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Essays on University Technology Management

by

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Professor Brian D. Wright, Chair

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Abstract

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In an era where ties between academia and industry have received considerable attention both in the social sciences literature and at the policy level, research is warranted to explore the relationship between these two institutions. In particular, the mechanisms where universities and corporations cooperate in terms of research needs to be examined given the increasingly important role of universities on innovation. By exploring this relationship, we can also understand the implication for all actors directly or indirectly affected by university research. The objective of this dissertation is to shed light on the important relationship between academia and industry under the lens of innovation and explore the ramifications for all the groups involved.

The first chapter tries to assess the role of exclusive licensing in diffusion of academic patented inventions. We employ a unique dataset of invention disclosures, and their associated patenting and licensing activity, by the University of California Office of Technology Transfer The metric for follow-on research employed is the patent citations the academic patent receives. This projects tests two long standing hypotheses/beliefs that are at the core of the discussion regarding the management of academic technologies. Namely, whether exclusive licensing motivates licensees to undertake research on the academic patent and whether exclusive licensing discourages non-licensees to use the knowledge embedded in the academic patent. Results show that exclusive licensing increases licensee citations regardless of the technology field; in addition start-up licensees conduct more follow-on research than established firms licensees implying the involvement of the primary inventor in the start-up. Finally licensees acquire patents mainly in the same narrow technology field as the academic patent they build on. Moreover, we find that exclusive licensing increases non-licensee citations and therefore we conclude that this type of technology transfer functions as a signal to other firms rather as a discouraging factor. This signal may be of the quality of the patent and/or information that a competitor is working on a new research path and therefore other firms should also pursue this research agenda; we provide evidence to support the signaling explanation. We find that the increase of non-licensee citations is more prevalent for computers, communications, electronics and engineering related patents while we also find that non-licensees “invent around” the academic patent or use it in entirely different technology fields.

In the second chapter, we try to explore the strategic behavior by the licensee to delay innovation output. A licensee may have an incentive to delay innovation output building on the invention licensed by the university to avoid paying royalty fees to the licensor (i.e. to the academic institution). By employing access to the same dataset as in the first chapter, we explore whether licensee citations increase around expiration of the licensed patent. Moreover, we test

recent theoretical findings on when it is more likely for licensees to delay innovation. In particular we examine whether low profitability inventions and broad scope patents are more likely to be associated with delays. The challenge is to approximate patent profitability and scope with patent characteristics. We find that patents of low quality (long prosecution time) and patent of broad scope (large number of International Patent Classifications) to be associated with significantly greater delays of licensee citations.

In the last chapter, we descriptively examine whether the type of research sponsor is associated with the rate of invention disclosure, the patenting rate, the likelihood and type of license. In a period where corporations sign multi-million research deals with universities, scholars have raised concerns with regards to the effect of business funding on the research focus and the overall mission of universities. Having access to this unique dataset, we offer the first empirical insight on the relationship between the type of the research sponsor and important outcomes of academic technology management such as patenting and licensing. We find that any differences associated with corporate funded and government funded inventions to be attributed to the cases where the research sponsor becomes the licensee in the case of business funded projects.

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Chapter I

The Role of Exclusive Licensing on Diffusion of Academic Patented Inventions

Introduction

The relations between academia and industry regarding research activity have received considerable attention over the past decades. Even though university research has traditionally played a key role in innovation activity, discussions have focused on the ongoing transformation of university technology management that has been taking place the past three decades. This transformation has resulted to a dramatic increase in patenting and licensing activity by these institutions, which is often attributed to the Bayh-Dole Act of 1980 that facilitated the way US universities can retain ownership of federally funded inventions.

The rapid transformation of technology management can be translated into the number of invention disclosures, patents and license activity. Total invention disclosures to University Offices of Technology Transfer (OTT) by academic faculty grew from 10,987 in 1998 to 20,115 in 2008 (AUTM 2008). While US universities accounted for approximately 0.75% of US patents granted to US entities in 1980, in 2005 they accounted for approximately 5% of this set of patents[1]. In addition, based on the AUTM 2005 report the license income of US universities rose from $218 million in the fiscal year of 1991 to $1.003 billion in the fiscal year of 2004 (real values of 1991).

Given this increase in patenting and licensing, concerns have been raised about the effects regarding follow-on research of university inventions. Licensing, widely used as a tool for channeling university technology from academia to the industry, can be potentially misused and defeat the purpose it was meant to serve. Concerns, raised by scholars, include narrow licensing of widely applicable inventions or narrowly licensing inventions to firms that intentionally or unintentionally do not develop the academic invention. On the other hand, the main argument for exclusively licensing inventions is to provide sufficient incentives to the licensee to invest on further research and development for the academic invention. Even though this discussion is at the core of university technology management, there has not been any empirical analysis that examines the effect of exclusive licensing on diffusion of academic inventions to licensees and non-licensees.

The objective of this paper is to examine the effect of exclusive licensing on follow-on research and patenting of academic patented inventions. In particular, two hypotheses are tested; the first hypothesis relates to the effect of exclusive licensing on follow-on research by licensees. The second hypothesis tests whether exclusive licensing affects follow-on patenting by non-licensees. Moreover, we examine whether these effects differ by the type of technology (Chemical, Drugs and Medical inventions versus technologies related to Computers, Communications, Electrical, Electronic and Mechanical advancements).

Given that the Bayh-Dole Act has been in the center of debate regarding academic-industry research collaboration, an empirical evaluation of an important technology transfer tool such as exclusive licensing is warranted. The contribution is relevant beyond US borders since a number of countries are considering or have already adopted similar legislations (Mowery and Sampat 2005). Moreover, exclusive licensing has been under heavy scrutiny as to whether and how it affects incentives to the licensee to pursue further research on the academic invention. This skepticism coupled with the prediction that non-licensees will be discouraged from conducting research on the academic invention (Nelson 2003), can result on strong policy recommendations such as mandatory nonexclusive licensing;

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[1] https://sites.google.com/site/patentdataproject/Home

however, aside from a handful of case studies discussed in the Literature Review Section, there is no rigorous empirical analysis addressing these concerns.

The focus of this project is solely on patented inventions. The metric employed as a proxy for licensee follow-on research is the number of licensee patents that cite the academic patented inventions of interest (i.e. forward citations). The possible limitations of using such a metric are discussed below. A standard Difference-in-Differences approach is employed. The group of interest (i.e. the "treated group") is patents that are exclusively licensed after grant while we employ, as comparison groups, patents that have been exclusively licensed prior to grant and unlicensed patents.

We should note that in the case of licensees, we try to examine to what extent licensing caused them to conduct follow-on research on the licensed patented invention. In the case of non-licensees we don't make the assumption that non-licensee citations reflect follow-on research necessarily but rather reflect the fact that non-licensees are doing research utilizing or influenced by, directly or indirectly, the academic patented invention.

One of the main reasons for the neglect of the interaction between licensing and diffusion (an exception is Mowery and Ziedonis (2001)) is the lack of comprehensive data. In this project we were granted access to a unique dataset of patents and their associated licensing activity that stem from University of California (UC) invention disclosures. Access to the dataset was provided by the UC-OTT led by Executive Director William Tucker; this dataset is augmented with patent information from NBER (Hall, Jaffe and Trajtenberg 2001) and Thomson.

Results show that licensee citations increase after a patent is licensed exclusively implying that utilization of the academic patented invention by the licensee is positively influenced by the licensing agreement. This result supports the rationale behind the Bayh-Dole Act that exclusive licensing can encourage firms to do further work developing academic inventions (Eisenberg 1996). We find this result to be more prevalent in the case of Chemical, Drugs and Medical related inventions, and in the cases where the licensee is a start-up, implying the indirect or direct involvement of the original inventor in the development of the initial technology. We also show that licensees patent primarily on the same narrow technology field as the licensed patent.

The interpretation of the above results relies heavily on the assumption that patent citations reflect follow-on research. We discuss findings that support this assumption; however, to the extent that this assumption is not realistic we offer alternative interpretations of the results.

In terms of non-licensees, we find no evidence to support the hypothesis that exclusive licensing discourages non-licensees from patenting and citing the licensed patent. On the contrary, findings show that non-licensee citations increase primarily in the fields of Computers, Communications, Electrical, Electronic and Mechanicals. The reason we propose is that (as many scholars have argued), patents tend to be less powerful mechanisms of competition in these fields than in the case of Chemical, Drugs and Medical related inventions. Moreover, we show that the growth of non-licensee citations is more pronounced in the cases where the licensee is an established firm. This observation offers an alternative/complementary explanation for the difference in non-licensee response, since there is a larger portion of start-up licensees in the case of Chemical, Drugs and Medical related inventions. Finally we find that in the case of these latter inventions, non-licensees tend to patent in different classes while in the case of the Computers, Communications, Electrical , Electronic and Mechanicals technologies, non-licensees produce innovation output that is not in the same broad technology field as the licensed patent.

We conclude that it is the case that exclusive licensing overall functions as a signal of quality (as proposed by Sampat and Ziedonis (2010)) or opportunity for a new research area (Austin 2000) for non-licensees rather than discouraging research on the patent.

The next section provides a review of the literature by offering a background on the Bayh-Dole Act and the management of academic inventions. A discussion on the concerns of the academic technology management for diffusion follows leading to the questions posed in this paper. The following section frames the hypotheses and outlines the econometric specifications employed to test these hypotheses. The next section describes the data and the idiosyncrasies of the dataset and is followed by the results section. Finally, the paper concludes.

Literature Review

Since the passage of the Bayh-Dole Act in 1980 there has been a dramatic increase in university patenting and licensing as a means of transferring university technology to the marketplace. The Bayh-Dole Act set a unified framework where universities could retain ownership of federally funded inventions and therefore able to file for patents for these inventions. Moreover, it encouraged them to use exclusive licensing, if needed, as a tool to transfer the technology from academia to the marketplace (Eisenberg 1996). Given that federal support of academic R&D has accounted for approximately 60-70% of total academic support for R&D since 1970 (National Science Board 2010), it is clear that such legislation might have a considerable impact on the way the management of academic inventions takes place. The rationale behind the Bayh-Dole Act was that most federally funded academic inventions could not pass to the marketplace since the government was retaining ownership. Thus, corporations and other types of potential licensees would incur significant transaction costs to be able to license such inventions[2]. Moreover, in the absence of an exclusive license, firms would not have sufficient incentives to pursue investments required to develop the inventions.

It should be noted that the reasons for the increase of university inventions, patenting and technology transfer by US universities are still debated by many scholars who have argued that the Bayh-Dole Act in 1980 was the driving reason behind this growth, while other scholars argue that Bayh-Dole Act was only one factor, along with other institutional changes during the late 70’s and early 80’s and remarkable developments in biotechnology during the same period (Mowery et al 2001). For instance, in Diamond vs. Chakrabarty (1980)[3], the US Supreme Court ruled that a genetically modified bacterium that was capable of breaking down crude oil could be patented, paving the way for inventors to patent discoveries of any novel living organisms. In addition, in 1980 the patent for technology of recombinant DNA by Cohen and Boyer was issued after a lot of debate between the Congress and the National Institute of Health; note that the initial application was filed in November of 1974. Based on these two decisions, the USPTO decided on two other cases that shaped the nature of agricultural

[2] A commonly cited study during that time was the Harbridge House, Government Patent Policy Study for the FCST Committee on Government Patent Policy in 1968. This study found that out of 28,000-30,000 government owned patents, only a small fraction had been successfully transferred to the marketplace. Even though most of these patents were inventions stemming from contracts with private firms which have relinquished their rights over the embedded invention in the first place, this study was commonly used as an argument in favor of transferring the ownership to the research institution and thus removing the ownership control from the government funding agency.

[3] US Supreme Court. “Diamond v. Chakrabarty, 447 US 303 (1980)”. No. 79-136. Argued March 17, 1980. Decided June 16, 1980.

biotechnology patenting. The ex parte Hibberd decision in 1985[4] essentially allowed for plant material to be patented while the ex parte Allen in 1987 allowed for animal material to be patented (Walter 1997). Eventually, in 2001, the US Supreme Court validated the two USPTO decisions in the case of Pioneer Hi-Bred International vs. J.E.M. Ag Supply Inc.

In recent years, concerns have been raised on the practices of university technology management and their implications for diffusion of academic inventions. These concerns are focused on, first, the increasing tendency of universities to pursue Intellectual Property Rights (IPRs), and in particular patents, for university inventions and second, the frequent use of exclusive licensing for such inventions.

In terms of patenting, Heller and Eisenberg (1998) and Walsh et al (2003, 2005) have raised concerns that the increased use of patenting may retard scientific advancements. This hypothesis has been coined as the anti-commons hypothesis by Heller and Eisenberg (1998).

Sampat (2004) tests this hypothesis by employing a dataset of genomic published papers that all resulted to a patent. He exploits the time variation of patent grant to identify the effect of patent grant on forward citations of the published article. He finds that published papers experience on average an 8% decrease in forward citations after patenting. Murray and Stern (2007) also test the hypothesis. They employ a sample of published papers from Nature Biotechnology in which a subset has also resulted to patents. They examine how the patenting event affects citations to the published paper in comparison with published papers that potentially could have resulted in a patent. They found that patenting decreases the rate of forward citations to the paper by approximately 10-13%. Lei, Juneja and Wright (2009) in a survey of agricultural biologists, find that the increase in patenting may delay access to research tools due to the induced use of material transfer agreements. Thus, the above studies find at least some evidence that support the validity of the anti-commons hypothesis.

The instrument of technology management closely related to patenting is the use of exclusive licensing. The above studies have not focused on the latter and therefore offer no insights as to whether it is the use of patents per se or the use of patents in combination with exclusive licensing the main factor of deterring the scientific advances. This is an important step towards the analysis of university technology management since the use of exclusive licensing is the most common technology transfer tool for academic patented inventions. As a survey by Henry et al (2002) showed, nonprofits institutions (primarily universities) have a 68% probability of licensing DNA patents exclusively in comparison to firms, which license 27% of their DNA patents exclusively. As the authors discuss, possible explanations for this difference are: (i) the university inventions are more basic and therefore require higher protection for the licensee to engage on development for such an invention or (ii) firms that have upstream inventions, have less need to license them since they have the capacity and motivation to develop them in-house.

In terms of exclusive licensing, a major concern is that follow-on research and diffusion may be impeded. At this point it is crucial to draw a distinction between licensees and non-licensees in performing follow-on research on the patented academic invention. Licensees can perform follow-on

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[4] LEXSEE 227 USPQ 443. Ex parte Kenneth A. Hibberd, Paul C. Anderson and Melanie Barker.
Appeal No. 645-91 from Art Unit 331. Application for Patent filed September 4, 1984. Serial No. 647,008. Tryptophan Overproducer Mutants of Cereal Crops. Board of Patent Appeals and Interferences. *1985 Pat. App. LEXIS 11; 227 U.S.P.Q. (BNA) 443* August 9, 1985, Heard September 18, 1985, Decided.

research on it while non-licensees may implicitly perform follow-on research but output, building on the licensed patent, may infringe the already exclusively licensed patent[5]. Unless the patentee (academic institution in our case), the licensee and non-licensee negotiate or have an agreement in place, the non-licensee who produces any invention building on the licensed patented invention without infringing it. However, licensees are allowed to perform research at the same research area as the licensed patent.

A university invention can be a research tool that is widely applicable and exclusive licensing might not optimally motivate exploitation (Nelson 2003). An example was the Oncomouse invented by Harvard faculty (US Patent 4,736,866). The invention was licensed exclusively to DuPont where it narrowed the research use of the invention by charging high price per mouse, requiring oversight over publications and a share of any commercial breakthroughs utilizing the Oncomouse. These terms had serious impediments to the use of the Oncomouse for research purposes (for a thorough discussion consult Murray (2006)). Another example is discussed in a case study by Merz et al (2002) of two US patents that cover the Human hemochromatosis gene. Moreover, Cho et al (2003) in a study of U.S. Laboratories conducting DNA gene tests found that patenting coupled with the use of exclusive licensing discourages U.S. laboratories from conducting experiments on such inventions. However, the latter study didn't separate the importance of each instrument on the discouragement of U.S. laboratories.

Regarding these findings, a recent survey by Pressman et al (2007) of OTT personnel from 19 top US research universities, which focused on NIH sponsored academic DNA patented inventions, found that the nature of the invention plays an important role in OTTs' policies on exclusive licensing. Additional factors that play a role include the amount of risk and further development investment that need to be undertaken for the invention to be utilized. They found that inventions such as DNA sequences that encode therapeutic proteins which require substantial investment and high risk would be licensed exclusively while for DNA sequences that are markers only, requiring modest and low risk investment, licensing nonexclusively is the more likely type of technology transfer. However, they found that defining a research tool is a difficult and subtle challenge for OTT personnel. If they could assess that it is a research tool then they would license it nonexclusively.

In addition, the type of licensing is the outcome of negotiations between the OTT and the potential licensee. The potential licensee may be in a better bargaining position than the OTT and therefore push harder for an exclusive license. For instance, it can be the case that the potential licensee may be willing to pay for all the patent prosecution costs subject to licensing the patented invention exclusively. Moreover, at that given time, it may be the only entity interested in licensing the patented invention and therefore easier to require and be awarded an exclusive licensing. Alternatively, the licensee may be demanding from the OTT to award him an exclusive license as in the case of Geron Corporation which exercised pressure to the Wisconsin Alumni Research Foundation (WARF) to extend exclusivity over a human stem cell technology[6]. Initially Geron had licensed human stem cells to

[5] Actually, even during development of the product the use of patented knowledge/material is illegal. A commonly mistaken impression is that research exemption allows researchers to freely use proprietary knowledge to develop a product. In the final stage, however, the product may be subject to infringement; nonetheless, the research process of developing the product is not breaking any laws. In the US, there is no research exemption rule for utility patents. In the 2002 *Madey v. Duke University* decision by the Court of Appeals for the Federal Circuit (CAFC), the argument of research exemption for experimental purposes did not hold (Eisenberg, 2003).

[6] Stolberg, S. G. "Suit Seeks to Expand Access to Stem Cells," *New York Times*, August 14, 2001.

develop in six tissue types. However, a few years later it tried to extend the license to exclusively cover twelve additional types. However, WARF argued to nonexclusively license this technology for development of the additional tissue types. Finally WARF sued Geron and the ruling was in WARF's favor. Therefore, it is unclear whether each patent is associated with the most efficient type of license and more importantly, it is unclear whether exclusive licensing will impede diffusion of certain patented inventions.

However, scholars have also identified cases in which a firm that exclusively licenses an academic invention might have distorted incentives or might not be capable of utilizing the invention (Colyvas et al 2002, Nelson 2004). For instance, a firm may want to shelve the academic invention if it is a substitute for an invention that the firm already possesses in-house while another possible scenario may be that while the firm initially intends to develop the invention, later realizes that it is not profitable for it to develop the patented invention and hence decides not to develop it (Thursby, Thursby and Dechenaux 2005). These issues indirectly affect non-licensees; that is, it can be the case that the licensee was not the best match for the academic invention while the best match was left in the non-licensee pool and therefore the invention wasn't developed. Two points need to be made here. First, in principle, universities can terminate the license and pursue a licensee that can develop the invention. However, termination of license, search for a new licensee and negotiation of a new licensing agreement are accompanied by significant transaction costs that might be prohibitive for universities to pursue a new license. Second, Bayh-Dole Act has shielded federally funded university inventions from such inefficient types of technology transfer through march-in rights; however, these rights can only be applied to federally funded inventions leaving corporate funded inventions and other sponsor type funded inventions (e.g. state sponsors, non-profit organizations and marketing boards) out. Moreover, these rights have never really been tested in real-life situations[7].

Having discussed the concerns of patenting and exclusive licensing it is important to explicitly address the counterargument in support of the use of such instruments by universities. Most university inventions are upstream and would require substantial investment in development to result in a commercial product (Bayh, May 25, 2004). Indeed, Jensen and Thursby (2001) in a survey of university technology transfer managers found that 71% of university inventions are of embryonic nature. Thus, universities should provide firms/licensees with enough incentives to engage on substantial investment for development of such inventions. For this reason, a common practice of universities is to file for patents for its inventions, retain ownership, and subsequently license them exclusively to firms to further

[7] To date, NIH has received three petitions to exercise "march-in" rights (BayhDole25, April 17, 2006). In the Case of Cellpro, Inc., the company requested "march-in" on the basis that John Hopkins University (the patent holder) and Baxter Healthcare (the licensee) had not developed the stem cell inventions. The NIH rejected the petition. In the most interesting case, Norvir requested from NIH to exercise its march-in rights on an AIDS drug that was manufactured by Abbott Laboratories. The grounds offered by Norvir was the fact that the Abbott Laboratories had increased the price of the drug by 400% (Morrissey, 2004). Were the argument valid, the march-in rights could become an instrument for controlling prices or more generally exercise competition policy. This could create such a precedent that Senator Bayh in a testimony before the NIH explained that the "march-in" provision was included to avoid failure to develop a technology (intentionally or unintentionally) and not for controlling drug prices (or prices of any developed product for that matter) (Bayh, May 25, 2004). Hence, "march-in" rights shouldn't be exercised as a way to "correct" price distortions. The NIH rejected the petition. In the Case of Xalatan, the story was similar since Xalatan argued for NIH to use the march-in rights as an instrument to control prices. NIH also rejected that petition.

develop these inventions. Indeed, Elfenbein (2007) found that patenting increases the rate of licensing for invention disclosures of Harvard University. Thus, the potential losses of blocking access to third parties (i.e. non-licensees) might be outweighed by the gains from development by the licensee.

In this project, the focus is on exclusive licensing and its effects on both licensees and non-licensees. As discussed above, there has been a growing literature on discussing the effects of patenting on subsequent follow-on research. However, the econometric studies reviewed above have focused on published paper citations while this paper, by examining patents and their subsequent citations, tries to offer insights on follow-on patenting by both firms and universities. In addition, the effects of exclusive licensing have been neglected in the literature mainly due to the scarcity of appropriate data so that the question whether the findings from previous studies can partly or in whole be attributed to licensing practices rather the patenting practices has remained unresolved. This is a first rigorous empirical project examining the effects of exclusive licensing on follow-on patenting.

Framing the Hypotheses and Econometric Specification

The first order of business is to identify the appropriate metric for licensee follow-on research related to patented inventions. The metric that we employ is the count of patents that cite the patents of interest; forward citations have been used extensively in the literature as a proxy for patent quality (Trajtenberg 1990). A number of scholars have found that forward citations are a good, but rather "noisy", proxy for patent quality (Harhoff 1999, Bessen 2008) while Hall, Jaffe and Trajtenberg (2005) found that forward citations are positively correlated with the market value of the patent holder. The landmark paper that explicitly employs patent citations as metric for knowledge spillovers is by Jaffe, Trajtenberg and Henderson (1993). This study spawned a vast literature that uses patent citations as a proxy for knowledge spillovers. A paper that has employed patent citations as metric for knowledge utilization, in the university-industry collaboration context, is by Mowery and Ziedonis (2001). They compare the degree of localization of non-market knowledge spillovers (approximated by patent citations) versus market channels of research commercialization (approximated by licenses). In this paper, we use forward citations as a way to approximate follow-on research by licensees and knowledge spillover to non-licensees. We discuss the limitations of this metric later on this section following the econometric specification and on the Results Section.

The discussion of the previous section suggests two main hypotheses can be stated regarding exclusive licensing and its effect on follow-on research. Starting with the licensees, follow-on patenting that cites that licensed patent is conditioned upon a successful technology transfer from the university to the licensee. In other words, the premise of exclusive licensing is that it gives sufficient incentives to the licensee to pursue further development of the invention. Given that indeed this occurs, further R&D of the university patented invention by the licensee should be observed, and this R&D should generate additional patents. Thus, upon licensing the number of licensee patents that cite the university patent should increase. Formally:

Hypothesis I: For patents that are licensed exclusively an **increase** of **licensee** citations to the licensed patent should be observed after a licensing agreement is awarded.

Regarding non-licensees, the main concern is that due to exclusive licensing they will be discouraged from undertaking research that could be related to the university patented invention, and therefore acquire patents that cite the licensed patent, given that a third party (i.e. the licensee) has exclusive rights over it. Therefore, the hypothesis posed by scholars is that research on the area of the licensed patent by non-licensees will be impeded due to the exclusive license. More formally:

Hypothesis I IA: For patents that are licensed exclusively we should observe a relative **decrease** in the number of forward **non-licensee** citations to the licensed patent after they become licensed.

However, an alternative hypothesis, mutually exclusive to Hypothesis IIA is that non-licensees view the exclusive license more as a signal rather than as an obstacle to conduct research on the university patented invention. This signal can be one of quality where other firms are influenced positively by another firm's action to license the patent. This explanation is supported by recent evidence (Sampat and Ziedonis 2010) arguing that licensing is a good proxy for patent quality. In addition, a study by Austin (2000) found that the issuance of valuable patents increases both the stock market value of the patent holder and its rivals. This finding may also apply to the use of exclusive licensing agreements since they explicitly award exclusive right of a patented invention to a single firm. Thus, the exclusive license maybe beneficial to non-licensee rivals, by motivating them to open a new research agenda due to the licensee signaling (through licensing the patent) that it is going to embark on a new R&D path building on the academic patent. In either case the alternative hypothesis can be formally stated as:

Hypothesis I IB: For patents that are licensed exclusively we should observe a relative **increase** in the number of forward **non-licensee** citations to the licensed patent after they become licensed.

A standard difference-in-differences approach is adopted. The baseline sample is patents first licensed after grant. As it will be shown in the Data Section, we can employ the variation in the timing of first license to identify the licensing effect absent a comparable/control group. However, given the small sample size, we try to utilize the majority of the data. Thus, in the alternative sample choice, we also include the patents that are licensed prior to grant and therefore remain licensed throughout their patent life. This group of patents functions as a comparison group to flesh out the effect of the exclusive license. In either sample choice, the specification is the following:

$$Y_{i,t} = k_0 + k_1 * Exclusive_{i,t} + k_2 * ExclusiveExpire_{i,t} + \sum_{i=1}^{N} \gamma_i * Patent_i + \sum_{t=1}^{T} \delta_t * Period_t + \sum_{t=issueyear+t}^{T+issueyear+t} \theta_{issueyear+t} * CiteYear_{\text{issue year}+t} \quad (1)$$

where

- $Y_{i,t}$ is:

  - For Hypothesis I, $LicCites_{i,t}$ which is the number of applications filed, that resulted in a patent, by licensee/future licensee, at period t and cited patent *i*. Take note that the forward citation patterns observed in this paper are by application year of patents.
  - For Hypotheses IIA and IIB, $NonLicCites_{i,t}$ which is the number of application filed, that resulted in a patent, net of assignee and net of licensee applications filed, that resulted in a patent, filed at period *t* that cite patent *i*.
- $Exclusive_{i,t}$ takes the value of 1 for patent *i* if patent *i* is under an exclusive license and the patent is still in effect at time *t* and takes the value of 0 otherwise.
- $ExclusiveExpire_{i,t}$ takes the value of 1 for an exclusively licensed patent *i* when it has expired or lapsed[8] and takes the value of 0 otherwise.
- $Patent_i$ are N dummies where $Patent_i$ takes the value of 1 for patent *i* and 0 otherwise.
- $Period_t$ are *T* dummies where $Period_t$ takes the value of 1 for period/year *t* after grant and 0 otherwise. These dummies control for the dynamic nature of the forward citation pattern.
- $CiteYear_{\text{issue year}+t}$ are *T* dummies where $CiteYear_{\text{issue year}+t}$ takes the value of 1 for the t^{th} calendar year after grant and 0 otherwise. These dummies control for macroeconomic aspects of citations. For instance, recent years are characterized by higher number of granted patents and therefore higher likelihood of citations to previous patents.

Note that definitions for the above and all other variables in the paper are listed in Table 1. To find support for Hypothesis I, k_1 should be positive and significant. In other words, upon exclusive licensing, an increase in *LicCites* should be observed. To find support for Hypothesis IIA k_1 should be negative while to validate Hypothesis IIB then $k_1>0$. To offer additional robustness to the result and utilize as much of the sample as we can, we can potentially include unlicensed patents as an alternative control group after we have excluded patents licensed before grant. In this case the specification includes one more variable:

(2)
$$Y_{i,t} = k_0 + k_1 * Exclusive_{i,t} + k_2 * ExclusiveExpire_{i,t} + k_3 * UnlicExpire_{i,t} + \sum_{i=1}^{N} \gamma_i * Patent_i + \sum_{t=1}^{T} \delta_t * Period_t + \sum_{t=issueyear+t}^{T+issueyear+t} \theta_{issueyear+t} * CiteYear_{\text{issue year}+t}$$

where,

- $UnlicExpire_{i,t}$ takes the value of 1 for an unlicensed patent *i* when it has expired or lapsed and takes the value of 0 otherwise.

In terms of modeling, the preference for employing a standard difference-in-differences method as opposed to a non-linear regression framework such as negative binomial should be noted. By construction in the negative binomial, we would drop all patents that in every period they receive zero

[8] In the US patent system for patents to continue being in effect, the owner of that patent (i.e. assignee) must pay maintenance fees periodically. In the USPTO, he must pay in the fourth eighth and twelfth years from the year of grant.

citations. Therefore, we would drop a significant part of the sample which under the current small sample size it could seriously impede our inferences. In all likelihood, it would downward bias our estimates; however, note that results acquired with negative binomial estimations are similar as in the case of difference-in-differences approach.

A note on the standard errors should also be made. In this paper, clustering the standard errors (Bertrand, Duflo, Mullainathan 2002 and Cameron and Trivedi 2005) at certain group levels is important; many patents are licensed together as a bundle; thus, assuming independence among these patents can lead to inefficient estimates. A way to correct this is to cluster the standard errors at the bundle level (Cameron, Gelbach, Miller 2006); thus, in all the difference-in-differences estimations we allow for serial correlation between the patents that have been licensed together.

