs. Third is the possibility that published research output is a complementary good for many inventions.; for example publications may lay the groundwork for experimenting with the new technology or extending it. In these cases publications are proxies for something other than invention quality and/or lower risk. Assessing the importance of these alternative explanations is left for future investigation.

References

Aghion, Philippe, and Jean Tirole. "Management of Innovation." *Quarterly Journal of Economics* 109, no. 4 (1994): 1185-209.

Agrawal, Ajay, and Rebecca M. Henderson. "Putting Patents in Context: Exploring Knowledge Transfer from MIT," *Management Science* 48, no. 1 (2002): 44-60.

Anand, Bharat N., and Tarun Khanna. "The Structure of Licensing Contracts." *Journal of Industrial Economics* 48, no. 1 (2000): 103-35.

Anton, James J., and Dennis A. Yao. "Expropriation and Inventions: Appropriable Rents in the Absence of Property Rights." *American Economic Review* 84, no. 1 (1994): 190-209.

Anton, James J., and Dennis A. Yao. "The Sale of Ideas: Strategic Disclosure, Property Rights, and Incomplete Contracts." *Review of Economic Studies* 69, no. 3 (2002): 513-31.

Akerlof, George A. "The Market for 'Lemons': Quality Uncertainty and Market Mechanisms." *Quarterly Journal of Economics* 84, no. 3 (1970): 488-500.

Azoulay, Pierre, Waverly Ding, and Toby Stuart. "The Impact of Academic Patenting on (Public) Research Output," mimeo, 2004.

Association of University Technology Managers. Annual Report 2002.

Arora, Ashish, Andrea Fosfuri, and Alfonso Gambardella. Markets for Technology: The Economics of Innovation and Corporate Strategy. Cambridge, MA: MIT Press, 2001.

Besen, Stanley M, and Leo J. Raskind. "An Introduction to the Law and Economics of Intellectual Property." *Journal of Economic Perspectives* 5, no. 1 (1991): 3-27.

Binmore, K. "Perfect Equilibria in Bargaining Models" pp. 77-105 in "The Economics of Bargaining" Binmore, K. and P. Dasgupta (eds.). Oxford: Blackwell, 1987.

Branstetter, Lee G, Raymond Fisman, and C. Fritz Foley. "Do Stronger Intellectual Property Rights Increase International Technology Transfer? Evidence from U.S. Firm-Level Panel Data." Unpublished Manuscript, Columbia University and University of Michigan, 2003.

Chukumba, Celestine O. and Richard Jensen. "University Invention, Entrepreneurship, and Start-Ups." mimeo, 2005.

Cox, D R. "Regression Models and Life-Tables." *Journal of the Royal Statistical Society, Series B (Methodological)* 34, no. 2 (1972): 187-220.

David, Paul A. "Clio and the Economics of QWERTY." *American Economic Review* 75, no. 2 (1985): 332-37.

Diamond, Peter A. "Consumer Differences and Prices in a Search Model." *Econometrica* 102, no. 2 (1987): 429-36.

Darby, Michael R., Qiao Liu, and Lynne G. Zucker. "Stakes and Stars: The Effect of Intellectual Human Capital on the Level and Variability of High-Tech Firm's Market Values." NBER Working Paper No. 7201, 1999.

Elfenbein, Daniel W. "The Rise and Fall of On-Line Intellectual Property Exchanges" Harvard University Working Paper, 2003.

Elfenbein, Daniel W. "Empirical Studies of Technology and Alliance Contracts." Unpublished dissertation. Chapter 4. Harvard University, 2004.

Gans, Joshua S., David H. Hsu and Scott Stern. “The Impact of Uncertain IP Rights on the Market for Ideas: Evidence from Patent Grant Delays.” Mimeo, 2003.

Gallini, Nancy T. and Brian D. Wright. “Technology Transfer under Asymmetric Information.” *RAND Journal of Economics* 21, no. 1 (1990): 147-60.

Gallini, Nancy T. “The Economics of Patents: Lessons from Recent U.S. Patent Reform.” *Journal of Economic Perpectives* 16, no. 2 (2002): 131-155.

