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Abstract

This paper exploits a particular facet of the US patent system, which thus far has been overlooked in the literature: the patent renewal fee scheme relating to switches from small to large entity status. Based on this observation, we are able to determine whether university patents are licensed over their enforceable lifecycle and at what point in time the licensing occurs. We find that while the funding source of patented inventions makes no difference to the propensity of an academic patent being licensed, federally sponsored patents are less likely to be licensed early compared to their non-federally funded counterparts.

Keywords: university patents, renewal fees, licensing, technology transfer, large entity status, federal sponsorship
JEL: O31, O32, O38, H50

1. Introduction

Universities have long been recognized as a driving force of innovation activity (Jaffe, 1989; Adams, 1990; Mansfield, 1991). In particular, university inventions are critical elements in Research and Development (R&D) in the industry sector. As universities cannot themselves fully develop and commercialize their, mostly embryonic in nature, inventions, the only way to fully realize the potential of their research outcome is by signing licensing agreements with the industry sector (Hall et al., 2003).[1]

Understanding the transfer of rights of university patents to the market, as well as, the specific characteristics of the transferred patents is of special interest for a number of agencies, such as national science and technology policymakers, lawmakers, and for those setting research funding priorities.[2] In the US, in particular, innovation and research public policy greatly favors the creation and diffusion of academic inventions via a wide range of activities. For instance, an important way has been the channeling of large federal funds to promoting academic research, which in many cases accounts up to 70% of a university's R&D activity (National Science Board, 2012, Figure 5-2). In addition, to facilitate universities (and small businesses) to file for subsequent patent applications for their inventions and to promote the development and commercialization of the latter, the US congress passed *The University and Small Business Patent Procedures Act of 1980* ('Bayh-Dole' Act) by establishing a unified framework where universities can elect to

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[1]Indeed, Jensen and Thursby (2001) in a survey of university technology transfer managers, find that 71% of US university inventions are of embryonic nature.

[2]The terms 'academic' and 'university' patent are used interchangeably throughout the paper.

retain ownership of federally funded inventions.[3] The rationale of the Act was to stimulate commercialization of the federally funded patents. Since its enactment, most US universities actively engaged in research, created and funded offices of technology transfer to facilitate the licensing, commercialization and transfer of federally funded and other university inventions.[4] Such policy issues, surrounding technology transfer of university patents, are also relevant beyond US borders as a number of European countries consider or have already adopted policies to facilitate the efficient transfer of academic technologies to the marketplace (Mowery and Sampat, 2005).

To date, quantitative analysis of technology transfer activity of university patents, in general, and federally funded university patents, in particular, has been limited by the lack of comprehensive and accessible data. As university technology transfer datasets are proprietary in nature, previous scholarly work in this field has focused on case study analyses of a single or a handful of large universities, documenting evidence that may not hold or extend to other academic research institutions (Mowery and Ziedonis, 2001; Ziedonis, 2007; Elfenbein, 2007; Drivas et al., 2013).

The present paper studies the propensity and the time length of transferring rights of university patents to the market. The novel aspect of this work lies in exploiting a particular piece of information, which has been overlooked thus far, and relates to a particular feature of the US patent system, the patent renewal fee structure. Based on this observation, we are able to determine whether university patents are licensed over their enforceable lifecycle, and at what point in time the licensing takes place. Therefore, we can study important issues such as the characteristics of transferred patents, the propensity and timing of licensing of federally funded academic patents compared to their counterparts, and the differences in licensing outcomes for the different funding institutions, which have not been adequately addressed so far in the literature.

Renewal patent fee scheme provides rich information, which can be exploited at least in two ways. First, to infer academic technology transfer to the marketplace. Changes in the patent fee schedule relate to changes of patent assignee (university, here) status, which, in turn, could imply engagement of a university patent in commercialization activities. More specifically, patent assignees in the United States Patent and Trademark Office (USPTO) system pay issue fees and subsequently renewal fees to maintain the enforceability of a US patent occurring at 3.5 years, 7.5 years, and 11.5 years after issuance. The US patent system has two different patent fee structures: one for small and non-profit institutions and the second for large entities. Universities have the right to pay and elect Small Entity Status (SES) fees for their patents. When a university enters into license agreement with a large corporation for a particular patent, loses its small entity status for the particular patent and is obliged to pay all of the particular patent's subsequent fees according to the Large Entity Status (LES) patent fee schedule. We employ this publicly available information, i.e., the switch from SES to LES status, to infer licensing of academic inventions and consequently academic transfer to the marketplace. Second, we assess the speed at which university patents are licensed. The time length of commercialization of an academic patent can be calculated by the time a patent switches to LES, i.e., at issuance and at the first, second, and third maintenance fee event, corresponding to 3.5, 7.5, and 11.5 years after patent grant, respectively.

Along with the information derived from the renewal fee scheme, we use information that comes this time from the patent document wrapper, which discloses government interest statements.[5] From this ob-

[3]Prior to 1980, each US federal government agency funding research had its own patent licensing agreements and practices. The lack of uniform government patent policy and the government ownership of inventions conceived during work on a federal contract, acted as a disincentive to obtain patents and commercialize these discoveries (Eisenberg, 1996).

[4]By 2009, the 180 university institutions that participated in the Association of Technology Managers (AUTM) reported that these organizations employed over 2,106 full time equivalent licensing and technology transfer personnel (AUTM, 2010). There has also been a dramatic increase in 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). In 2009, AUTM reported 20,309 invention disclosures, filing of 18,214 patent application and 3,414 granted patents awarded to the 180 university institutions that participated in the 2009 Licensing Survey. While US university patents accounted for approximately 0.75% of the US patents granted to the US entities in 1980, in 2005 they accounted for approximately 5% (NBER, Patent Data Project, 2013). 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 $1.54 billion in the fiscal year of 2009 (real values of 1991).

[5]Any research organization, which receives federal support, is obliged to include a statement at the patent application that the

servation, we are able to distinguish the government (federal) funded patents from the rest of the patents. As federal funds constitute a major financial support of the US academic research, it is interesting to examine whether federally funded patents differ in the propensity and time length required for commercialization. From the patent document wrapper, we are further able to distinguish among four big funding agencies, which account for the vast majority of the academic federal R&D support (National Science Board, 2012), namely the Department of Defense, the Department of Energy, the National Institutes of Health, and the National Science Foundation. Each of these agencies has different research and development imperatives focused on the agency's mission. Their research agendas and the associated licensing guidelines could therefore have different effects on the marketing management of their respective funded technologies (Eisenberg, 1996). Further, each funding agency has different criteria based for financing research and these criteria are also very likely to influence the nature of innovative output (Azoulay et al., 2011). Therefore, we further examine whether different federally funding agencies are associated with different propensities to engage in commercialization activities.

Our paper closely relates and contributes to the strand of literature that examines factors related to technology transfer and commercialization of university inventions.[6] A branch of this literature focuses on patent or invention level[7], while another stream of this literature considers university as the observation unit.[8] Our paper adds to the aforementioned literature by employing a wide spectrum of university patents, expanding thus upon previous work, which has either relied on proprietary information regarding licensing activity of a handful of universities or performed aggregate analysis at the university level. Instead, we employ the whole population of academic patents as provided by the USPTO and exploit a piece of information that has not been exploited before. Our paper contributes to the literature as it consists the first attempt so far that studies the relationship between academic innovation output and propensity of academic technology commercialization at a large scale and comprehensive manner.

We apply our proposed methodology to a large sample of US universities over the period 1990-2000 aiming to answer two main questions: (i) Are federally funded university patents more (less) likely to be transferred to the marketplace than non-federally funded? and (ii) Are federally sponsored university patents faster transferred to the marketplace than non-federally funded?

Our results are easy to summarize. Federally funded university patents are no less likely to be commercialized than non-federally funded patents. Accounting for different funding agencies, we find that patented inventions funded by the Department of Defense are about 6% less likely than non-federally funded patents to be licensed. With respect to other funding agencies the differences are not significant. In terms of timing, federally funded patents are less likely to be licensed at early stage compared to their non-federally sponsored counterparts. Among the government sponsored patented inventions, the Department of Energy funded patents appear to be the least likely to be licensed early, while at the opposite side of the spectrum, the patents funded by the National Institute of Health are the most likely to be licensed early. Along with government support, we also control for a range of patent characteristics that could be associated with the propensity and time of academic technology commercialization. The size of prior and posterior art base and scope of a patent, the number of inventors and assignees involved, as well as, their patenting experience are found to shape both the propensity and speed of university patents' licensing. Results are robust and do not alter even when we discuss peculiar cases of patent status fees and outliers.