Another issue to deal with is the use of patent citations as metric for licensee follow-on research[9] and non-licensee spillovers. Jaffe, Fogarty and Banks (1998), in a case study of NASA issued patents, find that two thirds of citations are associated with knowledge spillovers while a survey of Jaffe, Trajtenberg, Fogarty (2000) of patentees find that half of citations are or maybe related to knowledge spillovers. Even though there is substantial noise in citation data, it is evident, from the above studies, that at least a big subset of patent citations reflects research output related to the cited patent. Moreover, in this paper the interest is not in the absolute size of follow-on research or knowledge spillover but rather its change due to licensing; hence given that this noise is not correlated with the licensing event, the estimates obtained will be unbiased. Note that from the above discussion the use of patent citations as a metric of licensee follow-on research is an assumption that could be prone to a number of issues. These are discussed at the last part of the Results Section to address how the interpretation of the results can change to the extent that the issues are prevalent.

Moreover, in this paper no distinction between examiner and applicant citations is made since many of the citing patents have been filed before 2000[10]. As Alcacer and Gittelman (2006) showed, 40% of citations are added by the examiner which in turn can introduce a measurement error on knowledge spillover studies. However, a study by Thompson (2006) concluded that the way examiners add citations is to fill gaps that inventors didn't add. In terms of all other citations, examiners don't add citations to include background knowledge but rather to argue towards rejection of the patent application; nonetheless, the patent application may often be granted a patent (Lei and Wright 2010). Thus, examiner citations are not likely to depict knowledge utilization. Moreover, we wouldn't expect for examiner citations to differ systematically before versus after licensing. Licensing agreements are frequently not published while in addition to university-to-industry licensing agreements, there are also industry-to-industry licensing agreements. Therefore, it is not plausible for the examiner to keep track of all these transactions in addition to become updated on the relevant prior art. However, at the end of the Results Section, we discuss alternative interpretations of the results to the extent that examiner citations are affected directly or indirectly by the licensing agreement.

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[9] For a thorough discussion on the challenges of patent citations as a metric for knowledge utilization, consult Rosell and Agrawal (2009).

[10] In 2000, the American Inventors Protection Ac mandated for patent applications to become public after 18 months from application date. Therefore, for patents filed after that date, we can have information on applicant citations.

Data

Data Overview

For this project a unique dataset of patented inventions was available stemming from academic research that was undertaken on the University of California. UC-OTT has diligently monitored inventions disclosed by UC inventors (UC faculty, staff or students) to the OTT. Before outlining the dataset at hand, it is useful to outline the procedure following an invention disclosure[11]. After the inventor discloses an invention to the OTT, the OTT assesses the technology and assigns it to a technology management officer who in turn tries to find the best way to transfer and therefore utilize the technology. Usually, the officer will try to communicate with firms for which the technology falls in their field of research. Even if the officer doesn't find a licensee, he may apply for a patent given that the inventor may have already published the research and therefore a patent application needs to be filed within twelve months from publication (35 USC 102(b)). This procedure is called "at risk filing" while patent prosecution funds may be found by the university, the inventor's department or the inventor herself. Upon finding a licensee, the latter may be asked to pay some or all of the past prosecution costs. During an "at risk application" prosecution, the officer will keep searching for a licensee. Thus, a license maybe struck before patent application, between patent application and patent grant and even after grant. Moreover, a number of patents will not be licensed.

Note that the econometric design presented in the previous section exploits the patents that were licensed after grant. Since a difference-in-differences estimation is performed, the treated group (i.e. licensed patents) needs to be observed both at an unlicensed and a licensed state. Patents that are licensed before grant cannot be observed at an unlicensed state.

Overall, 3,232 utility patents were acquired with grant years spanning 1977 to 2009. These patents are associated with 2,033 inventions disclosed to UC-OTT between February 11, 1964 and June 30 2007 (i.e. fiscal year of 1997). Table 2 shows the frequency of inventions associated with number of patents, while Figure 1 plots the histogram. It can be seen that the majority of inventions (69.9%) have one patent while 612 inventions have more than one patent[12]. For all the patents their licensing history has also been recorded. Table 3 shows how many patents have been licensed, what kind of license they have been awarded and the time, in relation to the patent grant, they were first licensed. From Column 1, it can be seen that approximately half of the patents haven't been licensed while licensing a patent exclusively is approximately seven times more frequent (1,253 out of 3,232 implying a likelihood of 38.8%) than licensing a patent nonexclusively (178 out of 3,232 implying a likelihood of 5.5%). This overwhelming propensity to license exclusively is in accordance with previous studies examining the likelihood of exclusive licensing in academia (Schissel et al 1999 and Henry et al 2002, 2003).

Continuing with Column 1, there are also patents which have been licensed both exclusively and nonexclusively. From a cursory review of the dataset, the licensed patents in this last group can be the outcome of many circumstances; for instance, a certain patent might have been licensed first exclusively and then the license was abandoned and the same or different licensee obtained it in a nonexclusive license or vice versa. Even though these patents have been licensed exclusively at some point in time, a clear hypothesis is not at hand and therefore they will not enter the econometric analysis.

[11] For a more thorough description of UC technology management consult Graff, Heiman and Zilberman (2002).

[12] This is contrary to the notion that there is one-to-one correspondence between inventions and patents.

Before continuing with the analysis, we should address the issue of exclusivity and what it means in this context. In the dataset, there is a field that describes the type of the license. There are three distinct types: "exclusive", "exclusive-with-limit" and "nonexclusive". After discussions with OTT personnel to assess the meaning of each type, we concluded that patents that are licensed exclusively-with-limit are usually licensed within a field of use. For instance, the license by Geron, discussed in the previous section was an exclusive-with-limit license since initially it was licensed for the development of six tissue types. Another example could be a technique that transfers DNA in plant cells and it could be licensed exclusively for cotton research and exclusively for corn research. An example of an exclusive license was the Oncomouse since only DuPont could use the mouse (regardless if DuPont itself had the ability to sublicense it). However, it could be the case that licenses that are coded as "exclusive" may have clauses in which another firm can potentially license the invention in another geographical area or in another field of research. Given this subtlety in our data, we refer to all licenses that are coded with some form of exclusivity, exclusive licenses and the patents associated with these agreements as exclusively licensed patents.

It is also interesting to explore the number of patents licensed before and after grant. Column 2a shows patents licensed on or the year before grant and their license was not revoked/terminated. Since time is measured in years for this project, patents that have been licensed at the year of grant cannot be observed at an unlicensed state during patent life (unless license has been revoked). Thus, we assign all patents licensed at the year of grant to the group of patents licensed before grant even though certain of these patents may have been licensed months after grant but within the same calendar year of grant. For the remainder of the paper, we refer to these patents as patents licensed before grant.

Column 2b shows patents licensed before grant and their license was revoked/terminated. From an econometric standpoint these patents enter the treatment (i.e. licensing) and then exit it. In case any of these patents get licensed again, that might add noise to the estimates and make the interpretation of the treatment coefficients troublesome. This group of patents of which their license was revoked, even though initially will not be taken into account, will later be explored in the econometric analysis to provide additional robustness to the results since as can be seen from a comparison of Columns 2a and 2b, they account for roughly one third of patents exclusively licensed prior to grant.

Given that the interest group is patents licensed after grant and since we deal with a small number of patents, we also want to augment our results by including comparable groups in the econometric analysis. Exclusively licensed patents in Column 2a for instance will be employed as a comparable group. However, a group that can be closer to the group of interest is patents licensed on grant year or within two years before grant. Column 3a shows patents of which the license was not revoked while Column 3b shows the number of patents of which the license was revoked. This group is closer to the group of interest since the time of licensing cannot be set deterministically. Even if both parties are willing to sign a licensing agreement, it takes time for the parties to agree in all aspects of the contract and draft the final agreement.

Finally Column 4a displays the number of patents licensed after grant. There are 228 patents licensed after grant which the license was not revoked. For all intents and purposes and the remainder of this paper this group of patents will be referred to as *group of interest* or *treated group*. By comparing Columns 2a-2b with Columns 4a-4b, we can see that 946 patents have been licensed exclusively prior to grant while 307 have been license exclusively after grant. That implies that merely 24.5% of exclusively licensed patents were licensed post grant which is consistent with Elfenbein (2007) where he uses similar data from Harvard University.

Next it is useful to explore the frequency of exclusively licensed patents by grant year. As can be seen from Figure 2 the majority of patents have been granted between 1995 and 2005. The peak in 1999 is attributed to the fact that data in invention disclosures stop on June 30, 1997. Thus, as the time progresses, fewer patents would be expected to be issued associated with inventions that were disclosed before the fiscal year of 1997.

Moreover, it is useful to see the variation of exclusively licensed patents' grant year by year of first license. Figure 3 shows the frequency of first license for exclusively licensed patents by period since grant year. The first observation made is the big variation of first license before and after grant year. This is encouraging for the econometric design since the variation of when patents enter the treatment (i.e. exclusive license) will enhance the identification of the licensing effect. The second observation that stands out is that patents have been licensed 10-20 years before grant. Most of these patents didn't exist when the initial license agreement was signed but were covered by the license when the application was filed. In other words many of the licenses include patents that at the time of license didn't exist as an application or even as an invention; however, they became associated with these patents once the invention was disclosed or patent application was filed. From a review of these agreements, in most cases, these patents are continuations, continuations-in-part or divisionals of older patents or they can be independent patents which stem from the same lab/inventor of which the older patent was licensed. Figure 4 displays the same histogram only for the sample of patents first exclusively licensed after grant and were not abandoned; i.e. the group of interest. From this figure, it can be seen that there is enough variation of the period of first license. This can be exploited in the econometric analysis since, when estimating the regression absent a comparable group, the late licensed patents essentially function as a control group for the early licensed patents and vice versa. To the extent that the one group is a good control group for the other will be further explored thoroughly in the next sub-section.

Table 4 shows summary statistics for the sample of UC patents of Table 3 Column 1. As can be seen, exclusively licensed patents tend to get cited less per year than nonexclusive licenses with the difference being 0.32 citations. When excluding assignee citations, the difference remains approximately the same. In terms of licensee citations, exclusively licensed patents receive 36% (i.e. 0.11 citations) more citations per year than nonexclusively licensed patents (0.07). In terms of non-licensee citations, nonexclusively licensed patents receive considerably more citations. We also decompose by type of licensee (firm vs. university) and as can be seen approximately 60-70% of total citations stem from firms. This is to be expected since the majority of patent holders are firms. Note that assignee citations and licensee citations are excluded from these two variables. Before continuing with patent characteristics, we should note that the patents that have received nonexclusive and exclusive licensing agreements appear to have citations in between the numbers described for nonexclusively and exclusively licensed patents. This implies that for this group of patents some resemble the exclusively licensed patents and the others nonexclusively licensed patents. For the remainder of the paper, this kind of licensed patents is completely ignored; thus when referring to exclusively or nonexclusively licensed patents we refer to patents that have been licensed with a single type of license even if they have been licensed more than once throughout their life. Moreover, unlicensed patents have been cited considerably less than all kinds of licensed patents indicating that citations are a good proxy for patent quality assuming that a licensed patent is of higher quality than an unlicensed patent on average. This observation is also consistent with the finding by Sampat and Ziedonis (2010). When decomposing the citations by type of citing entity, we see that about half of citations come from firms while a small portion comes from universities. It should be noted that the significantly more NonLicCites in the case of nonexclusively licensed patents cannot be attributed to the nonexclusive license without rigorous econometric estimations. This finding merely states that nonexclusively licensed patents have on average more NonLicCites per period than in the case of exclusively licensed patents regardless of when they were licensed during that period. However, from these summary statistics we cannot infer whether the NonLicCites difference is to be attributed to the licensing event.

Now, it is useful to examine whether patent characteristics differ across licensing status and we focus primarily on exclusively licensed patents and nonexclusively licensed patents. In terms of claims, we see that exclusively licensed patents have on average 18.91 claims while nonexclusively licensed patents have 14.31; in terms of number of US classifications they are slightly different with 5.14 and 5.76 respectively. In terms of the number of International Patent Classifications (IPCs)[13], exclusively licensed patents have on average 6.71 while nonexclusively licensed patents have on average 5.03. In terms of both patent and scientific literature backward citations, exclusively licensed patents have considerably more citations than nonexclusively licensed patents. From the above analysis, it can be seen that exclusively licensed patents are considerably different from nonexclusively licensed patents. Finally as can be seen from Table 4, exclusively licensed patents are also different than the unlicensed patents with regards to these characteristics.

Group of Interest, Comparable Groups and Endogeneity

The main interest of this study is to examine citation behavior pre and post the exclusive licensing event. Figure 5 shows how licensee and non-licensee citations change after an exclusive license is awarded for patents licensed after grant. As can be seen prior to license, there are virtually no licensee citations while they increase dramatically after the agreement comes in effect. In the case of non-licensee citations, we observe no change for the first five periods since licensing followed by a decrease and a subsequent sharp increase; note that the shape of both lines is robust to the exclusion of outliers. From this figure it is difficult to examine whether licensing is associated with a relative increase or a decrease given that the age of the patent cannot be identified in this graph.

Figure 6 displays non-licensee citations for patents licensed after grant while in licensed and unlicensed state; Figure 7 displays a similar graph for licensee citations. From Figure 6 we can see that patents have on average same number of non-licensee citations in the early years from grant regardless of license status. However, in later years, with the exception nine through eleven years after grant, non-licensee citations are higher for patents while licensed than when unlicensed. A critical observation, however, is that the sample comprising the while unlicensed patents decreases in later years with the group of while licensed patents becoming bigger. From Figure 7, the behavior of licensee citations is clearer. When patents are unlicensed, there is little to no licensee patenting that cites the UC patent. However, when a licensing agreement comes into effect, licensee citations increase significantly during the entirety of the patent life.

[13] Lerner (1994) has argued that the number of IPCs is a good proxy for patent scope.

Now that we have overviewed the behavior of the group of interest with regards to citations, we turn our attention to the sample choice. As already stated the baseline specification will be comprised only by patents licensed after grant for which the license was not revoked[14]. Thus, in essence the late licensed patents will function as a control group for early licensed patents and vice versa. The motivation for this specification is to deal with the main critique of any difference-in-differences approach. In the cases where the treatment is not random, which in our case is the event of licensing which isn't randomly assigned to patents, we ideally aim for a control group that is as close as possible to the treated group. If this cannot be done then our estimates could be downward or upward biased. In our case the whole group in the baseline specification is licensed and therefore we avoid this endogeneity problem.

However, a new endogeneity problem emerges if patents that were licensed early are systematically different than patents that were licensed late[15]. Thus, it is imperative to compare early and late licensed patents to examine to what extent they constitute a good control group for each other. Table 5 shows summary statistics for different types of citations and patent characteristics for early licensed patents and late licensed patents. Note that for the remainder of the paper early licensed patents refer to patents licensed after grant and within five years from grant, while late licensed patents refer to patents licensed on or after the sixth year from grant. As can be seen in terms of citations, they don't differ in terms of non-licensee citations but differ substantially in terms of licensee citations. This is to be expected since early licensed patents have more years to accrue licensee citations since as was shown in Figure 5 there is licensee citation activity only when the patent is licensed. Also total citations per period differ since they are the sum of assignee, non-licensee, and licensee citations. In terms of patent characteristics, we don't observe any stark differences. Column 1 of Table 6 displays a probit regression on whether these patent characteristics can predict on whether a patent will be licensed early or late. As can be seen, only the NumberOfIPC and ApplicationLength can predict significantly the likelihood of a late license indicating that overall the two groups of patents are not significantly different with respect to these characteristics.

Thus, we've seen that these two groups don't have any stark differences in terms of citations or patent characteristics. However, it can still be argued that the two groups have different citation patterns while they are unlicensed which will result in biased estimates when they are licensed. For this reason, we display citation patterns for these two groups during licensed and unlicensed states. Figure 8 displays non-licensee citations while Figure 9 displays licensee citations. From Figure 8, an interesting pattern arises. For the first five periods from grant, both the early and late licensed patents receive on average same number of non-licensee citations. This is a very important finding since late licensed patents are unlicensed during these periods but still resemble early licensed patents well. This observation enforces our rationale of using each group as a control group for each other since as can be seen both groups start with similar citation behavior regardless of the timing of licensing.

Now in terms of licensee citations, Figure 7 shows that, while unlicensed, patents receive virtually no licensee citations implying that licensees start citing the patent only after they've licensed it.

[14] The attention to not abandoned licensed patents is to reduce noise even though in robustness checks, we will also include this group of patents. Thus, unless otherwise stated, when referring to licensed patents, we refer to patents that have been licensed of which the license hasn't been revoked.

[15] For instance, a common impression is that high quality technologies tend to be licensed early.

This is true both for early and late licensed patents which indicates that regardless of the timing of license, patents are not cited by the future licensee while in the unlicensed state but start receiving licensee citations only after the licensing agreement is in effect.

It should be noted that we are not arguing that big differences in the timing of licensing (e.g patents licensed in period three versus patent licensed in period eight) is random. We merely argue that late licensed patents are of similar quality as early licensed patents. Therefore, the event of licensing doesn't seem to be correlated with the quality of the patent which could bias our estimates since the quality of the patent is clearly correlated with citations.

However, we may find no significant effect since the sample size of the group of interest is small (i.e. 228 patents). Therefore, we ideally want to augment the sample size by a control group that is close to our treated group. Table 7 displays the summary statistics for three "candidates" comparable groups. The first group is patents first licensed within two years before grant; the second group is all exclusively licensed patents before grant while the last group is unlicensed patents that haven't lapsed. The p-values displayed denote the difference from the group of interest.

Intuitively, the group closest to the group of interest is patents licensed within two years before grant. As already stated the timing of licensing is not deterministic; that is, patents that have been licensed within two years before grant could as well be granted shortly after grant under different circumstances and vice versa. This group of patents, as can be seen from Table 7 and Column 2 of Table 6, doesn't differ systematically from the group of interest in terms of the patent characteristics (except backward citations and application length). Figures 10 and 11 compare the citation behavior of patents licensed within two years before grant and the group of interest in both licensed and unlicensed state. As can be seen, non-licensee citations are similar in the early years from grant supporting the idea that these patents could under different exogenous circumstances be licensed after grant. Even though they deviate in later years, this initial observation supports the rationale of employing this group of patents as a comparable group without introducing significant bias. Figure 11 shows that this group of patents accrues licensee citations with a steady increase towards later years which denotes a similar behavior as with the patents in the group of interest while they are licensed.

The next two groups in Table 7 are all patents exclusively licensed before grant and unlicensed patents that haven't lapsed. Both groups appear to differ substantially from the group of interest in terms of patent characteristics. This is also consistent with the probit regressions in Columns 3 and 4 of Table 6. Starting with the licensed patents it appears that this group is distinctively different from our group of interest. Figures 12 and 13 display the citation behavior of this group and the group of patents licensed after grant. As can be seen, non-licensee citations are considerably lower than the treated group regardless of licensing state. This observation is contrary to the belief that early licensed patents are of higher quality than late licensed patents. However, a different explanation can justify this behavior. As already stated early licensed patents (i.e. patents licensed more than five years before grant) are patents that have been filed and granted as continuing applications. This implies that there has been an earlier patent that became licensed and this patent was covered by the license once it was granted. Even though, in the literature, citation patterns haven't been explored between continuing applications and initial granted patents, an intuitive conclusion is that the initial patents are of the highest quality in that specific string of patents. Thus, the later a patent is licensed the more likely it is to be the first granted patent in the family while the earlier it is licensed the more likely it is to be a continuing application. From a cursory review of the data, we find this to be true. Now, in terms of licensee citations, we observe licensee activity for this group even though it is much lower than the treated group.

Turing to the final "candidate" group (i.e. unlicensed patents that haven't lapsed), we first make an interesting observation with regards to number of secrecies in last Column of Table 7 and Column 4 of Table 6. However, it is first useful to explain the use of secrecy and letter agreements. When a potential licensee is interested in the technology, but wishes to make a deeper review of the technology, the UC-OTT may offer to disclose the technology, and even supplemental information, to the licensee. To protect the technology, the UC-OTT will sign a secrecy agreement with the interested party; the UC-OTT can have multiple secrecy agreements in effect for the same patent simultaneously. A letter agreement is a stricter agreement where the licensee is seriously considering licensing the technology but for any reason needs more time (for instance acquiring funds for patent prosecution, funds for license issue fees) or wishes further review of the technology. The UC-OTT then takes the technology off the market and signs a letter agreement with the interested party; the duration of a letter agreement is usually six months. These two variables denote interest by the private sector for UC-OTT patented inventions. We see that the number of secrecy agreements is on average the same for both the treated group and the unlicensed patents. This indicates that the initial expressed interest by the private sector was the same. Even though citations to unlicensed patents are considerably less than in the case of the treated group (Figure 12 – We use CitesNetAssignee in the place of non-licensee and licensee citations for unlicensed patents), there is still good evidence that the two groups are related since they are both UC patents and have same initial interest by the private sector. In terms of licensee citations, we see that this group can constitute a good control group given they have considerably more citations in the early years. In other words, upon finding a positive coefficient with unlicensed patents as a control group it will be downwards biased.

In this sub-section we have tried to explore patent characteristics and citing behavior of our treated group and "candidates" control groups. The motivation is to examine the severity of the endogeneity problem. The problem arises when licensing is correlated with the underlying quality of the patent since citations are also correlated with patent quality. As already stated, the initial specifications will comprise solely by patents licensed after grant. Thus, the second criticism is whether the timing of licensing is correlated with unobservables which are also correlated with citation behavior. If that is the case, then our estimates will be biased. As we showed, regardless of the timing of license, early citation behavior is similar indicating that late licensed patents will function as good control group for early licensed patents and vice versa. However, given the small number of treated patents, we explored other "candidates" comparable groups. We found that patent licensed within two years before grant are a good comparable group while all patents licensed before grant and unlicensed patent that haven't lapsed don't have similar citation behaviors. To the extent that the endogeneity issue constitutes a severe problem of this dataset, we discuss at the end of the next section how estimates should be interpreted.

Results

Baseline Results

Table 8 displays how licensee (Columns 1,3,5 and 7) and non-licensee (Columns 2, 4, 6 and 8) citations change after the exclusive license is awarded. The first two columns are comprised only by the patents licensed after grant. Column 3 and 4 include patents licensed within two years before grant.

Columns 5 and 6 include all patents exclusively licensed before grant while Columns 7 and 8 are comprised of the group of interest and unlicensed patent that haven't lapsed. Unless otherwise noted, all subsequent tables will have the same structure. As can be seen Exclusive is significant across all regressions for LicCites. The 0.144 coefficient in the Column 1 implies that after licensing there are on average 0.144 licensee citations per period accrued to the patent. In terms of non-licensee citations all coefficients are significant at least at the 10% significance level except in the last column. However, given that this control group may not resemble the treated group well, we conclude that there is a significant positive change of non-licensee citations after an exclusive license is in effect[16].

Thus far in the discussion, we've neglected nonexclusively licensed patents. It can be the case that the significant results we've shown in the previous table to be uncorrelated with the type of licensing and merely be solely driven by the event of licensing. Table 9 shows an analogous set of regressions as that of Table 8 comprising solely nonexclusively licensed patents. Two out of four specifications, LicCites is significant at least at the 10% significance level. The coefficient for NonLicCites is positive but insignificant across the board. Moreover Figures 14 and 15 display the citation behavior. From Figure 14, two important observations should be made. First, patents that are licensed receive more citations than when unlicensed; an observation similar to the case of exclusive licenses. However, contrary to exclusively licensed patents, patents licensed nonexclusively after grant (treated group), receive fewer non-licensee citations as the patent becomes older. This implies that the insignificant coefficient may be due to small sample size but is also driven by the non-existence of a late increase in non-licensee citations. Second, notice that patents licensed within two years before grant receive more non-licensee citations than the group of interest (i.e. patents licensed nonexclusively after grant) especially towards the end of the patent life. This is consistent with the notion that early licensed patents are "hot" technologies. These two interesting observations imply that these kinds of patents (nonexclusively licensed and exclusively licensed) are of different nature as Pressman et al (2007) argued and therefore is unsuitable to compare the two groups with regards to licensing and its effect to non-licensee citations. Figure 15 also shows an inherent difference between exclusively and nonexclusively licensed patents. Patents receive licensee citations while in unlicensed state in early years from grant in contrast to exclusively licensed patents which have virtually no licensee activity during their unlicensed state.

Having discussed the inherent differences of exclusively and nonexclusively licensed patents, we focus our attention for the remainder of this paper solely on exclusively licensed patents. Table 10 shows the change in citations due to exclusive licensing for patents stemming only from government funding[17].As stated in the Literature Review Section, Bayh-Dole set a unified framework for federally funded inventions and also encouraged exclusive licensing when needed. Therefore it is interesting to examine our hypotheses for this group of patents since it seems to be the one directly affected by the Bayh-Dole Act. As can be seen licensee citations don't have the same magnitude as in Table 8 while the

[16] Note that all the following results are robust when decomposing the type of citing entity; i.e. university and private firm. Most of the results are primarily driven by firms, while we don't find any negative effects for universities' citation behavior due to exclusive licensing.

[17] As will be outlined in more detail in Chapter III, our dataset includes a field in which inventors disclose the name and type of the sponsors (for instance government, non-profit, corporation etc.) that the research project has been financed by. However, there is number of inventions that lack this information and therefore any results displayed for this issue should be interpreted with caution.

significance decreases with Column1 being the only one that has an insignificant coefficient. However, non-licensee citations appear to have larger and more significant coefficients for exclusive licensing than before. The less significant increase in licensee citations could be attributed to the smaller sample size while the decrease in magnitude could be attributed to the fact that the government usually sponsors more basic research projects which could result to an upstream invention. Thus, a more basic research project may take significantly more time for the licensee to deliver innovation output within the time span we observe. The upstream invention explanation can also explain the larger magnitude in non-licensee citations as it can be the case that non-licensees also cite the licensed patent as a background patent. Overall, the initial results appear to hold for the subset of government funded inventions.

An explanation that could justify the increase in licensee citations is that firms that have been the sponsors of the academic research and subsequently become the licensees are the ones to accredit this increase. Table 11 displays results in which we run the baseline data specifications excluding the patents that stem from a research grant financed by a firm that exclusively licenses the aforementioned patent. As can been seen from the remaining number of patents, the cases where the sponsor becomes the licensee are few in number (comparing Tables 8 and 11, for the group of interest 228-217 there is only 11 inventions for which the sponsor became the licensee). This is due to two reasons. As shown in Table 10, a large portion of patents stem from government funded research grants. Moreover, in our dataset we don't have sponsor information for approximately two thirds of the patents. Even though we are confident that the lack of sponsor information is primarily random, we are aware that we haven't excluded all the patents in which the sponsor becomes the licensee. With this in mind, we show that the increase in licensee citations is not caused solely by this group of patents. On the contrary we observe a small increase of the Exclusive coefficient in the first two specifications for licensee citations.

Thus far we have not taken into account patents where the license has been revoked in order to minimize noise. It is frequent to have a patent licensed for one year and then the license to be revoked. To verify that revoked licenses introduce noise to our results, we display Table 12 in which for all specifications we include patents exclusively licensed but were terminated before the expiration of the patent life. As can be seen, licensee citations still increase even though the magnitude of the coefficient has reduced. Moreover, the Revokelicense coefficient is negative but not significant. The greater noise takes place for non-licensee citations where as can be seen the coefficients for Exclusive are positive but have turned insignificant.

As already stated, the majority of patents when licensed are licensed in bundles. Even though assignee citations have been excluded from the analysis, it can be the case that the increase in both licensee and non-licensee citations are driven by the intricacies of the bundle rather than the event of licensing. Usually the patents in the bundle are related through a common priority date; thus, the later licensed patents are most likely to be continuing patents or they could stem by the same research lab. Therefore, citation increase could be observed if non-licensees or licensees are citing the latest patent in the bundle and for logistic reasons cite all the older patents as well. This could bias our coefficients upwards and therefore the thus far interpretation of the coefficients could be under scrutiny. To avoid this critique in Table 13, we display baseline specifications by keeping only the patents that were licensed in which the license covers a single patent. Thus, we avoid any complications that may arise by a bundle. The coefficients on licensee citations remain similar as in Table 8; however, they are less significant. Nonetheless, the sample size is smaller and it could explain the loss in significance. The same seems to hold for non-licensee citations. Thus, even though significance drops, primarily to the much smaller sample size, the magnitude of the coefficients remains the same implying that for both bundled and uniquely licensed patents, the same change is observed and therefore it isn't likely to incur any complications due to bundling patents within a license.

Signal Effect and Reverse Causality

Thus far we have showed and argued that exclusive licensing is associated with an increase in licensee and non-licensee citations. We have assumed that the licensee behavior is to be attributed to more follow-on research conducted on the licensed patent. Thus, we merely argue that upon exclusive licensing, licensees conduct follow-on research that builds on the licensed patents; therefore exclusivity facilitated the licensee to utilize the academic patented invention. In terms of non-licensees, the expectation from the literature was to find a negative sign due to exclusive licensing. Nonetheless, in all specifications, we have found an increase in non-licensee citations and in most of these estimations this increase is statistically significant. The explanation we propose is that non-licensees perceive the licensing agreement as a signal of the research potential of the licensed patent and therefore influenced to conduct research related to the licensed patent.

A necessary condition for the above explanation to hold is for non-licensees to be unaware or at the minimum not interested to the licensed patent. However, it can be the case that non-licensees are interested in the academic patent and despite that another firm exclusively licenses it they do research related to the licensed patent. If that is the case, then the signal explanation proposed above is flawed since non-licensees were already interest in the UC patent. We try to reject this scenario with three arguments. First, university policy mandates that if they are many interested parties to license the invention, then the invention should be licensed nonexclusively. Therefore, the patents implied by the above scenario would not enter in our treated group or any other group of the comparable groups; i.e they would have been licensed nonexclusively.

Second, the above scenario is more relevant for late licensed patents since patents that remain unlicensed for a longer time period have more time to attract interest by multiple parties. Table 14 displays the regressions by excluding late licensed patents. In two out of four cases the coefficient for non-licensee citations is significant whereas in the baseline data specifications, there were three out of four cases in which the coefficient was statistically significant. Given that the number of patents in the treated group reduced by approximately half, the loss in significance was anticipated. Therefore we show that the significant change due to licensing holds also for the subset of early licensed patents.

Third, the reverse causality justification requires multiple parties' interest prior to licensing. As already stated a secrecy agreement is a relative costless sign of interest by a firm. For this reason we employ patents that have received no secrecy agreements prior to licensing. Table 15 displays the results. As can be seen, non-licensee citations increase due to exclusive licensing for this type of patents. This implies that patents that haven't attracted any interest prior to licensing, after licensing non-licensee citations increase significantly.

