Federal Lab Patents, Licensing, and the Value of Patents: Exploring the Licensed Patents from NASA

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Taehyun Jung

Georgia State University
Andrew Young School of Policy Studies
14 Marietta Street, NW
Atlanta, GA 30303-2813

Georgia Institute of Technology
School of Public Policy
685 Cherry Street
Atlanta, GA 30332 - 0345

Email: taehyun.jung@gatech.edu
Fax: 404.385.0504

Abstract

One way for federal laboratories to contribute to industrial innovation is through licensing their inventions to firms. The licensing decisions of the federal labs have unique characteristics. They evaluate both the concreteness of the commercialization plan submitted by prospective licensee and the estimated degree of contribution to the US economy when the commercialization plan has been successfully fulfilled. Because of this screening process, licensed inventions in the federal labs can be regarded as having higher commercial value than non-licensed ones. This paper aims, first of all, to explore the NASA patents and attempts to identify distinctive characteristics of licensed patents and, secondly, to test hypotheses about the relationship between the value of patents and several different patent-based indicators.

We found that NASA was actively engaging in the private sector through licensing its patents. About 25% of patents filed by and assigned to NASA between 1994 and 2002 were licensed to firms. In terms of technology, chemical, drug, and medical related patents are more likely to be licensed than electronics patents which is the most popular field of NASA patents. This observation tells us that licensing decision depends on the technology and demands from the firms. Also, this observation is consistent with the results from the previous studies that firms in biomedical areas are more intertwined with the public/basic research than in other technology areas.

Regarding the commercial value of patents and the patent indicators, we found that the more technologically important (as measured by the number of subsequent patents citing the NASA patents or so called “forward citation counts”) and the broader in technology areas (as measured by the number of claims), the higher commercial value a patent is likely to have. We found some evidences that the non-obviousness (as measured by the number of US patents cited by a NASA patent or so called “backward citation counts”) and the commercial value of a patent are in a relationship looking like inverted-U shape. We also found a positive association between the number of inventors and the commercial value of a patent. We also suggest other noble indicators that can be regarded as a measure of the novelty of patents.

This paper contributes to studying innovation and technology transfer through systematically examining patents and licensing of a federal laboratory which is conducting

cutting-edge research in space-exploration. Furthermore, this paper contributes to science and technology policy literature through shedding new lights on the value of patents and patent-based indicators of innovation.

1 Introduction

The federal laboratories take unique positions in the US national innovation system. Although the amount of R&D expenditure and the number of researchers affiliated with the federal labs in total is relatively small compared to private sector or universities in total, they provide unique and complementary ingredients to the US national innovation system. One of the most distinguishable characteristics is the uniqueness of their research originated from mission-orientedness. The other characteristic is their capability to mobilize resources to fulfill their research.

More than 700 federal labs are spending about 12% of R&D money in 2002 (Crow & Bozeman, 1998; NSF, 2006). Since the 1980s, not only have they conducted their mission-oriented research but they have turned attention to the industrial innovation and technology transfer. This change had been initiated by and accompanied with policy changes (e.g. Stevenson-Wydler Act and Bayh-Dole Act), strengthened monitoring of federal budgets, and reduced role of defense R&D. The federal labs entered into a new era dominated by “cooperative research paradigm”(Crow & Bozeman, 1998). Several studies had looked into various aspects of federal labs including R&D efficiency, their impacts, and the effectiveness of technology transfer programs (See, for example, Bozeman, Crow, & Tucker, 1999; Jaffe, Fogarty, & Banks, 1998; Jaffe & Lerner, 2001; Rogers & Bozeman, 1997; Rubenstein, 2003; Rubenstein & Heisey, 2005; Saavedra & Bozeman, 2004). Also, their performance had been monitored by the Congress and the General Accounting Office. However, we know only a bit about them. The scarcity of the existing studies becomes more obvious when we compare the volume of literature focusing on the federal labs with those about industrial R&D or academic R&D. This paper attempts to fill in this blank of the extant literature.

Specifically, I look into the patents owned by NASA and its licensing decisions. By doing this we attempt to identify some distinctive characteristics of the licensed patents in terms of quality, generality of technology, and the degree of spillovers of a patent. In this version of the paper, we will only focus on the relationship between the commercially valuable patents (which are identified by whether or not they are licensed) and patent-based indicators indirectly measuring the importance, breadth, novelty, and network effects of the patent.

This paper briefly scans the legislature and the efforts of NASA with respect to technology transfer and reviews relevant previous studies. Then we proceed with the hypotheses relating the value of patents to several different patent-based indicators. After describing empirical models and data, we present the characteristics of NASA patents and licensing and report the test result of the suggested hypotheses. Finally, we conclude.

2 Brief Overview of Legislative Efforts Regarding Federal Technology Transfer

In the US, there are more than 700 federal laboratories employing more than 130,000 researchers and staff, and commanding more than $ 31 billion in 2002.[1] As Crow and Bozeman (1998) stated, federal labs represent "the single largest deployment of organized research units" (p.159). Apart from the size, federal labs play a distinguished role in the US national innovation system compared to other R&D performers. First of all, in many cases they conduct such unique R&D missions that other labs cannot perform or imitate. Second, they are more susceptible to direct and indirect policy measures than academic or industry R&D labs. Finally, they are subject to strict public accountability and established, in principle, to serve to the societal needs. These unique characteristics of federal labs bolster the advocacy of the necessity of such policies that can facilitate federal-industry technology transfer.