Greif, Avner. "Contract Enforceability and Economic Institutions in Early Trade: The Maghribi Traders' Coalition." *American Economic Review* 83, no. 3 (1993): 524-49.

Farrell, Joseph P., and Garth Saloner. "Installed Base and Compatibility: Innovation, Product Preannouncement, and Predation." *American Economic Review* 76, no. 5 (1986): 940-55.

Jensen, Richard A., and Marie C. Thursby. "Proofs and Prototypes for Sale: The Licensing of University Inventions." *American Economic Review* 91, no. 1 (2001): 240-59.

Jensen, Richard A., Jerry G. Thursby, and Marie C. Thursby. “Disclosure and Licensing of University Inventions: ‘The Best We Can Do with the S**t We Get to Work with.” *International Journal of Industrial Organization* 21, no. 9 (2003), 1271-1300.

Katz, Michael L., and Carl Shapiro. "Technology Adoption in the Presence of Network Externalities." *Journal of Political Economy* 94, no. 4 (1986): 822-41.

Liebowitz, Stan J., and Stephen E. Margolis. "The Fable of the Keys." *Journal of Law and Economics* 33, no. 1 (1990): 1-25.

Lowe, Robert. "Entrepreneurship, Invention, and Innovation: The Commercialization of University Research by Inventor-Founded Firms." Unpublished Dissertation. University of California, Berkeley, 2002.

Markiewicz, Kira R. and Alberto DiMinini. “Commercializing the Laboratory: The Relationship Between Patenting and Publishing.” Unpublished Manuscript, University of California, Berkeley, 2004.

Mas-Colell, Andreu, Michael D. Whinston, and Jerry R. Green. *Microeconomic Theory*. New York: Oxford University Press, 1995.

Merges, Robert P., Mark A Lemley, and Peter S Menell. *Intellectual Property in the New Technological Age*. New York: Aspen Law and Business, 1997.

Mowery, David C., Richard R. Nelson, Bhaven. Sampat and Arvids A. Ziedonis. *Ivory Tower and Industrial Innovation.* Palo Alto, CA: Stanford University Press, 2004.

Mowery, David C., and Arvids A. Ziedonis. "The Geographic Reach of Market and Non-Market Channels of Technology Transfer: Comparing Citations and Licenses of University Patents.". NBER Working Paper 8568, 2001.

Office of Trademark and Technology Licensing, Harvard University. Annual Report 2002.

Owen-Smith, Jason and Walter W. Powell. “The Expanding Role of University Patenting in Life Sciences: Assessing the Role of University Patenting in the Life Science.” *Research Policy* 32 (2003): 1695-1711.

Pakes, Ariel S. "Patents as Options: Some Estimates of the Value of Holding European Patent Stocks." *Econometrica* 54, no. 4 (1986): 755-84.

Podolny, Joel M. “Market Uncertainty and the Social Character of Economic Exchange.” *Administrative Science Quarterly* 39 (1994): 458-483.

Rogers, Everett M. *Diffusion of Innovations*. 5th ed. New York: The Free Press, 1995.

Rubinstein, Ariel. "Perfect Equilibrium in a Bargaining Model." *Econometrica* 50 (1982): 207-11.

Siegel, Donald S., David Waldman and Albert Link. "Assessing the Impact of Organizational Practices on the Relative Productivity of University Technology Transfer Offices: An Exploratory Study." *Research Policy* 32 (2003): 27-48.

Sine, Wesley David, Scott A Shane, and Dante DiGregorio. "The Halo Effect and Technology Licensing: The Influence of Institutional Prestige on the Licensing of University Inventions." *Management Science* 49, no. 4 (2003): 478-96.

Stephan, Paula E., Shiferaw Gurmu, A.J. Sumell, and Grant Black. "Who's Patenting in the University? Evidence from the Survey of Doctorate Recipients." Mimeo, 2004.

Spulber, Daniel F. *Market Microstructure: Intermediaries and the Theory of the Firm*. New York: Cambridge University Press, 1999.