This last argument, in addition to be employed to rejecting the view that the increase in non-licensee citations is attributed to a reverse causality explanation, also shows that licensing functions as a signal for non-licensees. That is, with no expressed interest from the private sector prior to licensing, non-licensee citations increased after licensing indicating that licensing operated as a signal to multiple parties. To further support a signaling explanation, we distinguish licensed patents by the type of licensee; namely, licensees that are star-ups and licensees that are established firms. The rationale for this distinction is that licensing will be a more pronounced signal if an established firm is the licensee than a start-up. Usually, start-ups begin with involvement by the academic inventor and usually start as small scale operations. Therefore, other firms may not view licensing by a newly established start-up as a strong signal as if the same patent had been licensed by an established firm. Table 16 displays the baseline specification with patents licensed only by established firms while Table 17 patents licensed only by start-ups. Even though the sample size has been reduced, we observe that non-licensee citations are increasing for both samples but in the case of established firms, this increase is more significant. This reinforces the signaling explanation. Interestingly, licensee citations increase for both samples but more significantly in the case of start-ups. This finding can be justified by the presence of the initial inventors in the start-up. Inventors may have a better understanding over the invention than a third party licensee and therefore innovation output may be produced faster in start-ups. Thus, given that we stop observing citations in 2009, it is possible that this lack of significance for established firms can be attributed to the above explanation.

Differences By Technology Fields and "Inventing Around"

Thus far we have argued that licensees do follow-on research after the exclusive agreement is awarded. We have also argued that non-licensees view exclusive licensing as a signal to conduct related research on this promising area. Next, we explore whether these patterns differ by technology fields. Given the small sample size we distinguish between two aggregate technology fields based on the US Classification and the aggregation by Hall, Jaffe and Tratjenberg (2001). Namely we bundle Chemical, Drugs and Medical in one category; we denote this category as CDM; the other category comprises of Computers, Communications, Electrical, Electronic and Mechanical related patents. We denote this as CCEEM. There are two main reasons we opted for this distinction. First, CDM technologies are related with industries where intellectual property is strong and is taken into account by all the interested parties (Levin, Cohen and Mowery 1985, Levin et al 1987) while CCEEM are related with industries where the enforcement of intellectual property rights is not as a serious concern as the former fields. Second, follow-on research in CDM technologies takes considerably more time than for CCEEM technologies (Hall, Jaffe and Tratjenberg 2001).

Table 18 display the baseline specifications for patents only in CDM related technologies while Table 19 for patents in CCEEM related technologies. As can be seen licensee citations increase in the case of CDM and CCEEM patents even though in the case of CDM patents the result is overall more significant. We find that non-licensee citations increase significantly in the case of CCEEM technologies while in the case of CDM patents even though non-licensee citations increase (with the exception of unlicensed patents as a control group) the increase is not significant.

Therefore, we find that licensee follow-on patenting takes place in both technology fields even though in the case of CDM, the result is more pronounced. In the case of non-licensee citations, we find that the increase due to exclusive licensing is mainly attributed to the CCEEM technologies. This is due to three reasons. First, as already stated CDM related technologies have stronger intellectual property enforcement and therefore non-licensees may be discouraged to do follow-on research on that area. Second, it takes more time for innovation output to be produced in the CDM technologies (Hall, Jaffe and Tratjenberg 2001) which could imply that we may not have captured the entire non-licensee citation behavior in these technologies. Finally, in the CDM patents, we observe a significantly higher portion of start-ups; 55 out of 142 patents have been licensed by start-ups (38.7%) in the CDM fields while 17 out of 80 (21.3%) in the CCEEM fields. As was seen in the previous subsection start-ups are related with more licensee citations and less non-licensee citations due to licensing which partially could explain the more pronounced increase in licensee citations in the CDM fields.

Thus far, we've referred to licensee citations as follow-on research. Nonetheless, it is interesting to explore on which technology fields relative to the field of the UC patents do licensees and non-licensees patent their inventions. There are two main classifications that each patent is assigned; US classification and IPC. There are approximately 480 US Classifications where Hall, Jaffe and Tratjenberg 2001 (2001) have aggregated to 36 technology fields; we refer to the former as narrow US technological fields and the latter as broad US technological field. There are approximately 320 four digit IPC classification where Palangkaraya, Webster and Jensen (2011) have aggregated them in 30 technology fields; we refer to the former as narrow IPC technological fields and the latter as broad IPC technological field. The next four tables take into account only patents licensed after grant for the sake of space.

Table 20 shows that there is a more significant increase for licensee citations coming from the same US classification as the licensed patent; on the contrary, we find that non-licensee citations in the same narrow US Classification drop (though insignificantly) but in other US classifications increase. However, we see that non-licensee citations increase in the same broad technology field as the UC patent. Table 21 explores the same changes with IPC classifications and we see that non-licensee citations behave in a similar fashion. Therefore, we find some crude evidence that in the case of CDM technologies, non-licensees do related research in the same broad technology field as the UC patent but not in the narrow technology field as the UC patent; this finding provides some ad-hoc support to the argument that non-licensees may try to invent around the licensed academic patent.

Tables 22 and 23 explore the same questions in the case of the CCEEM fields. Here we see that licensees behave in a similar fashion as in the case of the CDM technologies by doing most of the follow-on research at the same narrow field as the licensed patent. On the contrary we find that non-licensees are doing most of the related research at a different narrow and broad field of the UC patent indicating that in these technology fields, non-licensees may come from different industries that employ these technologies in their own needs.

Thus far, we argued that licensees are conducting follow-on research due to the exclusive license and non-licensees being positively influenced due to the license. We've found these phenomena to differ across technologies. Even though we have argued that the econometric design didn't suffer from severe endogeneity issues, we discuss how these problems may affect the interpretation of the coefficients. First, we start with licensees. Even if the timing of licensing is correlated with patent quality which in turn may be correlated with citations it isn't likely to be correlated with licensee citations. The inherent question here is whether the licensee would still conduct the follow-on research absent the exclusive license. The answer is no since a licensing contract is not a zero cost option. It is associated with high transactions costs and frequently with lump sum payments and reimbursements of the UC patent's prosecution fees. Thus, if the licensee was able to conduct the follow-on research absent the license then he would opt against it to avoid the significant costs and therefore these patents would not enter our treated group.

A final point in terms of licensees is the assumption made regarding licensee citations. We've postulated that licensee citations, to a large extent, reflect follow-on research on the licensed patent. We've given evidence that citations to a large extent reflect knowledge spillovers. However, another plausible interpretation is that licensees merely build a patent thicket over the licensed patent without conducting any substantial follow-on research. This explanation can actually reverse the interpretation of our findings since the license functioned as a means to impede follow-on research and amplify the patent "thicket" problem. However, this explanation is unlikely given that non-licensees are not discouraged due to the license indicating that a patent "thicket" is not likely. Also, the variation in the timing of licensee citations indicates a more random pattern consistent with arrival of innovations and not with a systematic building of patent thickets.

In terms of non-licensee citations, we first should also acknowledge that the non-licensees may not cite the UC patent due to related research but due to legal reasons as well. That is, firms that conduct research on the area of the licensed patent maybe more inclined to cite the UC patent if they know that a firm has licensed the patent. To the extent that this scenario is true, it will inflate our estimates for follow-on research and therefore we should be more conservative on interpreting the non-licensee citations change as an increase in research. Also, if examiners are positively affected by the licensing event and are more inclined to add the citation of the licensed patents, then this also upwards biasing our estimates. Finally, non-licensee citations may have had the tendency to increase prior to licensing which is a clear endogeneity issue. We have tried to show in the Data Section and in this section that the control groups are not likely to upward bias our estimates. However, if endogeneity issues exist and we haven't tackled them appropriately, then it is likely for the estimate of the exclusive coefficient on non-licensee citations to be upwards biased.

Conclusion

The concerns regarding management of academic technologies have been focused on the ramifications it may have on their diffusion and whether these inventions realize their full potential. In particular the types of technology transfer of academic inventions to the marketplace have been met with skepticism on whether they enhance or dissuade follow-on research. The most prevalent mean of transferring technology is the use of exclusive licensing; a type of licensing which has been encouraged by the Bayh-Dole Act, a legislation that in large part is credited for this technology management transformation by universities. Even though case studies are at a hand shedding some light on the role of exclusive licensing on follow-on research and diffusion, there hasn't been any rigorous empirical analysis on this question.

This paper, by exploiting a unique dataset of UC patents and their associated licensing history, examines the role of exclusive licensing on the diffusion of these academic patented inventions. By approximating follow-on research with patent citations, we find that exclusive licensing increases licensee citations. We find this increase to be more prevalent in the case of start-ups where inventor involvement is more likely. This implies that in the case of start-ups there is a clear knowledge advantage of the patent potential than in the case of an established firm. Nonetheless, note that also in the case of established firms we observe follow-on research. We find follow-on research to take place in all kinds of technology fields and we've shown that licensees produce innovations that are in the same narrow field as the licensed patent.

Moreover, we find no evidence to support the concern that non-licensees may be discouraged by the exclusive license. On the contrary, we find that non-licensee citations increase due to the exclusive license. This supports the view that exclusive licensing functions as a signal of quality for the patent or as a signal to competitors that the non-licensee enters a new research path in which case the competitors should also engage on that research path as well. We support this explanation by showing that non-licensee citations increase more prevalently for established firms where the signal may be stronger than in the case of start-ups. Moreover, we find that more significant related research takes place by non-licensees in the case of Computers, Communications, Electrical, Electronic and Mechanical technologies rather than in the case of Chemical, Drugs and Medical technologies. We argue that the more pronounced significance of non-licensee citations for patents in the latter technologies to be attributed to the substantially more time required for subsequent R&D and the higher frequency of start-ups in the case of Chemical, Drugs and Medical technologies. Finally, in the case of Chemical, Drugs and Medical technologies we find that non-licensees may invent around the UC patent while in the case of Computers, Communications, Electrical, Electronic and Mechanical technologies the bulk of non-licensee related research is patents in different technological fields as the licensed patent.

These findings have a series of limitations. First, to the extent that the endogeneity problem still persists then the results on non-licensee citations are upwards biased. Thus, these strong statistically significant positive coefficients may be inflated and warrant caution when interpreting the results. Second, the use of patent citations is merely a metric of follow-on research. Perhaps, surveys which can measure the true magnitude of follow-on research to licensees and diffusion to non-licensees can also shed more light on these findings. Third, and perhaps more importantly, this study has focused on one university; even though during that period it was the biggest patenting university, it may not be representative of academic technology management. Nonetheless, there is only a handful of universities that have diligently kept datasets with so early issued patents. This is important for answering this question since as it was seen citation patterns are non-trivial and seem to unfold after fifteen to seventeen years from issue year of the patent.

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Table 1. Variable names and definitions

Variable	Definition
Endogenous Variables	
Cites	Total citations to the patent per period/year.
CitesNetAssignee	Total citations net assignee citations to the patent per period/year.
LicCites	Licensee citations to the patent per period/year.
NonLicCites	Total citations net assignee and licensee citations to the patent per period/year.
CitesByFirms	Citations by firms net of assignee and licensee citations to the patent per period/year.
CitesByUnivs	Citations by universities net of assignee and licensee citations to the patent per period/year.
LicCitesSameIPC	Number of licensee citations per period that have the same IPC classification as the UC patent
LicCitesDiffIPC	Number of licensee citations per period that have different IPC classification as the UC patent
NonLicCitesSameIPC	Number of non-licensee citations per period that have the same IPC classification as the UC patent
NonLicCitesDiffIPC	Number of non-licensee citations per period that different IPC classification as the UC patent
LicCitesSameIPCTech	Number of licensee citations per period that have the same broad technology field based on the IPC classification as the UC patent
LicCitesDiffIPCTech	Number of licensee citations per period that have different broad technology field based on the IPC classification as the UC patent
NonLicCitesSameIPC	Number of non-licensee citations per period that have the same broad technology field based on the IPC classification as the UC patent
NonLicCitesDiffIPCTech	Number of non-licensee citations per period that different broad technology field based on the IPC classification as the UC patent
LicCitesSameUSC	Number of licensee citations per period that have the same US classification as the UC patent
LicCitesDiffUSC	Number of licensee citations per period that have different US classification as the UC patent
NonLicCitesSameUSC	Number of non-licensee citations per period that have the same US classification

	as the UC patent
NonLicCitesDiffUSC	Number of non-licensee citations per period that different US classification as the UC patent
LicCitesSameUSCTech	Number of licensee citations per period that have the same broad technology field based on the US classification as the UC patent
LicCitesDiffUSCTech	Number of licensee citations per period that have different broad technology field based on the US classification as the UC patent
NonLicCitesSameUSC	Number of non-licensee citations per period that have the same broad technology field based on the US classification as the UC patent
NonLicCitesDiffUSCTech	Number of non-licensee citations per period that different broad technology field based on the US classification as the UC patent
LicensedPatent	LicensedPatent=1 if the patent has ever been licensed exclusively and LicensedPatent=0 if patent has remained unlicensed.
LicensedLate	LicensedLate=1 for late licensed patents and LicensedLate=0 for early licensed Patents
LicensedAfterGrant	LicensedAfterGrant=1 for patents licensed after grant and LicensedAfterGrant=0 for patents licensed before grant
Exogenous Variables	
Exclusive	Exclusive=1 if the patent is under an exclusive license at that period and Exclusive=0 otherwise
ExcExp	ExclusiveExpire=1 if an exclusively licensed patent has expired or lapsed and ExclusiveExpire=0 otherwise
UnLicExp	UnlicensedExpire =1 if an unlicensed patent has expired or lapsed and UnlicensedExpire=0 otherwise
RevokeLicense	RevokeLicense=1 if patent has been licensed but is not in effect at the particular period and Revokelicense=0 otherwise. Note that RevokeLicense=1 if patent has lapsed but RevokeLicense=0 if patent has expired.
Patent Characteristics	
Claims	Number of claims of the patent.
NumberOfUSClass	Number of US Classifications of the patent.
NumberOfIPC	Number of International Patent Classifications of the patent.

BackCites	Number of the patents the patent is citing.
BackCitesJournals	Number of scientific papers the patent is citing.
IssueYear	Issue year of the patent.
AppLength	Time in years that lapsed from filing date to issue date of the patent.
NumberOfSecrecies	Number of secrecy agreements signed for the patent prior to license.
NumberOfLetters	Number of letter agreements signed for the patent prior to license.

Table 2. Frequency of inventions by number of patents within an invention.

Number of Patents Per Invention	**Number of Inventions**	**Percent of Inventions**
1	1,419	69.90%
2	358	17.61%
3	131	6.44%
4	49	2.41%
5	27	1.33%
6	16	0.79%
7	11	0.54%
8	9	0.44%
9	4	0.20%
10	2	0.10%
11	1	0.05%
12	1	0.05%
15	1	0.05%
16	1	0.05%
18	1	0.05%
Total	2,033	100%

Table 3. Frequency of patents by licensing status.

	1	2a	2b	3a	3b	4a	4b
	Number of Patents	**Patents Licensed on or Before the Year of Grant and Were Not Abandoned**		**Patents Licensed on or Before the Year of Grant or Within Two Years Before Grant and Were Not Abandoned**		**Patents First Licensed The Years Following The Year After Grant and Were Not Abandoned**	
		(License Not Revoked)	**(License Revoked)**	**(License Not Revoked)**	**(License Revoked)**	**(License Not Revoked)**	**(License Revoked)**
Unlicensed Patents	1,517	-	-	-	-	-	-
Only Exclusively Licensed	1,253	625	321	128	116	228	79
Only Nonexclusively Licensed Patents	178	58	41	32	17	56	23
Exclusively and Nonexclusively Licensed Patents	284	195	48	45	17	34	7

Table 4. Summary statistics of patents by licensing status.

	Exclusive		Non-Exclusive		Mix License		Unlicensed	
	Obs	Mean	Obs	Mean	Obs	Mean	Obs	Mean
Cites	15601	1.28	2557	1.60	3511	1.40	25258	0.77
		(3.12)		(3.77)		(3.10)		(1.98)
CitesNetAssignee	15601	1.18	2557	1.54	3511	1.29	25258	0.73
		(2.98)		(3.67)		(3.03)		(1.94)
LicCites	15601	0.11	2557	0.07	3511	0.09	-	-
		(0.90)		(0.44)		(0.76)		-
NonLicCites	15601	1.08	2557	1.47	3511	1.20	25258	0.73
		(2.76)		(3.47)		(2.83)		(1.94)
CitesByFirms	15601	0.76	2557	1.08	3511	0.81	25258	0.52
		(2.28)		(2.83)		(2.27)		(1.60)
CitesByUnivs	15601	0.11	2557	0.12	3511	0.15	25258	0.07
		(0.45)		(0.53)		(0.51)		(0.32)
Claims	1253	18.91	178	14.31	284	16.26	1517	15.16
		(17.26)		(9.77)		(13.18)		(12.38)
NumberOfUSClass	1253	5.14	178	5.76	284	6.83	1517	5.15
		(3.38)		(4.87)		(5.07)		(3.98)
NumberOfIPC	1253	6.71	178	5.03	284	7.72	1517	4.90
		(6.92)		(4.86)		(5.85)		(5.28)
BackCites	1253	12.34	178	5.86	284	9.27	1517	6.70
		(18.83)		(7.48)		(12.69)		(8.32)
BackCitesJournals	1253	26.33	178	13.92	284	23.02	1517	13.21
		(41.98)		(15.86)		(27.91)		(20.03)
IssueYear	1253	1997.5	178	1995.64	284	1997.64	1517	1993.35
		(5.58)		(6.31)		(5.74)		(7.19)
Period first Lisensed	1253	(3.11)	178	0.36	284	(3.90)	0	0.00
		(6.28)		(5.49)		(4.49)		0.00
AppLength	1253	3.00	178	2.85	284	3.11	1517	2.63
		(1.77)		(1.57)		(1.62)		(1.31)
NumberOfSecrecies	1253	1.05	178	1.67	284	2.10	1517	1.42
		(2.48)		(3.35)		(3.90)		(3.24)
NumberOfLetters	1253	0.30	178	0.55	284	0.96	1517	0.20
		(0.60)		(1.57)		(1.35)		(0.48)

Table 5. Summary statistics of patents licensed after grant. Distinguish between early and late licensed patents. Early licensed patents refer to patents licensed after grant and within five years from grant, while late licensed patents refer to patents licensed on or after the sixth year from grant

	Patents Licensed Exclusively Between 1 and 5 Years After Grant		**Patents Licensed Exclusively on or the 6th Year After Grant**		
	Obs	Mean	Obs	Mean	P-Value
Cites	1798	2.17	1582	1.91	0.0624
		(4.24)		(3.49)	
CitesNetAssignee	1798	2.05	1582	1.87	0.16
		(4.13)		(3.44)	
LicCites	1798	0.35	1582	0.12	0
		(1.92)		(0.91)	
CitesNetAssigneeNetLicensee	1798	1.71	1582	1.75	0.73
		(3.67)		(3.25)	
CitesByFirms	1798	1.17	1582	1.21	0.66
		(2.92)		(2.55)	
CitesByUniver	1798	0.18	1582	0.20	0.33
		(0.65)		(0.66)	
Claims	126	18.71	102	16.7	0.29
		-14.78		-13.64	
NumberOfUSClass	126	5.45	102	5.07	0.44
		-4.15		-3.04	
NumberOfIPC	126	7.41	102	5.59	0.03
		-7.44		-4.41	
BackCites	126	8.4	102	11.64	0.07
		-12.17		-14.89	
BackCitesJournals	126	10.42	102	9.36	0.56
		-12.26		-14.98	
IssueYear	126	1995.73	102	1994.49	0.09
		-5.51		-5.29	
AppLength	126	2.62	102	2.26	0.02
		-1.32		-0.8	
NumberOfSecrecies	126	1.98	102	1.36	0.18
		-4.17		-2.26	
NumberOfLetters	126	0.35	102	0.5	0.09
		-0.6		-0.73	

Table 6. Probit regressions. Standard errors in parentheses. Column 1 is comprised only by patents licensed after grant. LicensedLate=1 for patents first licensed after the sixth year since grant and LicensedLate=0 for patents licensed within five years since grants. Column 2 is comprised by the group of interest and patents licensed within two years before grant. LicensedAfterGrant=1 for patents licensed after grant (i.e. group of interest) and LicensedAfterGrant=0 for patents licensed before grant. Column 3 is comprised by the group of interest (LicensedAfterGrant=1) and all patents exclusively licensed before grant (LicensedAfterGrant=0). Column 4 is comprised by the group of interest (LicensedPatent=1) and unlicensed patents that haven't lapsed (LicensedPatent=0).

	(1)	(2)	(3)	(4)
VARIABLES	LicensedLate	LicensedAfterGrant	LicensedAfterGrant	LicensedPatent
Claims	-0.00232	-0.00214	-0.00138	0.00200**
	(0.00289)	(0.00188)	(0.000866)	(0.000833)
NumberOfUSClass	0.00441	0.00129	0.0151***	-0.00163
	(0.00964)	(0.00713)	(0.00402)	(0.00278)
NumberOfIPC	-0.0182***	-0.00381	-0.000488	0.00659***
	(0.00527)	(0.00389)	(0.00199)	(0.00189)
BackCites	0.00481	0.000331	-9.88e-05	0.00427***
	(0.00298)	(0.00195)	(0.000679)	(0.00113)
BackCitesJournals	-0.000163	-0.00456***	-0.00357***	-0.00412***
	(0.00270)	(0.00160)	(0.000640)	(0.000746)
IssueYear	-0.00671	-0.00750	-0.0133***	0.00732***
	(0.00659)	(0.00553)	(0.00280)	(0.00167)
ApplicationLength	-0.0704*	-0.0490**	-0.0361***	-0.0273***
	(0.0367)	(0.0239)	(0.0109)	(0.0101)
NumberOfSecrecies	-0.00644	0.00889	0.0258***	0.00104
	(0.0113)	(0.00837)	(0.00632)	(0.00360)
NumberOfLetters	0.0874	-0.0209	0.0731***	0.0573***
	(0.0552)	(0.0380)	(0.0234)	(0.0195)
Observations	228	356	853	1,165

Table 7. Summary statistics for the group of interest and "candidates" control groups. P-values displayed denote the difference of each control group with the group of interest.

	Patents First Licensed The Years Following The Year After Grant and Were Not Abandoned		**Patents Licensed Within Two Years Before Grant and Were Not Abandoned**			**Patents Licensed Before Grant and Were Not Abandoned**			**Unlicensed Patents that Haven't Lapsed**		
	1a	**1b**	**2a**	**2b**	**2c**	**3a**	**3b**	**3c**	**4a**	**4b**	**4c**
	Obs	Mean	Obs	Mean	P-Value	Obs	Mean	P-Value	Obs	Mean	P-Value
Cites	3380	2.05	1667	1.87	0.14	6775	1.24	0.00	15337	0.78	0.00
		(3.91)		(4.19)			(3.13)			(2.05)	
CitesNetAssignee	3380	1.97	1667	1.70	0.02	6775	1.08	0.00	15337	0.73	0.00
		(3.83)		(3.97)			(2.90)			(2.00)	
LicCites	3380	0.24	1667	0.16	0.04	6775	0.10	0.00	15337	-	-
		(1.54)		(0.98)			(0.80)			-	
NonLicCites	3380	1.73	1667	1.55	0.09	6775	0.99	0.00	15337	0.73	0.00
		(3.48)		(3.75)			(2.65)			(2.00)	
CitesByFirms	3380	1.19	1667	1.08	0.21	6775	0.72	0.00	15337	0.52	0.00
		(2.75)		(3.12)			(2.25)			(1.64)	
CitesByUniver	3380	0.19	1667	0.17	0.41	6775	0.10	0.00	15337	0.06	0.00
		(0.66)		(0.59)			(0.41)			(0.33)	
Claims	228	17.81	128	20.20	0.15	625	21.07	0.02	937	15.17	0.00
		(14.28)		(16.20)			(20.10)			(12.84)	
NumberOfUSClass	228	5.28	128	5.65	0.38	625	4.76	0.04	937	5.22	0.84
		(3.69)		(3.98)			(3.23)			(4.09)	
NumberOfIPC	228	6.60	128	7.76	0.12	625	6.79	0.72	937	5.10	0.00
		(6.32)		(7.59)			(7.09)			(5.40)	
BackCites	228	9.85	128	11.09	0.44	625	14.52	0.00	937	6.76	0.00
		(13.52)		(16.19)			(20.88)			(8.55)	

BackCitesJournals	228	9.95	128	18.45	0.00	625	35.59	0.00	937	14.84	0.00
		(13.52)		(24.27)			(52.12)			(21.98)	
IssueYear	228	1995.18	128	1996.98	0.00	625	1999.16	0.00	937	1993.63	0.00
		(5.44)		(5.21)			(5.51)			(8.03)	
Period first Lisensed After Grant	228	5.63	128	(1.13)	0.00	625	(6.74)	0.00	0	-	-
		(3.70)		(0.81)			(4.64)			-	
AppLength	228	2.46	128	2.89	0.00	625	3.28	0.00	937	2.73	0.00
		(1.13)		(1.42)			(2.06)			(1.42)	
NumberOfSecrecies	228	1.70	128	1.80	0.80	625	0.71	0.00	937	1.47	0.34
		(3.46)		(3.16)			(1.94)			(3.30)	
NumberOfLetters	228	0.42	128	0.48	0.37	625	0.22	0.00	937	0.23	0.00
		(0.66)		(0.73)			(0.54)			(0.51)	

Table 8. Baseline regressions with baseline data specifications. Columns 1 and 2 comprise of exclusively licensed patents after grant which license was not revoked. Columns 3 and 4 include patents exclusively licensed within two years before grant and license was not revoked. Columns 5 and 6 include patents exclusively licensed before grant and license was not revoked. Columns 7 and 8 are comprised of patents licensed exclusively after grant and were not revoked and unlicensed patents that haven't lapsed.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites
Exclusive	0.144**	0.746*	0.137**	0.745**	0.234**	0.586**	0.600***	0.221
	(0.0588)	(0.380)	(0.0622)	(0.309)	(0.102)	(0.249)	(0.155)	(0.227)
ExcExp	-0.178	-0.255	-0.0852	0.454	0.0816	0.529	0.392	0.165
	(0.297)	(1.017)	(0.150)	(0.825)	(0.107)	(0.346)	(0.268)	(0.408)
UnLicExp	0	0	0	0	0	0	-0.0996	-0.165
	(0)	(0)	(0)	(0)	(0)	(0)	(0.114)	(0.177)
Constant	0.412	0.406	0.813***	30.66***	0.891***	30.47***	-0.0440	-0.314
	(0.451)	(0.462)	(0.233)	(0.358)	(0.179)	(0.205)	(0.151)	(0.533)
Observations	3,380	3,380	5,047	5,047	10,155	10,155	18,717	18,717
R-squared	0.094	0.187	0.077	0.162	0.037	0.127	0.061	0.079
# of Patents	228	228	356	356	853	853	1,165	1,165
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 9. Baseline regressions comprised with non-exclusively licensed patents. Columns 1 and 2 comprise of nonexclusively licensed patents after grant which license was not revoked. Columns 3 and 4 include patents nonexclusively licensed within two years before grant and license was not revoked. Columns 5 and 6 include patents nonexclusively licensed before grant and license was not revoked. Columns 7 and 8 are comprised by patents licensed nonexclusively after grant and were not revoked and unlicensed patents that haven't lapsed.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites
NonExclusive	0.0623	0.813	0.0706*	0.347	0.0476	0.171	0.268***	0.00817
	(0.0731)	(0.550)	(0.0422)	(0.397)	(0.0340)	(0.373)	(0.0852)	(0.364)
NonExcExp	0.249	1.405	0.0697	0.255	0.0679	0.330	0.538***	0.0135
	(0.182)	(1.316)	(0.128)	(0.859)	(0.123)	(0.834)	(0.133)	(0.379)
UnLicExp	0	0	0	0	0	0	-0.0935	-0.0789
	(0)	(0)	(0)	(0)	(0)	(0)	(0.112)	(0.130)
Constant	-0.233	-3.251**	-0.0348	-1.745*	-0.0234	0.882	0.0695	0.0981
	(0.231)	(1.548)	(0.148)	(1.019)	(0.0790)	(0.729)	(0.146)	(0.168)
Observations	879	879	1,398	1,398	1,686	1,686	16,216	16,216
R-squared	0.103	0.179	0.065	0.135	0.053	0.138	0.066	0.073
# of Patents	56	56	88	88	114	114	993	993
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 10. Baseline data specifications of Table 8 comprised only of patents that have stemmed from government sponsored research grants.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites
Exclusive	0.0709	1.369**	0.0639*	1.398***	0.0651***	1.051***	0.549***	0.712**
	(0.0631)	(0.562)	(0.0342)	(0.484)	(0.0246)	(0.397)	(0.0955)	(0.329)
ExcExp	0	0	0	0	0	0	0.893***	0.840**
	(0)	(0)	(0)	(0)	(0)	(0)	(0.192)	(0.332)
UnLicExp	0	0	0	0	0	0	-0.799***	-0.951***
	(0)	(0)	(0)	(0)	(0)	(0)	(0.301)	(0.339)
Constant	-0.0802	-0.894	-0.0145	-0.163	-0.00446	-0.427	-0.826**	-0.989**
	(0.0572)	(0.586)	(0.0461)	(0.646)	(0.0164)	(0.520)	(0.373)	(0.451)
Observations	877	877	1,290	1,290	2,191	2,191	3,646	3,646
R-squared	0.057	0.257	0.042	0.236	0.028	0.176	0.063	0.098
# of Patents	74	74	114	114	227	227	318	318
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 11. Baseline data specifications of Table 8 excluding patents that have stemmed from research grants where the sponsor becomes the licensee.