From the outset of this work, we would like to stress two things that we do not do in this paper. First, we do not offer a causality explanation between (the type of) government funding and technology transfer. Rather, we provide insights on the licensing propensity of academic inventions that contain statements of government interest indicating federally funded research and market development, controlling for a series of patent characteristics. Proper discussion of causality requires information at a finer level and different

government has certain rights in the invention.

[6]For an in-depth literature review on university entrepreneurship and university technology transfer processes, consult Rothaermel et al. (2007) and Bradley et al. (2013).

[7]For theoretical contributions in the field see Hellmann (2007), and Hellmann and Perotti (2011). The studies of Mowery and Ziedonis (2001), Ziedonis (2007), Elfenbein (2007), Drivas et al. (2013) provide empirical evidence.

[8]On theoretical side, see the study of Jensen et al. (2003). Empirical contributions include the studies of Lach and Schankerman (2008) and Belenzon and Schankerman (2009) among others.

set up of the data.[9] However, data unavailability restricts us in performing such analysis; therefore, we are only able to talk about association and refrain from drawing nuanced policy statements. Second, another constraint relates to the efficiency of the funding source, federal or not. As we do not have information on the actual dollar amount of the research projects, we cannot infer on the relative efficiency of federal to non-federal research grants. In this paper, we condition all our findings on the patent level.

The remainder of the paper proceeds as follows. Section 2 introduces the empirical specification under estimation and discusses the sources and construction of our dataset. Section 3 presents the results. Section 4 summarizes our findings and concludes.

2. Methodology

This section presents the empirical specification and describes the data.

2.1. Empirical Specification

The first question this paper aims to answer is whether federally funded university patents are associated with different propensity toward technology transfer compared to all other university patents. The likelihood of a patent being licensed over its lifecycle can be described using a probit model defined as follows:

$$Prob(Switch\,to\,LES = 1/X_i^{'}\beta) = \Phi(X_i^{'}\beta) \tag{1}$$

where the endogenous variable *Switch to LES* takes the value of 1, if a patent, i, has paid LES fees at any point during its patent life, and 0 otherwise; Φ is the cumulative distribution function of the standard normal distribution; β is a set of coefficients of patent's characteristics included in the control set X, defined as:

$$\begin{aligned} X_i^{'}\beta = \beta_0 + \beta_1 Federal_i + \beta_2 Citations_i + \beta_3 Scope_i + \beta_4 Inventors_i + \beta_5 Assignees_i + \\ \beta_6 InventorActivity_i + \beta_7 AssigneeActivity_i + \beta_8 GrantYear_i + \epsilon_i \end{aligned}$$

The inclusion in X of a wide variety of patent metrics, allows us to explore a number of important characteristics of the transferred patents. The variable *Federal* is a dummy and takes the value of 1, if a patent i discloses federal support and 0 otherwise; The set variable *Citations* is a set of variables that consists of the number of backward patent citations, *BacwardCitesPat*, the number of backward non-patent citations, *BackwardCitesNonPat*, and the number of patent citations patent i receives, *ForwardCites* - all are measures of patent quality.[10] The variable *Scope* controls for the scope and usage of patent i and includes the number of claims, *Claims*, the application length, $ApplicationLength$, number of classification codes - the four-digit International Patent Classification, $IPC4Digit$, and three-digit US classification code, $USC3Digit$ - and technology field dummies, $TechnologyDummy$. The number of inventors (*Inventors*) in patent i and assignees (*Assignees*) that patent i is assigned, capture the level of difficulty and economic importance. The patenting experience of inventors and assignees' of patent i are denoted as $InventorActivity$ and $AssigneeActivity$, respectively. The variable $InventorActivity$ is a set of three dummies: $InventorActivity_{Low}$, which takes the value of 1 if patent i's lead inventor - we denote the first named inventor on a patent as the lead inventor on a patent - has no past patenting activity and 0 otherwise, $InventorActivity_{Medium}$, which takes the value of 1 if patent i's lead inventor has between 1 and 3 past patents and 0 otherwise, and $InventorActivity_{High}$,

[9] For example, one needs to match samples, where everything else would be alike (choosing similar research projects, with same probability of being patented and commercialized), but the funding source. In such set up, one is more comfortable in deriving causal implications.

[10] For example, granted patent with a larger prior art base may disclose a broader and ultimately more valuable invention - 'standing on the shoulders of giants'.

which takes the value of 1 if patent i's lead inventor has more than 3 past patents and 0 otherwise.[11] Analogously, $AssigneeActivity$ is a set of three dummies: $AssigneeActivity_{Low}$, which takes the value of 1 if patent i's assignee has less than 123 patents and 0 otherwise, $AssigneeActivity_{Medium}$, which takes the value of 1 if patent i's assignee has between 123 and 583 past patents and 0 otherwise, and $AssigneeActivity_{High}$, which takes the value of 1 if patent i's assignee has more than 583 past patents.[12] Finally, $GrantYear$ is a set of dummies for the grant (issue) year of the patent. Although there may be some noise in the aforementioned patent metrics, they are commonly used in the literature (Lanjouw and Schankerman, 1999; Harhoff et al., 1999; Bessen, 2008; Hall et al., 2005).

Among the set of coefficients of the control variables, the coefficient of $Federal_i$ is the primary coefficient of interest, which shows whether government sponsored patents are more or less likely to switch to LES fees than their non-federally counterparts. Arguably, federally supported patents are less likely to be licensed by corporate funded inventions. Further, in a case study of inventions at the University of California, Drivas et al. (2013) find that federally funded inventions are less likely to be licensed by corporate funded inventions; however, that difference between federally supported patents and corporate funded counterparts disappears when considering the cases where the corporate sponsor licenses the invention. However, given the limited work at the invention level, the licensing propensity of federally funded patented inventions is eventually an empirical issue.

An allied question worth examining is whether the nature of funding agencies affects the propensity to switch to LES status. In doing so, we replace Federal with five dummy variables $DODfunding_i$, $DOEfunding_i$, $NIHfunding_i$, $NSFfunding_i$, and $OTHERfunding_i$ denoting the source of federal funding, i.e, the Department of Defense (DOD), the Department of Energy (DOE), the National Institutes of Health (NIH), which is part of the Department of Health and Human Services, the National Science Foundation (NSF), and other unclassified federal source, respectively, and re-estimate equation (1). As before, the literature provides little guidance as to what to expect.[13]

The second question we attempt to answer is equally unexplored and further contributes to a debate in the literature that is, whether federally funded patents reach the marketplace faster compared to their non-federally supported counterparts. A longstanding premise is that federally funded patents may be more basic and upstream in nature than their non-federally funded counterparts (Cohen et al., 1998; Henderson et al., 1998) leading to longer timeframes for these discoveries to move from basic research to applied research to product/service development in the marketplace. In addition, non-federally funded patents, many of which derive from corporate-funded patents, can be licensed by the research sponsor. Therefore, it can be the case that federally funded patented inventions may take more time for their potential to be observed and therefore more time to be commercialized. To examine the dynamic aspects of technology transfer, we consider only patents that have switched to LES and estimate, with the use of an ordered probit model, the propensity a university patent i to switch to LES by grant year, first, second, and third maintenance fee event.

We use an index model for a single latent variable y_i^*, which is unobservable, described as below:

$$y_i^* = X_i^{'}\beta + u_i \tag{2}$$

$$y_i = j \quad if \;\; c_{j-1} < y^* < c_j$$

where y_i is the observed ordered outcome, i.e., the switch to LES, and j takes on the values of 1, 2, 3, and 4, depending on patent's i fee status: 1, if patent i has paid LES grant (issue) fees; 2, if i has switched at

[11] Classifications performed in such a way that sample sizes are fairly even ($InventorActivity_Low$=1 for 6,222, $InventorActivity_{Medium}$=1 for 7,040, and $InventorActivity_{High}$=1 for 7,615 patents). In the regressions we exclude $InventorActivity_{Low}$ to avoid the dummy variable trap.

[12] Classifications performed in such a way that sample sizes are fairly even ($AssigneeActivity_Low$=1 for 6,957, $AssigneeActivity_{Medium}$=1 for 6,909, and $AssigneeActivity_{High}$=1 for 7,011 patents). In the regressions we exclude $AssigneeActivity_{Low}$ to avoid the dummy variable trap.

[13] A study by Wu (2010) finds that NSF's Experimental Program to Stimulate Competitive Research has contributed positively to research competitiveness.

the first maintenance fee event (at 3.5 year after issuance), but not earlier; 3, if i has switched at the second maintenance fee event (at 7.5 year after issuance), but not earlier; and finally, 4, if i has switched at the third and final maintenance fee event (at 11.5 year after issuance), but not earlier; β, and X are defined as in equation (1).

