Near-Term Commercialization of University Inventions: Individual and Institutional Factors Affecting the Licensing of University Patents within a Four-Year Window

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Abstract

This paper examines individual and institutional factors that affect the probability of licensing university patents within the first four years from the time of award. Using a 2010 national survey of academic scientists in the United States in which respondents were asked specific questions about 2006 patents for which they were the primary inventors. We find that licensing outcomes are primarily determined by individual factors including inventors' attitude towards commercialization of research, the involvement of industry researchers in underlying research, and additional research conducted during patent review. Some institutional factors also play a limited role on licensing of university patents. This study provides empirical evidence to inform processes aimed at commercialization of university inventions during the critical time period soon after a patent award is made.

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Introduction

There is an increasing consensus that universities especially major research universities may play important roles in national and regional economic development. One important mechanism through which universities may contribute to economic growth is to convert scientific inventions to innovation through patenting and licensing their research outputs. The Bayh-Dole Act enacted in 1980 allows universities to patent publicly-funded research with the primary intent to engage universities and industries in technology transfer and research commercialization. In response to this major policy change, by 1998, every Carnegie I and II research university had established Technology Transfer Office (TTO) to help patent and commercialize university research (Bercovitz & Feldman, 2007).

Although prior research found significant increases in university patenting activities since the passage of the Bayh-Dole Act (Henderson, et al., 1998; Mowery, et al., 2001; Mowery, et al., 2002; Mowery & Ziedonis, 2002; Shane, 2004), only a limited portion of university patents has been licensed. For instance, only 35.5 percent of patents owned by University of California—one of the most profitable universities on research commercialization—had been licensed between 1984 and 1988 (Mowery & Ziedonis, 2002). An analysis of the Licensing Activity Survey 1995-2004 conducted by the Association of University Technology Managers (AUTM) further shows that the annual earnings of licensing university patents offset only 1.7 percent of total research expenditures in 1995 and 2.9 percent in 2004 (Swamidass & Vulasa, 2009). Given that university patents represent only one intermediate step toward commercialization of academic research outputs, it is important to investigate how to facilitate successful licensing of university patents.

Some scholars have identified factors that may determine the overall performance of university research commercialization through licensing (Carlsson & Fridh, 2002; Elfenbein,

2007; Friedman & Silberman, 2003; Sine, et al., 2003; Swamidass & Vulasa, 2009; Thursby & Kemp, 2002; Thursby, et al., 2001; Thursby & Thursby, 2002). However, most of them tested hypotheses using the AUTM's Licensing Activity Survey data that are only collected at the university level. The university level data does not allow a full examination of the impact of individual factors on commercialization of academic research.

Our study fills that caveat by investigating determinants of successful licensing of university patents using a 2010 national survey data of 430 academic scientists and engineers who are primary inventors of 2006 university patents awarded by the U.S. Patent and Trademark Office (USPTO). We take the patent as the unit of analysis to examine the extent to which primary inventors' attitudes and behaviors as well as their perceptions of TTOs' performance on research commercialization determine whether the awarded 2006 patents had been licensed. The statistical results show that the near-term licensing of a university patent is primarily determined by individual factors including inventors' attitude towards commercialization of academic research, the involvement of industry researchers in underlying research, and further research conducted by the inventor during patent review. At the institution-level, university TTOs' profit-driven practices—TTO's requirement that potential licensees be identified before submission of a patent application, and its unwillingness to cover patenting fees—increase the chance of near-term patent licensing.

This paper is organized as follows: The next two sections present a conceptual framework and the hypotheses as well as a review of relevant literature. These are followed by sections presenting the model and data, descriptive analysis, and regression analysis. Conclusions develop implications for university policy and management in research commercialization and discuss

ways in which universities could improve the effectiveness with which they facilitate near-term commercialization of university inventions.

Conceptual framework and hypotheses

Conceptual framework

It is recognized in the literature that the production and licensing of university inventions is a multi-stage process. Thursby and Thursby (2002) identify three stages of technology transfer with output of each stage being disclosure, patent application, and license and option agreement. In their work, production of university licenses is modeled as a function of invention disclosures, patent applications, commercialization potential and novelty of the technologies, the number of personnel in university TTOs, university' propensity to license inventions, and industry interest in university inventions. Those factors stand for both the importance of the market potential of research outputs and universities' and inventors' efforts to pursue research commercialization.

The institutional model provides an important foundation for a more complex model that incorporates the agency and interests of university scientists. A revised process model recognizes that a combination of individual and institutional factors influence a multistage university invention process that may include pre-disclosure, disclosure, patent application, and post-award stages. At the pre-disclosure stage, scientists may decide to develop or select projects that are more or less likely to produce inventions. When potentially commercializable research outputs are generated, scientists decide whether or not to disclose their inventions to university TTOs in an effort to protect intellectual property rights. For both of these initial stages, the university or department may provide an institutional context for patenting that ranges from favorable to unfavorable.

Once an invention is disclosed, the university often decides whether to pursue a patent through a formal patent application that may or may not be awarded as a result of USPTO's extended review. However, the scientist may also be involved at this stage by conducting further experiments or providing background information to support the application or by working with companies on potential applications. Once a patent is awarded, companies or other potential users may approach the university and obtain the legal right to use the invention for a particular purpose. Here also, the inventor scientist may actively promote or identify potential suitors. For inventions that reach this final stage, universities may license the patent to one or more interested parties. In sum, an individual and institutional decision-making approach to patenting and licensing recognizes that each stage of the process is influenced by both individual and institutional factors.

Given this, we propose a conceptual framework that integrates individual and institutional factors and links successful licensing of university patents to the applicability of the underlying research and the marketability of the disclosed inventions (see Figure 1). *Applicability* refers to the extent to which the underlying research produces novel technologies that can be further used in process or product development. In general, the applicability of the research output is at least partially dependent on the type of project selected or pursued, and university scientists who favor research that produces results transferable or translatable to practice are expected to select research projects that have a greater application potential. Stokes (1997) classifies scientific research into four quadrants separated by two dimensional continua: consideration of practical use and quest for fundamental understanding of scientific phenomenon. Research that aims to solve practical issues with little interest in fundamental knowledge is categorized to the Edison's quadrant. Basic research that is inspired by practical use is categorized to the Pasteur's quadrant.

Research activities that fall within these two quadrants are more likely to produce patentable and licensable inventions than those that fall into the Bohr's quadrant, where research is guided primarily by the pursuit of scientific knowledge and where application goals are minimal or absent (Azoulay, et al., 2007; Stephan, et al., 2007).