VARIABLES	(1) LicCites	(2) NonLicCites	(3) LicCites	(4) NonLicCites	(5) LicCites	(6) NonLicCites	(7) LicCites	(8) NonLicCites
Exclusive	0.156**	0.782*	0.146**	0.787**	0.249**	0.640**	0.603***	0.225
	(0.0650)	(0.402)	(0.0671)	(0.322)	(0.109)	(0.258)	(0.159)	(0.233)
ExcExp	-0.167	-0.206	-0.0733	0.519	0.0971	0.591*	0.397	0.169
	(0.295)	(1.033)	(0.149)	(0.839)	(0.109)	(0.355)	(0.266)	(0.409)
UnLicExp	0	0	0	0	0	0	-0.0995	-0.163
	(0)	(0)	(0)	(0)	(0)	(0)	(0.114)	(0.177)
Constant	0.426	0.440	0.828***	30.70***	0.0847	0.0626	-0.0328	-0.347
	(0.449)	(0.475)	(0.228)	(0.362)	(0.320)	(0.246)	(0.151)	(0.566)
Observations	3,244	3,244	4,831	4,831	9,531	9,531	18,581	18,581
R-squared	0.095	0.186	0.078	0.163	0.037	0.129	0.062	0.078
# of Patents	217	217	338	338	801	801	1,154	1,154
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 12. Baseline data specifications of Table 8 including patents of which the license has been revoked or in the case of unlicensed patents that have lapsed.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites
Exclusive	0.0748**	0.285	0.0900***	0.363	0.156**	0.275	0.452***	0.111
	(0.0362)	(0.310)	(0.0340)	(0.223)	(0.0632)	(0.191)	(0.131)	(0.187)
revokelicense	-0.396	-0.135	-0.179	0.206	0.0624	0.278	0.341***	-0.162
	(0.347)	(0.401)	(0.148)	(0.288)	(0.0841)	(0.234)	(0.0848)	(0.415)
ExcExp	-0.343	-0.180	-0.247	0.177	0.0459	0.528*	0.474**	-0.0160
	(0.338)	(0.516)	(0.212)	(0.362)	(0.120)	(0.274)	(0.201)	(0.274)
UnLicExp	0	0	0	0	0	0	-0.117*	-0.0505
	(0)	(0)	(0)	(0)	(0)	(0)	(0.0681)	(0.0674)
Constant	0.796***	30.42***	-0.220*	-14.14***	-0.705***	-17.29***	0.0310	-0.391
	(0.284)	(0.321)	(0.133)	(0.418)	(0.112)	(0.349)	(0.101)	(0.506)
Observations	4,678	4,678	8,124	8,124	15,601	15,601	29,936	29,936
R-squared	0.068	0.144	0.049	0.125	0.024	0.104	0.061	0.073
# of Patents	307	307	551	551	1,253	1,253	1,824	1,824
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 13. Baseline data specifications of Table 8 excluding patents of which the license covers more than one patent. Thus, only uniquely licensed patents have been used to estimated these regressions.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites
Exclusive	0.224*	1.063*	0.143	0.764	0.137	0.624	0.470***	0.526
	(0.133)	(0.624)	(0.0922)	(0.545)	(0.0887)	(0.511)	(0.123)	(0.507)
ExcExp	0.114	0.239	0.0789	0.180	0.165	0.192	0.514***	0.541
	(0.183)	(1.274)	(0.159)	(1.056)	(0.195)	(1.025)	(0.145)	(0.812)
UnLicExp	0	0	0	0	0	0	-0.107	-0.0667
	(0)	(0)	(0)	(0)	(0)	(0)	(0.115)	(0.126)
Constant	0.106	1.261*	-0.167	0.418	-0.279	0.271	0.0838	0.0867
	(0.0865)	(0.650)	(0.196)	(1.003)	(0.233)	(0.998)	(0.148)	(0.159)
Observations	752	752	1,029	1,029	1,155	1,155	16,089	16,089
R-squared	0.127	0.236	0.102	0.195	0.091	0.190	0.067	0.072
# of Patents	44	44	62	62	73	73	981	981
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 14. Baseline data specifications of Table 8 excluding late licensed patents. Thus, only early exclusively licensed patents comprise the treated group.

VARIABLES	(1) LicCites	(2) NonLicCites	(3) LicCites	(4) NonLicCites	(5) LicCites	(6) NonLicCites	(7) LicCites	(8) NonLicCites
Exclusive	0.106	0.236	0.163	0.670**	0.307*	0.710**	0.489**	0.317
	(0.107)	(0.427)	(0.122)	(0.329)	(0.172)	(0.288)	(0.229)	(0.267)
ExcExp	1.111	-2.538	0.502	-0.223	0.298	0.603	0.362	0.244
	(1.164)	(1.820)	(0.627)	(1.197)	(0.202)	(0.407)	(0.386)	(0.412)
UnLicExp	0	0	0	0	0	0	-0.0108	-0.196
	(0)	(0)	(0)	(0)	(0)	(0)	(0.165)	(0.183)
Constant	0.257	-0.846	-0.0120	-0.574	0.983***	30.41***	-0.0677	-0.336
	(0.230)	(0.685)	(0.0968)	(0.565)	(0.0831)	(0.287)	(0.195)	(0.561)
Observations	1,798	1,798	3,465	3,465	8,573	8,573	17,135	17,135
R-squared	0.129	0.238	0.088	0.175	0.035	0.131	0.063	0.074
# of Patents	126	126	254	254	751	751	1,063	1,063
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 15. Baseline data specifications of Table 8 excluding patents that have received secrecy agreements. Thus, only patents with no secrecy agreements comprise the samples below.

VARIABLES	(1) LicCites	(2) NonLicCites	(3) LicCites	(4) NonLicCites	(5) LicCites	(6) NonLicCites	(7) LicCites	(8) NonLicCites
Exclusive	0.0914**	1.479***	0.0610*	1.330***	0.138***	0.956***	0.333***	0.447*
	(0.0355)	(0.497)	(0.0340)	(0.390)	(0.0506)	(0.269)	(0.0790)	(0.248)
ExcExp	-0.200	1.095	-0.262	1.167*	0.0836	1.012***	0.573***	0.608
	(0.338)	(0.830)	(0.246)	(0.595)	(0.0819)	(0.304)	(0.182)	(0.519)
UnLicExp	0	0	0	0	0	0	-0.118	-0.0485
	(0)	(0)	(0)	(0)	(0)	(0)	(0.125)	(0.133)
Constant	0.448	0.975**	0.127	0.0225	0.200	-0.148	0.0458	-0.361
	(0.354)	(0.449)	(0.231)	(0.434)	(0.248)	(0.291)	(0.156)	(0.465)
Observations	1,889	1,889	2,868	2,868	6,989	6,989	12,810	12,810
R-squared	0.060	0.227	0.041	0.191	0.022	0.139	0.052	0.070
# of Patents	119	119	189	189	588	588	702	702
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 16. Baseline data specifications of Table 8 excluding patents that have licensed by start-ups. Thus, only patents licensed to established firms comprise the samples below.

VARIABLES	(1) LicCites	(2) NonLicCites	(3) LicCites	(4) NonLicCites	(5) LicCites	(6) NonLicCites	(7) LicCites	(8) NonLicCites
Exclusive	0.179	0.805	0.188	0.767**	0.275*	0.553*	0.674***	0.158
	(0.109)	(0.487)	(0.122)	(0.365)	(0.144)	(0.286)	(0.208)	(0.258)
ExcExp	-0.238	-0.443	-0.0438	0.374	0.110	0.464	0.396	0.0750
	(0.328)	(1.130)	(0.151)	(0.912)	(0.101)	(0.378)	(0.257)	(0.436)
UnLicExp	0	0	0	0	0	0	-0.0977	-0.178
	(0)	(0)	(0)	(0)	(0)	(0)	(0.115)	(0.177)
Constant	0.837**	30.45***	0.885***	30.70***	0.0559	0.131	-0.00230	-0.299
	(0.333)	(0.491)	(0.207)	(0.364)	(0.335)	(0.242)	(0.152)	(0.551)
Observations	2,430	2,430	3,667	3,667	8,108	8,108	17,651	17,651
R-squared	0.113	0.194	0.090	0.167	0.040	0.126	0.064	0.074
# of Patents	155	155	240	240	630	630	1,080	1,080
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Tab 17. Baseline data specifications of Table 8 excluding patents that have licensed by established firm. Thus, only patents licensed to start-ups comprise the samples below.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites
Exclusive	0.167*	0.711	0.139**	0.727	0.151***	0.592	0.227**	0.579
	(0.0974)	(0.697)	(0.0615)	(0.548)	(0.0533)	(0.482)	(0.0977)	(0.626)
ExcExp	0.410	2.429	0.377*	2.498*	0.387*	2.377	0.481*	2.324
	(0.259)	(1.657)	(0.221)	(1.489)	(0.215)	(1.442)	(0.257)	(1.587)
UnLicExp	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Constant	0.133*	1.246**	0.127*	1.642***	-0.295*	-1.971**	0.193**	1.153**
	(0.0731)	(0.490)	(0.0683)	(0.494)	(0.175)	(0.976)	(0.0845)	(0.505)
Observations	950	950	1,380	1,380	2,047	2,047	1,066	1,066
R-squared	0.068	0.194	0.050	0.168	0.052	0.156	0.064	0.174
# of Patents	73	73	116	116	223	223	85	85
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 18. Baseline data specifications of Table 8 comprised only by patents in Chemical, Drugs and Medical technology fields.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites
Exclusive	0.196**	0.129	0.153*	0.221	0.197**	0.193	0.497**	-0.0923
	(0.0927)	(0.412)	(0.0914)	(0.344)	(0.0935)	(0.306)	(0.194)	(0.304)
ExcExp	-1.155	0.105	-0.581	0.552	-0.121	0.434	0.0416	-0.405
	(1.024)	(0.808)	(0.541)	(0.608)	(0.326)	(0.431)	(0.364)	(0.364)
UnLicExp	0	0	0	0	0	0	-0.352***	-0.126
	(0)	(0)	(0)	(0)	(0)	(0)	(0.133)	(0.139)
Constant	0.00615	0.337	-0.177	0.290	0.694**	30.28***	0.293**	-0.737
	(0.658)	(0.479)	(0.499)	(0.246)	(0.349)	(0.198)	(0.141)	(0.951)
Observations	2,098	2,098	3,431	3,431	6,875	6,875	13,222	13,222
R-squared	0.125	0.220	0.101	0.177	0.056	0.144	0.065	0.076
# of Patents	142	142	246	246	629	629	849	849
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 19 Baseline data specifications of Table 8 comprised only by patents in Computers, Communications, Electrical , Electronic and Mechanical technology fields.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites	LicCites	NonLicCites
Exclusive	0.108	1.708***	0.127**	1.744***	0.150***	1.225***	0.924***	0.996***
	(0.0707)	(0.597)	(0.0552)	(0.534)	(0.0503)	(0.404)	(0.178)	(0.337)
ExcExp	0.0881	0.608	0.100	0.720	0.120***	0.409	1.295***	1.868
	(0.119)	(1.194)	(0.105)	(1.020)	(0.0370)	(0.443)	(0.375)	(1.154)
UnLicExp	0	0	0	0	0	0	0.146	-0.108
	(0)	(0)	(0)	(0)	(0)	(0)	(0.291)	(0.339)
Constant	0.0334	-1.470*	-0.126	2.753	-0.111	2.460	-0.0411	0.395
	(0.0553)	(0.872)	(0.116)	(2.798)	(0.119)	(3.307)	(0.360)	(0.397)
Observations	1,165	1,165	1,454	1,454	3,024	3,024	4,185	4,185
R-squared	0.059	0.262	0.047	0.244	0.038	0.174	0.092	0.148
# of Patents	80	80	101	101	204	204	253	253
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 20. All columns are comprised only by patents licensed after grant and license was not abandoned. Patents only in the fields of Chemical, Drugs and Medical technologies. Endogenous variables names are described in Table 1.

VARIABLES	(1) LicCites SameUSC	(2) LicCites DiffUSC	(3) NonLicCites SameUSC	(4) NonLicCites DiffUSC	(5) LicCites SameUSCTech	(6) LicCites DiffUSCTech	(7) NonLicCites SameUSCTech	(8) NonLicCites DiffUSCTech
Exclusive	0.0759**	0.120*	-0.0446	0.174	0.126**	0.0695	0.197	-0.0681
	(0.0363)	(0.0715)	(0.130)	(0.342)	(0.0524)	(0.0465)	(0.270)	(0.232)
ExcExp	-0.112	-1.043	-0.401	0.507	-0.00993	-1.145	0.0389	0.0663
	(0.173)	(0.893)	(0.466)	(0.609)	(0.260)	(0.956)	(0.624)	(0.370)
UnLicExp	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Constant	-0.0426	0.0488	-0.0784	0.416	-0.0154	0.0215	0.164	0.173
	(0.0867)	(0.616)	(0.250)	(0.340)	(0.137)	(0.582)	(0.325)	(0.253)
Observations	2,098	2,098	2,098	2,098	2,098	2,098	2,098	2,098
R-squared	0.054	0.118	0.375	0.134	0.090	0.101	0.211	0.123
# of Patents	142	142	142	142	142	142	142	142
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 21. All columns are comprised only by patents licensed after grant and license was not abandoned. Patents only in the fields of Chemical, Drugs and Medical technologies. Endogenous variables names are described in Table 1.

VARIABLES	(1) LicCites SameIPC	(2) LicCites DiffIPC	(3) NonLicCites SameIPC	(4) NonLicCites DiffIPC	(5) LicCites SameIPCTech	(6) LicCites DiffIPCTech	(7) NonLicCites SameIPCTech	(8) NonLicCites DiffIPCTech
Exclusive	0.0342	0.161**	0.0833	0.0459	0.0843**	0.111*	0.179	-0.0494
	(0.0222)	(0.0808)	(0.203)	(0.292)	(0.0355)	(0.0642)	(0.259)	(0.269)
ExcExp	-0.0514	-1.104	0.289	-0.184	-0.105	-1.050	0.310	-0.205
	(0.104)	(1.025)	(0.370)	(0.551)	(0.210)	(0.919)	(0.456)	(0.553)
UnLicExp	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Constant	-0.0444	0.0506	0.237	0.0999	-0.0480	0.0541	0.314	0.0229
	(0.0612)	(0.626)	(0.191)	(0.363)	(0.117)	(0.588)	(0.251)	(0.372)
Observations	2,098	2,098	2,098	2,098	2,098	2,098	2,098	2,098
R-squared	0.053	0.125	0.083	0.258	0.070	0.122	0.096	0.261
# of Patents	142	142	142	142	142	142	142	142
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 22. All columns are comprised only by patents licensed after grant and license was not abandoned. Patents only in the fields of Computers, Communications, Electrical , Electronic and Mechanical technologies. Endogenous variables names are described in Table 1.

VARIABLES	(1) LicCites SameUSC	(2) LicCites DiffUSC	(3) NonLicCites SameUSC	(4) NonLicCites DiffUSC	(5) LicCites SameUSCTech	(6) LicCites DiffUSCTech	(7) NonLicCites SameUSCTech	(8) NonLicCites DiffUSCTech
Exclusive	0.0867	0.0210	0.221	1.486***	0.0929	0.0148	0.317	1.391***
	(0.0627)	(0.0218)	(0.182)	(0.520)	(0.0626)	(0.0203)	(0.255)	(0.451)
ExcExp	0.0987	-0.0106	0.483*	0.125	0.104	-0.0161	0.543	0.0652
	(0.103)	(0.0609)	(0.285)	(1.127)	(0.103)	(0.0527)	(0.499)	(0.854)
UnLicExp	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Constant	0.0527	-0.0193	0.329	-1.799**	0.0357	-0.00235	-1.249***	-0.221
	(0.0389)	(0.0413)	(0.204)	(0.786)	(0.0395)	(0.0351)	(0.411)	(0.560)
Observations	1,165	1,165	1,165	1,165	1,165	1,165	1,165	1,165
R-squared	0.063	0.035	0.127	0.237	0.055	0.041	0.183	0.197
# of Patents	80	80	80	80	80	80	80	80
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Table 23. All columns are comprised only by patents licensed after grant and license was not abandoned. Patents only in the fields of Computers, Communications, Electrical , Electronic and Mechanical technologies. Endogenous variables names are described in Table 1.

VARIABLES	(1) LicCites SameIPC	(2) LicCites DiffIPC	(3) NonLicCites SameIPC	(4) NonLicCites DiffIPC	(5) LicCites SameIPCTech	(6) LicCites DiffIPCTech	(7) NonLicCites SameIPCTech	(8) NonLicCites DiffIPCTech
Exclusive	0.0986	0.00911	0.576*	1.132**	0.102	0.00572	0.781*	0.926**
	(0.0643)	(0.0187)	(0.300)	(0.452)	(0.0692)	(0.0183)	(0.399)	(0.362)
ExcExp	0.119	-0.0311	-0.0642	0.672	0.0927	-0.00458	-0.0486	0.656
	(0.103)	(0.0495)	(0.890)	(0.594)	(0.112)	(0.0368)	(0.987)	(0.440)
UnLicExp	0	0	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Constant	0.0449	-0.0116	-0.766	-0.704	0.0272	0.00617	-1.248*	-0.222
	(0.0403)	(0.0304)	(0.551)	(0.451)	(0.0473)	(0.0210)	(0.647)	(0.330)
Observations	1,165	1,165	1,165	1,165	1,165	1,165	1,165	1,165
R-squared	0.062	0.039	0.184	0.189	0.070	0.035	0.205	0.172
# of Patents	80	80	80	80	80	80	80	80
Patent FE	YES	YES	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Figure 1. Histogram of number of patents per invention.

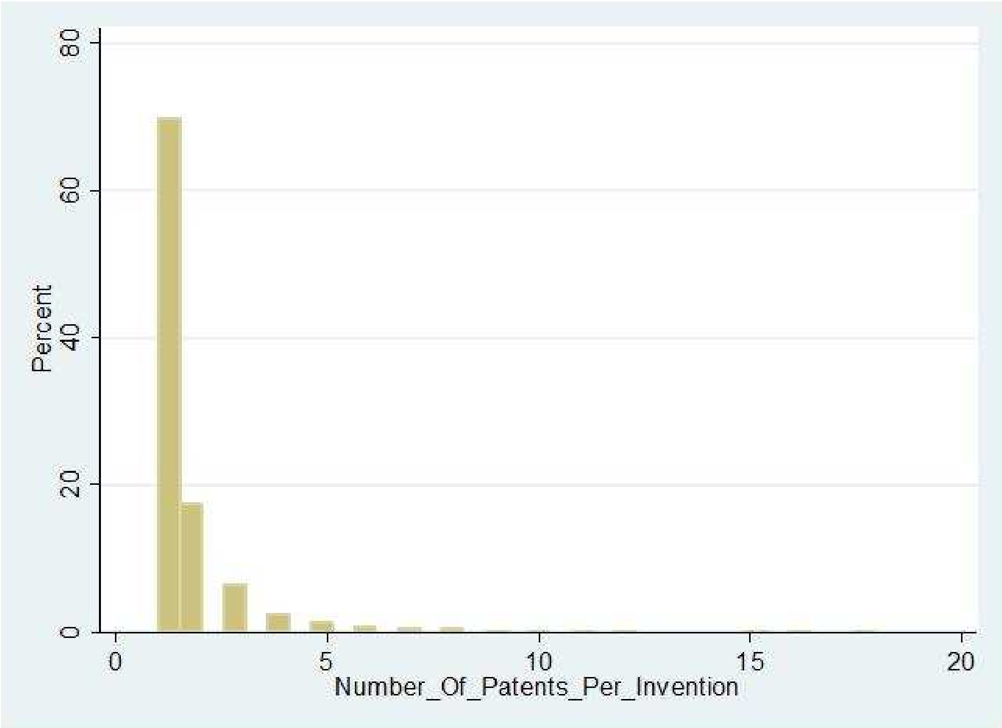


Figure 2. Frequency of exclusively licensed patents by grant year.

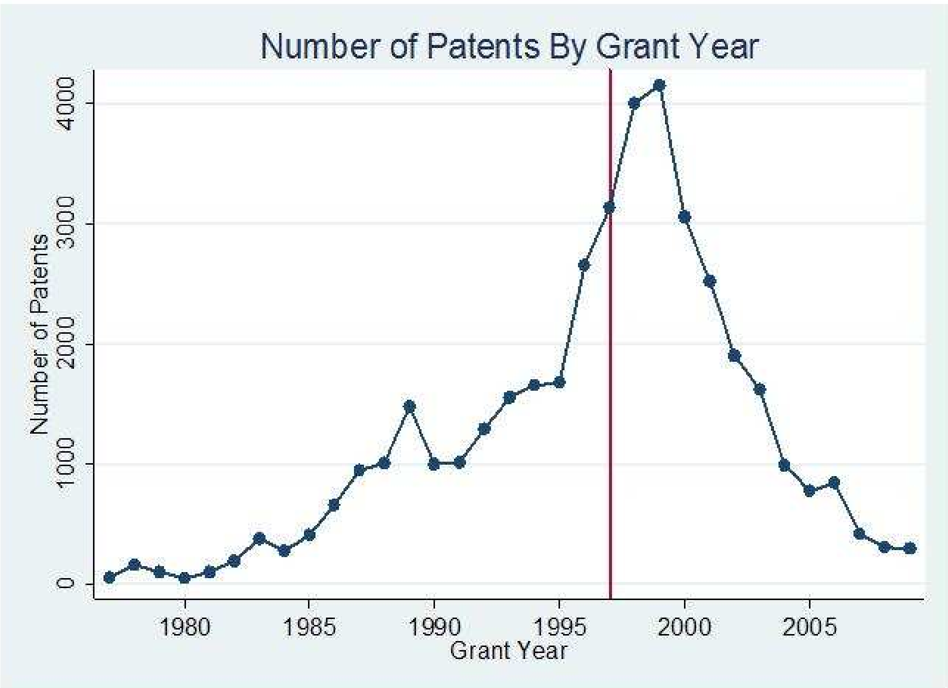


Figure 3.Histogram of first license by grant year. Patents licensed exclusively and license was not revoked. Note that period zero is the period of grant.

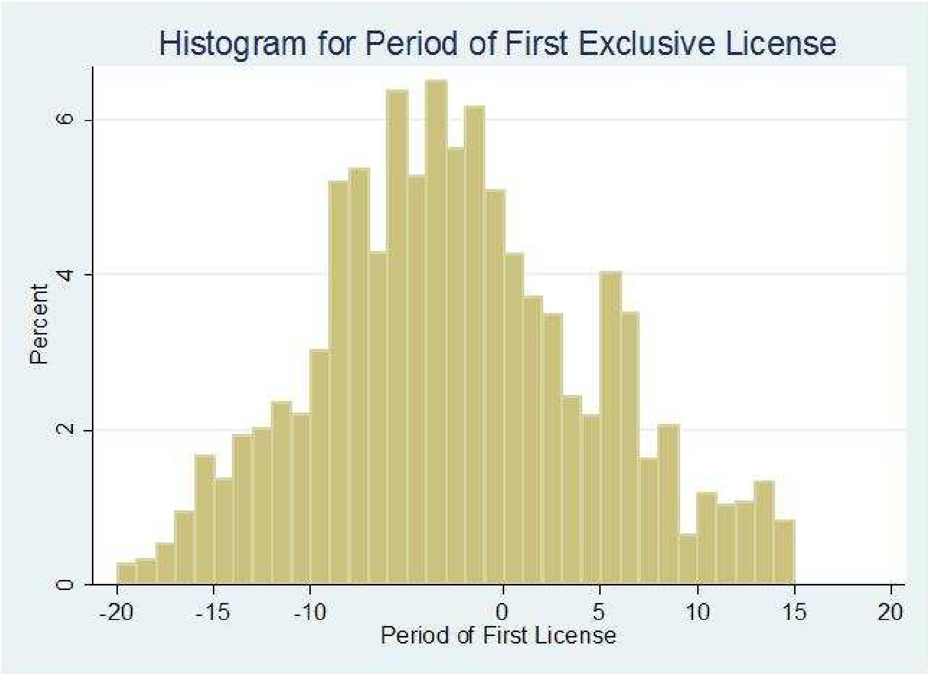


Figure 4. Histogram of first license by grant year. Patents licensed exclusively, after grant and license was not revoked.

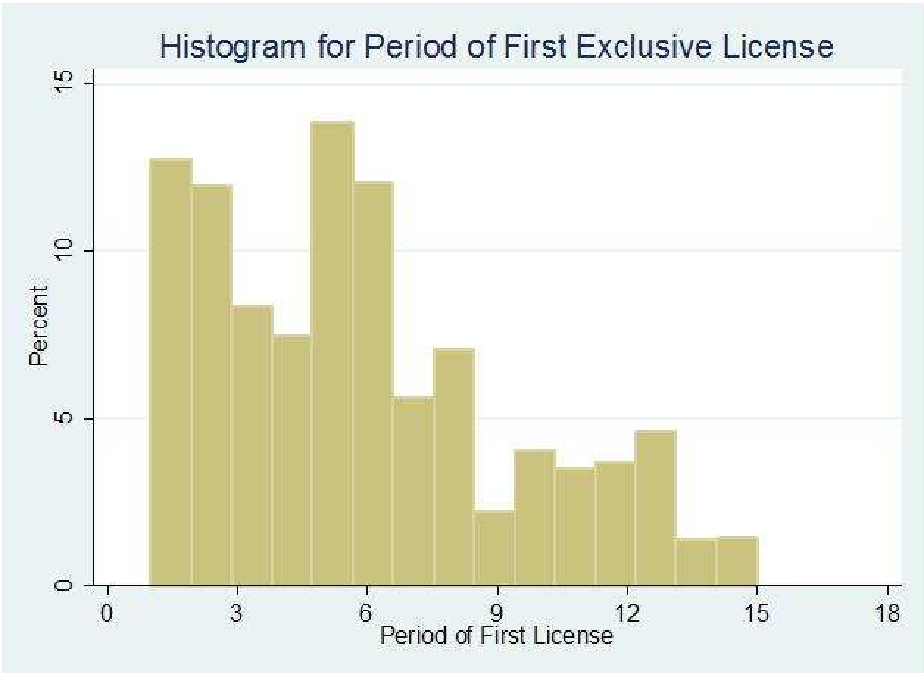


Figure 5. Event of exclusive licensing on licensee and non-licensee citations.
On the x axis, the period zero denotes the period of first license.

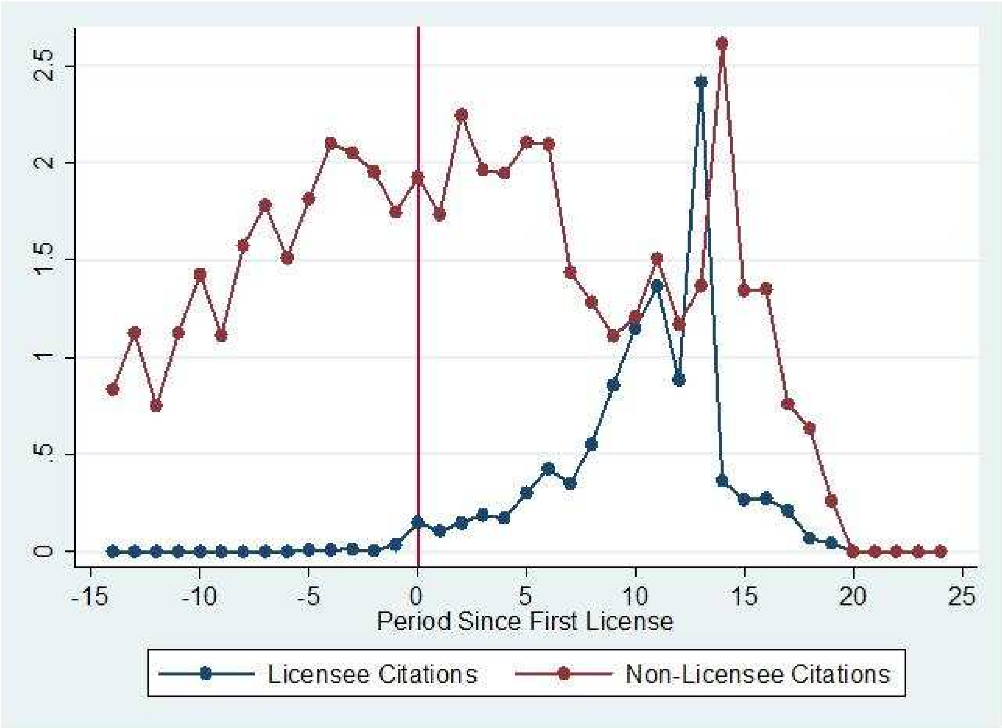


Figure 6. Patents that were licensed after grant exclusively and license was not revoked. Non-licensee citations.

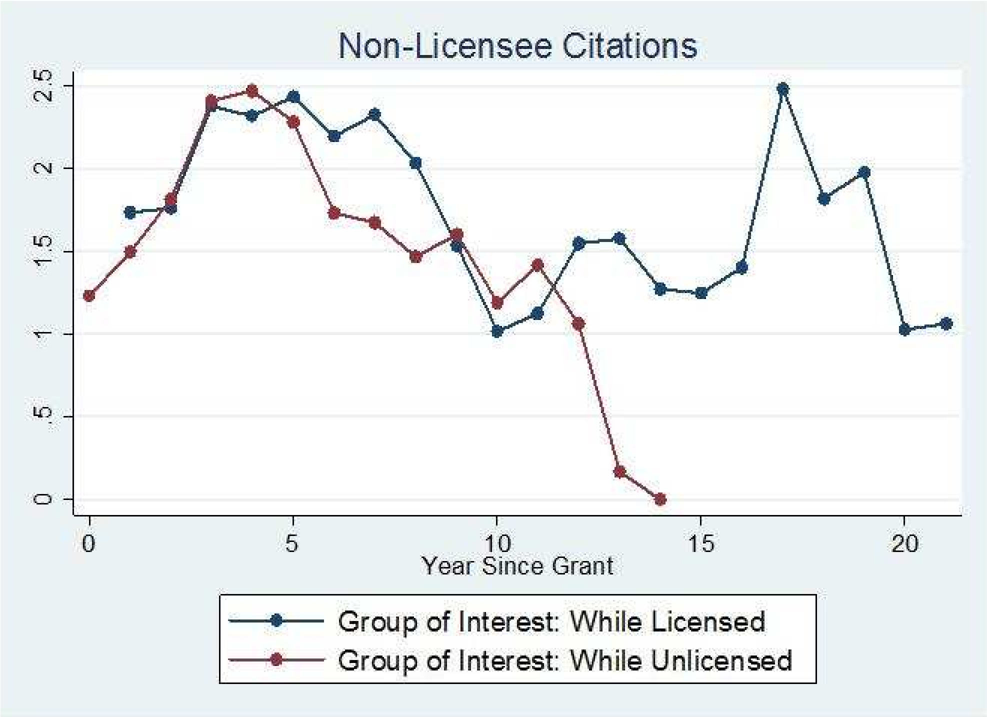


Figure 7. Patents that were licensed after grant exclusively and license was not revoked. Licensee Citations.