Major policy initiatives were taken in the early 1980s. The Bayh-Dole Act of 1980 allowed universities, nonprofits, and small business to claim the patent rights resulting from the federally-funded research. The subsequent act backed up the spirit in the Bayh-Dole act. Trademark Clarification Act of 1984 relaxed regulation further. First, government-owned contractor-operated (or GOCO) federal labs became to award licenses of patents on their wills and to collect royalties from them. Second, even large firms can obtain exclusive licenses. Third, universities and nonprofits that operated federal labs were allowed to own the patents invented in the labs. Another important policy initiative is Stevenson-Wydler Technology Innovation Act of 1980. By this law and following laws like Federal

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[1] This amount includes fund performed by federally-funded research and development centers. Number is from National Science Foundation

Technology Transfer Act of 1986, Omnibus Trade and Competitiveness Act of 1988, and National Competitiveness Technology Transfer Act of 1989, technology transfer activity and public-private partnerships were mandated for all federal labs. Among others, two common features are worth being highlighted. First, a policy focus is placed mostly in the early stage of technology commercialization. In doing so, second, institutions enabling transfer of the intellectual property rights to R&D performers is considered to be important. The technology transfer legislations in the 80s are evaluated to have positive impacts on the outcome and process of federal technology transfer. Comparing several cases of federal technology transfer in the 80s with those in 90s, Sally Rood concluded that researchers produced more prototypes and samples, university involvement was institutionalized, laboratory produced more patents, researchers became more aware of licensing royalties, and small firms involved more in the process, to list some (Rood, 2000, pp. 235-261).

Despite the legislative attention to promoting federal-industry technology transfer, only little has been known so far about this phenomenon. After describing the technology transfer efforts of NASA below, we will give a review of key studies on this issue.

2.1 National Aeronautics and Space Administration

NASA seems an adequate federal lab for the purpose of our study considering its size, technology transfer activity, and importance of its research from both technological and commercial view points.

NASA started its technology transfer activity very early. The founding legislature of NASA itself, the National Aeronautics and Space Act of 1958 (“the Space Act” hereafter), endowed the NASA administrator the decision authority for entering into commercial relationships with virtually any parties including individuals and firms. NASA commands a significant portion of federal R&D budget (more than 10%) and is devoting its research capacity to the development of cutting-edge technology for space mission, information and communication technology, and space-related bio-technology. Out of $17.6 billion of FY 2006 budget, more than $7 billion (41%) were used for scientific and aeronautic research. NASA centers and their missions are summarized in Table 1.

Table 1 NASA Centers

Centers (Abbreviation)	Year Est.	State	Mission	Employee*	’05 Budget (in million)
Headquarters (HDQS)	1958	DC	-	-	16,070
Ames Research Center (ARC)	1939	CA	Research of new technologies	4000	775
Dryden Flight Research Center (DFRC)	1946	CA	Flight research	1200	211 (‘02)
Glenn Research Center (GRC)	1941	OH	Aeropropulsion and communications technologies	3645	795 (’04)
Goddard Space Flight Center (GSFC)	1959	MD	Earth, the solar system, and Universe observations	10005	2,875 (’03)
Jet Propulsion Laboratory (JPL)	1930s	CA	Robotic exploration of the Solar System (operated by CALTECH)	5424	1,600
Johnson Space Center (JSC)	1961	TX	Human space exploration	17500	4,112 (’01)
Kennedy Space Center (KSC)	1962	FL	Prepare and launch missions around the Earth and beyond	12968	1,246
Langley Research Center (LaRC)	1917	VA	Aviation and space research	3300	728
Marshall Space Flight Center (MSFC)	1960	AL	Space transportation and propulsion technologies	8600	2,600
Stennis Space Center (SSC)	1961	MS	Rocket propulsion testing and remote sensing technology	4588	249

*Including contractors

(Compiled by the authors from various sources)

3 Previous Studies about Federal Lab-Industry Technology Transfer

The volume of literature about the federal technology transfer is very small compared to the literature about the technology transfer from university. Also, most of studies are based on case studies and interviews. Only a few studies are based on the large sample survey and quantifiable metrics. We categorize the extant studies into the following six groups according to their major focuses:1) impact of policy on the technology transfer and commercialization activity of the federal labs; 2) the needs of federal labs as external sources of knowledge for firms; 3) the effects of TT/commercialization efforts of federal labs both on the firm and on the federal labs; 4) comparisons of effectiveness among channels; 5) success and failure factors of TT/commercialization efforts; and finally 6) characterization of and lessons from a specific program such as spin-off, CRADA, SBIR, or licensing.

According to the previous studies, the policy change during the last two decades or so toward promoting technology transfer has positively impacts on the overall technology transfer and commercialization activities of the federal labs. The overall commercialization activities as measured by the number of patents issued to federal labs (Jaffe et al., 1998; Jaffe & Lerner, 2001) and the number of CRADA's (Jaffe & Lerner, 2001) have increased since the introduction of new activist technology policy. During the same period of time, the quality of patents as measured by citations received remain stable or increased (Jaffe & Lerner, 2001; Jaffe & Trajtenberg, 1996). However, the commercialization performance as measure by patent-related indices are observed a little bit retarded compared to university (Rubenstein & Heisey, 2005). Archibald and Finifter (2003) found that policy emphasis had brought higher commercial success to the firms in relationship with NASA through SBIR contracts.

The importance of federal labs as external knowledge source has increased (Roessner & Bean, 1990; J. D. Roessner & A. S. Bean, 1994). The sort of knowledge firms seek from the federal labs seem related to the current problem-solving. In a survey to R&D managers in the firms collaborating with the federal labs, Bozeman & Papadakis (1995) found that firms interacted with the federal labs to jointly conduct pre-commercial applied research and development rather than basic research. Also, firms often seek the federal labs not just for technology but for skills and expertise contained in the lab scientists and engineers (Bozeman & Papadakis, 1995; Xue & Naser, 1996). For the European firms, the likelihood of a firm to interact with public research organizations is reported to depend on the firm-level factors like R&D intensity, size, absorptive capacity, and speed of innovation (Mohnen & Hoareau, 2003).