Both individual and institutional factors determine applicability. Individual factors could include beliefs about the role of university research in economic development while institutional factors could include incentives set by the organization to reward application oriented research. As a result, the prospect of an invention being licensed, where licensing is a manifestation of commercialization, depends in part on how applicable the underlying research is, which in turn is a function of both individual and institutional factors.

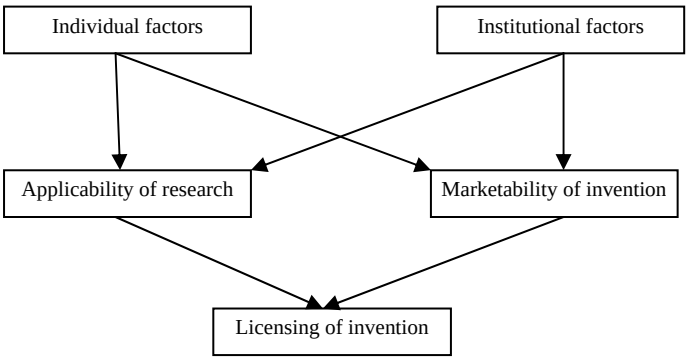

Figure 1: A Conceptual Framework of Licensing University Inventions

In addition to applicability of the research, the probability of commercialization also depends on how marketable the invention is. *Marketability* represents the degree to which the inventions are recognized by industry or other entities as important inputs for the development of processes or products that can be either sold in a market (most likely) or otherwise provided to potential

users. The Edition and Pasteur type projects are likely to generate patentable inventions but the underlying technologies may not be marketable, particularly when a significant amount of time is required for the development of commercial applications. As reported in Jensen and Thursby (2001), most of university patents are often too embryonic to use commercially at the time of licensing.

However, marketability is not simply a technological feature; it is also a function of the level of engagement that academic inventors and universities demonstrate in the commercialization process. Marketing efforts can occur at any stage from disclosure to the final negotiation of license agreement, and likely require university TTOs and inventors to identify potential licensees and successfully negotiate licensing agreements. Additionally, successful licensing frequently requires inventors to conduct follow-up research with potential licensees to verify findings, demonstrate techniques or actively contribute to product or process development. These types of post-disclosure and post-patent efforts can contribute to the marketability of university inventions to industry and other entities.

Based on the discussion, we posit that the applicability and marketability of an invention is influenced by key individual-level behavioral and perceptual factors as well as industry-related and university-level institutional factors. The following hypotheses specify the mechanisms by which select individual and institution factors affect the likelihood that a university patent will be licensed soon after it is awarded.

Hypothesis development

University scientists are generally granted substantial freedom to choose research projects. Given that human decisions are considerably driven by the extent to which the behavior fits

personal belief systems (Beach & Mitchell, 1987; Beach, 1990), the applicability of selected research projects is likely to be determined by scientists' perceptions and attitudes towards commercialization of academic research in addition to their disciplinary training. Academic scientists, who are trained in a traditional environment that promotes norms of open science to ensure integrity of science and to diffuse scientific knowledge, may be less likely to select high applicability projects (Merton, 1942). By contrast, scientists trained in the life sciences, where intellectual property goals have been broadly accepted (Powell & Owen-Smith, 1998), may be more likely to select projects with high applicability potential. These contrasting views have been debated in the literature on academic science and in practice where concern has been raised that research commercialization goals would displace basic research goals (Geuna & Nesta, 2006; Kumar, 2010), and the secrecy required in patenting process may impede accumulation of scientific knowledge (Mazzoleni & Nelson, 1998). We thus expect that university scientists who perceive patenting and licensing to be a barrier to improving scientific research may tend to select or develop projects that have lower applicability. Lack of university scientists' interest in research commercialization will reduce the likelihood that a patent would be licensed.

H1: The likelihood that a university invention will be licensed decreases as the attitude of the university inventor towards commercialization becomes more negative.

Scientists need to decide not only what research projects they are interested in doing but also from whom they will seek funding and how they will implement research projects. Scientists who are interested in research commercialization may be inclined to submit funding proposals to firms that may be interested in applying the underlying technologies in the future. This situation can also work the other way around. Because industry is generally more interested in research that practical payoffs can be expected (Lowe & Gonzalez-Brambila, 2007), scientists who

receive industry funding are usually required to conduct research that has higher applicability. Prior studies have shown that the application orientation of research increases in step with the proportion of total research budget funded by industry (Gulbrandsen & Smeby, 2005; Meyer-Krahmer & Schmoch, 1998). Industry can also influence the applicability of the underlying research in ways other than through funding. Interviews with university scientists conducted by Agrawal and Henderson (2002) found that industry partners are helpful in raising research questions that aim to solve real problems. Accordingly, we argue that higher levels of research funding from industry and collaboration with industry researchers will increase the applicability of research and thereby increase the likelihood that a university patent would be licensed.

H2: The likelihood that a university patent will be licensed increases as the proportion of industry funding underlying the patent increases.

H3: The likelihood that a university patent will be licensed increases as the level of collaboration between the university inventor and industry researchers on the underlying research increases.

Successful licensing also depends on active involvement of inventors in post-disclosure activities. As mentioned previously, many university inventions are still at an early stage of development when the patented inventions are licensed (Thursby, et al., 2001). Uncertainty in market potential may prevent industry from licensing university patents. The level of uncertainty may be reduced if university inventors become involved in follow-up activities to help convert the invention into a commercializable product or process (Fabrizio and Di Minin, 2008; Jensen, et al., 2003; Mansfield & Lee, 1996). Inventors are critical actors during the process of technology transfer because they hold knowledge that cannot be codified in patent documents

and they may be best capable of solving particular problems related to the invention when additional research is necessary for commercialization (Agrawal, 2006). Moreover, scientists may be in a better position than university TTOs to identify potential licensees because they are more knowledgeable about industrial counterparts who work in the similar field. Scientists who have industry experience may have already established a personal network with potential licensees. As reported in Ismail et al. (2008), half of the patents licensed to existing companies were marketed through the informal contacts of the inventors and the licensees. Accordingly, we expect that scientists who are more involved in research commercialization may be able to foster licensing activities, especially when TTOs are not knowledgeable about the invention or familiar with the industries that may be interested.

H4: The likelihood that a university patent will be licensed increases if the university inventor engages in follow-up research to inform the patent review process.