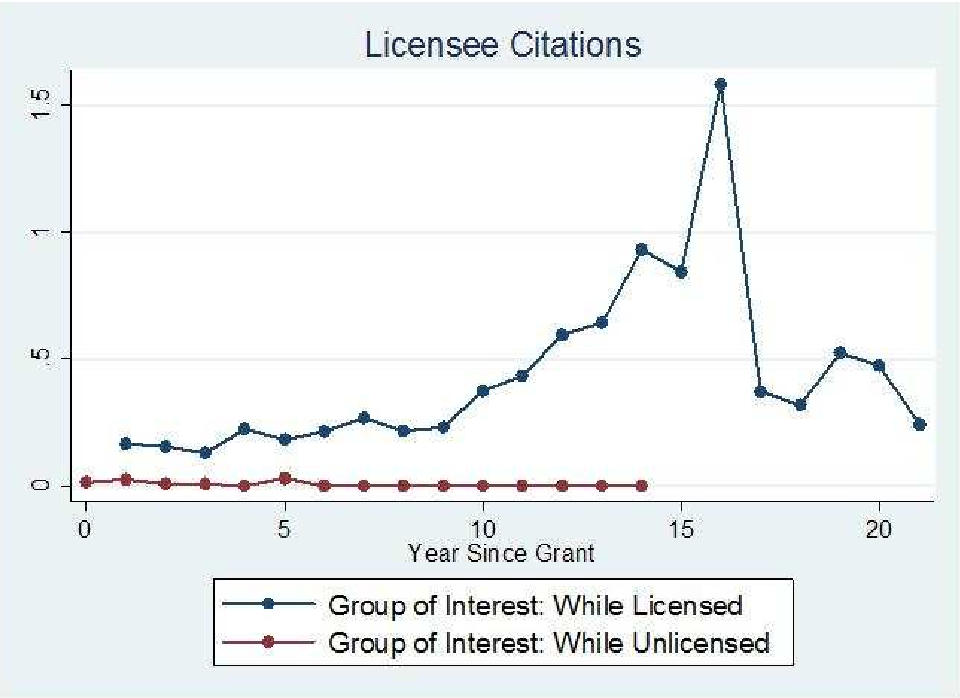


Figure 8. Comparing citations for early and late exclusively licensed patents while licensed and unlicensed states. Non-licensee citations.

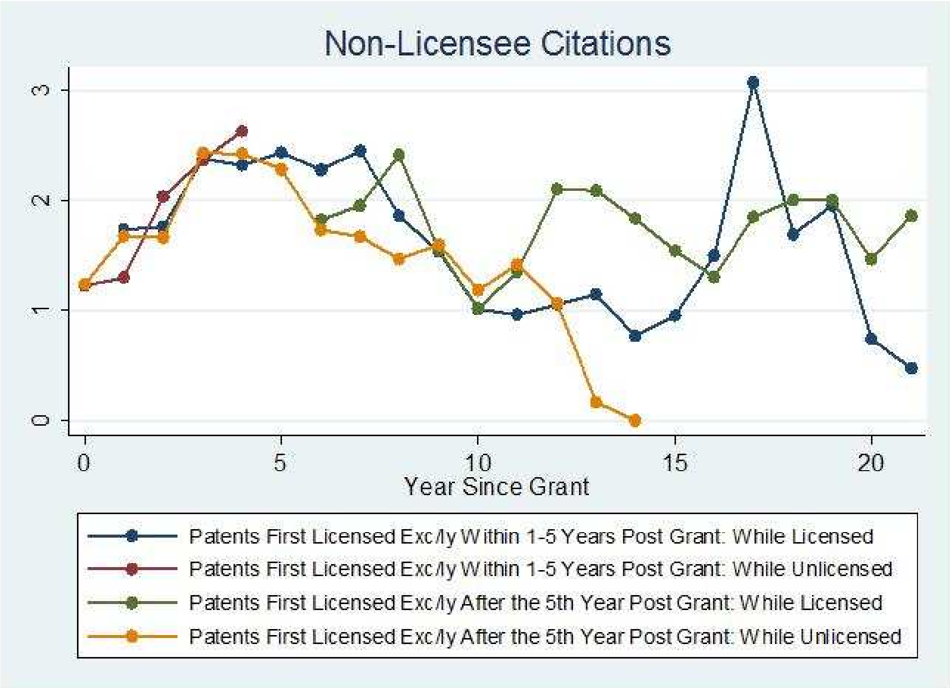


Figure 9. Comparing citations for early and late exclusively licensed patents while licensed and unlicensed states. Licensee citations.

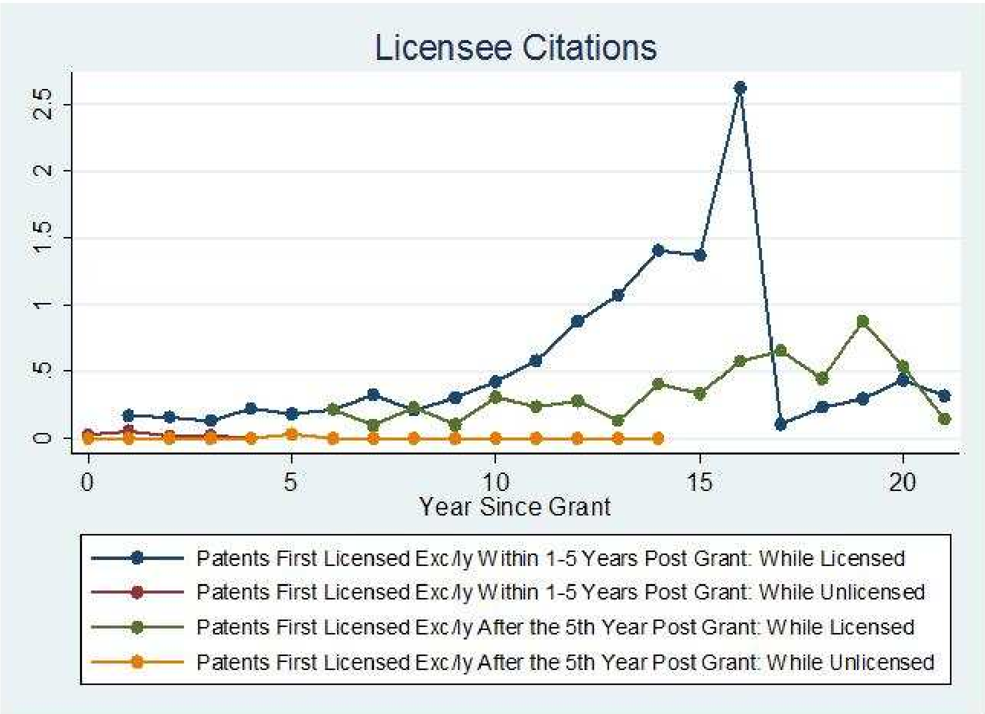


Figure 10. Comparing citations for patents licensed exclusively after grant versus patents licensed exclusively within two years before grant. Non-licensee citations.

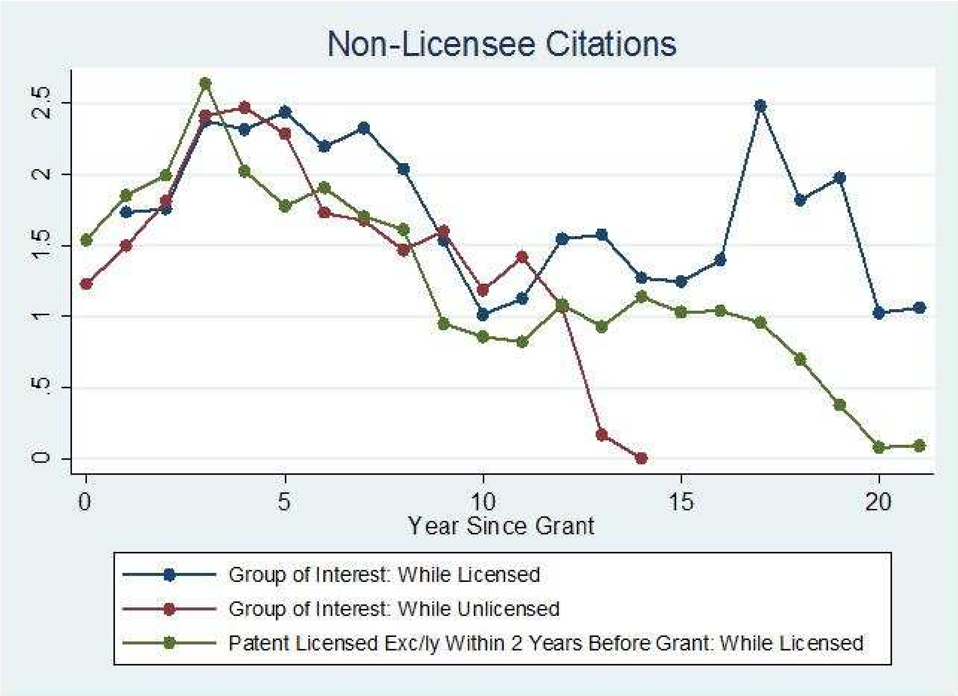


Figure 11. Comparing citations for patents licensed exclusively after grant versus patents licensed exclusively within two years before grant. Licensee citations.

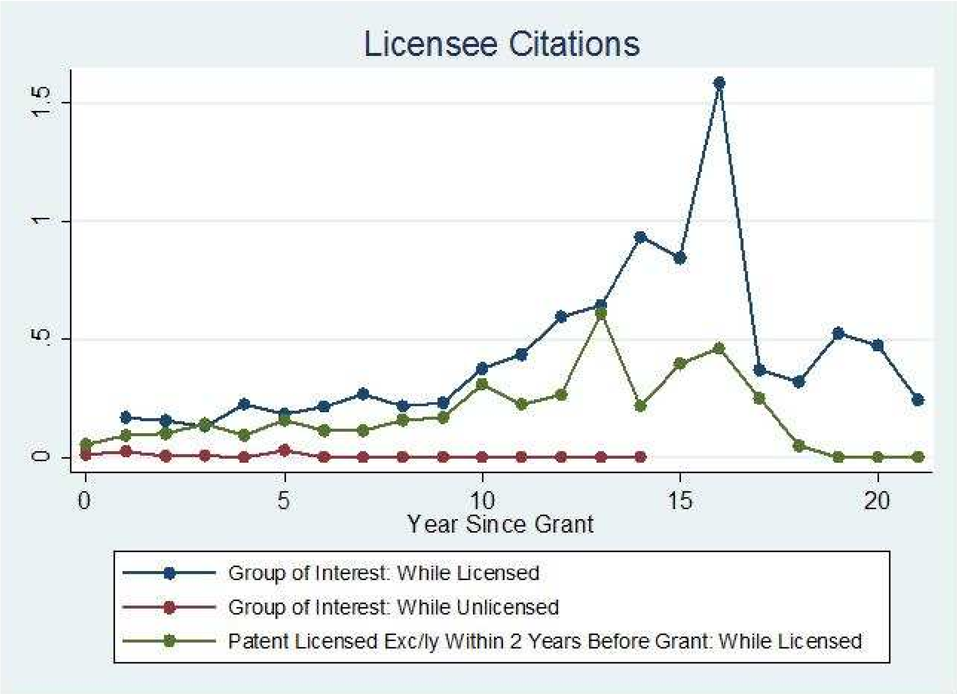


Figure 12. Comparing citations for patents licensed exclusively after grant versus patents licensed exclusively before grant and unlicensed patents that haven't lapsed. Non-licensee citations.

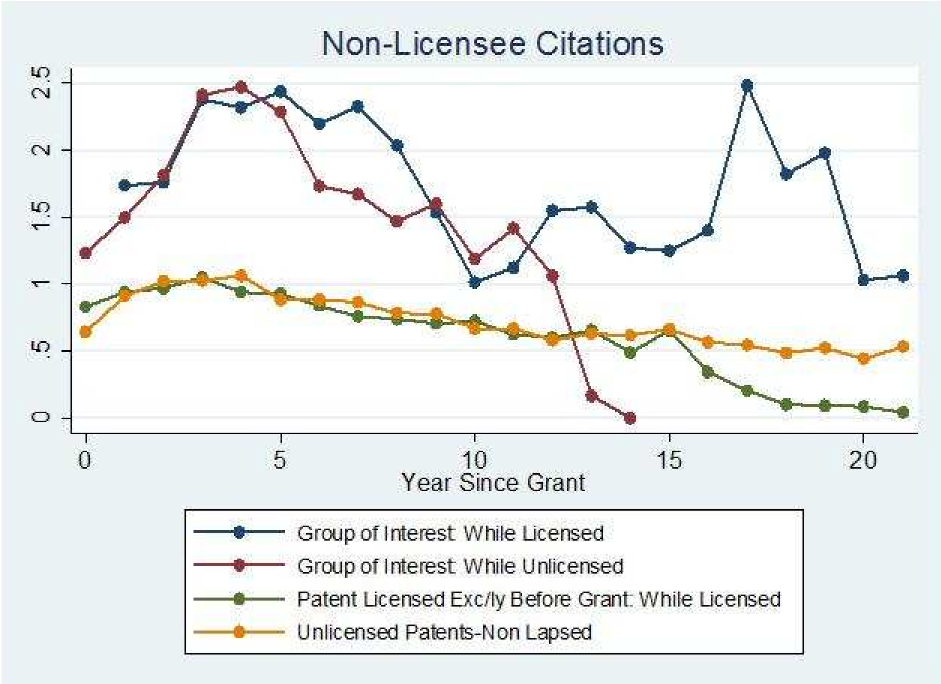


Figure 13 Comparing citations for patents licensed exclusively after grant versus patents licensed exclusively before grant and unlicensed patents that haven't lapsed. Licensee citations.

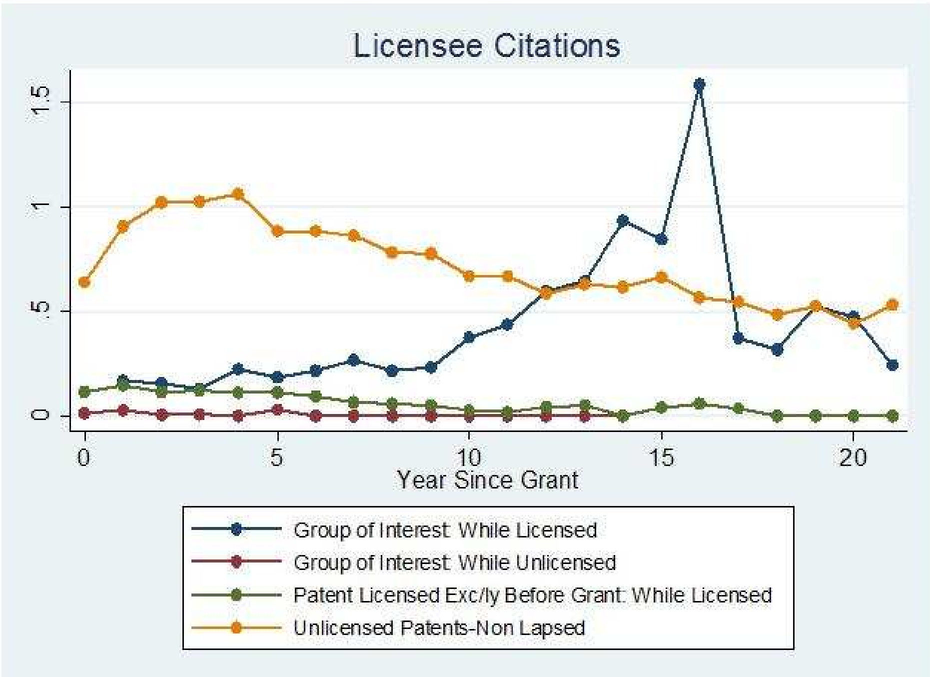


Figure 14. Comparing citations for patents licensed non-exclusively after grant versus patents licensed non-exclusively within two years before grant. Non-licensee citations.

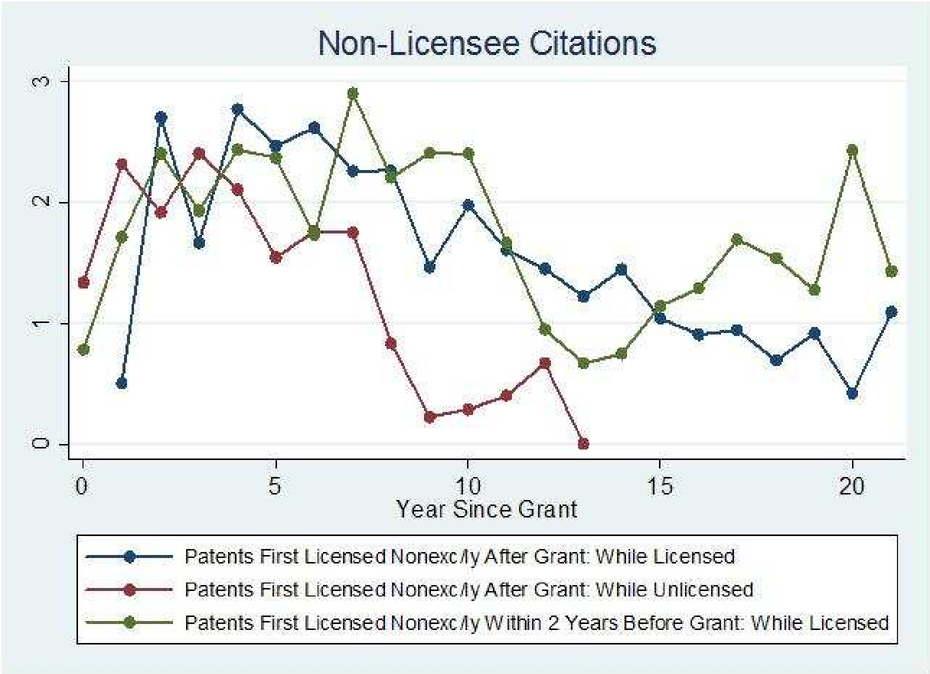
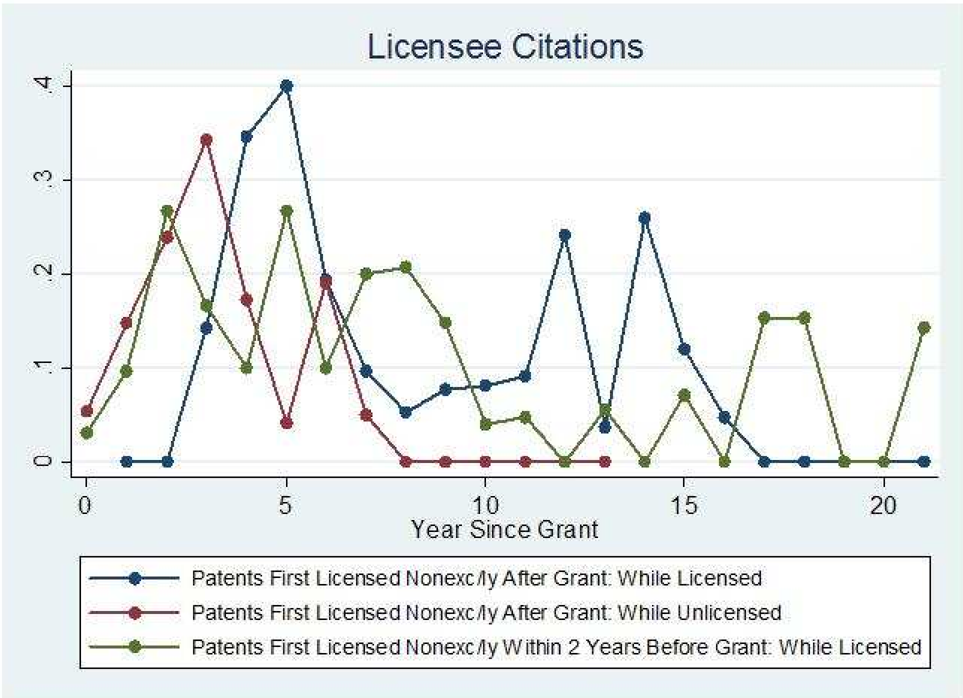


Figure 15. Comparing citations for patents licensed non-exclusively after grant versus patents licensed non-exclusively within two years before grant. Licensee citations.



Chapter II

A Dynamic Analysis of Licensee Citations

Introduction

The mechanism by which new technologies build on earlier past essential innovations has been an ongoing area of research in the economics and management literature, while it has also occupied policy discussions on whether and how it can be improved. In particular, patent policy instruments, such as patent length and breadth, have been employed to examine how they can influence the privately optimal investment of R&D of the first and second innovations to reach the socially desirable outcome (Green and Scotchmer 1995).

However, in this literature of sequential innovations, the timing decision of the second innovator has been treated as exogenous (Chang 1995, Chou and Haller 2007 and Gallini 1992). To my knowledge there is only one study that allows for the time to invest to be a decision variable of the firm that is capable of developing the subsequent innovation[18]. In particular, Koo and Wright (2010) (henceforth KW) find that it is optimal for the licensee to delay innovation output in a number of circumstances which will be outlined below.

In this chapter, we first try to empirically examine whether delaying further related innovation by the licensee is a frequent phenomenon. Second, we test two theoretical predictions by KW on when it is optimal for the licensee to delay innovation. Namely, is innovation output delayed if the invention is of low profitability? Are delays of innovation output associated with broad patent scope of the first essential patented invention? The availability of data by the University of California (UC) Office of Technology Transfer (OTT) allows us to answer these questions.

We employ the same dataset as in the first chapter including patents and their associated licensing activity that stem from UC invention disclosures. Access to the dataset was provided by the UC-OTT led by Executive Director William Tucker and is augmented with patent information from NBER (Hall, Jaffe and Trajtenberg 2001) and Thomson.

We characterize innovation output by the licensee as the number of licensee patents that cite the UC patent. Even though patents may serve other purposes than appropriating innovation output (e.g. defensive patenting, building patent thicket) at the end of the Robustness Section we further argue for employing this metric and display how the interpretation of our results changes if licensee citations capture other variables than innovation output. A difference-in-differences approach is followed; we employ exclusively licensed patents licensed both before and after grant and examine the timing of their licensee behavior, regarding citations, around expiration date of the licensed patent. Given that most patents in the sample expire at 17 years after grant, we cannot use time variation to identify an expiration window effect without a comparable group. As a control group, unlicensed UC patents are used; moreover, we exploit the fact that a number of them lapse at the fourth, eighth or twelfth year since grant[19]. To test the theoretical predictions, we approximate profitability of the patent as the quality of the UC patent; the proxy for patent quality used is the application length which has been found to be negatively correlated with patent quality (Regibeau and Rockett, 2010, Lei and Wright 2010). To

[18] Gans and King (2007) also relax the assumption in which the timing of innovation is exogenous in a slightly different context. They examine how the results of Gilbert and Shaprio (1990) regarding optimal patent length and breadth change when the inventor can choose when to innovate.

[19] For a US patent to remain in effect, the patent owner needs to pay maintenance fees at the fourth, eighth and twelfth years of patent life.

approximate patent scope we use the number of four digit International Patent Classifications (IPCs) (Lerner 1994).

The above difference-in-differences approach is susceptible to the critique that the control group (unlicensed patents) is distinctively different from the treated group (exclusively licensed patents). Thus, an increase in citations around the expiration window may be associated with the underlying nature of the licensed patents in contrast with the licensing treatment. For robustness, we examine the citations of smaller sample of nonexclusively licensed patents and contrast these findings with the results acquired for the exclusively licensed patents. Finally, we construct matched patents (from the unlicensed group) that resemble the exclusively licensed patents up until the years before the expiration window and compare their citation behavior with those of their exclusively licensed counterparts.

Results show that licensees often delay innovation output that builds on the licensed patent. While this finding is also consistent with an R&D cycle explanation, in which innovations take years to materialize and the timing of innovation may coincidentally fall within a patent expiration window, we find that licensees who licensed the patent before its grant are also observed to cite the licensed patent more around expiration. In terms of the theoretical predictions of the KW model, we find weak evidence that licensed patents of low quality (long prosecution time) are associated with more licensee citations around expiration while we don't observe the same licensee behavior for UC patents of high quality (short prosecution time). Finally, we find stronger evidence of delaying innovation for patents with broad scope and no expiration window effect for patents with narrow scope. Hence, overall we find significant evidence to support KW's theoretical predictions. The limitation of the hypotheses tests, however, is that they rely heavily on the patent metrics used as approximations for patent quality and patent scope.

The contribution of this chapter is twofold. First, we offer insights on the behavior of licensees with respect to the university innovations they acquire. It is interesting to examine whether innovators behave strategically in terms of timing follow-on research and its dissemination. Scholars have been concerned with the probability innovations might be shelved or not fully utilized although an equally relevant issue is whether development of subsequent innovations might be delayed. Second, patent policy instruments have been studied extensively to answer how they can induce the socially optimal solution. As KW showed, the social returns to innovation are related to the speed which sequential innovations are produced. Given that their model has linked this variable with patent policy features, we try to give some empirical insights on the relevance of delay follow-on research.

The next section frames the hypotheses and outlines the empirical model. The subsequent section describes the data and key summary statistics and figures relevant to the hypotheses. The Results Section outlines the main findings while the Robustness Checks Section addresses evidence from citations of nonexclusively licensed patents and also from matched patents regarding the robustness of the main findings. A concluding section follows.

Framing Hypotheses and Econometric Specification

When a licensee acquires rights to an innovation, he may find it optimal to delay investment in development of the subsequent innovation or delay making the innovation public. This can be the case when the resulting innovation is, or is embodied in, a developed product which leads to sales. If the licensee delays this innovation or shelves it until expiration of the licensed patent, then he is not obliged to pay royalty fees to the licensor. If he decides to delay to avoid paying any fees on the innovation, we would expect for the licensee to file for the patent application that builds on the licensed patent around expiration date of the latter.

However, this timing may vary since the patent application process is entailed with many stochastic elements. First, building a patent application is costly and time consuming while a large portion of the patent building process may be outsourced to external patent attorneys. Thus, it is difficult for the licensee to time exactly the date that he will file for the patent application. Second, for the licensee to maximize the present value of his innovation, he will pursue for his patent to be granted right after expiration of the initial patent. However, application length (time from patent application to patent grant) is also stochastic and depends on a number of factors not determined by the applicant (Johnson and Popp 2003 and Popp Juhl and Johnson 2004) since it involves decisions by the United States Patent and Trademark Office (USPTO). Therefore, it is impossible for the licensee to time exactly on when he will file for the application. Thus, if he delays innovation output, we should observe an increase in licensee citations around an expiration window of the licensed patent and not an exact year. Formally:

Hypothesis I: For patents that are licensed exclusively, an **increase** in licensee citations to the licensed patent should be observed **around patent expiration** year.

However, it should be noted that there are significant shortcomings for the licensee to delay innovation output. KW made predictions on when it is more likely for the licensee to delay innovation output. First of all, they found that for low to moderately profitable inventions, a licensee is more likely to delay innovation output since the present value of exploiting his innovation immediately is lower than waiting and exploiting it after expiration of the licensed patent in order to avoid paying royalty fees to the licensor. Formally:

Hypothesis IIA: For patents that are licensed exclusively, an increase in licensee citations to the licensed patent should be observed around patent expiration *if the subsequent innovation is of low profitability*.

Note that we will link the profitability of the subsequent innovation with the quality of the licensed patent. That is, we assume that the lower the quality of the licensed patent, the lower the profitability of the subsequent patent.

Moreover, KW assume that when the patent scope of the first invention is broad, then it is more likely that this patent may be litigated. This will in turn reduce expected present value for the licensee and therefore may find it optimal to wait and appropriate his innovation output around expiration of the licensed patent. Formally:

Hypothesis IIB: For patents that are licensed exclusively, an increase in licensee citations to the licensed patent should be observed around patent expiration *if the scope of the licensed paten is broad*.

Note that from KW, Hypotheses IIA and IIB are more likely to hold when the market for the subsequent innovation is not competitive. In other words, we are more likely to find support for Hypotheses IIA and IIB if the licensee is a monopolist. KW found that delaying innovation is less profitable in a competitive market. Given that we don't have market level information for each licensee, we cannot control for this aspect of the theoretical findings. However, any increases that we find for low profitability inventions and/or narrow scope inventions are likely to be downwards biased since a number of licensees in the sample are in competitive markets in which delaying follow-on research may not be a severe issue.

Another issue to discuss is the structure of licensing contracts with regards to payment schemes. KW had a simple royalty contract scheme and therefore ignored milestones, issue fees and maintenance fees commonly included in licensing contracts. Unfortunately, we don't have comprehensive data on these contract terms. The inclusion of these contract terms is likely to mitigate delay since these contract terms extract surplus before the royalty scheme. Thus, any results found, should be downwards biased since licensed patents in which the licensing contract has only royalty clauses, are likely to drive the delay of innovation output.

The baseline specification where the above three hypotheses are to be tested is the following:

$$\begin{aligned} LicCites_{i,t} = {} & w_0 + w_1 * ExclusiveI_{i,t} + w_2 * ExclusiveWindIJ_{i,t} + w_3 * ExcExpJ_{i,t} \\ & + w_4 * UnLicExpWindIJ_{i,t} + w_5 * UnLicExpJ_{i,t} \\ & + \sum_{i=1}^{N} \gamma_i * Patent_i + \sum_{t=1}^{T} \delta_t * Period_t + \sum_{t=issueyear+t}^{T+issueyear+t} \theta_{issueyear+t} * CiteYear_{\text{issue year}+t} \end{aligned} \tag{3}$$

where:

- $LicCites_{i,t}$ is the number of applications filed (that resulted in a patent), by licensee/future licensee, at period t and cited patent *i*. Take note that the forward citation patterns observed in this paper are by application year of patents.
- $ExclusiveI_{i,t}$ takes the value of 1 for patent *i* that is under an exclusive license and up until minus I periods from patent expiration period and takes the value of 0 otherwise.
- $ExclusiveWindIJ_{i,t}$ takes the value of 1 for an exclusively licensed patent *i* for the following periods: I periods before expiration period up until J periods after expiration period and takes the value of 0 otherwise.
- $ExcExpJ_{i,t}$ takes the value of 1 for an exclusively licensed patent *i* for the periods plus J from expiration period and takes the value of 0 otherwise.
- $UnLicExpWdIJ_{i,t}$ takes the value of 1 for an unlicensed patent *i* for the following periods: I periods before expiration (or lapse) up until J periods after expiration period (or lapse) and takes the value of 0 otherwise.
- $UnlicExpireOrLapseJ_{i,t}$ takes the value of 1 for an unlicensed patent *i* for the periods plus J from expiration period and takes the value of 0 otherwise.