Overall, the impact of federal-industry interactions is evaluated as positive on the firm-side but mixed on the federal lab-side. Adams, Chiang and Jensen (2003) conducted a survey of industry laboratories and FFRDC's and found that CRADA had positive impacts on patents and R&D money of participating firms. Looking at the patents citations, Adam Jaffe and his colleagues showed that the quality of the patents from the federal labs had not been degraded as much as university patents did while the quantity of patents from the federal labs had exploded (Jaffe et al., 1998; Jaffe & Trajtenberg, 1996). They also presented an evidence that the use of the federal lab patents as measured by citations was geographically bounded (Jaffe et al., 1998; Jaffe & Trajtenberg, 1996) but less so than general patents (Jaffe et al., 1998). Especially for NASA patents, although inconclusive, they suggest that NASA complexes are heavily citing the patents generated from each others (Jaffe et al., 1998). As for the impact of patenting and licensing on the federal lab, Rubenstein and colleagues examined the relationship between the increase patents and licenses in USDA's ARS and its research agenda. They concluded that there were no apparent impacts of patenting and licensing on the research agenda of ARS (Rubenstein, 2003; Rubenstein & Heisey, 2005). Despite the importance of evaluating the real effects of the interactions between the federal labs and industry, systematic studies have not been done.

Federal agencies use more than 20 channels/mechanisms for technology transfer. Among these, "formal" mechanisms include contracts, CRADA, cooperative research agreement, grants, patents, patent licensing, personnel exchanges, SBIR, use of facilities and loaned equipment, and technical assistance (Air Force Research Laboratory, 2003). Beyond these formal mechanisms, informal mechanisms also play a significant role. These informal mechanisms include information dissemination, publications, conferences, and lab visits. In 1988 survey to the executives of the US firms and in a consecutive survey in 1991, Roessner & Bean (1990; 1994) found that these informal mechanisms were more used by firms than formal ones (i.e. licensing or cooperative research). In a later study by Adams et al. (2003), CRADA is shown to be more effective than contracts. However, which mechanisms are most used and most effective in which ways are still an open question.

Many studies about federal lab technology transfer are actually focusing on the factors affecting the success or failure. Common findings from numerous studies are that the following features of technology transfer activities are critical for success. First, clear articulation of objectives related with the core mission of federal labs is important(Ham & Mowery, 1998; Hill & Roessner, 1998). Second, managerial and financial support such as internal and external champions, continuous support from lab researchers, and financial support count (Carayannis & Alexander, 1999; Ham & Mowery, 1998; Mora-Valentin, Montoro-Sanchez, & Guerras-Martin, 2004; Roessner & Bean, 1990). Third, institutional support is important. More business-like marketing model (Carr, 1992a), identification of user needs (Ham & Mowery, 1998), connection to university licensing office (Jaffe & Lerner, 2001) are identified factors. Fourth, matching in technical roles and adequate scoping of technical range matter (Bozeman & Wittmer, 2001; Saavedra & Bozeman, 2004). Finally, personal contacts are important (Bozeman & Papadakis, 1995; Roessner & Bean, 1990). On the firm side, among others, absorptive capacity (Ham & Mowery, 1998; Mohnen & Hoareau, 2003), strong champions(Ham & Mowery, 1998), and objectives matching agency mission(Ham & Mowery, 1998; Jaffe & Lerner, 2001) are identified as important. The most prominent impeding factors include the lack of bureaucratic, organizational, cultural, and institutional supports/congruence among the participants.

4 Licensing, the Value of Federal Lab Patents, and Patent-based Indicators

There are two different channels in licensing federally-owned inventions. One channel is to grant a license to those parties who had collaborated with the federal labs under cooperative research and development agreements. The other is rather general channel that is described as the following scenario: federal laboratories develop a technology that is intended to serve their missions. During or after the development, they discover commercial applicability of the technology. The invention is disclosed and private firms seeking technology request the right of (exclusive) use of that technology. Federal labs award the license whichever firm they assess can bring in the biggest contribution to the economy via successful commercialization of the technology they will license. This last point is actually stipulated in relevant laws.

The Technology Transfer Commercialization Act of 2000 and the Code of Federal Regulations (Title 37 section 404.5) clearly restrict the eligibility of the potential licensee of the federally owned inventions to those who provide concrete commercialization plan and be equipped with capability to fulfill the plan. The section 404.5 of title 37 of the Code of Federal Regulations revised in July 1, 1997 and effective since then reads as follows:

> Sec. 404.5 Restrictions and conditions on all licenses granted under this part.
>
> (a)(1) A license may be granted only if the applicant has supplied the Federal agency with a satisfactory plan for development or marketing of the invention, or both, and with information about the applicant's capability to fulfill the plan.
>
> (2) A license granting rights to use or sell under a federally owned invention in the United States shall normally be granted only to a licensee who agrees that any products embodying the invention or produced through the use of the invention will be manufactured substantially in the United States.

Sherry and Teece (2004) claim that the value of invention vary with its life-cycle and assert that the economic value of “proven-valid-and-infringed” patent should be higher than the value of granted (but not infringed) patent. Reflecting on the licensing strategies of federal labs, licensing can be regarded as an additional validating process beyond the granting process of a patent. Therefore, federal lab patents licensed to firms can be regarded as having higher commercial value than non-licensed ones.