Once an invention is disclosed to a university TTO, it is conventionally the TTO's decision whether to submit a patent application or not. A TTO is a special unit within a university to facilitate and manage the process of research commercialization. The importance of university TTOs for research commercialization is manifested in several ways. Prior studies find that experienced and resourceful TTOs are able to establish and maintain good connections with industry, which make it easier to identify potential licensees for university patents and enhance the level of licensing revenues (Carlsson & Fridh, 2002; Friedman & Silberman, 2003; Owen-Smith & Powell, 2001; Siegel, Waldman & Link, 2003; Thursby, Jensen, & Thursby, 2001). In contrast, university TTOs that only help with the paperwork for patent applications but lack ability to make university inventions visible and connect to industries likely lag behind

commercialization opportunities. Accordingly, the quality of services provided by university TTOs tends to be important to the marketability of patented inventions.

Bureaucracy and inflexibility of university management have been viewed as barriers for university-industry technology transfer (Blumenthal, Causino, Campbell, & Louis, 1996; Siegel et al., 2003; Siegel, Waldman, Atwater & Link, 2004). Given that university TTOs serve as a bridge among university, individual scientists and industry (Jensen, Thursby & Thursby, 2003), TTOs that set up unbending procedures and rules for research commercialization may discourage scientists' propensity to disclose inventions and provide little space for individual scientists to conclude an agreement with potential licensees. In-depth interviews with scientists conducted by Audretsch, Aldridge and Oettl (2006) also reveal that individual scientists may refuse to work with TTOs for commercial enterprise if the interaction with the TTOs disappoints them.

Given that university TTOs may have limited budget and manpower, the way they allocate resources is also relevant for successful licensing. Patenting is not only time consuming but also costly.[1] As a result, some universities may be inclined not to submit a patent application unless the underlying inventions have great commercialization potential and potential licensees are identified to cover patenting costs (Thursby & Thursby, 2002). Alternatively, university TTOs may not cover patenting fees until the patent right is granted. This measure tends to discourage university scientists from pursuing patent protection unless their inventions present high commercialization potential. Those practices may decrease the number of patent applications and patent awards, but allow universities to focus on inventions with high technological and commercial significance, thereby increasing the likelihood of university patents being licensed.

[1] According to one estimate, it on average costs about $30,000 to file a U.S patent application, pass through the examination process, and maintain the patent right.

Moreover, the requirement of identifying potential licensees prior to patent applications may drive scientists to consider the applicability of research projects during the early stages of the research process and to establish connection with industry that may be interested in the underlying invention. We thus expect that university TTOs' profit-driven practices will increase the likelihood of university patents to be licensed.

H5: The likelihood that a university patent will be licensed increases as the quality of TTO services increases.

H6: The likelihood that a university patent will be licensed increases as the TTO administrative processes become easier for the scientist to navigate.

H7: The likelihood that a university patent will be licensed increases as the university TTO becomes more profit-driven.

University scientists have varied interest in research commercialization. Some scientists actively seek opportunities to make their research applicable and marketable, whereas others may be more conservative in commercialization of academic research. The former may consider patenting and licensing opportunities when they write a grant proposal or seek external funding, while the later may not think of intellectual property rights until research projects are well underway. For research projects conducted by scientists who recognize commercialization opportunity at the latter stages of the research process, industry involvement may be either absent or probably not systematic or purposive, at least without clear intention of patenting and licensing the research outputs. We thus expect that industry funding and collaboration may have a modest impact on licensing outcome of the technology invented by scientists who recognize commercialization opportunity late. On the other hand, university TTOs are expected to play a

dominate role in the success of licensing university patents particularly when inventors are not experienced or highly motivated in research commercialization (Moutinho, et al., 2007). For scientists who are not initially interested in the pursuit of research commercialization, institutional support and motivation provided by university TTOs become more critical in the facilitation of patenting and licensing activities.

Model and data

We intend to explore the factors driving the licensing of university patents based on the *2010 National Survey on Intellectual Property in Academic Science and Engineering*. The survey was administrated to academic scientists who are listed as inventors on the 2006 university patents. A total of 7,506 inventors were identified in the Patents CLASS CD-ROM. After removing non-university inventors and those without valid contact information, we ended up with 3,032 university inventors. Given that 134 inventors were selected for a pilot study, the final survey was administered to 2,898 university inventors. 1,055 complete responses were received, with the response rate at 36 percent.

An inventor is either an inventor of a single patent, or listed as inventor of multiple patents awarded in 2006. The full names of all patents on which respondents were listed as inventors were electronically entered into the online survey. Respondents were asked to confirm their inventorship and role in the patented inventions. Respondents who were listed as inventors of multiple patents were asked to select the patent for which they were the most involved. Further, a scientist is either the primary inventor, one of the collaborators, or played other less important roles in the identified patent. Among the 835 inventors we have complete data, 510 are primary inventors (395 are primary inventors of single 2006 patents, and 115 are primary inventors of

one of the 2006 patents they were the most involved).[2] Because the data are based on scientists' responses to survey questions, the primary inventors most likely played a major role in project selection and post-disclosure activities, and hence most likely possessed the most comprehensive and updated information about the patents. To maintain consistency and accuracy of the data, we focus only on the patents of which the respondents are the primary inventors. As a result, our analysis is based on a sample of 430 patents awarded in 2006 to the U.S. universities, and the data are based on survey responses from the primary inventors.[3]

The survey asked the 430 primary inventors if the patents had been licensed or not as of 2010, leaving a four-year window between the patent award and the time of survey when the patent could have been licensed. According to their responses four years after receiving the patents, 209 had been licensed whereas 221 had not. In this sample of 430 university patents, the proportion of licensed university patents is about 48.6 percent, very close to 50 percent.[4] On the other hand, slightly more than one half of the 2006 university patents had not been licensed as of 2010. This provides us an opportunity to explore the factors driving the licensing of university patents, and specifically to test the hypotheses we develop in the prior section.

We intend to examine the effects of individual and institutional factors in facilitating licensing of university patents. The licensing outcome (whether a patent has been licensed or not) will be modeled as a function of individual factors—inventors' attitude towards

[2] A total of 999 respondents identified themselves as inventors of single or multiple patents. Among them, 19 did not answer the licensing question, 145 answered "Do not know" to the question. We exclude the 164 observations because the data are not usable for this analysis.

[3] We exclude seven primary inventors who did not work (full or part-time) at academic institutions when the patent was first disclosed. We also exclude 73 primary inventors who moved to other institutions during 2006 and 2010.