Note that definitions for the above and all other variables in the paper are listed in Table 1, while the construction of these variables is explained through an example in Section I of the Appendix. Also note that when the group of interest is patents licensed before grant the above regression will be ran excluding the $ExclusiveI_{i,t}$ variable to avoid a dummy variable trap. To support Hypothesis I, we should expect for w2>0. The verification of the next two hypotheses is a more challenging task. The challenge is to find appropriate metrics for patent quality and scope.

As already stated, we assume that profitability is positively and strongly correlated to patent quality of the licensed patent. Therefore, a metric for patent quality is warranted. The most commonly used metric for patent quality is forward citations. Trajtenberg (1990) was the first that employed this metric for patent quality. Later studies have found that forward citations are a good, but rather "noisy", proxy for patent quality (Harhoff 1999, Bessen 2008). In addition Hall, Jaffe and Trajtenberg (2005) found that forward citations are positively correlated with the market value of the patent holder. However, given that we employ patent citations as a proxy for follow-on research it is likely that using it as a metric for patent quality will bias our estimates. A patent variable that has recently been found to be correlated with patent quality and profitability is the application length; i.e. the time that it takes for the patent application to be granted. Regibeau and Rockett (2010) constructed the decision by the USPTO examiner who is in charge of the patent application review process and found that patent applications with high social welfare will be issued faster while the opposite holds for patent applications with low social welfare. They empirically verified their predictions in a set of patents associated with genetically modified crops technologies. A similar conclusion was also reached by Lei and Wright (2010) where they found that high quality patent applications would not take a lot of time by the examiner to be granted. Therefore, we would expect licensed patents with small application length for w2=0 while for patents with large application length w2>0. Note that application length is measured as the number of years that lapsed from filing of the relevant application to patent grant of this same application. Therefore, we exclude the influence of continuing applications in application length[20].

In terms of patent scope, the only study to my knowledge that has found a metric is by Lerner (1994). He found that the number of four digit International Patent Classifications to be associated with a higher probability for the patent to be litigated. Interestingly, KW build in the patent scope in their model as a probability of litigation. Therefore, we would expect licensed patents with narrow scope to have w2=0 while for patents with broad scope w2>0. We should note that in each specification in which we examine patents with a certain level of quality or scope, the control group will also be comprised of the respective patents. For instance in a specification where we use patents licensed after grant, when we examine only twenty five percent of these patents with largest application length (fourth quartile), as a control group we will include only the unlicensed patents in the fourth quartile of the application length distribution.

In terms of modeling, the preference for employing a standard difference-in-differences method as opposed to a non-linear regression framework such as negative binomial should be noted. By construction in the negative binomial, we would drop all patents that in every period they receive zero citations. Therefore, we would drop a significant part of the sample which under the current small sample size it could seriously impede our inferences. In all likelihood, it would downward bias our

[20] In the US, patent applicants can file for continuing applications claiming priority date of an earlier application. This mechanism has been frequently used by applicants to be granted a patent of questionable potential (Lemley and Moore 2004). Frequently, patent application length could be measured as the time lapsed from first application date to patent grant date. However, in this paper, we measure application length as the time lapsed from application date of the relevant application to patent grant date.

estimates; however, note that results acquired with negative binomial estimations are similar as in the case of difference-in-differences approach.

A note on the standard errors should also be made. In this paper, clustering the standard errors (Bertrand, Duflo, Mullainathan 2002 and Cameron and Trivedi 2005) at certain group levels is important; many patents are licensed together as a bundle; thus, assuming independence among these patents can lead to inefficient estimates. A way to correct this is to cluster the standard errors at the bundle level (Cameron, Gelbach, Miller 2006); thus, in all the difference-in-differences estimations we allow for serial correlation between the patents that have been licensed together.

Data

In this chapter we employ the same dataset as in Chapter I. For this chapter, we are interested in three distinct groups of patents; patents licensed exclusively for which the license has not been revoked, patents licensed nonexclusively for which the license has not been revoked and all unlicensed patents including those that have lapsed. Note two key points; for the remainder of this chapter when referring to licensed patents we refer to patents that first, have been licensed either exclusively or non-exclusively but not both, during their patent life (i.e. mix licensing) and second, we refer to patents for which the license has not been revoked and the patents have remained active during their entire patent life. Table 2 displays the number of patents for each group. Overall there are 853 patents licensed exclusively while there are 1,517 unlicensed patents, 580 of which have lapsed. Moreover, it is interesting to examine how many patents have been licensed before and how many have been licensed after grant. Both groups will be used to examine to what extent any increase can be attributed to an R&D time lag explanation. Columns 2a and 2b show the size of each group. Clearly the majority of patents that have been licensed exclusively has been licensed before grant while in the case of nonexclusively licensed patents, virtually half have been licensed before and half after grant. Nonetheless, the effort of this paper is to examine licensee behavior around expiration date of the patent. Thus, we need to focus on early issued patents. Columns 3a and 3b show the number of patents issued on or before 1996. For the remainder of the paper, we will focus on patents granted before 1996. As can be seen from this table, inference is very difficult given the small number of patents in each group. In particular, in the case of nonexclusively licensed patents any findings shown in this paper should be cautiously interpreted.

Table 3 displays summary statistics for patent characteristics. Note that, in the case of unlicensed patents, licensee citations are replaced by total citations net of assignee citations; henceforth, for unlicensed patents we will refer to this type of CitesNetAssignee. As can be seen, the average CitesNetAssignee per period for unlicensed patents are much bigger than exclusively licensed and nonexclusively licensed licensee citations. The choice of this type of citations for unlicensed patents introduces a downward bias in our estimates both for the licensing treatment and the expiration window; therefore, it should be noted that for any forthcoming positive coefficient the result may have been even stronger. Moreover, licensee citations are higher in the case of exclusively (0.16 before and 0.37 after grant) than in the case of nonexclusively licensed patents (0.07 before and 0.10 after grant).

We discuss the two patent characteristics that will be employed in the following analysis; namely, application length (AppLength) and number of four digit IPCs (NumberOfIPC). As can be seen exclusively licensed patents have a smaller application length than unlicensed patents. This observation lends support to the rationale that application length is a good approximation variable for patent quality assuming that licensed patents are of superior quality. Nonetheless, it should be noted that nonexclusively licensed patents have a larger application length than unlicensed patents; an observation that contradicts the above finding. In terms of NumberOfIPC, both types of licensed patents have more NumberOfIPC than unlicensed patents regardless of the timing of license. This implies that licensed patents are of broader scope than unlicensed patents.

After the discussion of patent characteristics, it is useful to visually assess the behavior of licensee citations for the exclusively licensed patents. Figure 1 displays licensee citations for patents licensed after grant and issued on or before 1996. As it can clearly be seen, unlicensed patents have a citation pattern similar to the population of US patents (Hall, Jaffe and Trajtenberg 2001); that is, an increase until some point during the patent life and then a monotonic decrease. Patents that are to be licensed exclusively appear to receive virtually no licensee citations while unlicensed while when they become licensed, there is a considerable increase as time progresses. Notice that from period 10 to period 15, licensee citations are constant while in period 16 they increase dramatically followed by a less sharp increase in period 19. Both increases remain even after the exclusion of 5% of the most highly cited patents.

However, it can be argued that this increase is correlated with a steady rise in licensee citations and should not be associated with any strategic choice by the licensee. Figure 2 shows licensee citations for exclusively patents licensed before grant issued on or before 1996. Even though the increase towards the later years of patent life is not as pronounced, there is a rise during periods 15 and 16. Therefore, the visual analysis shows some evidence to support a delaying innovation hypothesis. However, we need to control for a number of parameters before we can conclusively support this licensee behavior. For this reason we display the econometric results in the next section.

Results

Table 4 shows the baseline specifications. For patents licensed after grant we see that the ExclusiveI for I=1,2,3 is positive and significant; a result consistent with the findings of the first chapter. Except for the narrowest window (-1,+1), exclusive licensing is associated with an increase in licensee citations around the expiration year of the patent. The result is robust and statistically significant. We argue that licensees act strategically, delaying innovation output or waiting to file for patent applications that build on the licensed patent. However, a counterargument for this explanation is that time from one innovation to another takes time and is associated with considerable lags (Mansfield 1998; Hall, Jaffe and Trajtenberg 2001). These lags may coincide with the expiration window in many cases and therefore the positive and significant coefficients are to be attributed on this justification rather a strategic behavior.

However, one way to explore this possibility is to examine whether patents licensed before grant have similar behavior; if that is the case, then the R&D lag explanation will lose significant traction. The last three columns of Table 4 explore the effects of these patents around expiration. As can be seen all three windows are associated with positive and significant increases in licensee citations and therefore offering support to the strategic behavior explanation.

Thus far, we have shown that licensee citations increase for exclusively licensed patents around expiration date regardless of the timing of license. Before exploring Hypotheses IIA and IIB we should note two important points. Even though we allow for patents within the same bundle to be dependent, there is an issue on whether we comprehensively control for the bundling “effect”. Initial specification assumed as expiration date of the patent, the expiration date of the most recent patent in the bundle. However, given the small sample size of bundles which we observe to expire until 2009, we couldn't pursue these specifications. Second, we ideally wanted to examine the delaying innovation by technology fields and draw inferences similar to those of Chapter I. Unfortunately, given the small sample of patents that we observe to expire, we cannot safely display any results.

Now it is useful to empirically test the two hypotheses stated in the Framing Hypotheses and Econometric Specification Section. Starting with the profitability hypothesis (Hypothesis IIA), we approximate this with application length of the licensed patent; given the severe measurement error of this variable, we assign low quality patents as patents located in the fourth quartile of the application length distribution for each given group. As high quality patents, we assign patents that are located in the first quartile of the application length distribution for each given group. We assume that each group of patents, exclusively licensed before grant, exclusively licensed after grant, nonexclusively licensed before grant, nonexclusively licensed after grant and unlicensed patents to have a different distribution of application length.

Table 5 tests this hypothesis for patents licensed after grant; the first three columns include low quality patents while that last three include high quality patents. As can be seen low quality patents are associated with an increase in licensee citations around expiration window whereas high quality patents have an increase during patent life but, around expiration window, only the increase for the broadest window is statistically significant. This finding supports Hypothesis IIA which implies that low quality licensed patents are more likely to be associated with an increase in licensee citations around expiration.

Table 6 presents the results for patents licensed before grant. As can be seen patents of large application length (low quality) as well patents of small application length (high quality) are associated with an increase in licensee citations around the expiration windows. Thus, via this finding we cannot support Hypothesis IIA since as it seems delaying innovation output is independent of the application length of the licensed patent. However, it should be noted that for this group of patents, application length may have been affected in another way. That is, the licensing for these patents takes place before the grant which imply that the licensor and the licensee may have pursued more aggressively the grant of the patent once the licensing agreement was reached. In other words, for this group of patents, application length may not be a good proxy for patent quality due to the noise caused by the interaction between licensing and patent prosecution.

Next, we try to test empirically the patent scope hypothesis (IIB). We approximate patent scope with NumberOfIPC; as with the application length to minimize measurement error, we assign patents with broad scope as patents located in the fourth quartile of the NumberOfIPC distribution for each given group. As patents with narrow scope, we assign patents that are located in the first quartile of the NumberOfIPC distribution for each given group. For instance, for unlicensed patents we assume a different distribution from patents exclusively licensed before grant and so forth.

Table 7 tests hypothesis IIB for patents licensed after grant. The first three columns include patents with narrow scope while the last three columns comprise of patents with broad scope. For the narrowest window, there is an increase in licensee citations but is insignificant regardless of patent scope. In the (-2,+2) expiration window, both increases are significant at the 10% significance level but in the case of broad scope, the increase during the window is bigger than the overall increase of licensing during the patent life while the opposite holds for patents with narrow patent scope. Finally, the increase in licensee citations during the broadest expiration window is more pronounced for patents with broad scope. Table 8 tests hypothesis IIB for patents licensed before grant. The format is similar to that of Table 7. As can clearly be seen, patents with broad scope are associated with a considerably more pronounced increase in licensee citations than patents with narrow scope. Therefore, we find stronger evidence in favor of the patent scope hypothesis than in the case of the profitability hypothesis.

Thus far we have found significant evidence to support the hypothesis licensees delay innovation output towards expiration date of the licensed patent. This finding appears to be robust to an R&D lag explanation since we observe citations to increase regardless of the timing of license. We have also tried to offer support or reject two hypotheses on when it is more likely for licensees to delay innovation. In terms of profitability, we find weak evidence to support that output of low profitability is more likely to be delayed while we find stronger evidence to support the hypothesis that for patents with broad scope licensee citations increase around expiration.

Robustness Checks

It can be argued that the control group (i.e. unlicensed patents) is a distinctively different group from licensed patents. It should be noted that we are not arguing for an increase in licensee citations due to licensing (a question answered in the first chapter) but we merely ask the question whether there is an abnormal increase around expiration. As can graphically be seen from Figures 1 and 2 there appears to be such an increase that should be attributed to exclusive licensing.

In any case, in this section we will try to argue that this increase is to be attributed due the exclusive licensing and not due to some underlying higher quality of patents that are selected for licensing. First, we to examine whether the above result holds for nonexclusively licensed patents. Figure 3shows licensee behavior for patents licensed after grant (while licensed and while unlicensed) and for patents licensed before grant. Clearly nonexclusively licensed patents are different in nature from exclusively licensed patents since as can be seen there is no clear trend of licensee citations (partially attributed to small sample size) while in absolute size they are much smaller than exclusively licensed patents.

However, it can be argued that nonexclusively licensed patents are of higher quality than unlicensed patents on the same grounds that exclusively licensed patents are of higher quality. Thus, if the increase in citations is mainly due to patent quality attributes, we should expect a similar increase for this group of patents. Table 9 shows the baseline specifications for patents licensed after grant (first three columns) and patents licensed before grant (last three columns). We do not observe an increase in licensee citations around expiration date of the licensed patent while the results are contradictory between patents licensed before with patents licensed after grant. Therefore, we find that nonexclusively licensed patents don’t display a similar behavior as the exclusively licensed patents; this supports the rationale that the increase around expiration is not due to some underlying quality of a licensed patent but rather due to the exclusive license itself.

Finally, we construct a matched patent, out of the unlicensed patents, for each exclusively licensed patent. This matched patent is constructed in such a way that it has the same citing behavior as the licensed patent until period 13. The details of the process are described in Section II of the Appendix. Figure 4 shows the citing behavior for exclusively licensed patents after grant and their matched group of patents. Up until period 13, both groups have virtually identical licensee citations.

Nonetheless, after the thirteenth period the matched group's citations decrease while the exclusively licensed patents' citations increase. This implies that an ad-hoc group of patents that has an increasing rate of citations until late years of its patent life (period 13) is not associated with an abnormal increase around expiration. Table 10 shows whether differences between the groups of interest are statistically different than the matched groups for expiration windows. As can be seen the one-tail tests show that the difference is statistically greater than zero. Moreover, we construct similar matched patent groups for patents with low quality or broad scope. In terms of quality, we find that the difference is statistically significant for both quartiles while in case for patent scope, the difference is statistically significant only in the case of broad scope.

Figure 5 shows a similar graph for patents licensed before grant. While it is less clear in this case, the matched group cannot explain the full increase in citations around expiration window. Table 11 shows similar results for this group of patents. Results are less significant in this case while in the case of quality, results are not conclusive. In terms of patent scope results for the broad scope imply an increase but the difference between the two groups is not significantly greater than zero. It should be noted that this process is likely to introduce a severe downward bias in our estimates. To construct the matched group of patents, we employ total citations net assignee citations of unlicensed patents to match licensee citations. Therefore, when we explore the citing behavior of the matched group after period 13, this fact should be taken into account. Overall, this exercise shows that results regarding delaying innovation are robust (Hypothesis I), while we find little evidence to support the profitability hypothesis (IIA). Nonetheless, we find some evidence to support the patent scope hypothesis (IIB).

We have tried to argue that firms frequently delay innovation to avoid paying royalty fees. This finding relies heavily on the assumption that licensee citations reflect innovation output. We've argued in Chapter I that citations have been found to be a noisy but good proxy for knowledge spillovers. However, licensees might merely building a patent "thicket" without inventing anything substantial from the licensed patent. To the extent that this explanation is the most accurate, then our findings should be interpreted differently. That is, licensees do not delay innovation output but merely are delaying to maintain protection and broaden the scope of the licensed patent to retain monopoly in this area.

Conclusion

This chapter has tried to examine to what extent licensees may delay innovation output; a discussion which has been neglected in the literature of sequential innovation. Koo and Wright (2010) showed that delaying innovation is frequent and can affect the social welfare optimum. In this study, by employing academic patents coupled with their licensing history and their citation patterns, we try to empirically examine whether licensees indeed delay part of their innovation output.

We find an abnormal increase in licensee citations during the expiration window. We show that this increase cannot be attributed to an R&D lag explanation since similar increases are observed for patents licensed both before and after grant. Thus, we argue that this increase is a strategic choice by the licensee to delay innovation output. The result is robust to series of specifications.

Moreover, we test two hypotheses advanced by KW. We find some weak evidence to support the idea that low quality licensed patents are associated with a more pronounced increase around the expiration window. This observation is in accordance with the rationale that low profitability inventions will be delayed since it is not optimal for the licensee to commit to the invention immediately in order to avoid paying royalty fees. Regarding the second hypothesis, i.e. licensed patents with broad scope have higher probability of litigation and therefore lower expected profits and thus more likely to be associated with delay, we find significant evidence to support it. It should be noted that tests of both hypotheses are very difficult to validate or reject given that we employ patent characteristics as metrics for patent quality and scope. Moreover, these two hypotheses posed by KW are more likely to hold in a monopolistic market

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Appendix
Section I

Assume a patent gets granted in 1985, this patent is going to expire in 2002; i.e. 17 years from grant. Also, assume this patent gets licensed in 1990 and the license remains effect until patent expiration. At first we would like to examine whether licensee citations increase in a symmetric patent expiration window of one period. Thus, the specification will take the form:

$$LicenseeCITES_{i,t} = w_0 + w_1 * Exclusive1_{i,t} + w_2 * ExclusiveWind11_{i,t} + w_3 * ExclusiveExpire1_{i,t} + w_4 * UnlicExpireWind11_{i,t} + w_5 * UnlicExpire1_{i,t} + \sum_{i=1}^{N} \gamma_i * Patent_i + \sum_{t=1}^{T} \delta_t * Period_t + \sum_{t=issueyear+t}^{T+issueyear+t} \theta_{issueyear+t} * CiteYear_{\text{issue year}+t}$$

These variables for this particular patent have the following values:

Year Since Grant	Period	Exclusive1	ExclusiveWind11	ExclusiveExpire1	UnlicExpireWind11	UnlicExpire1
1985	0	0	0	0	0	0
1986	1	0	0	0	0	0
1987	2	0	0	0	0	0
1988	3	0	0	0	0	0
1989	4	0	0	0	0	0
1990	5	1	0	0	0	0
1991	6	1	0	0	0	0
1992	7	1	0	0	0	0
1993	8	1	0	0	0	0
1994	9	1	0	0	0	0
1995	10	1	0	0	0	0
1996	11	1	0	0	0	0
1997	12	1	0	0	0	0
1998	13	1	0	0	0	0
1999	14	1	0	0	0	0
2000	15	1	0	0	0	0
2001	16	0	1	0	0	0
2002	17	0	1	0	0	0
2003	18	0	1	0	0	0
2004	19	0	0	1	0	0
2005	20	0	0	1	0	0
2006	21	0	0	1	0	0
2007	22	0	0	1	0	0
2008	23	0	0	1	0	0
2009	24	0	0	1	0	0

Note that UnlicExpireWind11 and UnlicExpire11 will take similar values for unlicensed patents.

Section II

Let *P* be the number of patents in the group of interest and also name this group of patents as *P*; for instance when examining patents licensed after grant, *P=159*. When examining an expiration effect for patents licensed after grant of large application length (4^{th} quartile) then *P=26*. Let *Q* be the number of unlicensed patents in the control group or the appropriate control group; name this group as *Q*. For instance when examining an expiration effect for patents licensed after grant, *Q=461* while when examining an expiration effect for patents licensed after grant of large application length (4^{th} quartile) then *Q=107*. Note that for this analysis, we take into account only unlicensed patents that haven't lapsed.

Step 1:
For each patent *p* in the group of patents *P* run the following regression:
$Y = Xb$
where *Y* is a *14x1* vector with the licensee citations of the p^{th} patent from period *0* to period *13*. Vector *b* is a *Qx1* vector while *X* is a *14xQ* matrix where in the q^{th} column the CitesNetAssignee of the q^{th} patent from period *0* to period *13* are located.
Step 2:
Acquire $\hat{b}$.Multiple $Xext \times \hat{b}$ to acquire $\hat{Y}$ where $Xext$ is a *TxQ* matrix where *T* is the number of periods for which each *q* patent receives citations. $\hat{Y}$ has citations per period that resemble the p^{th} patent's licensee citation.
Step 3: Do Steps 1through Step 2 for all patents in *P*. Thus, we acquire P patents where each particular patent resembles the licensee citations of the p^{th} patent in the treated group up until period *13*.

Table 1. Variable names and definitions

Variable	Definition
Endogenous Variables	
CitesNetAssignee	Total citations net assignee citations to the patent per period/year.
LicCites	Licensee citations to the patent per period/year.
Exogenous Variables	
Exclusive	Exclusive=1 if the patent is under an exclusive license at that period and Exclusive=0 otherwise
ExclusiveI	ExclusiveI=1 if the patent is exclusively licensed and up until minus I periods from patent expiration period and ExclusiveI=0 otherwise.
ExclusiveWindIJ	ExclusiveWindIJ =1 if the patent is exclusively licensed for the following periods: I periods before expiration period up until J periods after expiration period and ExclusiveWindIJ =0 otherwise.
ExcExpJ	ExcExpJ =1 if the patent has been licensed exclusively for the periods plus J from expiration period and ExclusiveExpireJ =0 otherwise
UnLicExpWindIJ	UnLicExpWindIJ=1 for an unlicensed patent for the following periods: I periods before expiration (or lapse) up until J periods after expiration period (or lapse) and UnLicExpWindIJ=0 otherwise.
UnLicExpJ	UnLicExpJ =1 for an unlicensed patent for the periods plus J from expiration period and UnLicExpJ =0 otherwise.
Patent Characteristics	
Claims	Number of claims of the patent.
NumberOfUSClass	Number of US Classifications of the patent.
NumberOfIPC	Number of International Patent Classifications of the patent.
BackCites	Number of the patents the patent is citing.
BackCitesJournals	Number of scientific papers the patent is citing.
IssueYear	Issue year of the patent.
AppLength	Time in years that lapsed from filing date to issue date of the patent.
NumberOfSecrecies	Number of secrecy agreements signed for the patent prior to license.
NumberOfLetters	Number of letter agreements signed for the patent prior to license.

Table 2. Frequency of patents by licensing status.

	1	2a	2b	3a	3b
	Number of Patents	**Distinguish Between Patents Licensed Before and After Grant**		**Examine Early Issued Patents. Patents Granted on or Before 1996**	
		Before Grant	**After Grant**	**Before Grant**	**After Grant**
Unlicensed Patents	1,517	-	-	865	
Exclusively Licensed	853	625	228	159	107
Nonexclusively Licensed Patents	114	58	56	22	29

Table 3. Summary statistics for patents issued on or before 1996.

	Unlicensed Patents		Exclusively Licensed Patents				Nonexclusively Licensed Patents			
			Licensed Before Grant		Licensed After Grant		Licensed Before Grant		Licensed After Grant	
Variables	Obs	Mean	Obs	Mean	Obs	Mean	Obs	Mean	Obs	Mean
CitesNetAssignee	18614	0.77	2910	1.27	2062	2.17	467	1.82	608	1.77
		(1.98)		(3.24)		(4.22)		(3.28)		(4.31)
LicCites	-	-	2910	0.16	2062	0.37	467	0.07	608	0.10
		-		(1.11)		(1.93)		(0.35)		(0.61)
Claims	865	14.68	159	18.25	107	16.48	22	13.36	29	14.03
		(12.24)		(14.35)		(11.39)		(8.06)		(9.83)
NumberOfUSClass	865	4.98	159	4.14	107	4.68	22	9.14	29	4.66
		(4.03)		(3.33)		(2.90)		(8.95)		(3.89)
NumberOfIPC	865	4.26	159	4.85	107	5.56	22	8.27	29	5.03
		(3.89)		(4.17)		(5.10)		(8.63)		(4.60)
BackCites	865	6.33	159	7.87	107	7.83	22	3.91	29	2.90
		(7.29)		(8.92)		(10.98)		(3.93)		(4.55)
BackCitesJournals	865	6.47	159	9.66	107	6.83	22	9.23	29	10.93
		(9.47)		(18.43)		(10.11)		(17.16)		(13.69)
IssueYear	865	1988.48	159	1991.70	107	1990.73	22	1988.77	29	1989.03
		(5.57)		(3.72)		(4.83)		(5.26)		(5.47)
Period first Lisensed	-	-	159	(6.92)	107	6.52	22	(1.82)	29	6.55
		-		(5.02)		(4.36)		(0.91)		(4.10)
AppLength	865	2.24	159	2.20	107	2.15	22	2.34	29	2.78
		(0.97)		(1.11)		(0.77)		(1.28)		(2.26)
NumberOfSecrecies	865	1.09	159	0.51	107	1.22	22	1.27	29	1.17
		(2.93)		(1.45)		(2.84)		(2.03)		(2.39)

NumberOfLetters	865	0.15	159	0.20	107	0.39	22	0.18	29	0.48
		(0.44)		(0.53)		(0.61)		(0.39)		(0.91)

Table 4. Baseline regressions. The first three columns comprise of unlicensed patents issued on or before 1996 and patents exclusively licensed after grant issued on or before 1996. The last three columns comprise of unlicensed patents issued on or before 1996 and patents exclusively licensed after grant issued on or before 1996. Note that for unlicensed patents, LicCites are replaced with CitesNetAssignee.

VARIABLES	(1) LicCites	(2) LicCites	(3) LicCites	(4) LicCites	(5) LicCites	(6) LicCites
Exclusive11	0.589**					
	(0.284)					
ExcWind11	0.111			0.440***		
	(0.191)			(0.121)		
ExcExp1	0.222			0.458***		
	(0.322)			(0.117)		
UnLicExpWind11	-0.158*			-0.107		
	(0.0861)			(0.0691)		
UnLicExp1	-0.272**			-0.188**		
	(0.124)			(0.0913)		
Exclusive22		0.554**				
		(0.254)				
ExcWind22		0.344***			0.403***	
		(0.126)			(0.127)	
ExcExp2		0.298			0.467***	
		(0.265)			(0.121)	
UnLicExpWind22		-0.146			-0.0867	
		(0.0910)			(0.0742)	
UnLicExp2		-0.291**			-0.202**	
		(0.128)			(0.0985)	
Exclusive33			0.515**			
			(0.213)			
ExcWind33			0.623**			0.390***
			(0.245)			(0.128)
ExcExp3			0.475***			0.475***
			(0.172)			(0.141)
UnLicExpWind33			-0.117			-0.0688
			(0.0820)			(0.0714)
UnLicExp3			-0.212*			-0.153
			(0.115)			(0.106)
Constant	0.430***	0.426***	0.438***	0.368***	0.366***	0.374***
	(0.107)	(0.108)	(0.108)	(0.0887)	(0.0894)	(0.0898)
Observations	20,676	20,676	20,676	21,524	21,524	21,524
R-squared	0.064	0.064	0.063	0.058	0.058	0.058
Number of p	972	972	972	1,024	1,024	1,024
Patent FE	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES

Table 5. Baseline regressions. All columns comprise of unlicensed patents issued on or before 1996 and patents exclusively licensed after grant issued on or before 1996. The first three columns include only the patents that are on the fourth quartile of the application length distribution of each group (low quality). The first three columns include only the patents that are on the first quartile of the application length distribution of each group (high quality). Note that for unlicensed patents, LicCites are replaced with CitesNetAssignee.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	LicCites	LicCites	LicCites	LicCites	LicCites	LicCites
Exclusive11	0.204*			1.283*		
	(0.115)			(0.652)		
ExclusiveWind11	0.456***			0.246		
	(0.171)			(0.206)		
ExcExp1	1.089***			-0.140		
	(0.269)			(0.467)		
UnLicExpWind11	0.0481			-0.181		
	(0.124)			(0.173)		
UnLicExp1	0.120			-0.266		
	(0.136)			(0.304)		
Exclusive22		0.208*			1.235**	
		(0.120)			(0.621)	
ExcWind22		0.563***			0.382	
		(0.183)			(0.240)	
ExcExp2		1.155***			-0.0292	
		(0.268)			(0.384)	
UnLicExpWind22		0.0430			-0.238	
		(0.121)			(0.186)	
UnLicExp2		0.174			-0.343	
		(0.156)			(0.327)	
Exclusive33			0.194			1.099**
			(0.125)			(0.508)
ExcWind33			0.677***			1.160*
			(0.241)			(0.629)
ExcExp3			1.118***			0.463**
			(0.260)			(0.233)
UnLicExpWind33			0.0335			-0.174
			(0.130)			(0.154)
UnLicExp3			0.200			-0.135
			(0.182)			(0.250)
Constant	0.186	0.198	0.205	0.684***	0.671***	0.711***
	(0.160)	(0.162)	(0.163)	(0.186)	(0.191)	(0.189)
Observations	5,057	5,057	5,057	5,114	5,114	5,114
R-squared	0.090	0.090	0.089	0.096	0.095	0.092
Number of p	241	241	241	240	240	240
Patent FE	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES

Table 6. Baseline regressions. All columns comprise of unlicensed patents issued on or before 1996 and patents exclusively licensed before grant issued on or before 1996. The first three columns include only the patents that are on the fourth quartile of the application length distribution of each group (low quality). The first three columns include only the patents that are on the first quartile of the application length distribution of each group (high quality). Note that for unlicensed patents, LicCites are replaced with CitesNetAssignee.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	LicCites	LicCites	LicCites	LicCites	LicCites	LicCites
ExclusiveWind11	0.458***			0.690***		
	(0.142)			(0.171)		
ExcExp1	0.760***			0.780***		
	(0.167)			(0.298)		
UnLicExpWind11	0.0383			-0.0611		
	(0.123)			(0.110)		
UnLicExp1	0.0958			-0.0632		
	(0.130)			(0.154)		
ExcWind22		0.434***			0.688***	
		(0.151)			(0.180)	
ExcExp2		0.832***			0.730***	
		(0.188)			(0.246)	
UnLicExpWind22		0.0331			-0.102	
		(0.117)			(0.118)	
UnLicExp2		0.136			-0.0991	
		(0.150)			(0.159)	
ExcWind33			0.397**			0.701***
			(0.155)			(0.181)
ExcExp3			0.883***			0.973***
			(0.211)			(0.235)
UnLicExpWind33			0.0247			-0.0718
			(0.126)			(0.108)
UnLicExp3			0.157			0.0141
			(0.175)			(0.161)
Constant	0.538***	0.549***	0.553***	0.0989	0.555***	0.575***
	(0.184)	(0.185)	(0.186)	(0.211)	(0.154)	(0.154)
Observations	5,232	5,232	5,232	5,344	5,344	5,344
R-squared	0.084	0.084	0.084	0.074	0.075	0.075
Number of p	254	254	254	253	253	253
Patent FE	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES

Table 7. Baseline regressions. All columns comprise of unlicensed patents issued on or before 1996 and patents exclusively licensed after grant issued on or before 1996. The first three columns include only the patents that are on the fourth quartile of the NumberOfIPC distribution of each group (broad scope). The first three columns include only the patents that are on the first quartile of the application length distribution of each group (narrow scope). Note that for unlicensed patents, LicCites are replaced with CitesNetAssignee.