The probability, P that patent i will select event j is, $P_{ij} = P(y_i = j) = P(c_{j-1} < y_i^* \leq c_j) = \Phi(c_j - X_i^{'}\beta) - \Phi(c_{j-1} - X_i^{'}\beta)$ and Φ is the standard normal cumulative density function (cdf).

The effect of a change in a regressor X_r on the probability of selecting alternative j is called marginal effect and defined as: $\partial P_{ij}/\partial X_{ri} = \Phi'(c_{j-1} - X_i^{'}\beta) - \Phi'(c_j - X_i^{'}\beta)\beta_r$. The marginal effects on different alternatives should sum up to zero.

We estimate equations (1) and (2) using Maximum Likelihood Estimation (MLE) techniques.[14]

Next section discusses the data.

2.2. Data

We derive information from various sources to analyze technology transfer activity of university patents to the marketplace. First and foremost, we need to identify patents where the assignee (owner) of the patent is a US university. Second, we compile information on maintenance renewal fee events for both types of patents in order to record whether and when they change their statues, over their enforceable lifecycle, in order to proxy technology transfer and the time length of realization. Third, we use additional information to distinguish between federally and non-federal funded university patents. The former, are further classified according to the funding provider. Lastly, we gather information on patent, inventor, and assignee, among other, characteristics of both federally and non-federally funded patents.

Below, we describe how we constructed our dataset and provide a brief discussion of its important aspects.

Data Construction

Our empirical analysis relies on a sample of 20,877 US university patents issued between 1990 and 2000.

The main source of our data is the *Patent Data Project*, sponsored by the National Bureau of Economics Research (NBER).[15] The NBER identifies and classifies all the patent owners to types of entities. We collect patents, which identified as assignee a 'US University'. Patents assigned to a single or multiple US universities are included in our sample. Patents that have co-assignees that are not US universities are excluded.

Information on maintenance renewal fee events for the patents of our sample is acquired from the *Patent Maintenance Fee Event Data* from the Google bulk downloads, a dataset created and updated weekly by the USPTO.[16] This dataset includes all renewal events for all utility patents issued by the USPTO. All patents, issued from applications filed on or after December 12, 1980, are subject to maintenance fees, which must be paid to maintain the patent in force. Maintenance renewal event data are coded to a finer level. In addition to cataloging the specific events of renewals at the 3.5 (first renewal), 7.5 (second renewal) and 11.5 (third and final renewal) years after issuance for each patent, we assembled the event codes in the dataset indicating whether the university has paid SES fees or LES fees at that event for a particular patent. To claim SES, universities and academic research organizations must also certify that they have not assigned, granted, conveyed, or licensed, any rights in the invention to any person, concern, or organization, which would not qualify as a person, small business concern, or a nonprofit organization. When a university patent enters into license agreement, it loses its small entity status and is obliged to pay all of the particular

[14] The log-likelihood function for the ordered probit is $lnL(\beta) = \sum_{j=1}^{N}\sum_{j=0}^{m} Z_{ij} ln[\Phi_{ij} - \Phi_{i,j-1}]$, where Z_{ij} an indicator variable, which is equal to 1 if $y_i = j$, and $\Phi_{ij} = \Phi[c_j - X_i'\beta]$ and $\Phi_{ij-1} = \Phi[c_{j-1} - X_i'\beta]$.

[15] https://sites.google.com/site/patentdataproject/

[16] http://www.google.com/googlebooks/uspto-patents-maintenance-fees.html

patent's subsequent fees according to the Large Entity Status (LES) patent fee schedule (see, Chapter 37 of the Code of Federal Regulations §1.27 (a)). For the rest of the patents in the university's portfolio that are not licensed to a LES corporation, the university still pays SES fees.[17] The latter, are typically 50% lower than LES fees (§35 U.S. Code 41 (a),(b) and (d)(1)); such fees represent a significant cost of patent ownership and maintenance to universities. Therefore, universities have high incentives to claim SES, whenever they are entitled. Falsely claiming SES status for the purpose of filing or maintaining a patent is considered fraud by the USPTO and can render a patent unenforceable and invalid. Consequently, there is a high level of compliance in accurately reporting the entity status among patent owners. For these reasons, the switch from SES to LES provides a reliable indication of academic technology transfer to large entity corporations.

To distinguish between university patents, which received federal support (*Federal*), from those which did not, we rely on information provided in the patent document wrapper that discloses government interest statements. This piece of information has only been recently used in the literature.[18] When a research organization retains US domestic patent rights to a patent, which derives from federally funded research, the research organization is under an obligation to include a statement at the patent application that informs the reader the government has certain rights in the invention. The statement usually appears either in the "Government License Rights" section that follows the second paragraph of the specification or as the first paragraph of the specification (Manual of Patent Examination Procedures, Section 310). The patent contains the following generic statement, "The invention was made with Government support (Grant Number)" indicating also the type of the institution which provided the funding.[19] Based on this information, we further distinguish among the four biggest funding agencies of university patents, which account approximately 91% of the academic federal R&D support (National Science Board, 2012): the Department of Defense, the Department of Energy, the National Institutes of Health, and, lastly, the National Science Foundation, and accordingly define $DODfunding$, $DOEfunding$, $NIHfunding$, and $NSFfunding$.[20] The remaining government patents, ($Otherfunding$) belong to funding agencies that appear considerably less frequently in the data (such as National Aeronautics and Space Administration, NASA, and United States Department of Agriculture, USDA) or that we could not classify them.

We should note, however, the switch from SES to LES entity status represents a lower bound of patent licensing and commercialization activity since universities are free to license the patent to other educational institutions or organizations that also quality for small entity status, university spin-outs, start-ups, and other small businesses. Indication of licensing activity in these cases will not be apparent. Nonetheless, successful start-ups are those that generally grow or are bought by large corporations which by default will result in paying LES fees for their licensed patents. Therefore, while we cannot capture all licensing activity by small corporations through this methodology, we can capture the licensing activity that became successful down the road.

We accessed the dataset on February 15, 2013, which enables us to study the entire renewal history of all university patents issued until 2000. The Google bulk download maintenance fee dataset does not provide information on the kind of status entities claimed by the time of grant. This information was graciously supplied to us by the Office of the Chief Economist at the USPTO. This final addition to the data enabled us to analyze SES/LES status information over the entire lifecycle of an issued university patent during the timeframe of the study.

[17] Recently through the passage of the *Leahy-Smith America Invents Act* in 2011, there was an addition of a micro-entity status for issue and renewal fees purposes. However, this status does not enter our sample since it came in effect by the USPTO in March 19, 2013 (Federal Register, 2012).

[18] Pressman et al. (2006) employed this information to identify which DNA patents had disclosed NIH funding and examined whether the NIH-licensing guidelines were violated. Drivas and Economidou (2013) used this information to examine whether federally funded patents are more basic in nature than their non-federally funded counterparts.

[19] For example, for patent 5,710,287, the statement is "This invention was made with Government support under the NIH Grant#CA 42031 and the NIH Grant#CA 55131 awarded by the National Institutes of Health. The Government has certain rights in the invention." For patent 5,268,573: "This invention was made with support from the National Science Foundation, United States Government, under Grant No. CHE-9158375. The government has rights in this invention."

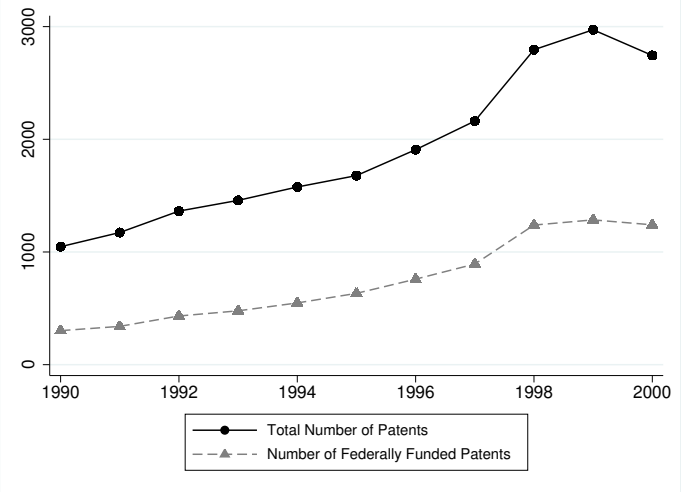
[20] Specifically, the DOD accounts for 9%, the DOE for 4%, the NIH for 65%, and the NSF for 13% of the academic federal R&D support (National Science Board, 2012, Appendix Table 5-3).