Thusby, Jerry G. and Thursby, Marie C. "Are Faculty Critical? Their Role in University-Industry Licensing." NBER Working Paper 9991, 2003.

Thursby, Jerry G., Marie C. Thursby and Swastika Mukherjee. "Are There Real Effects of Licensing on Academic Research." Mimeo, 2005.

Zucker, Lynne G., Michael R. Darby and Jeff Armstrong. "Geographically Localized Knowledge: Spillovers or Markets?" *Economic Inquiry* 36:1 (1998): 65-86.

Zeckhauser, Richard. "The Challenge of Contracting for Technological Information." *Proceedings of the National Academy of Science* 93 (1996): 12743-48.

Figure 1. Timing of Invention, patenting, and licensing

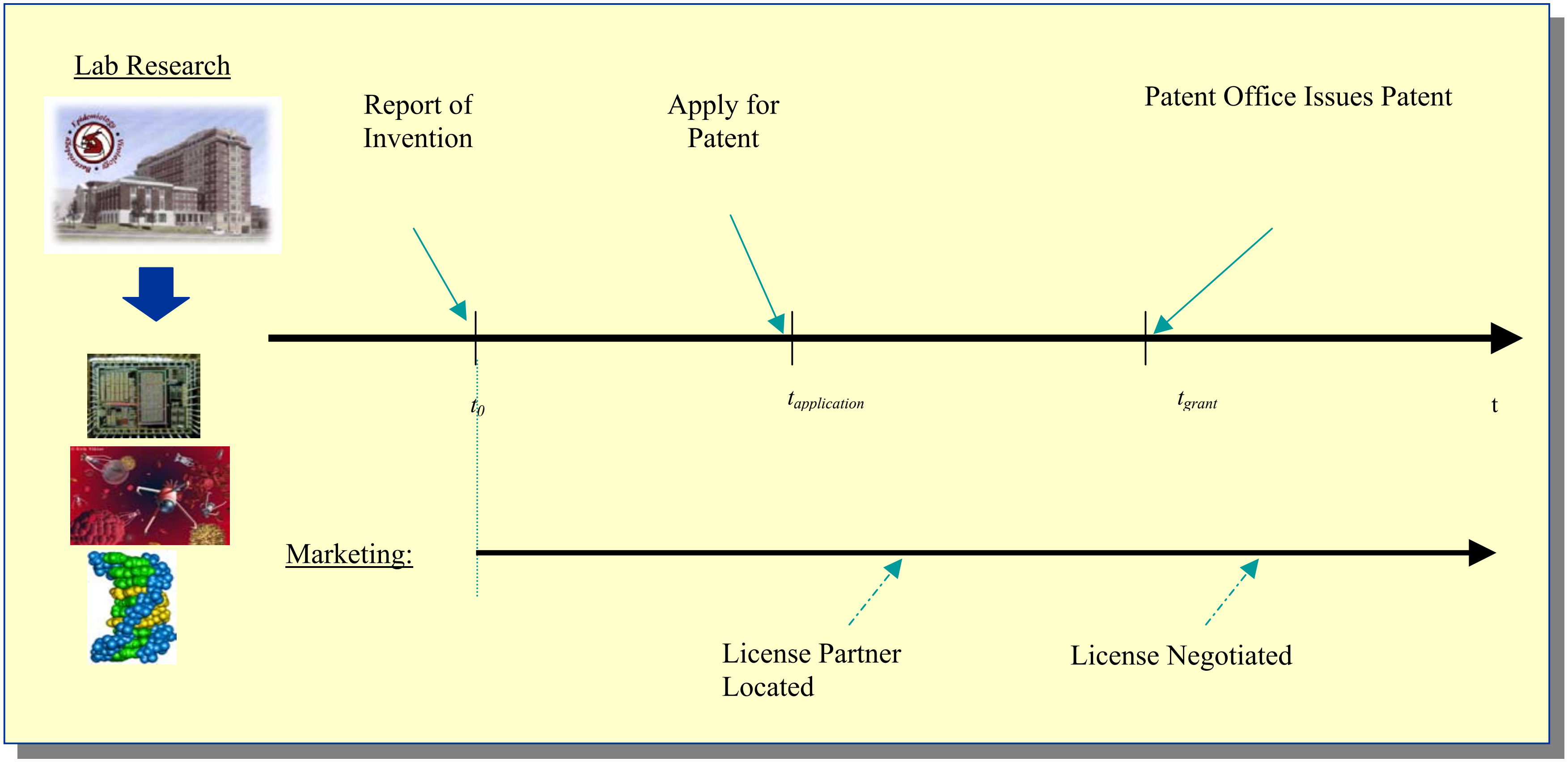
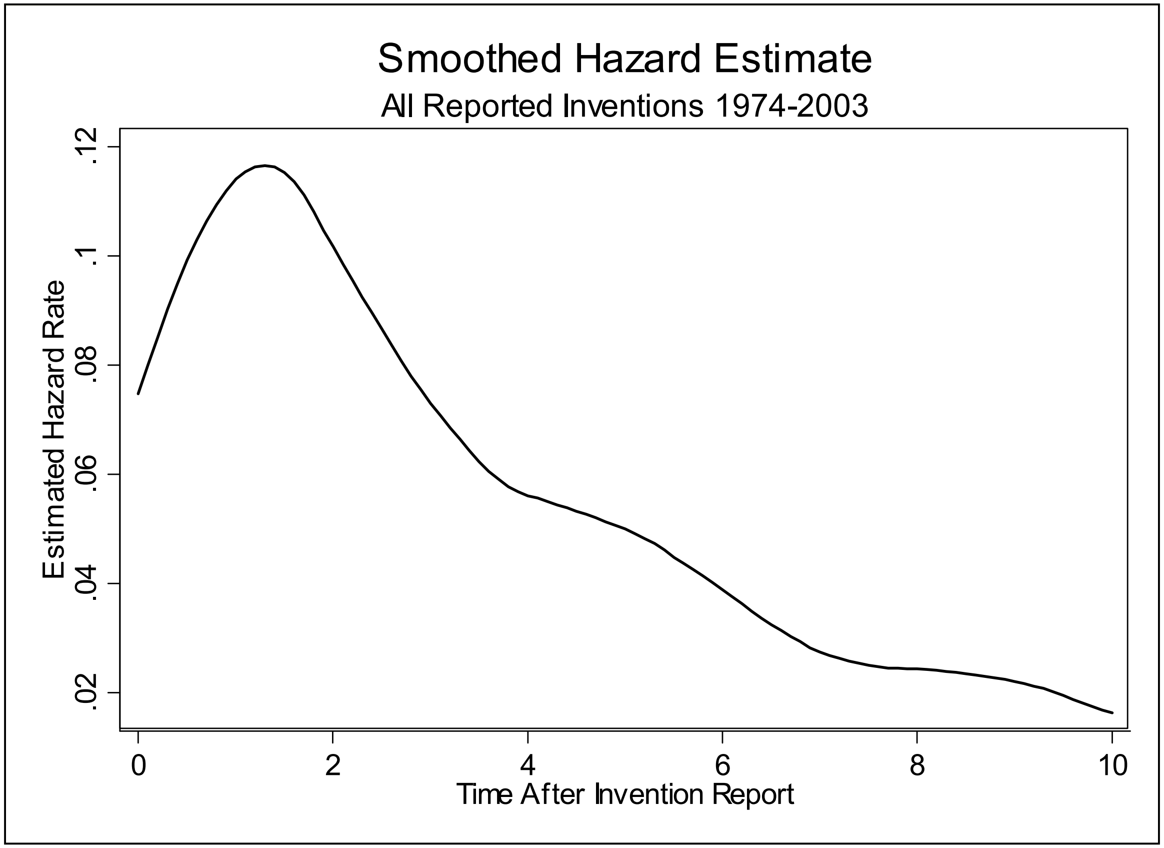


Figure 2. Hazard rate of first sale following invention disclosure.



Note: Estimates based on submitted invention disclosures.