VARIABLES	(1) LicCites	(2) LicCites	(3) LicCites	(4) LicCites	(5) LicCites	(6) LicCites
Exclusive1	0.938			0.422**		
	(0.580)			(0.170)		
ExclusiveWind11	0.670			0.227		
	(0.419)			(0.248)		
ExcExp1	0.331			0.341		
	(0.577)			(0.228)		
UnLicExpWind11	-0.102			-0.179		
	(0.106)			(0.110)		
UnLicExp1	-0.234			-0.243*		
	(0.157)			(0.136)		
Exclusive22		0.830*			0.381**	
		(0.486)			(0.152)	
ExcWind22		1.385*			0.323*	
		(0.758)			(0.166)	
ExcExp2		0.501			0.369*	
		(0.482)			(0.200)	
UnLicExpWind22		-0.0447			-0.195*	
		(0.108)			(0.115)	
UnLicExp2		-0.183			-0.300**	
		(0.154)			(0.137)	
Exclusive33			0.782*			0.377**
			(0.435)			(0.154)
ExcWind33			1.638**			0.307*
			(0.754)			(0.160)
ExcExp3			0.581			0.412**
			(0.377)			(0.196)
UnLicExpWind33			0.00626			-0.211*
			(0.101)			(0.109)
UnLicExp3			-0.0463			-0.315**
			(0.151)			(0.146)
Constant	0.473***	0.496***	0.533***	0.736***	0.721***	0.714***
	(0.170)	(0.173)	(0.172)	(0.193)	(0.193)	(0.194)
Observations	10,294	10,294	10,294	9,705	9,705	9,705
R-squared	0.073	0.073	0.074	0.062	0.062	0.062
Number of p	498	498	498	438	438	438
Patent FE	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES

Table 8. Baseline regressions. All columns comprise of unlicensed patents issued on or before 1996 and patents exclusively licensed before grant issued on or before 1996. The first three columns include only the patents that are on the fourth quartile of the NumberOfIPC distribution of each group (broad scope). The first three columns include only the patents that are on the first quartile of the application length distribution of each group (narrow scope). Note that for unlicensed patents, LicCites are replaced with CitesNetAssignee.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	LicCites	LicCites	LicCites	LicCites	LicCites	LicCites
ExclusiveWind11	0.488**			0.358*		
	(0.203)			(0.212)		
ExcExp1	0.449*			0.346**		
	(0.249)			(0.164)		
UnLicExpWind11	-0.0544			-0.174		
	(0.0898)			(0.106)		
UnLicExp1	-0.162			-0.242*		
	(0.123)			(0.127)		
ExcWind22		0.594***			0.236	
		(0.182)			(0.221)	
ExcExp2		0.574***			0.306**	
		(0.201)			(0.154)	
UnLicExpWind22		-0.00817			-0.195*	
		(0.0987)			(0.112)	
UnLicExp2		-0.136			-0.310**	
		(0.134)			(0.131)	
ExcWind33			0.645***			0.154
			(0.194)			(0.220)
ExcExp3			0.797***			0.151
			(0.200)			(0.185)
UnLicExpWind33			0.0384			-0.219**
			(0.0931)			(0.107)
UnLicExp3			-0.0107			-0.351**
			(0.137)			(0.142)
Constant	0.374***	0.380***	0.415***	0.720***	0.703***	0.692***
	(0.121)	(0.123)	(0.121)	(0.193)	(0.194)	(0.195)
Observations	10,385	10,385	10,385	10,084	10,084	10,084
R-squared	0.067	0.067	0.067	0.058	0.058	0.057
Number of p	506	506	506	460	460	460
Patent FE	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES

Table 9. Baseline regressions. The first three columns comprise of unlicensed patents issued on or before 1996 and patents nonexclusively licensed after grant issued on or before 1996. The last three columns comprise of unlicensed patents issued on or before 1996 and patents nonexclusively licensed after grant issued on or before 1996. Note that for unlicensed patents, LicCites are replaced with CitesNetAssignee.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	LicCites	LicCites	LicCites	LicCites	LicCites	LicCites
NonExclusive1	-0.0821					
	(0.0860)					
NonExcWin11	-0.0747			0.288		
	(0.0889)			(0.184)		
NonExcExp1	0			0		
	(0)			(0)		
UnLicExpWind11	-0.105			-0.101		
	(0.0698)			(0.0704)		
UnLicExp1	-0.178**			-0.165*		
	(0.0876)			(0.0890)		
NonExclusive2		-0.0689				
		(0.0884)				
NonExcWin22		-0.0758			0.198	
		(0.0914)			(0.167)	
NonExcExp1		0			0	
		(0)			(0)	
UnLicExpWind22		-0.0926			-0.0850	
		(0.0742)			(0.0750)	
UnLicExp2		-0.198**			-0.180*	
		(0.0911)			(0.0930)	
NonExclusive3			-0.0511			
			(0.0897)			
NonExcWin33			-0.0437			0.190
			(0.0973)			(0.154)
NonExcExp1			0			0
			(0)			(0)
UnLicExpWind33			-0.0779			-0.0663
			(0.0703)			(0.0712)
UnLicExp3			-0.146			-0.123
			(0.0951)			(0.0973)
Constant	0.414***	0.410***	0.416***	0.419***	0.416***	0.424***
	(0.0883)	(0.0888)	(0.0892)	(0.0885)	(0.0890)	(0.0893)
Observations	19,222	19,222	19,222	19,081	19,081	19,081
R-squared	0.065	0.065	0.065	0.066	0.065	0.065
Number of p	894	894	894	887	887	887
Patent FE	YES	YES	YES	YES	YES	YES
Period FE	YES	YES	YES	YES	YES	YES
Cite Year FE	YES	YES	YES	YES	YES	YES

Table 10.Difference between matched group of patents and patents exclusively licensed after grant. Note that the pool of unlicensed patents, for this table, excludes patents that have lapsed. One-Tail P-Values, Ha>0. Note that for the matched group, LicCites are replaced with CitesNetAssignee.

	Baseline		**High Quality**		**Low Quality**		**Narrow Patent Scope**		**Broad Patent Scope**	
Window	Difference	P-Value	Difference	P-Value	Difference	P-Value	Difference	P-Value	Difference	P-Value
(-1,+1)	1.42	0.04	5.21	0.07	0.14	0.1	-1.4	0.95	2.4	0.06
	0.84		3.24		0.11		0.84		1.49	
(-2,+2)	2.25	0.03	5.67	0.08	0.43	0.22	-1.28	0.93	2.43	0.13
	1.2		3.82		0.54		0.84		2.1	
(-3,+3)	3.44	0.02	8.85	0.06	1.15	0.16	-1.4	0.92	4.9	0.06
	1.63		5.35		1.14		0.95		2.96	

Table 11.Difference between matched group of patents and patents exclusively licensed after grant. Note that the pool of unlicensed patents, for this table, excludes patents that have lapsed. One-Tail P-Values, Ha>0.

	Baseline		**High Quality**		**Low Quality**		**Narrow Patent Scope**		**Broad Patent Scope**	
Window	Difference	P-Value	Difference	P-Value	Difference	P-Value	Difference	P-Value	Difference	P-Value
(-1,+1)	0.14	0.22	0.48	0.06	-0.03	0.6	-59	0.71	0.46	0.25
	0.18		0.3		12		1.1		0.66	
(-2,+2)	0.14	0.32	0.63	0.09	-0.1	0.8	-1.24	0.77	0.63	0.31
	0.29		0.45		0.11		1.68		1.26	
(-3,+3)	0.13	0.36	0.77	0.13	-0.11	0.9	-1.53	0.79	0.87	0.28
	0.37		0.67		0.09		1.91		1.48	

Figure 1. Compare licensee citations for patents licensed exclusively after grant (while licensed and while unlicensed). Note that licensee citations for unlicensed patents are replaced by total citations net assignee citations.

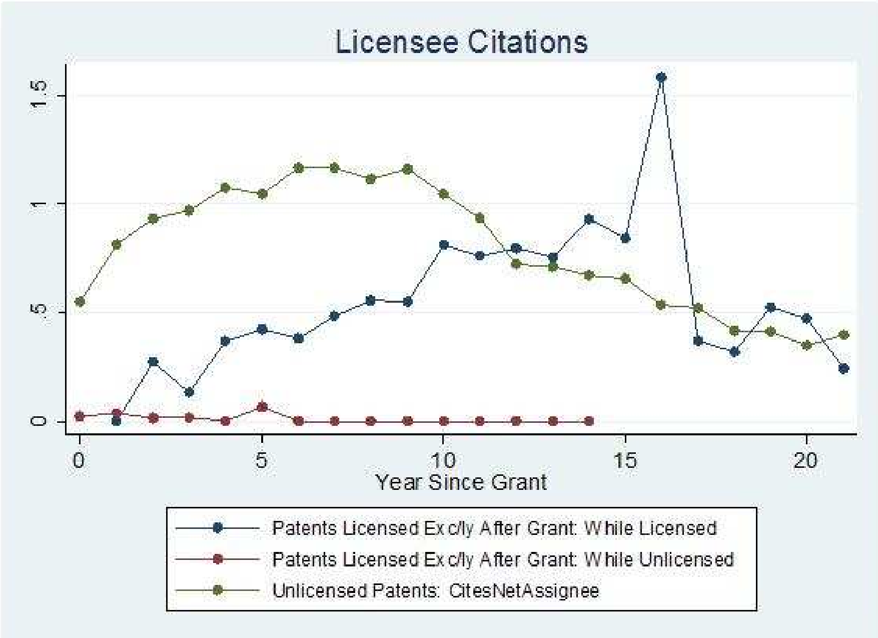


Figure 2. Compare licensee citations for patents licensed exclusively before grant. Note that licensee citations for unlicensed patents are replaced by total citations net assignee citations.

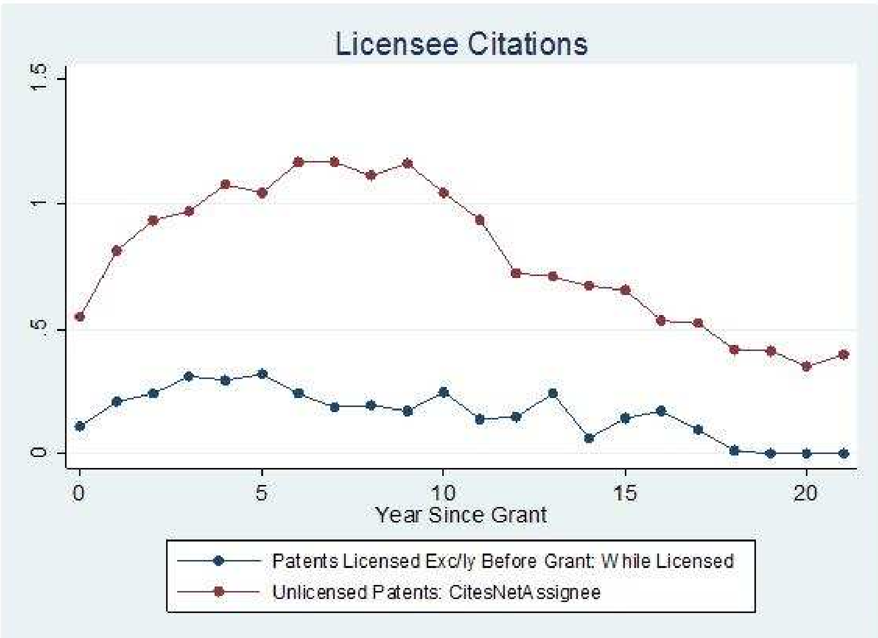


Figure 3. Display licensee citations for patent licensed nonexclusively before grant and after grant (while licensed and while unlicensed)

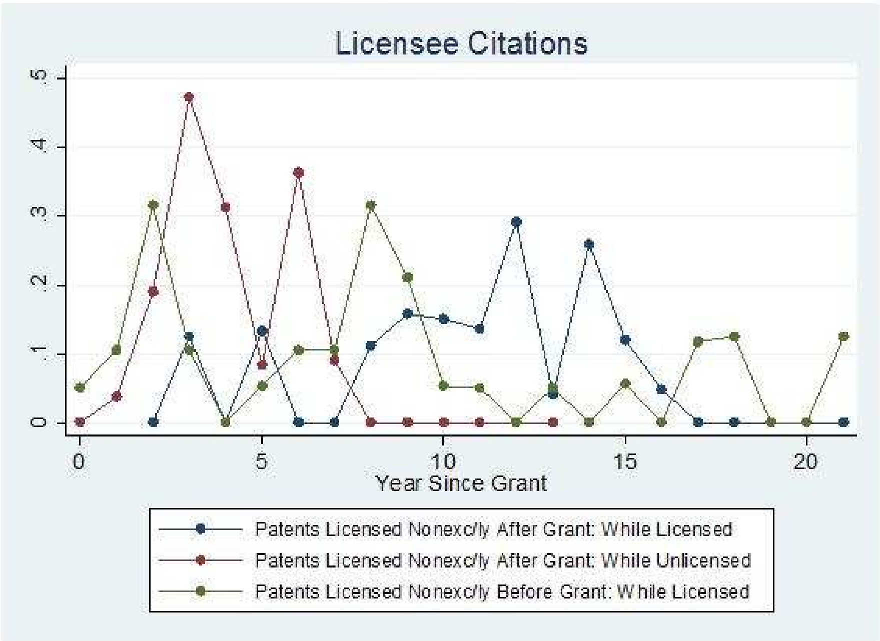


Figure 4. Compare licensee citations for patents licensed exclusively after grant (merge while licensed and while unlicensed observations) with the matched group of patents.

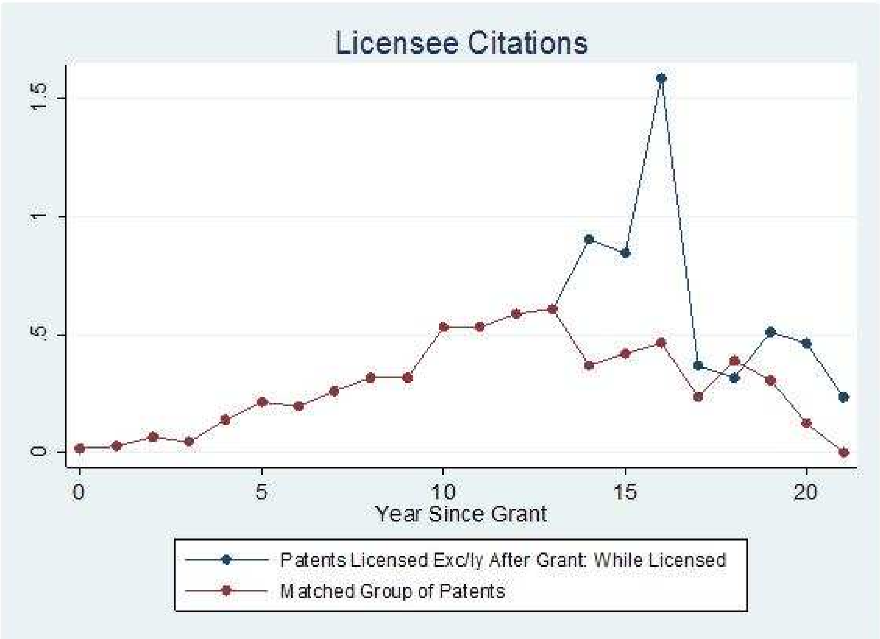
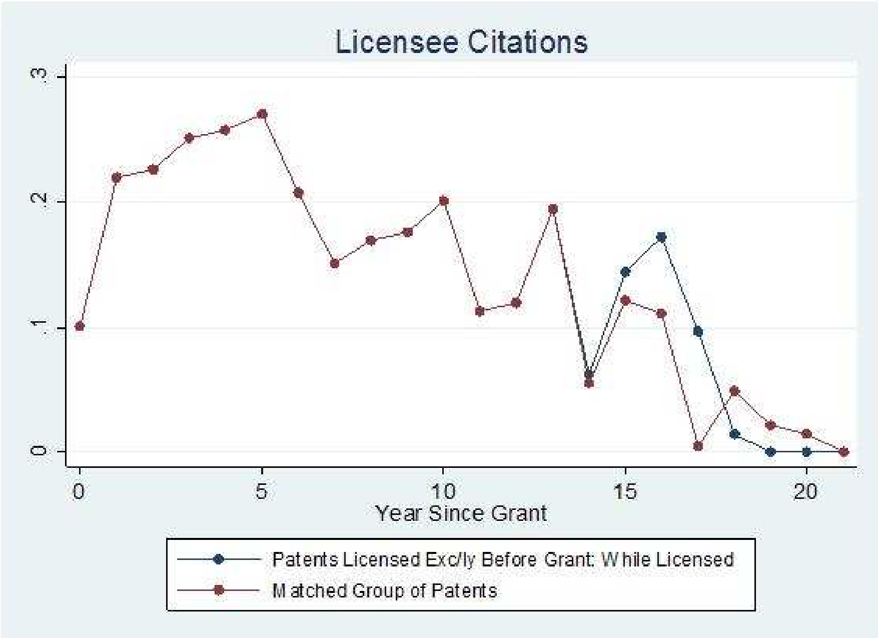


Figure 5. Compare licensee citations for patents licensed exclusively before grant (merge while licensed and while unlicensed observations) with the matched group of patents.



Chapter III

The Role of Research Sponsor on University Technology Management

Introduction

University technology management has experienced a dramatic transformation in the last thirty years in the US. In 1974, technology managers established the Association of University Technology Managers, with 75 members. Nowadays it counts approximately 3,500 members primarily in the US and Canada. Most universities now have Offices of Technology Transfer (OTT) which are responsible for receiving inventions by university inventors (faculty, students and staff) and marketing them in the most efficient way.

However, this change is still controversial; some have claimed that it can endanger the mission of the university on a number of significant dimensions (Press and Washburn 2000, Washburn 2005). First, a number of scholars have pointed that the increasingly restrictive and secretive management of technologies might impede diffusion of key scientific advances stemming from university researchers (Heller and Eisenberg 1998; Walsh, Arora and Cohen 2003). Murray and Stern (2007) and Sampat (2004) provided evidence, by examining citations of related scientific publications, that patenting discourages knowledge diffusion of university technologies while Lei, Juneja and Wright (2009) and Thompson (2010) found that the transactions costs imposed on the exchange of materials for research by university administrators anxious to protect intellectual property can have serious impediments to academic research. The first two chapters of the dissertation contribute to this literature by examining the relation between exclusive licensing and follow-on research by licensees and non-licensees.

A second concern that has been raised is that university inventors might conduct more applied research at the expense of basic research (Henderson, Jaffe and Trajtenberg 1998, Cohen et al 1998, Foltz, Barham and Kim 2007). Concerns about the mix of applied versus basic research are not new (Nelson 1959), but researchers are still trying to measure the extent to which this is a relevant issue within the university context, to decide on its policy implications. For instance, Lach and Schankerman (2008) conclude that inventors respond to royalty incentives by conducting more commercially-oriented research, while Thursby, Thursby and Gupta-Mukherjee (2007) considered theoretically the research profile of an academic inventor throughout her career and found that licensing income may direct the faculty towards more applied research. Another influence that can tilt the focus of a university's research agenda is private sector funding. The prevalent research sponsor of universities in the United States is the federal government which provides approximately 60-70% (National Science Board 2010) of total university research funding. However, non-negligible amounts of research funds come from private sponsors; in particular, in recent years a number of private firms have signed multi-million dollar research agreements with universities. Examples include the $500 million research grant of BP to University of California-Berkeley, Lawrence Berkeley National Laboratory and University of Illinois at Urbana-Champaign for research on renewable energy and in particular cellulosic biofuels and the $250 million research grant of a number of firms (ExxonMobil, General Electric, Schlumberger and Toyota) to Stanford for related research[21].

This paper examines the relationship between the type of research sponsorship (i.e. public versus corporate funding) and the flow of invention disclosures to the OTT. By disclosing an invention, a university faculty member indicates the path to its

[21] For a survey on recent multi-million research grants of corporations to universities regarding biofuels consult Washburn (2010).

commercialization which usually involves licensing. As we shall see, the majority of inventions that are licensed by the University of California are accompanied by some form of Intellectual Property (IP). Moreover, Agrawal and Henderson (2002) argued that university patents are more likely than university scientific publications to represent applied research. By examining the relationship between the type of sponsor, the propensity to disclose inventions and the propensity to patent, we hope to gain insight into the way in which research sponsorship influences the practice of university innovations (i.e. disclosing versus not disclosing inventions) and the direction of the research agenda (i.e. applied versus basic).

Moreover, we examine whether corporate research funding leads to unforeseen restrictions on innovative output relative to cases where the sponsor is a public agency. A common concern regarding corporate research funding is that firms may exercise pressure to the university to exclusively license any inventions stemming from the research project[22] (Press and Washburn 2000). For inventions that are widely applicable, exclusive licensing might seriously retard their diffusion.

To address these issues, we use the unique dataset of invention disclosures, and the associated patenting and licensing activity, made accessible to us, on a confidential basis, by University of California Office of Technology Transfer (UC-OTT). First we examine the relation between the type of sponsorship and the likelihood of an invention disclosure. Second, we address the relation between the type of sponsorship and the propensity to patent. Finally, we examine whether the likelihood and type of licensing of inventions is associated with the type of the sponsor that financed the research grant.

The next section of the chapter examines average relations between the type of research sponsor, technology fields, rate of disclosure and patenting. The following section explores these relationships under the lens of licensing. Finally, the paper concludes.

Invention Disclosures, Technology Fields, Sponsorship Information and Patenting Activity

We exploit a unique dataset of inventions disclosed to the UC-OTT. Specifically, the Director, William Tucker, has generously allowed us to access, with appropriate confidentiality agreements, data elements regarding 7,801 inventions disclosed to the UC-OTT from January 1st 1975 until June 30th 1997. These invention disclosures are accompanied by comprehensive information regarding subsequent patent prosecution and licensing history. They are also associated with (incomplete) information regarding their technology field and research sponsorship.

Figure 1 shows the frequency of these inventions by disclosure year. Inventions steadily increased throughout the eighties and nineties; the drop in 1997 is attributed to the fact that we observe inventions disclosed only up until June 30th instead of the end of the year. This upward trend is in accordance with a steady increase in inventions disclosed by US universities since 1980 where the Bayh-Dole Act passed (AUTM, 2005-2008).

To examine the variety of technology fields covered by UC inventions, we exploit a field which in most cases is recorder by OTT staff, with the collaboration of the inventor, at the time when the invention is being disclosed. The aim is to assign the technology to the field that best describes the category of the invention. Table 1 shows the frequency of

[22] For an excellent review of challenges that can arise from ties between academia and industry consult (Washburn 2005).

technology fields. Note that there are 1,312 inventions for which we have no technology field information. Most inventions are related to Biological (1,718 – 22%), Medical (1,136 – 14.6%) and Pharmaceutical (1,106 – 14.2%) advances. Other fields with high frequency of inventions include Electronics (479), Automation Equipment (592) and Chemical Sciences (426). Though the definitions of these fields are broad, a first assessment can be made of the fields that are more frequently reported on UC invention disclosures. Given that throughout this chapter, we will display information for all technology fields (19 fields excluding the inventions with no technology information), we construct acronyms for each technology field which are reported in Table 2.

Finally, note that some fields (such as engineering) may be underrepresented in this sample. As will be shown in this chapter, and as Elfenbein (2007) has argued, the most frequent route followed by inventions disclosed to OTT to pass to the marketplace is via patenting and licensing. However, as Levin and his co-authors (1985, 1987) have shown, patents are more essential in some fields (e.g. pharmaceutical, medical fields) than others (e.g. engineer, computer software). This could explain the under-representation of certain fields in this dataset where UC has traditionally been on the cutting edge of research. For instance, in engineering (as well as economics and business) the main tool of transferring knowledge from the university is via consulting (Graff, Heiman and Zilberman 2002). Hence, this research project focuses on those technologies where the UC has a strong research tradition and on technologies where inventions are more likely to follow the OTT management route.

The next variable of interest is the type of research sponsor. When an inventor discloses an invention to the OTT, she is obligated to disclose all the organizations or firms or agencies that have financed the specific invention. In other words, the inventor should disclose all the research sponsors that have financed equipment, students and other tangible and intangible material that was essential for the invention. Given that in most cases faculty members obtain funds from different research grants and research sponsors, she frequently discloses more than one sponsor or may disclose the sponsor of which the research grant is intuitively closest to the invention. For instance, consider a faculty member with two research projects that run simultaneously; one sponsored by NIH that examines ways to make corn drought resistant and one sponsored by Monsanto that examines ways to make corn Bt resistant. If the faculty discovers a DNA sequence that makes corn resistant to drought, then if she discloses this invention to OTT she might disclose only the NIH as research sponsor, since it is the one closest to the invention. However, if the inventor has used equipment or other resources financed by Monsanto, then she may also have to disclose Monsanto as a research sponsor.

It should be noted that for approximately 68.7% of the inventions we don't have sponsor information. One reason could be that the invention is not derived from a research grant while a second, probably more important, could be that the sponsorship field was not filled out during disclosure. To examine which explanation dominates the data, we graph in Figure 2 the number of inventions with no sponsor information by disclosure year and compare them with the number of total invention disclosures. As can be seen the number of inventions with no sponsor information relative to the total number of inventions declines with time. This might imply that the data entry have become more accurate during the late years in our sample. Note that all the findings regarding the type of research sponsor rely heavily on the assumption that inventions with no sponsor information are randomly distributed across the types of sponsors. Given that we don't have any prior knowledge in which this lack of sponsor information is biased in favor of certain types of sponsors, we have no reason to conjecture that our following estimates will be biased.

Table 3 shows the number of inventions by sponsorship type. The majority of invention disclosures that report a sponsor type have been financed by the government (1,471 – 18.9%) while 206 (2.6%) have been financed by organizations; these can be universities, marketing boards or foundations. 296 (3.8%) have been financed solely by corporations. There are also 89 inventions (1.1%) that have been financed by both the government and a corporation; it should be noted that these inventions do not necessarily stem from a research contract where an industry sponsor and a government sponsor jointly signed. It seems more likely that the inventor filled in two sponsors since she believed that the invention can be linked to both research grants intuitively as well as financially. Finally, there are 294 inventions that we assign as unclassified. These inventions have been financed by a mix of sponsor types and therefore it is not clear what this may imply for the technology management.

A first important observation from Table 3 is that after excluding the inventions with no sponsor information from the sample, the percentages of inventions by sponsor closely resemble the overall support by each type of sponsor. Primarily, we focus on government sponsorship which accounts for approximately 70% of research funds to universities (National Science Board 2010). In Table 3, 60.3% of inventions disclosed stem from purely government sponsored research grants. After including the business-government sponsored inventions and the set of the unclassified ones which have at least one government sponsor, then this percentage climbs up to 70%. This rather crude finding gives a significant insight as to whether industry sector funding influences university technology management practices. In particular, a concern that has been raised is that corporate funding can divert academic faculty from a research oriented agenda to a more administrative oriented agenda (Press and Washburn 2000) by imposing a series of limitations to publishing and exercising pressure to faculty to actively explore market potential for the inventions stemming from corporate financed research projects. To the extent that an invention disclosure indicates active pursuit of market potential by the faculty, we see that the type of research sponsor doesn't seem to be correlated with a particular type of practice of invention disclosure. On the contrary, we observe the portion of inventions disclosures stemming from government funding to resemble the overall portion of research funding to universities. It should be noted that the above conclusion is derived from observing a single (multi-campus) university; i.e. University of California. Thus, it should be interpreted with caution.

Next, we examine the relationship between the type of sponsor and the type of technology field, as reported in Tables 4i-4iv. Only 52.7% of Biological inventions lack any sponsor information while 28.3% have stemmed from research grants with government involvement only. Other fields with high frequency in the data have substantially higher likelihood of having no sponsor information (Chemicals – 82.2%, Medical – 82%, Pharmaceutical 69.4%). The major reason for this stark difference is that the fields of Biology and Biotechnology are "younger" with respect to Medical and Pharmaceutical inventions and come from later years in the sample where the lack of sponsor information is less severe. Figure 3 shows that the rate of disclosures of inventions in the Biology field increases substantially more than for Pharmaceutical and Medical technology fields during the later years of our sample.