Information on variables included in the control set, X, comes from two sources. The number of claims (*Claims*), of assignees (*Assignees*), of the 4-digit International Patent Code (*IPC4Digit*), and technology field (*TechnologyField*) are extracted from the NBER.[21] A variable within the NBER data (denoted as *pdpass*), disambiguates assignee names and tags each patent applicant with a unique assignee number, supporting the accurate identification of each university. We are therefore able to construct the number of patents that each assignee has at each point in time (*AssigneeActivity*). The rest of the control variables namely, all types of citations (*BackwardCitesPat*, *BackwardCitesNonPat*, and *ForwardCites*), number of inventors (*Inventors*), the 3-digit US Classification code (*USC3Digit*), application length (*ApplicationLength*), and grant year (*GrantYear*), are obtained from the database of Lai et al. (2011).[22] The same database disambiguates inventor names and gives them a unique inventor identification number. This enabled us to construct the number of patents that each inventor has at each point in time (*InventorActivity*).

Data Analysis

Figure 1, below, shows the number of university patents issued per year in the US during the period 1990-2000.

Figure 1: University Patents Issued in the US



From the visual inspection, we observe a notable increase in the number of academic patents issued per year (bold line), as well as, in the number of federally funded patents (dashed line). The latter, comprises a big share of total university patents for all years under consideration. Out of 20,877 patents used in this study, 8,150 patents (39%) disclose federal support, 18,709 patents (89.6%) were renewed at the first renewal, 14,106 (67.6%) in the second renewal, and 9,577 (45.9%) in the third renewal. These statistics are consistent with Bessen (2008), who considers the cohort of US patents issued between 1985 and 1991.

Table 1 below provides summary statistics of the switch in status from SES to LES of all patents in our sample (panel A) and of federally funded according to their funding source (panel B).

[21] We first classify each patent according to its primary US Classification, in one of the 37 technology fields, as defined in Hall et al. (2001). The latter study had categorized US classifications in 36 broad technology fields; however, in the 2006 NBER update, there was an addition of a 37th technology field in the area of Computers and Communication Technologies.

[22] Information on the data is provided at http://hdl.handle.net/1902.1/15705 UNF:5:9kQaFvALs6qcuoy9Yd8uOw== V1.

Table 1: Allocation of University Patents by Funding

		University Patents		
		All	**Fed Funded**	**Non-Fed Funded**
Switch to LES (%)		34.0	36.2	32.6
Switch to LES (%) by year:	of grant	43.2	36.6	47.8
	3.5	32.0	33.5	30.9
	7.5	16.7	19.2	14.8
	11.5	8.1	10.7	6.4
Observations		20,877	8,150	12,727

		DOD	**DOE**	**NIH**	**NSF**	**OTHER**
Switch to LES (%)		31.9	33.1	39.0	35.4	36.1
Switch to LES (%) by year:	of grant	29.2	22.0	43.3	34.9	37.6
	3.5	36.0	24.4	34.4	34.9	36.2
	7.5	24.8	23.9	16.1	19.8	19.5
	11.5	10.0	29.7	6.2	10.4	6.7
Observations		1,063	1,301	3,377	971	1,438

Abbreviations denote DOD: Department of Defense, DOE: Department of Energy, NIH: National Institutes of Health, and NSF: National Science Foundation.

On average, 7,095 (34%) patents in our sample have switched to LES. This should be considered as a lower bound of successful technology transfer as patents licensed to small business and other non-profit organizations need not change their status to LES.[23] Federally funded patents are approximately 3.5% more likely to be licensed than their non-federally funded counterparts. While this difference is small, there is considerable variation when examining each funding source individually. For instance, patented inventions funded by the NIH are the most likely to be licensed (34%), while funded from the DOD are the least likely (26.5%) ones. In terms of dynamics, Table 1 shows that 43.2% of the patents that switched to LES, did so by the issue year and an additional 32%, 3.5 years after patent issuance. This finding is consistent with other case studies that find most academic inventions are licensed prior to patent grant or shortly thereafter (Elfenbein, 2007; Drivas et al., 2013). We observe that federally funded patents are licensed less frequently by issue year than non-federally funded patents. As before, there is significant variation across funding agencies. Patented inventions funded by the DOE are considerably less likely to be licensed early, while patented inventions funded by the NIH are the federally funded patents that are transferred fastest to the marketplace.

We continue with the analysis of patent characteristics of transferred university patents. Table A.1 in the Appendix displays summary statistics for patents by renewal status. In general, patents that have switched to LES receive significantly more citations than those that have not. Such finding is consistent with Sampat and Ziedonis (2005), who find that citations are correlated with the economic value of patents as it is approximated by patent licensing. We observe that LES patents have more backward patent (*BackwardCitesPat*) and non-patent citations (*BackwardCitesNonPat*) than those that do not. Furthermore,

[23]To provide some external validation of this method, of identifying patents that were licensed, we examine for the case of Harvard University how many inventions that were patented during 1991-2000 were licensed from evidence reported in Elfenbein (2007). While the study does not observe licensing events until 2012 as we do, it finds 51% of these inventions to be licensed. We find that 46.9% of Harvard University patents have switched to LES. We should also note that there is not one-to-one relation between invention disclosures and patents Drivas et al. (2013). With this in mind, the two figures are reasonably close.

the scope of patent, captured by the four-digit International Patent Classification ($IPC4Digit$), is bigger, on average, for LES patents. All the differences in patent characteristics are statistically significant at the 1% level. With respect to university patenting experience, the likelihood of switching to LES is significantly associated with larger universities. Similarly, for the case of lead inventors, we observe LES patents to be associated with more experienced inventors. Finally, there is higher probability for a LES patent to be federally funded than a SES patent.

Table 2 below provides the summary statistics of status switching from SES to LES of federally funded university patents in six broad technological classes (sectors).

Table 2: LES Status and Federally Funded University Patents by Sector

	University Patents		
	All Patents	Federally Funded (share of All)	Switch to LES (share of All)
Chemical	5,059	41.2	33.7
Computers	1,724	36.3	34.6
Drugs	8,624	39.4	36.0
Electronics	3,314	41.2	33.4
Mechanical	1,178	36.8	27.1
Others	978	24.6	27.1

As Table 2 shows, the greatest proportion of university patents can be found in Chemical (24.2%) and Drugs (41.3%) related fields and federally funded patents are mainly in Chemical and Electronics sector. However, the difference is not big for patents in the rest of the fields except in Others. Finally, patents in Chemical, Computers, and Electronics have similar propensities of switching to LES, while patents in Drugs have slightly higher (36%) and patents in the Mechanical sector have a considerably lower likelihood (27.1%). The under-representation of Mechanical patents can be explained from the fact that patents are more essential in some fields, e.g. pharmaceutical, medical fields, than others; for instance, engineer, computer software (Levin et al., 1985, 1987). Moreover, while the most frequent route followed by inventions disclosed to the university OTT to pass to the marketplace is via patenting and licensing (Elfenbein, 2007), the main tool of transferring knowledge in the engineering discipline from the university to the marketplace is via consulting (Graff et al., 2002).

Finally, it is crucial to also report a complication that arose with the fee data. We found that a large number of patents had not claimed SES for patent issue fees, while at the first maintenance renewal event the university claimed SES. In our sample, 3,063 university patents did not claim SES at issuance and also paid LES at the first renewal. However 2,014 patents did not claim SES at issuance, but later paid SES at the first renewal event at 3.5 years after issuance. While it could be the case that some of them were indeed transferred to a corporation by issue year, by first maintenance fee event after grant, the license was revoked, it is more likely that for most of them the university did not claim SES at filing year and elected to pay the LES fees.[24] We argue that this is the most likely case for the 2,014 patents that did not claim SES at filing, but paid SES at 3.5 years after grant. This is consistent with the concern that claiming the incorrect filing status may affect the enforceability of the patent. If an office of technology transfer had been engaged in discussions with any organization or individual on the potential to license a patent, universities, will most likely, let the patent issue with LES in an abundance of caution. The concern is that

[24]Note that the internal data were actually collected at filing and therefore it could be the case that patent applicants later claimed SES.

if they claim SES status at issue and the patent is later subject to any kind of invalidity action, then they will run the risk of the patent being declared unenforceable because a claim of the wrong entity status is viewed as inequitable conduct. When the patent comes up for renewal, particularly, if there is no licensing agreement or associated revenue, the university is clear to claim SES. To provide some evidence towards this argument, from Table A.2 in the Appendix, we observe that patents that did not claim SES at filing, but paid SES at the first maintenance event after grant are similar in characteristics to patents that never switched to LES. However, patents that did not claim SES at filing and paid LES at the first maintenance event after grant are actually quite different from the previous two sets of patents. Hence, we treat the former group as patents that never switched to LES.