Table 1. 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%*

Table 2. 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. 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 D. Measures of Academic Credentials Adjusting for Year and Cohort					
	Obs	*Mean*	*Std. Dev*	*Min*	*Max*
Residual from regression of journal publications weighted by journal impact factor on year polynomial at t_0	1424	263.18	705.89	-703.60	3840.84
Regression from Journal Publications weighted by journal impact factor and number of authors on year polynomial at t_0	1424	76.81	203.41	-225.23	1085.93
Panel E. 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
Panel F. Payment Structure of Licensee					
	Obs	*Mean*	*Std. Dev.*	*Min*	*Max*
Upfront Payment (1996 dollars)	340	26,388	64, 573	0	confidential
Royalty Rate	325	3.13%	3.22%	0	confidential
Equity	340	.129	.336	0	1
Milestones	340	.263	.441	0	1
Maintenance Fees	340	.356	.479	0	1

[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".

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

Table 4. 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. Publication residuals are obtained from a regression of inventor *i*'s cumulative (weighted) publications at time *t* on a fourth order polynomial of time within his or her field of research. 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	Piecewise exponential	Piecewise exponential
Column:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Academic Standing:								
Publications at t_0 weighted by journal impact factor[a]	***.213 [.065]							
Publication residual at t_0[a]		***.214 [.066]			**.148 [.073]	**.374 [.157]	***.216 [.066]	**.369 [.158]
Commercialization Experience:								
Five or more prior disclosures at t_0			***.355 [.117]		**.282 [.130]			
Cumulative Disclosures at t_0				***.019 [.006]				
Field								
Chemistry	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
Medical / Biological	*–.232 [.131]	**–.264 [.128]	–.188 [.128]	***–.11 [.140]	–.200 [.132]	**2.490 [1.07]	**–.262 [.128]	13.5 [346]
Other	***–.78 [.281]	***–.84 [.277]	***–.72 [.274]	**–.676 [.278]	***–.72 [.283]	**2.327 [1.07]	***–.83 [.277]	13.4 [346]
Year of Invention Report	*.017 [.010]	**.021 [.098]	.013 [.010]	.015 [.098]	.015 [.010]	.012 [.012]	***.025 [.010]	.017 [.012]
Post-1998	–.185 [.156]	–.177 [.157]	–.100 [.155]	–.179 [.157]	–.163 [.157]	–.111 [.169]	–.203 [.156]	–.132 [.167]
Inventor Fixed Effects[b]	N	N	N	N	N	Y	N	Y
Observations	1359	1358	1383	1383	1358	1358	1356	1356
Log Likelihood	–2657.7	–2657.4	–2722.4	–2721.6	–2655.0	–2576.7	–1408.1	–1324.9
LR χ^2 statistic	***34.2	***34.1	***30.6	***32.3	***38.7	***195.4	***551.8	***718.2

[a]Coefficients and standard errors in this row are multiplied by 1000.
[b]Fixed effects included for all inventors with five or more disclosures.
*** = significant at $p \leq 0.01$; ** = significant at $p \leq 0.05$; * = significant at $p \leq 0.1$ (two sided test)

Table 5. 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	
Timing relative to Patent Milestones:	Events Observed	Events Expected
Prior to first submission	93	82.74
After first submission before first grant	220	245.67
After first grant	42	26.59
All	355	355.00
$\chi^2_{(2)}$		***16.5