Given that inventions with no sponsor information make the interpretation of the results difficult and since we want to focus on a handful of technology fields that have a substantial number of inventions, Table 5 excludes inventions with no sponsor information and technology fields with small number of inventions. Biological and Pharmaceutical inventions are relatively similar with respect to the types of sponsors. However, Chemical and Medical inventions are less likely to stem from purely government research grants (43.4% and 49.8% respectively) while they are more likely to stem from purely private sector research grants (18.4% and 24.4% respectively). Moreover, we see that the inventions with no technology information are close to the total average, suggesting that the lack of this information is randomly distributed across fields.

Next we try to examine the rate of patenting by technology field and type of sponsor. Tables 6i-6iv examine the relationship of technology field and likelihood of an invention being awarded a patent. Of 7,801, 2,072 (26.6%) inventions have been awarded at least one patent. The technology fields with the highest frequency of inventions have similar likelihoods of being awarded a patent. Of Biological invention disclosures 29.5% receive at least one patent while the frequencies for Medical and Pharmaceutical inventions are 27.5% and 32.5% respectively. Even though the difference is statistically significant, between Pharmaceutical and the other fields (i.e. Biological and Medical inventions), these differences are relatively small.

Given that the rate of patenting appears to be relatively constant across the most important technology fields, we turn our attention to the relationship between patenting and type of research sponsor in Tables 7i-7ii. The main comparisons throughout this chapter are between inventions stemming from government and from business sponsored projects. The table shows that 38.2% of purely government sponsored inventions obtained at least one patent while for purely business sponsored inventions the frequency is 34.1%. The difference is not statistically significant at the 10% level. This finding sheds light to the debate on whether corporate funding leads to an increased tendency of universities to pursue patent protection. The frequency of patenting is not significantly correlated with whether the research sponsor is a firm or a government agency.

This finding implies that the increased tendency of universities to pursue IP, and in particular patents, may not be influenced by corporate research funding. This result is in accordance with evidence by Foltz, Kim and Barham (2003) where they conducted a university level empirical analysis and examined whether non-federal funding increases agricultural biotechnology patenting by universities. They concluded that non-federal funding doesn’t influence university patenting in that area. This chapter supplements this literature by examining this question at a more disaggregate level of analysis; i.e. at the invention disclosure level.

Finally, to the extent that patents tend to stem from applied research better than basic research, as Agrawal and Henderson 2002 and Foltz, Barham and Kim 2007 have argued, we also find that the type of research sponsor does not seem to be related to more basic or applied research output. That said, we do not argue that both government agencies and private firms finance approximately similar research projects. Even if corporate funding is directed towards more applied research than government funding, the final research output could be similar. Faculty might tailor their research projects to their actual research interests instead of following the research projects’ deliverables to the letter. Though, in an era where federal funding is becoming more scarce, inventors might increasingly turn to industry funding, we do not find evidence that this kind of funding to distort their research agenda.

Invention Disclosures and Licensing Activity

We now turn to the rate of licensing by type of sponsor and type of technology. In so doing, we want first to address the type of licensing and the meaning of each type. In the dataset, there is a field that describes the type of the license. There are three distinct types: “exclusive”, “exclusive-with-limit” and “nonexclusive”. After discussions with OTT personnel to assess the meaning of each type, we concluded that patents that are licensed exclusively-with-limit are usually licensed within a field of use. Licenses that are coded as “exclusive” may have clauses which allow another firm can potentially license the invention in another geographical area or in another field of research. Even absent such clauses, licensees in one field have been willing to allow the inventions to be licensed to other fields.

Second, there is a substantial subset of inventions that reportedly have been licensed, but have no form of intellectual property. These 85 inventions constitute 6.8% of all licensed inventions; the majority (53) of those is located in the Biological sciences. Webster and Jensen (2009) find that Australian inventors frequently pursue commercialization of an invention even if they have failed to receive patent for it. In our dataset, approximately 63.5% of these unpatented inventions are licensed non-exclusively; furthermore 45% of these nonexclusively licensed inventions are licensed more than once. This finding sheds light on the interaction between licensing and patenting and points out that it is not always necessary for a licensed invention to be associated with some form of formal IP.

We now turn our attention to the bulk of licensed inventions; i.e. inventions that have been licensed and are associated with some form of IP. There are in total 1,129 inventions that have been licensed and are associated with (or at least have pursued) a patent. As can be seen from Table 8, 55.4% of licensed inventions have been licensed exclusively, 15.3% exclusively-with-limit while 15.7% non-exclusively. Moreover, there are two separate groups of inventions based on the type of exclusivity. The first group of inventions has been licensed both exclusively and exclusively-with-limit while the second group of inventions consists of inventions that have been licensed exclusively (or exclusively-with-limit) and nonexclusively. From a cursory review of the dataset, inventions belonging in these groups are primarily inventions that first have been licensed in one fashion and later the license is terminated and another type of license is struck. A small portion of these inventions has been licensed to the same firm in another type of license once the first is terminated. If we add across groups that were licensed nonexclusively, only 27.2% of inventions have been licensed nonexclusively. This finding regarding the propensity of exclusive licensing is in accordance with survey data of university technology managers which reports that the majority of academic inventions is licensed exclusively (Henry et al 2003, Pressman 2006).

Tables 9i-9iv explore the relationship between licensing and technology fields. First of all, from the above tables it can be inferred that 20.7% of Biological inventions are licensed while for Medical and Pharmaceutical the frequencies are 17.3% and 18% respectively. Of Biological inventions, 12.6% are licensed with some form of pure exclusivity (Exclusive, Exclusive-With-Limit or Mix-Exclusives) while for Medical and Pharmaceutical inventions the chances are 15.8% and 15% respectively. On the other hand Biological inventions are more likely to be licensed nonexclusively. Note that the differences between Biological inventions and the other two fields are statistically significant at the 10%

level. This simple comparison among the three most frequent technology groups reveals an important finding; that is, exclusivity depends heavily on the type of technology with Medical and Pharmaceutical inventions being more likely to be licensed with some form of exclusivity than the Biological inventions.

Tables 10i-10ii explore the relationship between licensing and type of sponsor. As before, the most important comparison is that between purely government sponsored inventions and purely business sponsored inventions. Clearly business sponsored inventions are significantly more likely to be licensed (33.3%) than purely government sponsored inventions (20.3%) with the difference being statistically significant at the 1% significance level. Moreover, 25.2% of business funded inventions are licensed with some form of exclusivity, whereas only14.6% of government sponsored inventions are licensed with some form of exclusivity. Therefore, inventions that are financed by corporations appear more likely to be licensed than government funded inventions (difference statistically significant at the 1% level), and they are also much more likely to be licensed with some form of exclusivity. However, note that this difference in exclusivity disappears when conditioning on the invention being licensed.

This finding accords with concerns that corporate funded inventions might be more likely to be licensed exclusively if the research sponsor becomes the licensee. Two negatively publicized cases were outlined in Chapter I where DuPont licensed exclusively the OncoMouse from Harvard University (DuPont had financed a significant amount of the relevant faculty research) and Geron licensed stem cells exclusively-with-limit, from the University of Wisconsin, which later wanted to extend exclusivity on other human tissue types for research (Geron had financed the faculty's research project). However, an equally relevant observation is that corporate funded inventions are substantially more likely to be licensed. To the extent a license is a first indication for the commercialization of the technology, corporate funded inventions appear to achieve more effective technology transfer than their government funded counterparts.

To refine our understanding of the source of this difference in the likelihood of licensing and its implications on the type of exclusivity, we consider Tables 11i-11ii which exclude inventions which have been licensed by the research sponsor. The table shows that government and corporate funded inventions have virtually the same likelihood of licensing (20.1% and 20.6% respectively) implying that the difference we observed in licensing propensity is attributable to sponsors that license inventions they have funded. This finding extends to the type of exclusivity since for this subset of inventions (unlicensed inventions or licensed inventions in which research sponsor is not the licensee) 12.5% have been licensed with some form of exclusivity while this figure is 14.5% for government funded inventions; note that this difference is not statistically significant.

This result implies that any difference between government funded and corporate funded inventions with regards to propensity and type of licensing is attributed to the cases where the sponsor becomes the licensee. This interesting observation sheds light to the role of sponsor on technology management by arguing that substantial differences are mainly attributed to the cases where the research sponsors become the licensees. Note that these important findings regarding the type of research sponsor rely heavily on the assumption that inventions without sponsor information are randomly distributed across all the types of research sponsors.

Conclusion

This chapter addresses the influence of the research sponsor on university technology management. The two main types of research sponsors that were examined were corporations and the government. Though there has been a long-standing debate on the role of corporate funding on university research, the empirical evidence is scarce, primarily due to the lack of comprehensive disaggregate level data. By gaining access to invention disclosures by UC-OTT, we have been able to examine the relationship between the type of sponsor on the rate of invention disclosures, the propensity of patenting, the likelihood and type of licensing.

With respect to the rate of invention disclosure we find no significant differences between business sponsors and government sponsors. Similarly, the propensity to patent appears to be independent to the type of sponsor. Differences in rates of disclosure and patent appear to reflect differences on faculty attributes and university management practices rather than influences of the type of sponsor. There are however large differences in the overall propensity to achieve a licensing agreement and propensity for exclusivity for corporate funded inventions. These differences are mainly attributed to the cases where the sponsor becomes the licensee. The limitation of this result is the argument that research sponsors will license the high quality inventions and therefore with some form of exclusivity thus hindering the diffusion of these technologies. Even though this argument may hold, we see that the remaining inventions have similar likelihood of licensing as the government funded inventions implying that the research sponsor does not necessary license the higher quality inventions but the inventions closest to his research/business interests.

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Table 1. Frequency of inventions by technology field.

Technology Field	No.	Col %
Advanced material products and service	195	2.5
Computer systems, peripherals, accessories, and services	183	2.3
Electrical, electronic, electromechanical or mechanical, equipment services	479	6.1
Eqp. and services for the analysis, protection and treatment of the environment	59	0.8
Eqp. and services for the medical industry	1,136	14.6
Eqp. and services for the transportation industry	33	0.4
Eqp. and services relating to power generation	117	1.5
Factory automation eqp. and services	592	7.6
Ground defense radar systems/eqp.	33	0.4
Pharmaceutical products and services	1,106	14.2
Photonic products and services	104	1.3
Plant material	1	0
Products and services related to chemical substances and processes	426	5.5
Products and services relating to biological sciences	1,718	22
Software applications, systems, and services, middleware	62	0.8
Systems and services for manufacturing high-tech products	43	0.6
TAN	4	0.1
Telecommunications and internet services, Internet eqp., Web related services, Web related eqp.	31	0.4
Test, measurement, control, scientific, and laboratory equipment and services	167	2.1
UNCLASSIFIED	1,312	16.8
Total	7,801	100

Table 2. Technology field names and acronyms.

Acronym	Technology Field Name
AUT	Factory automation eqp. and services
BIO	Products and services relating to biological sciences
CHE	Products and services related to chemical substances and processes
COM	Computer systems, peripherals, accessories, and services
DEF	Ground defense radar systems/eqp.
ENR	Eqp. and services relating to power generation
ENV	Eqp. and services for the analysis, protection and treatment of the environment
MAN	Systems and services for manufacturing high-tech products
MAT	Advanced material products and service
MED	Eqp. and services for the medical industry
NO INFO	UNCLASSIFIED
PHA	Pharmaceutical products and services
PHO	Photonic products and services
PLV	Plant material
SOF	Software applications, systems, and services, middleware
SUB	Electrical, electronic, electromechanical or mechanical, equipment services
TAM	Test, measurement, control, scientific, and laboratory equipment and services
TAN	TAN
TEL	Telecommunications and internet services, Internet eqp., Web related services, Web related eqp.
TRN	Eqp. and services for the transportation industry

Table 3. Number of inventions by type of research sponsor.

Sponsor	No.	Col %	Percentage After Excluding No Sponsor
Business-Government	89	1.1	3.7
NonProfit	82	1.1	3.4
Organization	206	2.6	8.4
Purely Business	296	3.8	12.1
Purely Government	1,471	18.9	60.3
Unclassified	294	3.8	12.1
ZNoSponsor	5,363	68.7	-
Total	7,801	100	100

Table 4i. Number of inventions by type of technology field and by type of sponsor.

Type of Sponsor	AUT		BIO		CHE		COM		DEF		ENR	
	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %
Business-Government	1	0.2	53	3.1	0	0	0	0	0	0	0	0
NonProfit	2	0.3	40	2.3	7	1.6	0	0	0	0	0	0
Organization	3	0.5	60	3.5	14	3.3	1	0.5	1	3	1	0.9
Purely Business	6	1	78	4.5	14	3.3	5	2.7	0	0	2	1.7
Purely Government	16	2.7	486	28.3	33	7.7	24	13.1	3	9.1	9	7.7
Unclassified	1	0.2	95	5.5	8	1.9	4	2.2	0	0	1	0.9
ZNoSponsor	563	95.1	906	52.7	350	82.2	149	81.4	29	87.9	104	88.9
Total	592	100	1718	100	426	100	183	100	33	100	117	100

Table 4ii. Number of inventions by type of technology field and by type of sponsor.

Type of Sponsor	ENV		MAN		MAT		MED		NO INFO		PHA	
	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %
Business-Government	0	0	0	0	1	0.5	2	0.2	16	1.2	9	0.8
NonProfit	0	0	0	0	2	1	5	0.4	15	1.1	10	0.9
Organization	2	3.4	1	2.3	3	1.5	23	2	51	3.9	34	3.1
Purely Business	1	1.7	4	9.3	9	4.6	50	4.4	71	5.4	35	3.2
Purely Government	20	33.9	9	20.9	44	22.6	102	9	407	31	199	18
Unclassified	0	0	5	11.6	2	1	23	2	94	7.2	51	4.6
ZNoSponsor	36	61	24	55.8	134	68.7	931	82	658	50.2	768	69.4
Total	59	100	43	100	195	100	1136	100	1312	100	1106	100

Table 4iii. Number of inventions by type of technology field and by type of sponsor.

Type of Sponsor	PHO		PLV		SOF		SUB		TAM		TAN	
	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %
Business-Government	2	1.9	0	0	4	6.5	1	0.2	0	0	0	0
NonProfit	0	0	0	0	0	0	0	0	1	0.6	0	0
Organization	2	1.9	0	0	3	4.8	3	0.6	3	1.8	0	0
Purely Business	6	5.8	0	0	5	8.1	7	1.5	2	1.2	0	0
Purely Government	28	26.9	0	0	18	29	31	6.5	30	18	2	50
Unclassified	3	2.9	0	0	2	3.2	4	0.8	1	0.6	0	0
ZNoSponsor	63	60.6	1	100	30	48.4	433	90.4	130	77.8	2	50
Total	104	100	1	100	62	100	479	100	167	100	4	100

Table 4iv. Number of inventions by type of technology field and by type of sponsor.

Type of Sponsor	TEL		TRN		Total	
	No.	Col %	No.	Col %	No.	Col %
Business-Government	0	0	0	0	89	1.1
NonProfit	0	0	0	0	82	1.1
Organization	0	0	1	3	206	2.6
Purely Business	1	3.2	0	0	296	3.8
Purely Government	6	19.4	4	12.1	1471	18.9
Unclassified	0	0	0	0	294	3.8
ZNoSponsor	24	77.4	28	84.8	5363	68.7
Total	31	100	33	100	7801	100

Table 5. Number of inventions by type of sponsor conditioned by technology field. Include inventions in technology fields with the highest frequency. Exclude inventions that have no sponsor information.

Type of Sponsor	BIO		CHE		MED		NO INFO		PHA		Total	
	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %
Business-Government	53	6.5	0	0	2	1	16	2.4	9	2.7	80	3.7
NonProfit	40	4.9	7	9.2	5	2.4	15	2.3	10	3	77	3.4
Organization	60	7.4	14	18.4	23	11.2	51	7.8	34	10.1	182	8.4
Purely Business	78	9.6	14	18.4	50	24.4	71	10.9	35	10.4	248	12.1
Purely Government	486	59.9	33	43.4	102	49.8	407	62.2	199	58.9	1,227	60.3
Unclassified	95	11.7	8	10.5	23	11.2	94	14.4	51	15.1	271	12.1
Total	812	100	76	100	205	100	654	100	338	100	2,085	100

Table 6i. Propensity of patenting by technology field.

	AUT		BIO		CHE		COM		DEF		ENR	
	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %
Invention With Patent	510	86.1	1212	70.5	306	71.8	134	73.2	25	75.8	91	77.8
Invention Without Patent	82	13.9	506	29.5	120	28.2	49	26.8	8	24.2	26	22.2
Total	592	100	1718	100	426	100	183	100	33	100	117	100

Table 6ii. Propensity of patenting by technology field.

	ENV		MAN		MAT		MED		NO INFO		PHA	
	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %
Invention With Patent	44	74.6	31	72.1	147	75.4	824	72.5	957	72.9	746	67.5
Invention Without Patent	15	25.4	12	27.9	48	24.6	312	27.5	355	27.1	360	32.5
Total	59	100	43	100	195	100	1136	100	1312	100	1106	100

Table 6iii. Propensity of patenting by technology field.

	PHO	PHO	PLV	PLV	SOF	SOF	SUB	SUB	TAM	TAM	TAN	TAN
	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %
Invention With Patent	72	69.2	1	100	44	71	382	79.7	147	88	4	100
Invention Without Patent	32	30.8	0	0	18	29	97	20.3	20	12	0	0
Total	104	100	1	100	62	100	479	100	167	100	4	100

Table 6iv. Propensity of patenting by technology field.

	TEL	TEL	TRN	TRN	Total	Total
	No.	Col %	No.	Col %	No.	Col %
Invention With Patent	27	87.1	25	75.8	5729	73.4
Invention Without Patent	4	12.9	8	24.2	2072	26.6
Total	31	100	33	100	7801	100

Table 7i. Propensity of patenting by type of research sponsor.

Patent	Business-Government		NonProfit		Organization		Purely Business	
	No.	Col %	No.	Col %	No.	Col %	No.	Col %
Invention With Patent	40	44.9	51	62.2	143	69.4	183	61.8
Invention Without Patent	49	55.1	31	37.8	63	30.6	113	38.2
Total	89	100	82	100	206	100	296	100

Table 7ii. Propensity of patenting by type of research sponsor.

	Purely Governement		Unclassified		ZNoSponsor		Total	Total
	No.	Col %	No.	Col %	No.	Col %	No.	Col %
Invention With Patent	969	65.9	167	56.8	4176	77.9	5729	73.4
Invention Without Patent	502	34.1	127	43.2	1187	22.1	2072	26.6
Total	1471	100	294	100	5363	100	7801	100

Table 8. Number of inventions by type of licensing.

TypeOfLicense	No.	Col %
1.Exclusive	626	55.4
2.Exclusive-With-Limit	173	15.3
3.Non-Exclusive	177	15.7
4.Mix - Exclusives	41	3.6
5.Mix - Exclusive and Non-Exclusive	112	9.9
Total	1,129	100

Table 9i. Propensity of licensing and type of licensing by technology field.

Type of License	AUT	AUT	BIO	BIO	CHE	CHE	COM	COM	DEF	DEF	ENR	ENR
	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %
1.Exclusive	30	5.1	137	8.3	36	8.5	12	6.6	0	0	4	3.4
2.Exclusive-With-Limit	3	0.5	61	3.7	2	0.5	0	0	1	3	0	0
3.Non-Exclusive	1	0.2	78	4.7	8	1.9	2	1.1	0	0	1	0.9
4.Mix - Exclusives	0	0	10	0.6	1	0.2	0	0	0	0	0	0
5.Mix - Exclusive and Non-Exclusive	1	0.2	57	3.4	4	0.9	0	0	0	0	2	1.7
6.No License	557	94.1	1314	79.3	375	88	169	92.3	32	97	109	94
Total	592	100	1657	100	426	100	183	100	33	100	116	100

Table 9ii. Propensity of licensing and type of licensing by technology field.

Type of License	ENV	ENV	MAN	MAN	MAT	MAT	MED	MED	NO INFO	NO INFO	PHA	PHA
	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %
1.Exclusive	2	3.5	4	9.3	9	4.6	161	14.3	78	6.1	104	9.5
2.Exclusive-With-Limit	9	15.8	0	0	0	0	12	1.1	31	2.4	48	4.4
3.Non-Exclusive	0	0	0	0	1	0.5	11	1	50	3.9	19	1.7
4.Mix - Exclusives	0	0	0	0	0	0	4	0.4	13	1	12	1.1
5.Mix - Exclusive and Non-Exclusive	1	1.8	0	0	2	1	7	0.6	22	1.7	14	1.3
6.No License	45	78.9	39	90.7	183	93.8	929	82.7	1093	84.9	899	82
Total	57	100	43	100	195	100	1124	100	1287	100	1096	100

Table 9iii. Propensity of licensing and type of licensing by technology field.

Type of License	PHO	PHO	PLV	PLV	SOF	SOF	SUB	SUB	TAM	TAM	TAN	TAN
	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %	No.	Col %
1.Exclusive	10	9.6	0	0	6	9.8	25	5.2	5	3	0	0
2.Exclusive-With-Limit	2	1.9	0	0	0	0	3	0.6	0	0	0	0
3.Non-Exclusive	1	1	0	0	1	1.6	2	0.4	1	0.6	1	25
4.Mix - Exclusives	0	0	0	0	0	0	1	0.2	0	0	0	0
5.Mix - Exclusive and Non-Exclusive	1	1	0	0	0	0	1	0.2	0	0	0	0
6.No License	90	86.5	1	100	54	88.5	447	93.3	161	96.4	3	75
Total	104	100	1	100	61	100	479	100	167	100	4	100

Table 9iv. Propensity of licensing and type of licensing by technology field.

Type of License	TEL	TEL	TRN	TRN	Total	Total
	No.	Col %	No.	Col %	No.	Col %
1.Exclusive	1	3.2	2	6.1	626	8.1
2.Exclusive-With-Limit	1	3.2	0	0	173	2.2
3.Non-Exclusive	0	0	0	0	177	2.3
4.Mix - Exclusives	0	0	0	0	41	0.5
5.Mix - Exclusive and Non-Exclusive	0	0	0	0	112	1.5
6.No License	29	93.5	31	93.9	6560	85.3
Total	31	100	33	100	7689	100

Table 10i. Propensity of licensing and type of licensing by type of research sponsor.

TypeOfLicense	Business-Government		NonProfit		Organization		Purely Business	
	No.	Col %	No.	Col %	No.	Col %	No.	Col %
1.Exclusive	16	18.6	13	16.5	10	4.9	62	21.1
2.Exclusive-With-Limit	6	7	1	1.3	3	1.5	9	3.1
3.Non-Exclusive	5	5.8	4	5.1	9	4.4	11	3.7
4.Mix - Exclusives	1	1.2	1	1.3	1	0.5	3	1
5.Mix - Exclusive and Non-Exclusive	5	5.8	2	2.5	5	2.5	13	4.4
6.No License	53	61.6	58	73.4	176	86.3	196	66.7
Total	86	100	79	100	204	100	294	100

Table 10ii. Propensity of licensing and type of licensing by type of research sponsor.

Type of License	Purely Governement		Unclassified		ZNoSponsor		Total	
	No.	Col %	No.	Col %	No.	Col %	No.	Col %
1.Exclusive	124	8.8	36	12.5	365	6.9	626	8.1
2.Exclusive-With-Limit	67	4.7	22	7.6	65	1.2	173	2.2
3.Non-Exclusive	44	3.1	21	7.3	83	1.6	177	2.3
4.Mix - Exclusives	15	1.1	2	0.7	18	0.3	41	0.5
5.Mix - Exclusive and Non-Exclusive	38	2.7	4	1.4	45	0.8	112	1.5
6.No License	1129	79.7	204	70.6	4744	89.2	6560	85.3
Total	1417	100	289	100	5320	100	7689	100

Table 11i. Propensity of licensing and type of licensing by type of research sponsor. Exclude the inventions where the research sponsor became the licensee.

Type of License	Business-Government		NonProfit		Organization		Purely Business	
	No.	Col %	No.	Col %	No.	Col %	No.	Col %
1.Exclusive	7	9.6	13	16.5	7	3.5	26	10.5
2.Exclusive-With-Limit	4	5.5	1	1.3	3	1.5	4	1.6
3.Non-Exclusive	4	5.5	4	5.1	9	4.5	8	3.2
4.Mix - Exclusives	0	0	1	1.3	1	0.5	1	0.4
5.Mix - Exclusive and Non-Exclusive	5	6.8	2	2.5	4	2	12	4.9
6.No License	53	72.6	58	73.4	176	88	196	79.4
Total	73	100	79	100	200	100	247	100

Table 11ii. Propensity of licensing and type of licensing by type of research sponsor. Exclude the inventions where the research sponsor became the licensee.

Type of License	Purely Governement		Unclassified		ZNoSponsor		Total	
	No.	Col %	No.	Col %	No.	Col %	No.	Col %
1.Exclusive	123	8.7	34	11.9	365	6.9	575	7.5
2.Exclusive-With-Limit	67	4.7	22	7.7	65	1.2	166	2.2
3.Non-Exclusive	42	3	21	7.3	83	1.6	171	2.2
4.Mix - Exclusives	15	1.1	2	0.7	18	0.3	38	0.5
5.Mix - Exclusive and Non-Exclusive	37	2.6	3	1	45	0.8	108	1.4
6.No License	1129	79.9	204	71.3	4744	89.2	6560	86.1
Total	1413	100	286	100	5320	100	7618	100

Figure 1. Number of inventions by disclosure year.

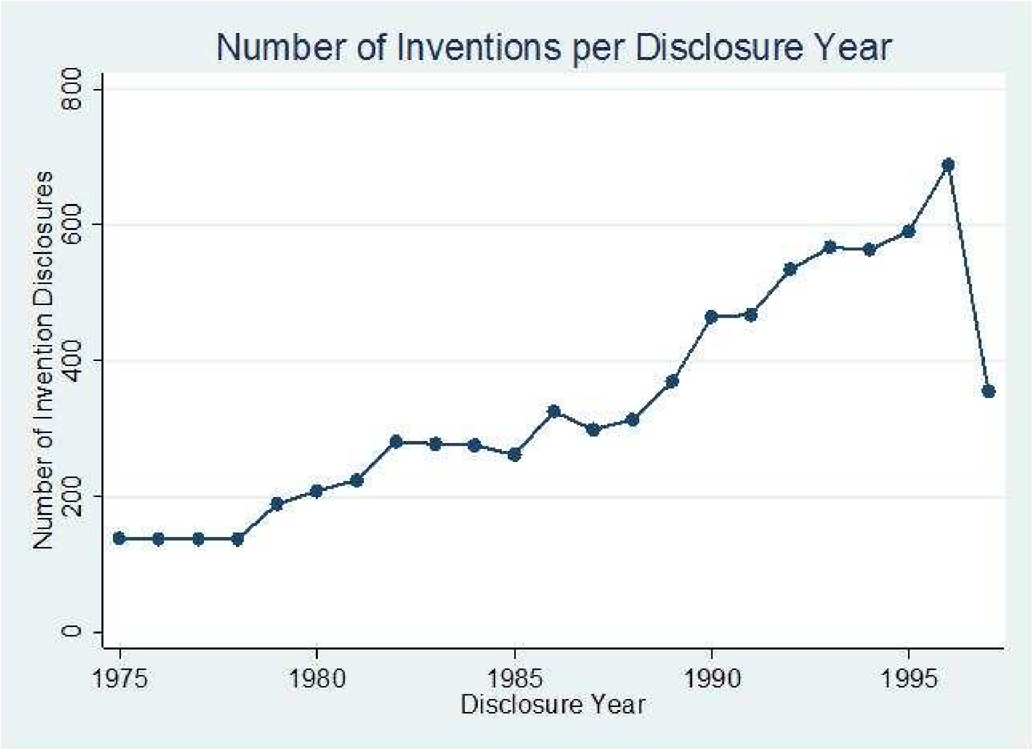

Figure 2. Compare total number of inventions with number of inventions without sponsor information.

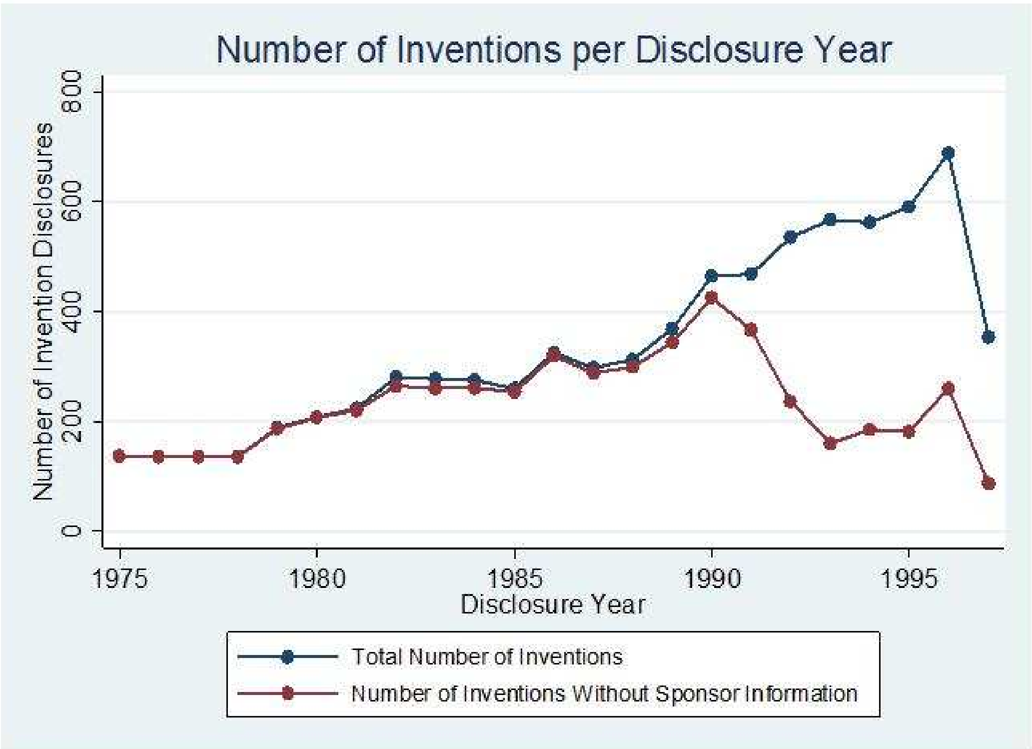

Figure 3. Number of invention disclosures by technology type per disclosure year.