3. Empirical Results

3.1. Are Federally Funded University Patents More (Less) Likely to be Transferred to the Marketplace than Non-Federally Funded?

The first objective of the paper is to assess, along with other important patent characteristics, whether a patent, which discloses federal support, has different propensity of switching to LES, and consequently passing to the marketplace, compared to a non-federally funded patent. Table 3 reports probit estimates (marginal effects) of equation (1). Estimates of all university patents accounting for federal funding and for different types of funding are presented in columns (1) and (2), respectively. To control for outlier effects, we re-estimate specifications in columns (1) and (2) this time excluding the two largest, in patent activity, US universities, which behave as outliers, the Massachusetts Institute of Technology (MIT) and the University of California.

Column 1 shows that the propensity of federally funded patents of switching to LES is not any different from that of non-federally funded patents. Holding all other variables at their means, a patent that is federally funded (*Federal*) is only 0.68% less likely to be licensed than a non-federally funded patent; however, this difference is not statistically significant.

Shifting our focus on the type of funding agent reported in column (2), we observe that only the patents financed by the Department of Defense ($DODfunding$) are significantly less likely to be licensed than non-federally funded patents. Patents supported by the rest of funding agents vary with respect to their difference in the likelihood of switching to LES; however, these differences are not statistically significant. This difference with respect to the Department of Defense funded patents, while significant, it is size-wise rather small (approximately 6%). In any case, this difference could be attributed to the fact that the DOD funded research is usually highly specialized and can only be developed by a limited number of firms. In addition, the DOD technology transfer program is unique in the federal government, because DOD itself is the primary customer of the military technology being developed. Therefore, while other federal departments develop technologies for private sector consumers, for DOD funded research there may be less opportunity for commercialization.[25]

In their majority, patent characteristics also seem to be associated with statistically significant propensities of switching to LES. All kinds of citations, backward (*BackwardCitesPat*, *BackwardCitesNonPat*) and forward (*ForwardCites*) are positively related to the propensity of switching to LES. Assuming that these citation metrics are approximations to patent quality, one can infer that patents which eventually switch to LES are higher quality patents. Among these three citation metrics, forward citations are the ones associated with the highest predicted probability in switching to LES. Namely, holding all other variables at their means, an additional forward citation is associated with 0.4% greater likelihood of licensing. This finding is consistent with Harhoff et al. (1999), Sampat and Ziedonis (2005), and Bessen (2008). Further, the number of inventors (*Inventors*) involved in the patent, the number of assignees (*Assignees*) the patent belongs to, and the 4-digit International Patent Classification (IPC4Digit), which proxies for patent scope (Lerner, 1994) are significantly and positively associated with the propensity to switching to LES.

[25] "Report to Congress on the activities of Department of Defense Office of Technology Transition" (August 2006).

Table 3: Propensity of Switching to LES

	All University Patents		Excluding University Outliers (*)	
Federal	-0.0069		-0.0017	
	(0.007)		(0.008)	
$DODfunding$		-0.0591***		-0.0587***
		(0.015)		(0.019)
$DOEfunding$		-0.0103		-0.0261
		(0.014)		(0.020)
$NIHfunding$		0.00573		0.0095
		(0.0101)		(0.0108)
$NSFfunding$		-0.0200		-0.009
		(0.016)		(0.018)
$Otherfunding$		0.0145		0.020
		(0.014)		(0.014)
ForwardCites	0.0043***	0.0043***	0.0044***	0.0044***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
BackwardCitesPat	0.0015***	0.0015***	0.0015***	0.0016***
	(0.0003)	(0.0003)	(0.0004)	(0.0004)
BackwardCitesNonPat	0.0007***	0.0007***	0.0006***	0.0006***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
ApplicationLength	-0.0045	-0.0045	-0.0061*	-0.0062*
	(0.003)	(0.003)	(0.004)	(0.004)
Claims	0.0003	0.0003	0.0004	0.0004
	(0.0002)	(0.0002)	(0.0003)	(0.0003)
IPC4Digit	0.0345***	0.0343***	0.0342***	0.0340***
	(0.003)	(0.003)	(0.003)	(0.003)
USC3Digit	-0.0040	-0.0040	0.0015	0.0015
	(0.003)	(0.003)	(0.003)	(0.003)
Inventors	0.0152***	0.0152***	0.0139***	0.0141***
	(0.003)	(0.003)	(0.003)	(0.003)
$InventorActivity_{Medium}$	0.0600***	0.0608***	0.0596***	0.0601***
	(0.009)	(0.009)	(0.010)	(0.010)
$InventorActivity_{High}$	0.1250***	0.1260***	0.1110***	0.1120***
	(0.009)	(0.009)	(0.010)	(0.010)
Assignees	0.0486**	0.0469**	0.0572***	0.0553***
	(0.021)	(0.021)	(0.021)	(0.021)
$AssigneeActivity_{Medium}$	0.0904***	0.0903***	0.0743***	0.0747***
	(0.009)	(0.009)	(0.010)	(0.010)
$AssigneeActivity_{High}$	0.1600***	0.1620***	0.1360***	0.1350***
	(0.009)	(0.009)	(0.010)	(0.010)
Observations	20,877	20,877	17,286	17,286

All columns report probit estimates (marginal effects). In all estimations time dummies (*GrandYear*) and technology field dummies (*TechnologyDummy*) are included, but for brevity not reported here. Heteroskedastically robust standard errors are reported in the parentheses.
(*) The MIT and the University of California are excluded (outliers) due to their exceptional patenting performance.

In addition, the (lead) inventor's prior patenting activity is associated with significant increases in the likelihood of having the patent licensed. First, holding all other variables at their means, when the lead inventor has between 1 and 3 prior patents, her current patent is approximately 6% more likely to be transferred than a lead inventor's patent that has no past patents. When the lead inventor has more than three

prior patents, she is between 11.1% and 12.6% more likely to have her current patent licensed than a lead inventor's patent that has no prior patents. This finding is consistent with Elfenbein (2007).[26] The university patenting activity is also associated with greater propensities of patents switching to LES. Holding all other variables at their means, a medium-sized university in terms of prior patent stock ($AssigneeMedium = 1$) is 7.4% to 9% more likely to have its current patent licensed than a less patenting active university. For the largest universities ($AssigneeHigh = 1$) their patents are 13.5% to 16.2% more likely. This positive correlation between university patenting activity and likelihood of licensing is consistent with Jensen et al. (2003) and Belenzon and Schankerman (2009).

We perform a number of robustness checks. To verify that our results are not driven by just a handful of large universities, we exclude the two biggest universities in terms of patenting activity: the University of California and Massachusetts Institute of Technology. Results are displayed in Columns (3) and (4). As before, government sponsorship of research (column (3)) does not seem to be associated with different propensity of licensing compared to non-federally funded patents. When we distinguish by funding source (column (4)), estimates are very similar to those in column (2). Results remain unchanged. For further robustness, we drop from our analysis the patents that had not claimed SES for patent issue fees, while at the first maintenance renewal event the university claimed SES. Table A.3 in the Appendix, re-estimates the propensities of switching to LES given government sponsorship and types of funding agents, along with patent characteristics, for all universities (columns (1) and (2)) and when excluding the University of California and the MIT (columns (3) and (4)). Results are qualitatively similar with those discussed so far. Overall, results did not change in any significant way.

In sum, federal funding does not matter for technology commercialization of university patents. Our results have shown that government sponsored patents do not appear to be systematically associated with different propensity of being licensed compared to non-federally funded patents. The only notable exception is the DOD funded patents, which are less likely, compared to non-federally sponsored counterparts, to be licensed. Among the patent characteristics considered, we find that the prior and posterior art base (citations), the number of patent inventors and assignees, along with the size of their patenting activity, and, finally, the scope of the patent are positively related with the propensity of a university patent being commercialized.

3.2. Are Federally Sponsored University Patents Faster Transferred to the Marketplace than Non-Federally Funded?

The second objective of this paper is to examine whether federally sponsored university patents are licensed faster compared to their non-federally funded counterparts, and whether the source of funding makes any difference in the speed of technology transfer to the marketplace.

Table 4 shows the estimation results from the ordered probit model as it is described in equation (2). Column (1) shows the average effect and columns (2) to (5) the marginal effects of a patent switching to LES at issue, at the first maintenance, at the second maintenance, and at the third maintenance event, corresponding to 3.5, 7.5, and 11.5 years after patent grant, without differentiating by the source of funding. Analogously, columns (6) to (10) display average and marginal effects by funding agent.