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

Table 6. Hazard rate model incorporating differences in the status of IP protection. The sample consists of 692 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 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	Cox	Cox
Subset	All inventors	All inventors	All inventors	All inventors	All inventors	All inventors	Experienced Inventors	Inexperienced Inventors
Column:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Patent Status:								
First patent granted	***.741 [.210]	***.748 [.211]	***.775 [.218]	***.755 [.220]	***.737 [.212]	***.704 [.210]	.352 [.320]	***.996 [.284]
Academic Standing								
Publication Residual at t_0		*.132 [.069]	**.142 [.071]	.118 [.073]				
Publication Residual at t_0 X Pre-Patent								
Publication Residual at t_0 X Post-Patent			.038 [.233]	.046 [.237]				
Commercialization Experience:								
More than Five Disclosures at t_0					**.304 [.125]			
One or more Deals at t_0						***.515 [.121]		
Other								
Year	.004 [.010]	.003 [.010]	.003 [.010]	.001 [.010]	–.005 [.010]	–.011 [.011]	**-.048 [.017]	.017 [.014]
New Regime	–.048 [.170]	–.057 [.170]	–.059 [.170]	–.070 [.170]	–.034 [.170]	–.028 [.171]	**.420 [.215]	**-.653 [.319]
Field Dummies	N	N	N	Y	Y	Y	Y	Y
Observations	1407 (692 subjects)	1407 (692 subjects)	1407 (692 subjects)	1407 (692 subjects)	1407 (692 subjects)	1407 (692 subjects)	677 (359 subjects)	730 (333 subjects)
Log Likelihood	–2026.7	–2025.0	–2024.8	–2022.6	–2020.9	–2014.7	1045.2	-743.1
LR χ^2 statistic	***11.8	***15.3	***15.5	***20.2	***23.4	***35.9	**12.3	***16.1

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

Table 7. Regression of Upfront Fees on Technology and Inventor Characteristics for Licensed Patentable Inventions. The sample consists of 307 inventions licensed by Harvard University between 1974 and March 2003 for which patent applications were submitted. The dependent variable is the total amount of non-contingent, upfront payments due within the first year of the license agreement in thousands of 1996 dollars. Columns 1 though six present the results of a tobit estimation, using 0 as the censoring level of the dependent variable. Standard errors are in brackets.

Specification:	Tobit	Tobit	Tobit	Tobit	Tobit	Tobit
Subset:	All Licenses	All Licences	All Licenses	Medical / Biological	Medical / Biological	Medical / Biological
Column:	(1)	(2)	(3)	(4)	(5)	(6)
Inventor Characteristics:						
Publication Residual at t_0		**.028 [.014]	*.028 [.014]	**.057 [.024]	**.057 [.024]	**.061 [.028]
Prior Invention Discl. at t_0				.		**8.25 [4.14]
Prior Invention Discl. at t_0^2						**–.481 [.201]
Technology Characteristics:						
Diagnostic	omitted	omitted	omitted	omitted	omitted	omitted
Research Product	0.12 [14.7]	2.39 [14.8]	3.20 [14.2]	13.35 [21.2]	15.41 [21.3]	18.27 [21.1]
Therapeutic / Vaccine	25.21 [15.9]	*28.8 [16.0]	*29.29 [16.0]	28.22 [22.4]	29.43 [22.4]	33.42 [22.1]
Process	–16.39 [15.9]	–20.26 [15.9]	–20.56 [15.9]	–45.04 [38.1]	–46.87 [38.1]	–38.38 [37.5]
Other Product	–27.99 [17.3]	–26.86 [17.3]	–27.14 [17.2]	–39.44 [30.4]	–37.86 [30.4]	–34.12 [30.2]
Multiple Applications	5.86 [12.8]	6.29 [12.8]	6.00 [12.8]	4.18 [16.6]	3.90 [16.6]	3.90 [16.6]
License Characteristics						
Year	.768 [.846]	.437 [.858]	.556 [.867]	.824 [1.32]	.940 [1.32]	.911 [1.40]
Exclusive	**19.30 [8.44]	**16.44 [8.5]	**17.00[8.53]	**29.38 [14.0]	**30.91 [14.0]	**29.81 [13.9]
Bundle of Disclosures	5.08 [10.8]	8.19 [10.8]	8.49 [10.8]	3.08 [17.1]	3.36 [17.1]	2.97 [16.8]
$t_{agreement} - t_0$	–.003 [.003]	–.003 [.003]	–.006 [.005]	–.004 [.005]	–.008 [.007]	–.007 [.007]
After patent grant			10.83 [12.1]		15.04 [18.7]	14.17 [18.7]
Observations	307	307	307	192	192	192
Log Likelihood	–1540.4	–1538.5	–1538.1	–966.5	–966.2	–963.2
LR χ^2 statistic	***30.35	***34.2	***35.0	***24.9	***25.5	***31.6