Main focus of this paper is to compare the licensed patents assigned to a federal lab (NASA in particular) with those not-licensed (or yet-to-be-licensed). Keeping in mind the role of licensing in the federal lab as a mechanism screening commercial viability of patents, we attempt to identify the different characteristics of the licensed patents and test the validity of patent-based indicators. Especially, we focus on some widely-used indirect indicators of patent value such as forward citation counts, the number of claims, the number of technology classes, and the number of inventors.

4.1 Commercial Value and Technological Importance of Patents

The screening role of the federal license process provides a unique opportunity to identify the factors affecting the commercial value of a patent. The previous studies examining the value of patents are mostly indirect. One most adopted method is to count the citations received from the subsequent patents. Although this method was widely accepted among scholars, it has several important limitations. First, citations count may represent the technological importance but not necessarily the commercial use or value. Second, many citations are actually added by the patent examiners rather than inventors. Third, strategic patents filed by a technology monopoly with a purpose of foreclosing competing firm’s innovation may actually cited by the subsequent patents but not necessarily used by others because the monopoly will not allow other to use its invention.

Forward Citations. One widely-used indicator of the value of patents is asking to the inventors. This method is based on the basic postulation that the inventors should have the most information and knowledge not only about the technology but for the use of the technology also. Dietmar Harhoff and his colleagues attempted to identify the relationship of inventor-assessed values with some of the indirect measures based on the inventor survey (Harhoff, Narin, Scherer, & Vopel, 1999; Harhoff, Scherer, & Vopel, 2003). Their studies provide some evidences that the forward citations measure could be a predictor for the patent value. Our first question is to reexamine this relationship using the NASA patents and license information of them. Following the consistent results from the most of the extant empirical studies, we predict that the more a patent is technologically important, the higher the commercial value will it have.

Theoretically, this relationship seems obvious. Here, we used the concept of "technological importance" as equivalent to the number of subsequent inventions building on some arts provided by the current invention. Thus, technologically important invention may bear broader technological opportunities and include more advanced level of arts than ordinary inventions. The odds of commercial exploitation of an invention, in general, must go hands-in-hands with the technological opportunity and the level of arts it may provide.

In operational terms, this hypothesis can be stated as the following.

Hypothesis 1. *The more technologically important a Federal lab patent is, as measured by the forward citations counts, the higher commercial value the patent will have.*

4.2 Commercial Value and Technological Breadth of Patents

Patents and inventions are not always mapped one-to-one to each others. Obviously, technological scope and boundary of a patent are not clearly defined. Oftentimes, they are determined by the economic value, consideration for the strategic use of the patent, and patentability as well as technological consideration (Harhoff?). This variance in technological scope of a patent is called the technological breadth and can be indirectly measured by the number of claims or the number of technology classes covered by a patent.

<u>**The Number of Claims.**</u> The most of US patents include one main claim and several (in some cases hundreds of) dependent claims under the single title. Tong and Frame (1994) assert that each claim in a patent should be more appropriate measure of fundamental units of inventiveness rather than patent itself. They investigated the correlation between both indicators (patent counts vs. counts of claims) and other indicators measuring scientific and technological capacity and found that claims are more highly correlated with them than patent counts. More powerful empirical result was provided by a recent study of European inventors. As in a part of a large scale survey of European inventors, Gambardella and his colleagues asked inventor themselves to rate the economic value of patents and found that

the number of claims was a good predictor of the value (Gambardella, Harhoff, & Verspagen, 2006). Using the US patents data at the firm level, Lanjouw and Schankerman(2004) also found a similar result.

Theoretically, if each claim in a patent represents a unit of invention, one patent including more number of claims will give more technological opportunities to the user of the patent than another patent with smaller claims. The more technological opportunities a patent can give, the higher commercial value of the patent will have. This composes our second hypothesis.

Hypothesis 2a. *The broader technological width of a Federal lab patent covers, as measured by the number of claims, the higher commercial value the patent will have.*

The Number of Technology Classes. The number of claims included in a patent is not the only measure of technological breadth. Although they did not find a significant relationship, Harhoff et al. (2003) suggested that the number of International Patent Classes might be related to the economic value of European patents. Because the technology classes are assigned and examined by the experts based on the relevance of the invention to certain technology areas represented by the class, this measure must be a sign of the breadth of the invention. Certainly, this measure does not go without noise originating from different sources which include non-uniformity of the sizes of classes, non-differentiation between product-like classes and process/parts-like classes, and non-established practice for classifying emerging technology especially in fundamental, cross-cutting technology areas (e.g. nano- or bio-related technology). We will reexamine this measure using the US patents assigned to NASA. Empirical details related to the construction of this measure will be discussed in the Data section which includes decisions about whether to use USPC or IPC and whether to count only different main classes or to take the sub-classes into considerations.

Hypothesis 2b. *The broader technological width of a Federal lab patent covers, as measured by the number of different technology classes, the higher commercial value the patent will have.*