As the coefficient of federally funded patents (*Federal*) in column (1) indicates, there is a positive association between federal sponsorship of a university patent and switching to LES at a late stage. Indeed, federally funded patents are more likely to be licensed later in time, as it can also be seen in columns (2) to (5). In particular, holding all other variables at their means, federally funded patents, as is shown in column (2), are 11.3% less likely to be licensed by the issue year than non-federally funded university patents. In contrast, the propensity of the federally sponsored patents to be licensed at a late stage, for example, by the 7.5th or 11.5th year (columns (4) and (5)), is about 5% higher compared to their non federally sponsored counterparts. This finding comes as no surprise, as a set of the non-federally funded patents are corporate funded. In general, when the research funder is a corporation it, usually, licenses the invention early as it has information in advance for the research project.

[26] The study of Thursby et al. (2001) also finds a negative relationship between frequency of sponsored research agreements in a license and faculty quality.

Table 4: Timing of Switching to LES

	All University Patents					Excluding University Outliers (*)				
		by grant year	by 3.5 years	by 7.5 years	by 11.5 years		by grant year	by 3.5 years	by 7.5 years	by 11.5 years
		Marginal Effects					Marginal Effects			
Probability		0.4278	0.3326	0.1670	0.0725		0.4258	0.3355	0.1685	0.0702
Federal	0.2910***	-0.1133***	0.0215***	0.0500***	0.0418***					
	(0.0277)	(0.0107)	(0.0022)	(0.0049)	(0.0042)					
DODfunding						0.3188***	-0.1199***	0.0119***	0.0553***	0.0527***
						(0.0619)	(0.0220)	(0.0015)	(0.0104)	(0.0122)
DOEfunding						0.8554***	-0.2853***	-0.0288***	0.1265***	0.1876***
						(0.0622)	(0.0158)	(0.0093)	(0.0068)	(0.0192)
NIHfunding						0.1353***	-0.0526***	0.0094***	0.0238***	0.0194***
						(0.0375)	(0.0144)	(0.0022)	(0.0066)	(0.0057)
NSFfunding						0.2801***	-0.1061***	0.0121***	0.0488***	0.0452***
						(0.0620)	(0.0224)	(0.0012)	(0.0106)	(0.0118)
Otherfunding						0.2044***	-0.0784***	0.0113***	0.0359***	0.0312***
						(0.0501)	(0.0187)	(0.0017)	(0.0088)	(0.0086)
ForwardCites	0.0042***	-0.0016***	0.0003***	0.0007***	0.0006***	0.0041***	-0.0016***	0.0003***	0.0007***	0.0006***
	(0.0005)	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0005)	(0.0002)	(0.0001)	(0.0001)	(0.0001)
BackwardCitesPat	-0.0045***	0.0018***	-0.0004***	-0.0008***	-0.0006***	-0.0046***	0.0018***	-0.0004***	-0.0008***	-0.0006***
	(0.0010)	(0.0004)	(0.0001)	(0.0002)	(0.0001)	(0.0010)	(0.0004)	(0.0001)	(0.0002)	(0.0001)
BackwardCitesNonPat	-0.00004	0.00016	-0.00003	-0.00007	-0.00006	0.00002	-0.000008	0.000002	0.000003	0.000003
	(0.0006)	(0.0003)	(0.0001)	(0.0001)	(0.0001)	(0.0006)	(0.0003)	(0.0001)	(0.0001)	(0.0001)
ApplicationLength	0.0050	-0.0020	0.0004	0.0009	0.0007	0.0073	-0.0029	0.0006	0.0013	0.0010
	(0.0134)	(0.0053)	(0.0011)	(0.0023)	(0.0018)	(0.0135)	(0.0053)	(0.0011)	(0.0024)	(0.0018)
Claims	-0.0009	0.0004	-0.0001	-0.0002	-0.0001	-0.0010	0.0004	-0.0001	-0.0002	-0.0001
	(0.0008)	(0.0003)	(0.0001)	(0.0001)	(0.0001)	(0.0008)	(0.0003)	(0.0001)	(0.0001)	(0.0001)
IPC4Digit	-0.0015	0.0006	-0.0001	-0.0003	-0.0002	0.0017	-0.0007	0.0002	0.0003	0.0002
	(0.0083)	(0.0033)	(0.0007)	(0.0014)	(0.0011)	(0.0083)	(0.0033)	(0.0007)	(0.0015)	(0.0011)
USC3Digit	0.0251**	-0.0099**	0.0021**	0.0043**	0.0035**	0.0268**	-0.0105**	0.0022**	0.0047**	0.0036**
	(0.0107)	(0.0042)	(0.0009)	(0.0019)	(0.0015)	(0.0108)	(0.0042)	(0.0009)	(0.0019)	(0.0015)
Inventors	-0.0275***	0.0108***	-0.0023***	-0.0047***	-0.0038***	-0.0255**	0.0100**	-0.0021**	-0.0045**	-0.0034**
	(0.0103)	(0.0040)	(0.0009)	(0.0018)	(0.0014)	(0.0103)	(0.0040)	(0.0009)	(0.0018)	(0.0014)
$InventorActivity_{Medium}$	-0.0241	0.0095	-0.0020	-0.0042	-0.0033	-0.0317	0.0125	-0.0027	-0.0056	-0.0042
	(0.0368)	(0.0145)	(0.0031)	(0.0064)	(0.0050)	(0.0369)	(0.0145)	(0.0032)	(0.0065)	(0.0049)
$InventorActivity_{High}$	-0.1490***	0.0585***	-0.0125***	-0.0257***	-0.0203***	-0.1694***	0.0664***	-0.0143***	-0.0296***	-0.0225***
	(0.0358)	(0.0140)	(0.0031)	(0.0062)	(0.0048)	(0.0360)	(0.0141)	(0.0032)	(0.0063)	(0.0048)
Assignees	0.3356***	-0.1317***	0.0275***	0.0579***	0.0463***	0.3760***	-0.1474***	0.0309***	0.0659***	0.0506***
	(0.0540)	(0.0212)	(0.0047)	(0.0094)	(0.0075)	(0.0547)	(0.0215)	(0.0049)	(0.0098)	(0.0074)
$AssigneeActivity_{Medium}$	-0.2114***	0.0832***	-0.0192***	-0.0362***	-0.0278***	-0.1947***	0.0766***	-0.0177***	-0.0339***	-0.0250***
	(0.0367)	(0.0145)	(0.0038)	(0.0063)	(0.0047)	(0.0369)	(0.0146)	(0.0038)	(0.0064)	(0.0046)
$AssigneeActivity_{High}$	-0.0682*	0.0268*	-0.0057*	-0.0118*	-0.0093*	-0.0799**	0.0313**	-0.0067**	-0.0140**	-0.0106**
	(0.0366)	(0.0144)	(0.0031)	(0.0063)	(0.0050)	(0.0369)	(0.0145)	(0.0032)	(0.0065)	(0.0049)
Observations	7,095	7,095	7,095	7,095	7,095	7,095	7,095	7,095	7,095	7,095

Columns (1) and (7) report estimates of average effects and the rest of the columns marginal effects of ordered probit. In all estimations time dummies (*GrandYear*) and technology field dummies (*TechnologyDummy*) are included but for brevity not reported here. Heteroskedastically robust standard errors are reported in the parentheses.
(*) The MIT and the University of California are excluded (outliers) due to their exceptional patenting performance.

Next, we account for different funding agencies. Column (6) distinguishes by type of funding agents and presents the average effects. The coefficients of the funding agencies ($DODfunding$, $DOEfunding$, $NIHfunding$, $NSFfunding$, and $OTHERfunding$) show that the switch is more probable to take place at a late stage, with the DOE funded patents to be the latest in being licensed and the NIH the first.

More specifically, when examining the marginal effects, in columns (7) to (10), two noteworthy findings emerge. First, as column (7) shows, not only all federally funded patents are less likely to switch to LES by the issue year than non-federally supported patents, but also the funding agent greatly matters, as differences in the probability of a patent being licensed depends on the source of funding. For example, the DOE funded patents are the least likely among the federally funded patents to be licensed by issue year, whereas the NIH funded are the most. In particular, holding all other variables at their means, DOE funded patents are 28.5% less likely to switch to LES by issue year than non-federally funded patents. In the other extreme, NIH funded patents are only 5.3% less likely to be licensed by issue than non-federally funded patents. This difference could be partially explained by the nature of the funded patents. Second, at later stages, and in particular by the 7.5th and 11.5th year, federally funded patents compared to their non federally counterparts are more likely to be licensed, with patents being funded by the DOE to now exhibit the highest propensity (about 19% in column (10)) and the NIH the smallest (about 2% in column (10)). The large difference between the DOE and NIH funded patents can be attributed to various reasons. Link and Ruhm (2009) argue that commercialized technologies that result in improvements in health are particularly likely to have high rates of return, which results in higher incentive for an early license. This may not be true for patents funded by the DOE. According to Herzog and Kammen (2002), the sparse federal investment in energy technologies has resulted in financial and policy uncertainty, which, in turn, discourages energy technology from early development.