[4] The proportion of licensed university patents from our survey is in line with the survey result by Jensen and Thursby (2001) who reported that less than half of disclosed university inventions were licensed and only 31 percent of licenses either exclusively or nonexclusively were used in the field.

commercialization, and follow-up research activities—and institutional factors such as collaboration with industry, proportion of funding from industry, as well as TTO's quality of service, bureaucracy, and profit-driven practices.

It would provide additional insights about licensing of university inventions if we examine how the individual and institutional factors affect different types of inventors. One survey question asked when the inventors first recognized that the research outputs underlying the patent could be patented. The responses to this question allow us to differentiate the "late recognizers" from the "early recognizers". University inventors who recognized the patentability of the research outputs prior to seeking external funding or during the grant application process are labeled as "early recognizers". Those who did not recognize that the patentability of the research outputs until the start of the research project are labeled as "late recognizers". Slightly over 70 percent of the inventors in our sample are late recognizers, which is consistent with prior work indicating that patenting decision is usually made in the middle of research process rather than being initiated during the stage of project selection (Agrawal & Henderson, 2002).

Descriptive analysis

As a preliminary analysis, we examine the relationship between each of the hypothesized factors and the likelihood of university patents being licensed. The first hypothesis is that inventors' negative attitude towards commercialization reduces the likelihood that a university patent will be licensed. The survey asked about an inventor's level of agreement or disagreement with the statement that commercial opportunity distracts academic scientists from doing good research. The respondents were allowed to select one out of four choices: strongly disagree, somewhat disagree, somewhat agree, and strongly agree. We count the number (and percent) of

respondents who selected a particular answer and further decompose the number and percent by licensing outcome. Table 1 presents the tabulation of the results.

(Insert Table 1 about here)

The descriptive results clearly support the hypothesis. Scientists who strongly agree with the statement have a smaller proportion of licensed patents (38 percent) than unlicensed patents (62 percent). On the other hand, scientists who strongly disagree with the statement have a larger proportion of licensed patents (59 percent) than unlicensed patents (41 percent). If we dichotomize the responses (agree vs. disagree), scientists who (strongly or somewhat) agree with the statement have a much smaller percent of their patents being licensed (32 percent licensed vs. 68 percent unlicensed) whereas scientists who (strongly or somewhat) disagree with the statement have a larger percent of their patents being licensed (55 percent licensed vs. 45 percent unlicensed). We further conduct the Pearson chi-square test, and the test statistics is highly significant with p value virtually zero.

The second hypothesis is about funding sources for the underlying research. We posit that a patent from underlying research with a higher proportion of industry funding is more likely to be licensed. The survey collected data on the percent of funding from industry for underlying research project of each patent. To explore the effect of industry funding, we calculate the average percent of funding from industry for licensed and unlicensed patents. As expected, the patents that had been licensed are based on research projects supported by an average of 17.1 percent of funding from industry as compared with 9.8 percent of industry funding for research underlying patents that had not been licensed. The difference of the two mean percentages of

funding from industry is statistically significant at one percent level.[5] This preliminary result suggests that the likelihood that a university patent will be licensed increases as the proportion of industry funding underlying the patent increases.

The third hypothesis is that an inventor's collaboration with industry researchers on the underlying research project makes a university patent more likely to be licensed. One survey question asked whether industry scientists or engineers collaborated on the research underlying the 2006 patent. This is a dichotomous variable with yes/no answer. We count the number (and percent) of respondents who answered yes or no and further decompose the number and percent by licensing outcome. Table 2 provides the tabulation of the results.

(Insert Table 2 about here)

The collaboration with industry scientists and engineers on the underlying research is an important factor with regard to the likelihood of a patent that can be licensed. For research projects that involved industry scientists or engineers, 61 percent of the patents got licensed within four years after award whereas 39 percent of those patents had not been licensed. For research with no industry involvement, the majority of the patents (54 percent) had not been licensed. We further conduct the Pearson chi-square test, and the test statistics is highly significant with p value below three percent. This is clear evidence that collaboration with industry researchers can increase the likelihood of a patent being licensed whereas absence of industry collaborators may decrease the likelihood of patent licensing.

The likelihood of patent licensing may also depend on the level of follow-on involvement of university inventors in the post-disclosure activities. We hypothesize that inventors' follow-up involvement after disclosure will increase the likelihood of university patents to be licensed. One

[5] This is based on one-way ANOVA of the variable for percentage of funding from industry for research underlying a patent. The F value is 8.4, and the p value is 0.004.

common and important type of follow-up activity is to conduct additional research to facilitate patent application and get the invention closer to practical application. The survey asked about inventors' involvement in the conduct of additional research related to patent application. Some summary statistics are provided in Table 3:

(Insert Table 3 about here)

The results generally support our hypothesis that the likelihood that a university patent will be licensed increases if the university inventor engages in follow-up additional research. If inventors' involvement in additional research was substantial, 55 percent of their patents were licensed and the remaining 45 percent were not. If inventors were not involved in additional research, only 33 percent of the patent got licensed whereas 67 percent remained unlicensed. We further group the responses into two categories—no or little involvement vs. moderate or substantial involvement. For the category of moderate to substantial involvement, the percent of the patents that had been licensed is slightly larger than the percent that had not. In case of no or little involvement of inventors in additional research, only 39 percent of the patents got licensed whereas as high as 61 percent of the patents remained unattended. The difference is statistically significant at one percent level.

University TTOs are expected to play an important role in the post-disclosure efforts to commercialize university inventions. We hypothesize that the service quality, management style and profit-driven practices of TTOs may affect the licensing outcome of university patents because the TTO factors may affect inventors' inclination to be involved in the post-disclosure activities. The survey asked inventors' level of agreement or disagreement with each of the following statements:

- The TTO at my university provides high quality services to faculty.

- The TTO at my university is a highly bureaucratic organization.
- The TTO at my university is not inclined to file a patent application with USPTO unless a licensee has been identified.
- The TTO at my university covers all patenting fees.

Table 4 presents data to test the fifth hypothesis: Perceived high quality services of TTOs increases the likelihood that a university patent will be licensed. If inventors strongly agree that the TTOs provide high quality service, 56 and 44 percent of their patents were licensed and unlicensed, respectively. If inventors strongly disagree with the statement, 48 and 52 percent of their patents were licensed and unlicensed, respectively. The result provides some modest support to this hypothesis. However, the evidence is not strong enough to be statistically significant.