4.3 Commercial Value and Non-obviousness of Patents

The United States Code for patentability (Title 35, sections 102 and 103) states that

patentable inventions must be "new" and not be "obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains."
The relationship between novelty and the commercial value of a patent is not clearly known. On one hand, the more novel a patent is, the higher the commercial value it will have. The rationale behind this can be drawn from the resource-based view of firms (Barney, 1991, 2001). According to the resource-based view, profitability of a firm is determined by the uniqueness or non-imitability of the resources it has. It is no doubt that technological knowledge is an important intellectual resource for the most of contemporary firms. The more novel the technology is, the harder may other firms imitate it. However, we can argue that the novelty should have negative impacts on the commercial value of an invention. Think about the helicopter-like flying vehicle designed by Leonardo Da Vinci in the 16^{th} century. This must have been a quite novel and even revolutionary idea although it was not patented due to the lack of patent system at that time. The commercial value of that invention in the 16^{th} century (or even several hundreds since then), however, must have been negligible because of two factors: First, complementary technologies that could help Da Vinci to manufacture and sell the antecedent of helicopters was a way far from their births. Second, the market for that revolutionary product was yet to be formed. So to speak, the commercial value of an invention is not just determined by the technological value of itself but depends on other external factors such as market, demands, and complementary technologies. Therefore, we argue that an extremely novel invention will have less commercial value than moderately novel ones. In conclusion, combining two opposite arguments presented above, we hypothesize that the novelty and commercial value of a patent would fall in an invert-U shape-like relationship. The next step is to find appropriate measures of the novelty or "non-obviousness" of a patent. We will examine three different measures: word counts of the first claim, backward citations count, and the number of cited scientific references.

Word Counts of the First Claim. Operationalization of the concept of the novelty, especially without consulting on experts but relying upon pure bibliometric ways, is actually problematic. Although problematic, some proxy measures of non-obviousness or inventive step of inventions have been empirically suggested. For the patents filed in the European Patent Office, Reitzig(2004) suggested that word counts describing the state of the art and the technical problem should be regarded as proxy measure of the non-obviousness of patents. Obviously, this is a very noisy measure because the draft of description of the inventions not only depends on the novelty or technological difficulty of the invention but also depends on the personal style of writing and strategic decision of patent attorney. We use the number of words in the first claim as the first measure of the novelty. Our prediction is the invert-U shape but weakly so due to the noisiness of the measure.

Hypothesis 3a. *The novelty of a Federal lab patent, as measured by the number of words in the first claim, will be positively associated with the commercial value of the patent. However, extremely novel patent will have less commercial value than the moderately novel ones.*

Backward Citations. Another candidate measure of the novelty is backward citations to the US patents. In the US patent system, every patent must indicate the prior arts on which it is building on. Thus, as a patent cites more prior patents, perhaps it is likely to be more novel because of higher yield of knowledge through broader hybridization. However, this is not necessarily so in many cases. Most of all, we do not know much about the creative process and, accordingly, we cannot assure that the more knowledge will necessarily bear more novel technology. Consider the following counter-argument: extremely novel knowledge will have no prior arts to refer to. Despite this ambiguity and noisiness, we will test the model based on the former postulation in the similar line of argument as we did for the word counts. The hypothesis is stated as the following.

Hypothesis 3b. *The novelty of a Federal lab patent, as measured by the number of backward citations to the US patents, will be positively associated with the commercial value of the patent. However, extremely novel patent will have less commercial value than the moderately novel ones.*

Scientific References. One last candidate for measuring the novelty of a patent is the number of scientific literature cited in that patent. In the traditional view of science-technology relationship, science is regarded as the source of ideas and knowledge for technological innovation. If this view is valid, the degree to which a patent refers to scientific literature will be related to the novelty of the patent. However, it also does not go without a problem. Most of all, we do not know whether the counts of cited scientific papers are adequate measure of knowledge flows from science. This is because every paper transfers different amount and quality of scientific knowledge. Many bibliometric studies, therefore, adopt complementary methods such as citation-weighted counts or journal-quality assessment. Recognizing this points, though, we test the simplest methods – simple count of other references – in this paper. A variant hypothesis for this measure is stated in a similar way as for the above two measures.

Hypothesis 3c. *The novelty of a Federal lab patent, as measured by the number of scientific references cited in the patent, will be positively associated with the commercial value of the patent. However, extremely novel patent will have less commercial value than the moderately novel ones.*

All of these novelty measures we suggested in this section do include lots of noise. So, we forecast that these indicators will be only weakly associated with the value measure, if ever.

4.4 Commercial Value of Patents and Inventor Networks

The inventors registered in patent documents share the legal rights of the patent and should have contributed to the invention, in principle. In this sense, the number of inventors can be related to the level of difficulty or the breadth of the invention. As discussed above, the level of difficulty (which is approximately equivalent to the novelty) or the breadth of the invention, in turn, will be positively associated with the value of the patent. If we control the novelty or the breadth of the patent, we predict that the number of inventors will still have positive association with the value of the patent. One reason for this is drawn from the social network theory. Assume that there are two patents equivalent in every way (in the sense of the novelty, technological area, breadth, and the degree of advertisement) but in the number of inventors. Patent A having more inventors will have higher odds to be advertised through (in)formal networks among the inventors and potential users than patent B with less inventors. Thus, patent A will be exposed to more chances of commercial use than patent B.

Hypothesis 4. *Holding the novelty, breadth, and technological area of a patent constant, the larger the number of inventors, the more likely the patent will be to have higher commercial value.*

5 Data and Model

5.1 NASA Patents

We collected all the patents assigned to NASA between 1971 and 2005 from the US patents database provided by the Community of Science[2]. This enumerates to 3778 after removing a small number of design patents. Then, using USPTO database we gather supplemental information about forward citation counts and retrieved the body texts of patent publications for calculating additional indicators such as the number of claims, word counts of the first claim, and others.