With respect to the rest of the patent characteristics, there is no important difference between estimates reported in columns (1) to (5) and the corresponding ones, in columns (6) to (10). Given government sponsorship, we further find that patents with a larger prior art base (*BackwardCitesPat*) are more likely to be licensed early, while patents with larger posterior art base (*ForwardCites*) are more likely to be licensed at a later stage. In contrast, the number of prior non patent citations (BackwardCitesNonPat) is not significantly associated with the speed of switching to LES. Large number of backward citations may indicate that the invention is in a relatively mature technology area. The resulting patent presumably suggests that the cited innovation is economically valuable Hall et al. (2005), giving the incentive to profit seeking organizations for faster transfer in the marketplace. The opposite could be the case for the forward citations, which indicate a later incentive to protect the property's rights Lanjouw and Schankerman (2001).

Furthermore, patents which have more inventors (*Inventors*) are licensed early, while the opposite seems to be the case for patents that belong to many co-assignees/universities (*Assignees*). Inventor's patenting experience, also shapes the speed of licensing. Patents, whose inventors have substantial prior patenting experience show 5.8% to 6.6% greater likelihood to be licensed early than patents whose inventors have no prior patenting experience. This finding is consistent with Elfenbein (2007). In terms of university's patenting experience, we find that medium-sized universities are more likely to have their patents licensed early than small-sized universities by, approximately, 8%. While large universities are also more likely to have their patents licensed early than small-sized universities, the difference is about 3%. Finally, the number of 3-digit US classifications (*USC3Digit*), which proxies patent scope, is positively associated with delayed licensing.

Overall, we find that federally funded university patents are more likely to be licensed at later years over their lifecycle compared to non-federally funded patents with the DOE funded patents to take the most time to be licensed and the NIH funded patents the least. The greater the prior art base of a patent, the more inventors involved, the larger their patent experience, and the larger the size of the patent stock of the university, the earlier a patent is commercialized. In contrast, the higher the posterior art base, the larger the number of assignees a university patent belongs to, and the smaller the patent experience of the inventor and stock of patents in a university, the higher the propensity of a university being licensed at a later stage.

4. Conclusion

The present paper addressees two issues that thus far have not been approached in a comprehensive manner in the literature, mainly due to data limitations: (i) Are federally funded university patents more (less) likely to be transferred to the marketplace than non-federally funded? and (ii) Are federally sponsored university patents faster transferred to the marketplace than non-federally funded?

To answer these questions, this paper exploits a unique facet of the US patent system that has been overlooked so far, the fee payment data scheme associated with statutory rules on how and when university patent holders pay these fees. Based on this observation, we are able to determine the propensity and time of technology transfer from the university to the marketplace of both federally sponsored - distinguishing also by funding agent - and non-federal funded patents and the associated characteristics of transferred patents.

Based on a large sample of 20,877 university patents issued between 1990 and 2000, we find, with respect to the first question, that government sponsorship of research does not seem to be associated with a systematically different propensity of licensing compared to non-federally funded patents. The only notable exception is the Department of Defense funded patents, which are less likely compared to non federally sponsored counterparts to be licensed.

Furthermore, and with respect to the second question, we find that federally funded university patents are more likely to be licensed at later years over their lifecycle compared to non-federally funded patents, with the Department of Energy funded patents to take the most time to be licensed and the National Institute of Health funded patents the least.

Finally, patent characteristics, such as the prior and posterior art base of a patent, the number of inventors and assignees involved in a patent, along with the size of their patenting activity, and the scope of the patent are significantly associated with both the propensity and the speed of patent transfer to the marketplace.

References

Adams, J. D. (1990). Fundamental stocks of knowledge and productivity growth. *Journal of Political Economy 98(4)*, 673–702.

AUTM (2005). *AUTM U.S. Licesensing Activity Survey: FY2004. Survey Summary*. AUTM.

AUTM (2008). *AUTM U.S. Licesensing Activity Survey: FY2007. Survey Summary*. AUTM.

AUTM (2010). *AUTM U.S. Licesensing Activity Survey: FY2009. Survey Summary*. AUTM.

Azoulay, P., J. Zivin, and G. Manso (2011). Incentives and creativity: Evidence from the academic life sciences. *Rand Journal of Economics 42(3)*, 527–554.

Belenzon, S. and M. Schankerman (2009). University knowledge transfer: Private ownership, incentives, and local development objectives. *Journal of Law and Economics 52(1)*, 111–144.

Bessen, J. (2008). The value of us patents by owner and patent characteristics. *Research Policy 37(5)*, 932–945.

Bradley, S. R., C. S. Hayter, and A. N. Link (2013). Models and methods of university technology transfer. *University of Carolina at Greensboro, Department of Economics Working Paper No 13-10*.

Cohen, W., R. Florida, L. Randazzese, and J. Walsh (1998). Industry and the academy: Uneasy partners in the cause of technological advance. In *Challenges to the Research University*, Chapter 7. Brookings Institution, Washington D.C.

Drivas, K. and C. Economidou (2013). Government sponsorship and nature of patenting activity of us universities and corporations. *Economics of Innovation and New Technology (forthcoming)*.

Drivas, K., Z. Lei, S. Merrill, and B. D. Wright (2013). Corporate-sponsored academic research: What does the data tell us? *University of California, Berkeley, Mimeo*.

Eisenberg, R. S. (1996). Public research and private development: Patents and technology transfer in government-sponsored research. *Virginia Law Review 82(8)*, 1663–1727.

Elfenbein, D. (2007). Publications, patents, and market for university inventions. *Journal of Economic Behavior and Organization 63(4)*, 688–715.

Federal Register (2012). Changes to implement micro entity status for paying patent fees. *Federal Register 77*, 75019.

Graff, G. D., A. Heiman, and D. Zilberman (2002). University research and offices of technology transfer. *California Management Review 1*, 87–116.

Hall, B., A. Jaffe, and M. Trajtenberg (2001). The nber patents citations data file: Lessons, insights and methodological tools. *NBER Working Paper No. 8498.*.

Hall, B. H., A. Jaffe, and M. Trajtenberg (2005). Market value and patent citations. *Rand Journal of Economics 36(1)*, 16–38.

Hall, B. H., A. N. Link, and J. Scott (2003). Universities as research partners. *Review of Economics and Statistics 85(2)*, 485–491.

Harhoff, D., F. Narin, F. M. Scherer, and K. Vopel (1999). Citation frequency and the value of patented inventions. *Review of Economics and Statistics 81(3)*, 511–515.

Hellmann, T. (2007). The role of patents for bridging the science to market gap? *Journal of Economic Behavior and Organization 63(4)*, 624–647.

Hellmann, T. F. and E. Perotti (2011). The circulation of ideas in firms and markets. *Management Science 57(10)*, 1813–1826.

Henderson, R., A. Jaffe, and M. Trajtenberg (1998). Universities as a source of commercial technology: A detailed analysis of university patenting, 1965-1988. *Review of Economics and Statistics 80(1)*, 119–127.

Herzog, V. and M. Kammen (2002). Energy r&d: Investment challenge. *Materials Today 5(5)*, 28–33.

Jaffe, A. (1989). Real effects of academic research. *American Economic Review 79(5)*, 957–970.

Jensen, R. and M. Thursby (2001). Proofs and prototypes for sale: The licensing of university inventions. *American Economic Review 91(1)*, 240–259.

Jensen, R. A., J. G. Thursby, and M. C. Thursby (2003). Disclosure and licensing of university inventions: 'the best we can do with the s**t we get to work with. *International Journal of Industrial Organization 21(9)*, 1271–1300.

Lach, S. and M. Schankerman (2008). Incentives and invention in universities. *Rand Journal of Economics 39(2)*, 403–433.

Lai, R., A. D'Amour, A. Yu, Y. Sun, V. Torvik, and L. Fleming (2011). Disambiguation and co-authorship networks of the u.s. patent inventor database (1975-2010). *http://hdl.handle.net/1902.1/15705 UNF:5:RqsI3LsQEYLHkkg5jG/jRg== V3 [Version]*.

Lanjouw, J. O. and M. Schankerman (1999). The quality of ideas: Measuring innovation with multiple indicators. *NBER Working Paper No 7345*.

Lanjouw, O. J. and M. Schankerman (2001). Characteristics of patent litigation: A window on competition. *RAND Journal of Economics 32(1)*, 129–151.

Lerner, J. (1994). The importance of patent scope: An empirical analysis. *RAND Journal of Economics 25(2)*, 319–333.