(Insert Table 4 about here)

Table 5 presents data to test the sixth hypothesis: Perceived less bureaucratic administrative processes of TTOs increase the likelihood that a university patent will be licensed. The data lend modest support to this hypothesis. For inventors who strongly disagree with the statement that TTOs in their universities are bureaucratic, 56 percent of their patents were licensed whereas 44 percent were not. However, for inventors who strongly agree that TTOs in their universities are highly bureaucratic organizations, no difference was observed with regard to the proportions of their licensed or unlicensed patents. Again, the evidence is not strong enough to be statistically significant.

(Insert Table 5 about here)

Table 6 presents data to test the seventh hypothesis about TTOs' profit-driven practices. We only focus on the perceived TTO's coverage of patenting fees, and hypothesize that TTO's

unwillingness to cover all patenting fees increases the likelihood of university patents to be licensed. The data strongly support this hypothesis suggesting that a more profit driven TTO led to a larger chance for a licensed patent. For instance, if inventors strongly disagree with the statement that TTO covers all patenting fees, 66 percent of their patents were licensed with the remaining 34 percent unlicensed. For inventors who strongly agree with this statement, 40 percent of the patents got licensed whereas 60 percent were unlicensed. If we dichotomize the responses into groups who disagree or agree with the statement, the pattern remains and becomes more significant.[6]

(Insert Table 6 about here)

Regression analysis

We also test the hypotheses using a logistic regression model that relates the dichotomous licensing outcome variable to a number of explanatory factors. A list of variables and definitions is provided in Table 7. We run regressions based on several different specifications of the model to check the sensitivity of the results. The first regression includes only two individual factors and two industry-related institutional factors—inventors' attitude towards commercialization, their involvement in post-disclosure follow-up research, industry funding, and industry collaboration. We then add the TTO factors as well as three dummy variables as controls—gender of inventor (male=1), discipline of research (biological and medical sciences=1), and position of inventor (full professor=1). In particular, we use either of the two TTO's profit-driven practices—perceived requirement of licensee before patent application, and perceived TTO's

[6] For inventors who disagree with the statement, 62 and 38 percent of their patents got licensed and unlicensed, respectively. For inventors who agree with the statement, 43 and 57 percent of their patents got licensed and unlicensed, respectively. The test statistics is significant at 1 percent level.

coverage of patenting fees, or a combination of both measures as a single variable, with or without the three control variables. The number of observations varies depending on the missing data of some variables used in different regressions. The logistic regression results are presented in Tables 8-9.

(Insert Table 7 about here)

(Insert Table 8 about here)

(Insert Table 9 about here)

The Wald chi-square values are highly significant in all the regressions indicating that our model as a whole fits the data significantly better than an empty model. The statistical results suggest that primary inventors play an important role in licensing their patents, and industry collaboration and TTO's profit-driven practices matter for licensing outcomes of university patents as expected. Scientists' attitude towards commercialization of academic research is the most consistent factor in this study. The estimated coefficients are highly significant in all specifications of the model. The negative estimates indicate that the greater the degree that university scientists perceive research commercialization to distract them from doing good research, the less likely the patented invention will be licensed. This finding makes sense as the perceived compatibility between research commercialization and the conduct of science determines not only the type of projects that university scientists select at the start, but also their willingness to participate in commercialization efforts throughout the entire patenting and licensing process. If scientists perceive that research commercialization is complementary to scientific research, they will be more likely to engage in applicable research and to help identify potential licensees for patented inventions.

The variable of additional research conducted by university scientists for patent review is significant at the 10 percent level.[7] The estimates are consistent with our hypothesis that scientists' follow-up involvement after disclosure increases the likelihood that a university patent will be licensed. Given that many university inventions are still at embryonic stage of development when they are disclosed or patented (Thursby, et al., 2001), it requires substantial additional research by university inventors to clear the way towards industry application. Therefore, it is certain that inventors' willingness to engage in post-disclosure activities during the process of patent review will enhance applicability of university inventions and make them more marketable to industries.

The involvement of industry scientists or engineers in research is also important in licensing a patent successfully. The variable of industry collaboration on underlying research is statistically significant and the estimates are all positive.[8] It supports our hypothesis that collaboration with industry researchers on the underlying research project makes a university patent more likely to be licensed. Collaboration by industry researchers is a clear sign of industry interest in the research topic and potential outputs; collaboration is also likely to enhance the applicability of invention. In contrast, the percent of funding from industry is insignificant in the regressions. It suggests that the involvement of industry scientists or engineers is more important than industry funding with regard to licensability of university patents. Provision of research funding by industry is an early sign of industry interest in the research, whereas the actual participation of industry researchers further confirms the applicability of the underlying research, and will make the research output more ready for industry application.

[7] Five of the seven estimates are statistically significant at 10 percent level. The other two estimates are nearly significant at 10 percent level, with p values between 0.11 and 0.12.

[8] Four of the seven estimates are statistically significant at 10 percent level. The other three estimates are nearly significant at 10 percent level, with p values between 0.10 and 0.14.

Among the university-level factors, only the two measures of TTO's profit-driven orientation are statistically significant in the expected way. The estimates of either of the two measures or the combined variable of the two measures are positive and highly significant. The TTO's profit-driven measures primarily serve as screening devices to filter out inventions with low commercial significance. They may reduce the number of university patent applications. However, they help to invest TTOs' limited professional and financial resources on inventions that are likely to be licensed and generate revenues for universities. As a result, the inventions that are eventually patented have a higher likelihood to be licensed.

We also examine how the individual and institutional factors affect the "late recognizers" differently as compared with the results from the full sample. As such, we run logistic regression analysis on a sample of 259 "late recognizers", and the results are presented in Tables 10-11. As we expected, industry collaboration on the underlying research becomes insignificant while scientists' attitudes toward research commercialization and their involvement in additional follow-up research for patent review are consistently significant. The results indicate that late recognizers' projects do not attract sufficient and systematic industry interest at the early stage of research planning and implementation. They also show that for late recognizers post-disclosure activities, such as the conduct of additional research, become more important explanators of the likelihood of licensing.