5.2 Identification of the Licensed Patents

Technology Transfer Commercialization Act of 2000 (Public Law 106-404) amends Stevenson-Wydler Act regarding the licensing practice of the federal labs. Section 4 of TTC Act mandates federal agency to make public notice of its intention for exclusive or partially-exclusive license of a federally owned invention at least 15 days before the license is granted. Also, by the title 37, section 404.7 of the Code of Federal Regulations, these public notices must be printed on the Federal Register. This regulation, however, does not apply to those inventions resulting from CRADA or owned by contractors of GOCO labs (Section 209 (e) of title 35, United States Code). Therefore, the Federal Register as a source for licensing activity in federal laboratories has several limitations. First, the FR cannot reveal the licensing activity of GOCO's which take dominant shares of DOE, DOD, and most other federal labs. Only two organizations, NASA and NIH, operate almost all research centers and labs by themselves. Jet Propulsion Laboratory of NASA is the only one lab that is operated by a contractor- California Institute of Technology. The National Institute of Cancer is the only institute affiliated with NIH that is operated by a contractor. Second, federal agency does not have any obligations to publicize prospective license for those inventions resulting from the CRADA and title of which is given to the partner. Third, because the law enforces the federal organization to make a notice for prospective licenses the information contained in the Federal Register may be different from the actual agreements. Thus, our dataset is not including the inventions from GOCO or CRADA. The third problem, however, does not make big difference for our purpose because the published intention for licensing still reveals the commercial value of inventions even though that the actual agreements were not made or changed (What proportions of

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[2] First, we fetched all the records matching the following search term in the Assignee field: "(National pre/1 (Aeronautics)) or NASA or (Space and Administration) or (by and national) or (by and Administrator)." Then, we removed irrelevant one by eye-inspection.

agreements were actually changed or even not made will be further investigated afterwards).

The information about licensing agreements is acquired using the following procedures. First, we collected all the public notices made by NASA between 1994 and 2006 and titled patent, license, or related terms[3] using the electronic version of the Federal Register provided by the Community of Science. Second, using a text-mining software, we extracted patent number, patent application number, and NASA case number included in each of licensing agreements. Because licensing agreements are not necessarily made after patent issuance, some of agreements refer only the NASA case number and some others the patent application numbers. Therefore, we need additional steps to match the NASA case numbers and patent application serial numbers found in the Federal Register to actual patents granted till 2006. Those with only patent application number were relatively simple to match. We searched the USPTO database using the patent application number. To match the inventions referred only by NASA case number, first, we retrieved the description about each NASA case from the NASA website and then searched USPTO database using the title and the abstracts of NASA inventions.

At last, we identified 334 licensed patents issued between 1981 and 2005. Although we have identified lots of licensed patents filed before 1994 and after 2002, we can not use them for our analysis. First, we do not have complete licensing information about the pre-1994 patents because we only have the information about the licensing notices since 1994. As for post-2002 patents, many NASA inventions intended to be licensed are yet granted till the point when we have searched the USPTO database. Furthermore, some of our indicators (e.g. forward citations) need a few years for stabilization. Therefore, 892 NASA patents (222 of which licensed) filed between 1994 and 2002 and granted before February 2007 comprise our final dataset.

5.3 Empirical Models and Variables

Because our dependent variable is binary (whether or not a patent is licensed), we use the logit model. We control the technology class dummies (constructed by the authors through reclassifying the primary USPC into 36 classes as suggested by Hall, Jaffe, & Trajtenberg,

[3] Search strategy includes following terms: patent* or licens* or prospective or grant* or intent* or inventi* or CRADA or cooperative

2001).

$$\frac{\Pr(licensed = 1)}{\Pr(licensed = 0)} = \exp(\beta_0 + \beta_1 \cdot X_{control} + \beta_2 \cdot X_{indicators})$$

Our independent variables are patent-based indicators related to technological importance, technological breadth, the novelty, and inventor networks. Descriptions of variables are summarized in Table 2.

Table 2 Description of Variables

Name	Description	mean	min	max
licensed	Licensed=1	0.25	0	1
diy13~21	Dummies for issue year (reference=1994)	NA	0	1
dnber6_chem	NBER class: Chemical	0.18	0	1
dnber6_com	NBER class: Computers & Communications	0.16	0	1
dnber6_med	NBER class: Drugs & Medical	0.08	0	1
dnber6_elec	NBER class: Electrical & Electronic (reference)	0.31	0	1
dnber6_mech	NBER class: Mechanical	0.17	0	1
dnber6_misc	NBER class: Others	0.08	0	1
FCitations	Counts of forward citations	5.37	0	192
NoClaims	Number of claims	17.72	1	92
NoIPC	Number of different IPC classes	3.47	0	28
NoInv	Number of inventors	2.31	1	11
WCFirstClaim	Number of words in the first claim	149.25	7	689
NoRefs	Number of othere references cited	1.30	0	57
NoUSPats	Number of US patents cited	10.71	0	65