Levin, R., W. M. Cohen, and D. Mowery (1985). R & d appropriability, opportunity, and market structure: New evidence on some schumpeterian hypothesis. *The American Economic Review 75(2)*, 20–24.

Levin, R. C., A. K. Klevorick, R. R. Nelson, and S. Winter (1987). Appropriating the returns from industrial research and development. *Brooking Papers on EconomicActivity 3*, 783–831.

Link, A. N. and J. C. Ruhm (2009). Bringing science to market: Commercializing from nih sbir awards. *Economics of Innovation and New Technology 18(4)*, 381–402.

Mansfield, E. (1991). Academic research and industrial innovation. *Research Policy 20(1)*, 1–12.

Mowery, D. and A. Ziedonis (2001). The geographic reach of market and non-market channels of technology transfer: Comparing citations and licences of university patents. *NBER Working Paper No. 8568*.

Mowery, D. C. and B. N. Sampat (2005). The bayh-dole act of 1980 and university dindustry technology transfer: A model for other oecd governments? *Journal of Technology Transfer. 30(1-2)*, 115–127.

National Science Board (2012). *National Science Board: Science and Enginnering Indicators*. National Science Board.

NBER, Patent Data Project (2013). *NBER, Patent Data Project*. NBER, http://sites.google.com/site/patentdataproject/.

Pressman, L., R. Burgess, R. M. Cook-Deegan, S. J. McCormack, I. Nami-Wolk, M. Soucy, and L. Walters (2006). The licensing of dna patents by s academic institutions: An empirical survey. *Nature Biotechnology 24(1)*, 31–39.

Rothaermel, F., S. Agung, and L. Jiang (2007). University entrepreneurship: A taxonomy of the literature. *Industrial and Corporate Change 16(4)*, 691–791.

Sampat, B. N. and A. A. Ziedonis (2005). Patent citations and the economic value of patents. In H. F. Moed, W. Glänzel, and U. Schmoch (Eds.), *Handbook of Quantitative Science and Technology Research*, pp. 277–298. Kluwer Academic Publishers.

Thursby, J., R. Jensen, and M. Thursby (2001). Objectives, characteristics and outcomes of university licensing: A survey of major u.s. universities. *Journal of Technology Transfer 26(1-2)*, 59–72.

Wu, Y. (2010). Tackling undue concentration of federal research funding: An empirical assessment on nsf's experimental program to stimulate competitive research (epscor). *Research Policy 39(6)*, 835–841.

Ziedonis, A. A. (2007). Real options in technology licensing. *Management Science 53(10)*, 1618–1633.

Appendix

Table A.1: Summary Statistics of University Patents by LES

	Never Switch to LES	Switch to LES	P-value
Federal	0.38	0.42	0.00
	(0.48)	(0.49)	
ForwardCites	9.87	16.82	0.00
	(15.34)	(25.15)	
BackwardCitesPat	8.83	10.69	0.00
	(10.26)	(14.65)	
BackwardCitesNonPat	12.21	16.47	0.00
	(18.21)	(23.38)	
ApplicationLength	2.30	2.38	0.00
	(1.04)	(1.08)	
Claims	17.27	18.73	0.00
	(13.43)	(16.49)	
IPC4Digit	2.97	3.41	0.00
	(1.25)	(1.65)	
USC3Digit	3.19	3.29	0.00
	(1.19)	(1.28)	
Inventors	2.33	2.55	0.00
	(1.27)	(1.38)	
$InventorActivity_{Low}$	0.33	0.23	0.00
	(0.47)	(0.42)	
$InventorActivity_{Medium}$	0.34	0.33	0.01
	(0.47)	(0.47)	
$InventorActivity_{High}$	0.32	0.45	0.00
	(0.47)	(0.50)	
Assignees	1.02	1.03	0.00
	(0.13)	(0.19)	
$AssigneeActivity_{Low}$	0.38	0.25	0.00
	(0.48)	(0.43)	
$AssigneeActivity_{Medium}$	0.33	0.34	0.09
	(0.47)	(0.47)	
$AssigneeActivity_{High}$	0.30	0.41	0.00
	(0.46)	(0.49)	
Observations	13,782	7,095	

Table A.2: Summary Statistics of University Patents by Different Entity Status Behavior

	Not Switching to LES	Not claiming SES at filing but at the 1st renewal	Not claiming SES at filing and LES claimed at the 1st renewal
Federal	0.38	0.36	0.35
	(0.49)	(0.48)	(0.48)
ForwardCites	9.84	10.03	14.19
	(15.02)	(17.05)	(20.23)
BackwardCitesPat	8.82	8.91	11.00
	(10.16)	(10.83)	(15.27)
BackwardCitesNonPat	12.05	13.16	16.66
	(18.13)	(18.67)	(23.35)
ApplicationLength	2.25	2.60	2.35
	(0.97)	(1.34)	(1.13)
Claims	17.29	17.20	18.18
	(13.20)	(14.67)	(16.20)
IPC4Digit	2.95	3.06	3.36
	(1.24)	(1.28)	(1.53)
USC3Digit	3.18	3.22	3.23
	(1.19)	(1.18)	(1.21)
Inventors	2.33	2.33	2.56
	(1.27)	(1.22)	(1.36)
$InventorActivity_{Low}$	0.34	0.31	0.21
	(0.47)	(0.46)	(0.41)
$InventorActivity_{Medium}$	0.34	0.34	0.31
	(0.47)	(0.48)	(0.46)
$InventorActivity_{High}$	0.32	0.35	0.47
	(0.47)	(0.48)	(0.5)
Assignees	1.02	1.03	1.02
	(0.13)	(0.16)	(0.13)
$AssigneeActivity_{Low}$	0.38	0.37	0.25
	(0.48)	(0.48)	(0.43)
$AssigneeActivity_{Medium}$	0.33	0.31	0.37
	(0.47)	(0.46)	(0.48)
$AssigneeActivity_{High}$	0.29	0.32	0.38
	(0.45)	(0.46)	(0.48)
Observations	11,768	2,014	3,063

Numbers in parentheses are standard errors.

Table A.3: Propensity of Switching to LES Excluding Patents Not Claiming SES at filling but at 1st Renewal

	All University Patents		Excluding University Outliers	
	Funding	Type	Funding	Type
Federal	-0.0121		-0.0089	
	(0.008)		(0.009)	
$DODfunding$		-0.0677***		-0.0686***
		(0.016)		(0.020)
$DOEfunding$		-0.0137		-0.0328
		(0.016)		(0.021)
$NIHfunding$		-0.0016		0.0005
		(0.011)		(0.012)
$NSFfunding$		-0.0239		-0.0147
		(0.017)		(0.019)
$Otherfunding$		0.0144		0.0181
		(0.015)		(0.016)
ForwardCites	0.0046***	0.0046***	0.0047***	0.0047***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
BackwardCitesPat	0.0017***	0.0017***	0.0018***	0.0018***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
BackwardCitesNonPat	0.0006***	0.0006***	0.0005**	0.0005**
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
ApplicationLength	0.0077**	0.0076*	0.0049	0.0047
	(0.004)	(0.004)	(0.004)	(0.004)
Claims	0.0004	0.0004	0.0004	0.0004
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
IPC4Digit	0.0365***	0.0363***	0.0367***	0.0366***
	(0.003)	(0.003)	(0.003)	(0.003)
USC3Digit	-0.0051	-0.0051	0.0007	0.0008
	(0.003)	(0.003)	(0.003)	(0.003)
Inventors	0.0149***	0.0148***	0.0138***	0.0140***
	(0.003)	(0.003)	(0.003)	(0.003)
$InventorActivity_{Medium}$	0.0658***	0.0667***	0.0650***	0.0656***
	(0.010)	(0.010)	(0.010)	(0.010)
$InventorActivity_{High}$	0.138***	0.138***	0.124***	0.125***
	(0.009)	(0.009)	(0.010)	(0.010)
Assignees	0.0657***	0.0644***	0.0744***	0.0726***
	(0.023)	(0.023)	(0.023)	(0.023)
$AssigneeActivity_{Medium}$	0.0956***	0.0955***	0.0798***	0.0802***
	(0.010)	(0.010)	(0.010)	(0.010)
$AssigneeActivity_{High}$	0.177***	0.179***	0.147***	0.146***
	(0.010)	(0.010)	(0.011)	(0.011)
Observations	18.863	18.863	15.609	15.609

All columns report probit estimates (marginal effects). In all estimations time dummies (*GrandYear*) and technology field dummies (*TechnologyDummy*) are included but for brevity not reported here. Heteroskedastically robust standard errors are reported in the parentheses.
(*) The MIT and the University of California are excluded (outliers) due to their exceptional patenting performance.