(Insert Table 10 about here)

(Insert Table 11 about here)

However, the perceived requirement of *a priori* licensee identification is not statistically significant in the regressions on "late recognizers". This may be because TTOs' requirement of identifying potential licensees before filling patent applications tends to determine licensing

outcomes by driving scientists to think through applicability and marketability when selecting research projects. Once the project is chosen, there is not much latitude to change the nature of the research and the chance to identify potential licensees. On the other hand, lack of TTOs' coverage of patenting fees tends to increase the likelihood of university patents to be licensed for the group of late recognizers, as anticipated. When university inventors are responsible for financing patent application fees, they may be less inclined to file a patent application if they are unsure about the commercialization potential of the underlying invention. This institutional arrangement will enable university TTOs to concentrate on marketing a few inventions with high commercialization potential, thereby increasing the likelihood of successful licensing while also reducing TTO administrative costs.

In terms of control variables, the statistical results show that only the position of inventor is marginally significant in some of the regressions.[9] The other two variables—the gender of inventor and the discipline of research show no significant effects on the licensing outcome of university patents.

Discussion and conclusion

The commercialization of university inventions has been institutionalized for the past three decades. Expectations of university contributions to innovation are particularly high during the current economic situation. In response, universities may become increasingly aggressive about gaining revenues from sources such as licensing royalties to replace lost state funding and attracting industry dollars for academic research. Additionally, today's tough economic climate

[9] The three estimates of the position of inventor are nearly significant at 10 percent level for the full sample, with p values between 0.11 and 0.14. In the regressions on the sample of "late recognizers", one of the three estimates is significant at 10 percent level. The other two estimates are nearly significant at 10 percent level, with p values between 0.11 and 0.13.

increases pressure on research universities to play a more important role in regional economic development through the transfer of academic research outputs to industry. The two forces are driving commercialization of university inventions into the spotlight of policy dialogue on higher education and economic development.

This study is motivated by the fact that a significant portion of patented university research is not licensed, making it important to explore what factors may play a role in licensing university patents. We find that licensing outcomes are primarily determined by individual factors including inventors' attitude towards commercialization of academic research, and additional research conducted for patent review. The findings imply that academic scientists who are positive about commercialization of university research may be more successful licensers of university patents as they may select and conduct research with greater application potential or they may be more engaged in post-disclosure activities.

Institutional factors are also relevant to some degrees. The involvement of industry researchers in underlying research makes university inventions more likely to be licensed. The two TTOs' profit-driven screening measures also show significant impact on the probability of a patent being licensed. The findings inform us that a university may be able to enhance licensing performance by establishing a mechanism that better connects university research with industry application and enables the focus of scarce resources on a few inventions with high commercialization potential. Furthermore, our analysis shows that for scientists who recognize commercialization opportunity during the latter stage of research process, neither the TTO requirement to identify potential licensees before patent application nor the existence of industry collaboration on underlying research affect the chance of patent licensing. Instead, licensing of university patents is mainly driven by scientists' attitudes towards and willingness to engage in

commercialization activities. For late recognizers, university TTOs may also be able to increase the likelihood of successful licensing by asking inventors to pay for their patenting costs which will then pressure scientists to rule out inventions with low commercialization potential prior to patent application.

It is important for patented inventions to be licensed as soon as possible because industry and TTOs' attention to the underlying inventions may decrease as time passes. Our study provides some management implications regarding how to facilitate successful licensing soon after university patents are awarded. Since individual attitudes towards and involvement in research commercialization play a critical role in successful licensing, it is recommended that universities cultivate patenting norms and legitimize the pursuit of research commercialization through education or official university policy. While universities could generally encourage scientists to disclose their inventions, which may contribute to the production of patents, commercialization potential of patents is likely more important than the quantity of patents produced. It is probably more cost-efficient for universities not to file a patent application unless there is clear indication of interest from a potential licensee. Administratively TTO staff would be able to concentrate limited resources and manpower on a narrower range of patents with greater potential for commercial use. The requirement that the identification of potential licensees should precede a patent application may be a particularly important intervention at the stage of project selection as it may result in a reduction in the proportion of unlicensed patents. Moreover, it may be counterproductive for universities to provide or share financial support for patenting costs. Greater self-funding may increase the gatekeeper role of university inventors encouraging them to only pursue intellectual property rights for inventions with high commercialization potential and thereby increasing the likelihood that any particular university patent would be licensed. For

most inventions, where patentability is recognized at the latter stage of research process, the university could design a set of policies that can motivate scientists to engage in bringing inventions closer to application and marketing their inventions through personal networks with industry.

U.S. universities play a unique role in the nation's overall R&D system. As the primary producer of new knowledge, university scientists and engineers perform more than half of U.S. basic research. We in no way advocate expansion of applied research and development aimed at commercialization and economic benefits at the expense of shrinking basic scientific research. We do not argue for more applied research and development, or more patent applications and awards. Instead, we have identified opportunities and means by which universities could commercialize more of their patented inventions, which may fulfill their expected economic development role.

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Table 1:

Commercial opportunity distracts academic scientists from doing good research	*Has the patent been licensed?*		Total
	Yes	No	
Strongly disagree	106 (59.22)	73 (40.78)	179 (100)
Somewhat disagree	63 (49.61)	64 (50.39)	127 (100)
Somewhat agree	33 (31.43)	72 (68.57)	105 (100)
Strongly agree	5 (38.46)	8 (61.54)	13 (100)

Table 2:

Industry scientists or engineers collaborated on research	*Has the patent been licensed?*		Total
	Yes	No	
Yes	39 (60.94)	25 (39.06)	64 (100)
No	167 (46.01)	196 (53.99)	363 (100)

Table 3:

Involvement of inventors in additional research related to patent application	*Has the patent been licensed?*		Total
	Yes	No	
No involvement	7 (33.33)	14 (66.67)	21 (100)
Little involvement	20 (40.82)	29 (59.18)	49 (100)
Moderate involvement	46 (40.35)	68 (59.65)	114 (100)
Substantial involvement	133 (54.96)	109 (45.04)	242 (100)

Table 4:

University TTO provides high quality service to faculty	*Has the patent been licensed?*		Total
	Yes	No	
Strongly disagree	25 (48.08)	27 (51.92)	52 (100)
Somewhat disagree	38 (46.91)	43 (53.09)	81 (100)
Somewhat agree	76 (45.51)	91 (54.49)	167 (100)
Strongly agree	47 (55.95)	37 (44.05)	84 (100)

Table 5:

University TTO is a highly bureaucratic organization	*Has the patent been licensed?*		Total
	Yes	No	
Strongly disagree	25 (55.56)	20 (44.44)	45 (100)
Somewhat disagree	66 (47.14)	74 (52.86)	140 (100)
Somewhat agree	62 (48.44)	66 (51.56)	128 (100)
Strongly agree	33 (50.00)	33 (50.00)	66 (100)