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

Table 8. Seemingly unrelated regression of contract structure payment terms and inventor characteristics for licensed medical & biological inventions. The sample consists of 184 inventions licensed by Harvard University engaged in medical or biological research between 1974 and March 2003 for which patent applications were submitted and full contract payment terms were available. The dependent variables are (a) the total amount of non-contingent, upfront payments due within the first year of the license agreement in thousands of 1996 dollars, (b) royalty rates in percent of sales, (c) a dummy variable indicating whether equity was part of the university's compensation, (d) a dummy variable indicating that milestones were specified in the contract, and (e) a dummy variable indicating that maintenance fees were specified. Significance levels calculated using small sample test statistics. Standard errors in brackets

Dependent Variable	Upfront	Royalty	Equity	Milestone	Main. Fee	Upfront	Royalty	Equity	Milestone	Main. Fee
Column:	(1a)	(1b)	(1c)	(1d)	(1e)	(2a)	(2b)	(2c)	(2d)	(2e)
Inventor Characteristics:										
Publication Residual at t_0	**.057	.001	*.001	.013	-.004	**.056	.000	**.013	.003	-.015
	[.026]	[.001]]	[.001]	[.013]	[.015]	[.026]	[.001]	[.065]	[.010]	[.014]
Prior Invention	**7.86	.235	-1.08	-3.07	*-4.13	*6.43	.147	-.603	-2.89	-3.46
Disclosures at t_0	[3.80]	[.177]	[.976]	[1.93]	[2.14]	[3.85]	[.181]	[.956]	[1.95]	[2.11]
Prior Invention	**-.448	-.014	.045	.111	*.192	*-.365	-.010	-.046	.105	.161
Disclosures at t_0^2	[.184]	[.008]	[.047]	[.090]	[.104]	[.187]	[.088]	[.047]	[.095]	[.102]
License Characteristics										
Year	-.338	.090	3.58	***2.05	***2.89	-.608	.101	*-.555	***2.23	***2.89
	[1.25]	[.058]	[3.22]	[.640]	[.704]	[1.34]	[.062]	[.329]	[.707]	[.704]
Exclusive	**29.47	.202	5.06	***26.3	*12.60	**30.71	.305	1.18	***23.50	*12.60
	[12.6]	[.586]	[3.23]	[6.42]	[7.07]	[13.2]	[.622]	[3.28]	[6.50]	[7.07]
Bundle of Disclosures	6.25	1.96	**8.86	11.8	.400	3.30	1.97	**11.72	**16.85	11.51
	[15.6]	[7.27]	[4.01]	[7.90]	[8.76]	[16.2]	[7.38]	[3.91]	[8.09]	[8.84]
$t_{agreement} - t_0$	-.006	-.000	*.003	-.000	.003	-.006	-.001	**-.004	.002	*.005
	[.006]	[.001]	[.002]	[.000]	[.003]	[.006]	[.002]	[.002]	[.003]	[.003]
After patent grant	19.2	-.895	-2.64	-13.6	-3.89	22.8	-1.168	.570	-13.28	-2.28
	[16.7]	[.779]	[4.29]	[8.52]	[9.39]	[16.8]	[.782]	[4.14]	[8.46]	[9.24]
Additional Controls										
Technology Dummies			Yes					Yes		
Other Contract Terms			No					Yes		
Observations	184	184	184	184	184	184	184	184	184	184
Adj. R2	.139	.149	.118	.435	.187	.142	.151	.135	.436	.197
F-Stat	***2.28	***2.48	**1.89	***10.88	***3.25	***2.41	***2.50	***5.82	***10.02	***5.38
Breusch-Pagan Test p-value			*p = .026*					*p=.023*		

[a]Coefficients and standard errors in this row are multiplied by 1000.
*** = significant at $p \leq 0.01$; ** = significant at $p \leq 0.905$; * = significant at $p \leq 0.1$ (two sided test)