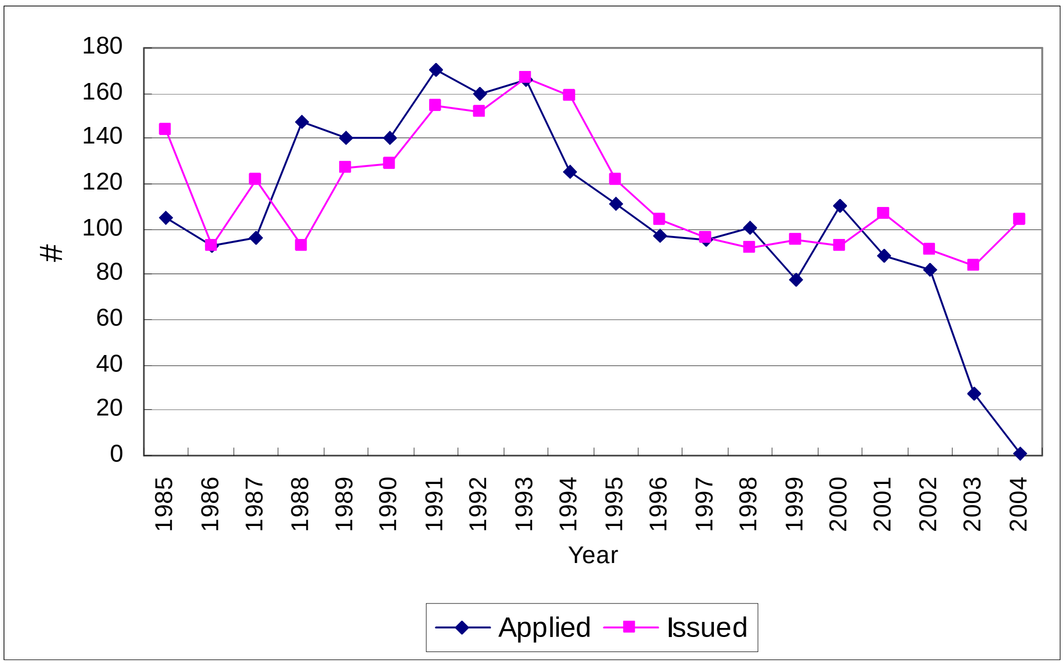
6 Analysis and Findings

This section is composed of three parts. First, we examine the trends of patenting, invention disclosure, licensing, and licensed patents in NASA. Then, we analyze technological, institutional, and other characteristics of the licensed patents. Finally, regression results for testing proposed hypotheses are presented.

6.1 Patents, Inventions, and Licenses

Between 1985 and 2004, NASA has filed 2132 patent applications and acquired 2328 patents. Patenting activity has increased up to mid 90s culminating with 167 patents issued in 1993 and rapidly decreased for the following 3 years (See Figure 1). Since the late 90s both the number of issued and applied patents is flattening by counting to 95 on average[4].

Figure 1 NASA Patents (1985-2004)*



(Compiled by the authors from patents.cos.com[5])

* Not including JPL patents assigned to CALTECH

NASA discloses its inventions on the website. Jet Propulsion Lab is producing the dominant share of inventions followed by the Glenn Research Center and Goddard Space Flight Center (See Table 3). Excluding software, total number of inventions disclosed till December 2006 enumerates 11,671 (See Table 4). Unfortunately, we could not identify the time of invention but only the time of disclosure. The disclosures made before 1996 seem

[4] The rapid drop in the number of applied patents after 2002 is due to issuance lag causing the right truncation in data.

[5] Following search strategy was used: "(Assignee=((National pre/1 (Aeronautics)) or NASA or (Space and Administration) or (by and national) or (by and Administrator)))"

to be publicized in a batch on January 1, 1996. There is no single case made during 1997-1999 period but they seem to have been publicized in 2001. The number of the invention disclosures roughly matches with the number of filed patents. NASA promotes some of these inventions as the possible candidates of licensing. After 2000 these inventions of "Licensing Opportunity" occupy about one-third to a half of the disclosed inventions (See the bottom row of Table 4).

Table 3 Invention Disclosures by NASA Centers (till Dec. 2006)*

Centers	JPL	GRC	GSFC	JSC	MSFC	DFRC	LaRC	HDQS	ARC	SSC	KSC	Total
# Disclosures	5527	3001	1420	1143	692	414	173	161	71	71	36	12709
% share	43.5	23.6	11.2	9.0	5.4	3.3	1.4	1.3	0.6	0.6	0.3	100.0

(Compiled by the authors from http://technology.nasa.gov/Advanced_Search.cfm)

* Including the software inventions

Table 4 Licensing Opportunity and Invention Disclosures by Published Year*

Year	<1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
All Invention Disclosures	10187	0	0	0	136	738	184	64	176	94	92	11671
Licensing Opportunity	221	0	0	0	47	94	60	28	74	40	42	606

(Compiled by the authors from http://technology.nasa.gov/Advanced_Search.cfm)

* Excluding the software inventions.

Among the advertised licensing opportunities (and probably other technologies), only a portion reach to an actual agreement. I obtained this information from the Federal Register. Between 1994 and 2005, 390 licensing agreements were made (Table 5). The inventions and patents included in these agreements are, however, a lot more than this number because a single license agreement includes multiple inventions and patents. From the initial look of data, we identified 218 patents in 178 agreements. The remaining agreements mention either the filed patent application (but not issued by the time of the agreement) or NASA inventions as named with "NASA Case number." We guess that many of these patent applications and inventions would be finally granted. Note that most of licenses made by the JPL are not probably included in this statistics because the JPL is operated by a contractor-CALTECH which can own the JPL inventions and does not have any obligation to publicly announce its intention to grant a license.

Table 5 NASA Licensing Agreements (1994-2005)*

year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	total
# of agreements	18	34	61	46	38	38	29	32	29	24	33	18	11	411

(Compiled by the authors using the Federal Register)

* Probably not completely including those agreements made by CALTECH on behalf of the JPL

6.2 Characteristics of the Licensed Patents

About 25% of NASA patents filed between 1994 and 2002 were licensed. The share hit the ceiling in 1997 and has been continuously decreasing since then (Table 6).

Table 6 NASA Patents and Share of Licensed Patents (94-02)

Year	Filed Patents	Licensed patents	Share of licensed patents
1994	125	37	29.60%
1995	111	31	27.93%
1996	99	26	26.26%
1997	95	29	30.53%
1998	102	31	30.39%
1999	79	23	29.11%
2000	112	21	18.75%
2001	89	14	15.73%
2002	82	10	12.20%
Total	894	222	24.83%

Top 6 NBER subclasses in which NASA patents were filed are “Measuring & Testing” (133 patents), “Computer Hardware & Software” (84), “Miscellaneous/chemical” (79), “Power Systems” (45), “Communications” (57), and “Resins” (54). In terms of aggregated NBER classes, patents in chemical or drug & medical classes are significantly more licensed (Table 7).