Table 6:

TTO covers all patenting fees	*Has the patent been licensed?*		Total
	Yes	No	
Strongly disagree	33 (66.00)	17 (34.00)	50 (100)
Somewhat disagree	28 (58.33)	20 (41.67)	48 (100)
Somewhat agree	47 (50.00)	47 (50.00)	94 (100)
Strongly agree	74 (39.57)	113 (60.43)	187 (100)

Table 7: Variables and definitions

Variable	Data Source
Attitude of inventor towards commercialization of research	Responses from survey question: *Your level of agreement or disagreement with each statement—Commercial opportunity distracts academic scientists from doing good research.*
Percent of funding from industry	Responses from survey question: *What percent of funding for research underlying the patent came from industry?*
Industry collaboration on underlying research	Responses from survey question: *Which statement best reflect your relationship with industry on research underlying the patent—Industry scientists or engineers collaborated on the research underlying this patent?*
Additional follow-up research of inventor for patent review	Responses from survey question: *How much involvement did you have with each follow-on activity related to patent application review—Additional research?*
Perceived quality of TTO service to faculty	Responses from survey question: *Your level of agreement or disagreement with each statement—The TTO at my university provides high quality service to faculty.*
Perceived bureaucracy of TTO	Responses from survey question: *Your level of agreement or disagreement with each statement—The TTO at my university is a highly bureaucratic organization.*
Perceived requirement of licensee before patent application	Responses from survey question: *Your level of agreement or disagreement with each statement—Typically, the TTO at my university is not inclined to file a patent application with USPTO unless a licensee has been identified.*
Perceived TTO's coverage of patenting fees	Responses from survey question: *Your level of agreement or disagreement with each statement—The TTO at my university covers all patenting fees.*
Perceived profit orientation of TTO	Combined measure of responses from perceived requirement of licensee before patent application and perceived TTO's coverage of patenting fees.
Gender of inventor	Responses from survey question: *What is your sex?*
Discipline of research	Responses from survey question: *What is your primary academic discipline?*
Position of inventor	Responses from survey question: *What is your current position?*

Table 8: Logistic regression results – Coefficient estimates

Variable	Logistic (1)	Logistic (2)	Logistic (3)	Logistic (4)	Logistic (5)	Logistic (6)	Logistic (7)
Attitude of inventor towards commercialization of research	-0.4737*** (0.1239)	-0.5092*** (0.1334)	-0.5190*** (0.1356)	-0.5451*** (0.1346)	-0.5550*** (0.1372)	-0.5416*** (0.1363)	-0.5507*** (0.139)
Percent of funding from industry	0.0064 (0.0041)	0.0038 (0.0045)	0.0045 (0.0045)	0.0044 (0.0044)	0.0051 (0.0044)	0.0031 (0.0045)	0.0038 (0.0045)
Industry collaboration on underlying research	0.4943* (0.2963)	0.6046* (0.3189)	0.5571* (0.3184)	0.5115 (0.3132)	0.4595 (0.3148)	0.5523* (0.3216)	0.5039 (0.3227)
Additional follow-up research of inventor for patent review	0.3108** (0.124)	0.2129 (0.1346)	0.2168 (0.1377)	0.2380* (0.1355)	0.2481* (0.1386)	0.2470* (0.136)	0.2523* (0.1394)
Perceived quality of TTO service to faculty		0.1342 (0.1345)	0.1318 (0.1375)	0.1387 (0.1356)	0.133 (0.1388)	0.1669 (0.1374)	0.1586 (0.141)
Perceived bureaucracy of TTO		0.0075 (0.1349)	0.0097 (0.1393)	-0.0006 (0.1395)	0.0055 (0.1435)	-0.0361 (0.1382)	-0.0368 (0.1434)
Perceived requirement of licensee before patent application		0.2384** (0.1176)	0.2287* (0.119)				
Perceived TTO's coverage of patenting fees				0.4235*** (0.1157)	0.4188*** (0.116)		
Perceived profit orientation of TTO						0.2538*** (0.0728)	0.2474*** (0.0732)
Gender of inventor			-0.068 (0.3926)		0.0954 (0.3884)		0.0833 (0.3967)
Discipline of research			0.328 (0.2304)		0.2698 (0.2349)		0.3251 (0.2351)
Position of inventor			0.4271 (0.2907)		0.4723 (0.2951)		0.4389 (0.292)
Constant	-0.357 (0.4772)	-0.8956 (0.85)	-1.2816 (0.9274)	-1.1411 (0.8293)	-1.7226* (0.9462)	-1.4399* (0.8638)	-1.9487** (0.9572)
N	407	359	359	357	357	355	355

Note: The dichotomous dependent variable is the *whether a patent had been licensed*. The model is logistic regression on full sample. The coefficient estimates are presented in the table. Robust standard errors are in parentheses. *** denotes significance level <1%, ** for 5%, and * for 10%.

Table 9: Logistic regression results – Odds ratios

Variable	Logistic (1)	Logistic (2)	Logistic (3)	Logistic (4)	Logistic (5)	Logistic (6)	Logistic (7)
Attitude of inventor towards commercialization of research	0.6227*** (0.0772)	0.6010*** (0.0802)	0.5951*** (0.0807)	0.5798*** (0.0780)	0.5741*** (0.0788)	0.5818*** (0.0793)	0.5765*** (0.0801)
Percent of funding from industry	1.0064 (0.0042)	1.0038 (0.0045)	1.0045 (0.0045)	1.0044 (0.0044)	1.0051 (0.0045)	1.0031 (0.0045)	1.0039 (0.0045)
Industry collaboration on underlying research	1.6393* (0.4858)	1.8305* (0.5838)	1.7457* (0.5559)	1.6678 (0.5224)	1.5832 (0.4985)	1.7372* (0.5587)	1.6552 (0.5341)
Additional follow-up research of inventor for patent review	1.3646** (0.1693)	1.2372 (0.1666)	1.2421 (0.1711)	1.2687* (0.1719)	1.2816* (0.1777)	1.2802* (0.1741)	1.2870* (0.1794)
Perceived quality of TTO service to faculty		1.1437 (0.1538)	1.1409 (0.1569)	1.1488 (0.1558)	1.1422 (0.1585)	1.1816 (0.1624)	1.1719 (0.1653)
Perceived bureaucracy of TTO		1.0076 (0.1360)	1.0097 (0.1406)	0.9994 (0.1394)	1.0055 (0.1443)	0.9645 (0.1333)	0.9639 (0.1382)
Perceived requirement of licensee before patent application		1.2693** (0.1493)	1.2570* (0.1496)				
Perceived TTO's coverage of patenting fees				1.5274*** (0.1767)	1.5201*** (0.1764)		
Perceived profit orientation of TTO						1.2889*** (0.0938)	1.2807*** (0.0937)
Gender of inventor			0.9343 (0.3668)		1.1001 (0.4272)		1.0868 (0.4312)
Discipline of research			1.3882 (0.3198)		1.3097 (0.3077)		1.3842 (0.3254)
Position of inventor			1.5328 (0.4456)		1.6038 (0.4733)		1.5510 (0.4529)
N	407	359	359	357	357	355	355

Note: The dichotomous dependent variable is the *whether a patent had been licensed*. The model is logistic regression on full sample. The odds ratios are presented in the table. Robust standard errors are in parentheses. *** denotes significance level <1%, ** for 5%, and * for 10%.

Table 10: Logistic regression results – Coefficient estimates (2)

Variable	Logistic (1)	Logistic (2)	Logistic (3)	Logistic (4)	Logistic (5)	Logistic (6)	Logistic (7)
Attitude of inventor towards commercialization of research	-0.4003*** (0.1439)	-0.4486*** (0.1525)	-0.4499*** (0.154)	-0.4773*** (0.1573)	-0.4748*** (0.1591)	-0.4717*** (0.1561)	-0.4718*** (0.1581)
Percent of funding from industry	0.0081 (0.0052)	0.0056 (0.0054)	0.0067 (0.0057)	0.0069 (0.0055)	0.008 (0.0058)	0.0065 (0.0056)	0.0077 (0.0058)
Industry collaboration on underlying research	-0.0382 (0.415)	0.0109 (0.4274)	-0.0268 (0.4259)	-0.1034 (0.4447)	-0.1438 (0.4481)	-0.1437 (0.4488)	-0.1865 (0.4495)
Additional follow-up research of inventor for patent review	0.4313*** (0.1455)	0.2958* (0.1572)	0.3017* (0.1576)	0.3104** (0.1582)	0.3256** (0.1583)	0.3003* (0.1576)	0.3113** (0.1575)
Perceived quality of TTO service to faculty		0.0679 (0.161)	0.0785 (0.1653)	0.0567 (0.1624)	0.0655 (0.1676)	0.0659 (0.1628)	0.0686 (0.1677)
Perceived bureaucracy of TTO		-0.0907 (0.16)	-0.0773 (0.1665)	-0.1428 (0.1656)	-0.1271 (0.1721)	-0.149 (0.1645)	-0.1408 (0.1723)
Perceived requirement of licensee before patent application		0.163 (0.1348)	0.1491 (0.1376)				
Perceived TTO's coverage of patenting fees				0.3553*** (0.1293)	0.3514*** (0.1301)		
Perceived profit orientation of TTO						0.1985** (0.0807)	0.1912** (0.0822)
Gender of inventor			0.0348 (0.4245)		0.2161 (0.4268)		0.2135 (0.4309)
Discipline of research			0.2896 (0.2684)		0.2453 (0.2749)		0.2822 (0.273)
Position of inventor			0.5021 (0.3335)		0.5721* (0.3418)		0.5447 (0.3374)
Constant	-0.9314 (0.5731)	-0.7024 (1.0271)	-1.3183 (1.0953)	-0.8156 (0.9837)	-1.696 (1.1154)	-0.9818 (1.023)	-1.7742 (1.1161)
N	292	259	259	257	257	256	256

Note: The dichotomous dependent variable is the *whether a patent had been licensed*. The model is logistic regression on a sample of "late recognizers". The coefficient estimates are presented in the table. Robust standard errors are in parentheses. *** denotes significance level <1%, ** for 5%, and * for 10%.

Table 11: Logistic regression results – Odds ratios (2)

Variable	Logistic (1)	Logistic (2)	Logistic (3)	Logistic (4)	Logistic (5)	Logistic (6)	Logistic (7)
Attitude of inventor towards commercialization of research	0.6701*** (0.0965)	0.6385*** (0.0974)	0.6377*** (0.0982)	0.6205*** (0.0976)	0.6220*** (0.0990)	0.6239*** (0.0974)	0.6239*** (0.0987)
Percent of funding from industry	1.0082 (0.0053)	1.0057 (0.0055)	1.0067 (0.0057)	1.0069 (0.0056)	1.0080 (0.0058)	1.0066 (0.0056)	1.0077 (0.0059)
Industry collaboration on underlying research	0.9625 (0.3995)	1.0110 (0.4321)	0.9736 (0.4146)	0.9018 (0.4010)	0.8661 (0.3881)	0.8662 (0.3887)	0.8298 (0.3730)
Additional follow-up research of inventor for patent review	1.5393*** (0.2239)	1.3442* (0.2113)	1.3522* (0.2131)	1.3640** (0.2158)	1.3849** (0.2192)	1.3503* (0.2128)	1.3652** (0.2150)
Perceived quality of TTO service to faculty		1.0702 (0.1723)	1.0817 (0.1788)	1.0583 (0.1719)	1.0677 (0.1790)	1.0682 (0.1739)	1.0710 (0.1796)
Perceived bureaucracy of TTO		0.9133 (0.1461)	0.9256 (0.1542)	0.8669 (0.1436)	0.8807 (0.1516)	0.8616 (0.1417)	0.8687 (0.1497)
Perceived requirement of licensee before patent application		1.1771 (0.1586)	1.1608 (0.1597)				
Perceived TTO's coverage of patenting fees				1.4266*** (0.1844)	1.4211*** (0.1849)		
Perceived profit orientation of TTO						1.2196** (0.0985)	1.2107** (0.0995)
Gender of inventor			1.0354 (0.4395)		1.2412 (0.5298)		1.2380 (0.5335)
Discipline of research			1.3359 (0.3585)		1.2780 (0.3513)		1.3261 (0.3620)
Position of inventor			1.6523 (0.5511)		1.7720* (0.6056)		1.7242 (0.5817)
N	292	259	259	257	257	256	256

Note: The dichotomous dependent variable is the *whether a patent had been licensed*. The model is logistic regression on a sample of "late recognizers". The odds ratios are presented in the table. Robust standard errors are in parentheses. *** denotes significance level <1%, ** for 5%, and * for 10%.