Table 7 Patents by NBER Classes (Licensed vs. Non-licensed)

	Full (N=892)		Licensed (n1=222)		Non-licensed (n2=670)	
	mean	sd	mean	sd	mean	sd
dnber6_chem	0.18	0.39	0.24*	0.43	0.17	0.37
dnber6_com	0.16	0.37	0.14	0.34	0.17	0.38
dnber6_med	0.08	0.27	0.18**	0.39	0.05	0.21
dnber6_elec	0.31	0.46	0.26*	0.44	0.33	0.47
dnber6_mech	0.17	0.38	0.14+	0.34	0.19	0.39
dnber6_misc	0.08	0.28	0.05*	0.23	0.09	0.29

Unequal variance two sample t-test: + significant at 10%; * significant at 5%; ** significant at 1%

[Top licensee]

Licensee	# Proposed Agreements
Phoenix Systems	13
Bigelow Development Aerospace Division, LLC	4
HITCO Technologies,	4
Wessex, Inc.	4
AirFlow Catalyst Systems	3
Associated Technical Management Corporation	3
GeoTech Chemical Company	3
Imitec, Inc.	3
Makel Engineering, Inc.	3
NanoConduction Inc.	3
Thermosurgery Technology, Inc.	3
UbiquiTex Technologies Corporation	3
Veatronics Corporation	3
3M Company	2
Alan Neuman Productions, Inc.	2

6.3 Commercial Value and Patent-based Indicators

In this section, we report the results of the regression analysis regarding the relationship between commercial value of NASA patents and patent-based indicators.

Correlation table is presented in Table 8.

Table 8 Correlations Table

	fcitations	noclaims	noipc	noinv	wcfirstclaim	norefs	nouspats
licensed	0.14	0.06	-0.02	0.1	-0.05	0.06	0.03
dnber6_chem	-0.07	-0.03	0.15	0.05	-0.19	0.01	-0.14
dnber6_com	0.13	0.17	-0.16	-0.04	0.21	0.09	-0.05
dnber6_med	0	0.04	0.07	0.11	-0.05	0.1	0
dnber6_elec	-0.01	-0.06	-0.05	-0.06	0.04	-0.1	0.06
dnber6_mech	-0.02	-0.07	0	-0.03	0.01	-0.01	0.09
dnber6_misc	-0.04	-0.04	0	0.02	-0.04	-0.05	0.05
fcitations	1	0.05	0.02	0.03	0.11	0.15	0.03
noclaims		1	-0.03	0.02	-0.03	0.05	0.16
noipc			1	0	-0.09	0	0.02
noinv				1	-0.09	0.02	0
wcfirstclaim					1	0.06	0.09
norefs						1	-0.01

The results from the logistic regressions are reported in Table 9. Starting from the base model having only the controls (model 1), we tested to the full model having all the independent variables (model 9) by adding one variable at a time. All the models fit well with the data and have good amount of explanatory powers.

Looking at the NBER class dummies, chemical and medical patents are more likely than electronic patents to be licensed, holding others constant. This result is consistent with observations in the previous literature that biomedical industry conducts more “use-inspired research” and is more inclined to exploit the public sector research.

Technological Importance Hypothesis. Technological importance as measured by forward citations is significantly and positively associated with the odds of a patent’s being licensed. The odds of a patent’s being licensed increase by 2.9% as the patent receives additional citation from the subsequent patents in the full model (model 9). Holding all the other variables at their means, as the forward citation counts change from 5 to 6, the probability of a patent’s being licensed increases by .5 percentage points.

Technological Breadth Hypotheses. To say conclusion first, the hypothesis 2a (with respect to the number of claims) is supported but 2b (with respect to the number of IPC classes) not. Holding all the other variables at their means, as the number of claims change from 18 to 19, the probability of a patent's being licensed increases by .2 percentage points. The coefficients of the number of IPC's in the results table have negative values. This tells us that as a patent becomes more focused the probability of its being licensed increases. This is contradictory to what we have predicted and needs further investigation.

Inventor Network Hypothesis. The number of inventors is positively associated with the probability of being licensed and supports the hypothesis 4.

Novelty Hypotheses. We suggested three measures to quantify the novelty of a patent. The word count measure is tested in model 7, the number of scientific references in model 8, and the number of backward citations to the US patents in the full model. Among these three measures, we found significant relationship only in the backward citations measure. In model 9, NoUSPats has positive coefficient while its quadratic term (nuspatsq) is negative. This result is interpreted as the following: the probability of being licensed increases at decreasing rate as the backward citation approaches to about 23 and then decreases at increasing rate. Consequently, this looks like inverted U as we predicted. The remaining two measures are not significant. However, the number of scientific references shows inverted-U shape. The word count measure may be contaminated by several different types of noises including what we mentioned above.

Table 9 Results from Logistic Regressions (coefficients are log odds)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
year dummies					positive and significant				
dnber6_chem	0.550	0.625	0.607	0.695	0.674	0.648	0.585	0.650	0.733
	(2.43)*	(2.73)**	(2.64)**	(2.99)**	(2.90)**	(2.78)**	(2.46)*	(2.78)**	(3.08)**
dnber6_com	0.037	-0.072	-0.157	-0.116	-0.198	-0.187	-0.178	-0.197	-0.119
	(0.14)	(0.28)	(0.59)	(0.44)	(0.74)	(0.70)	(0.65)	(0.73)	(0.44)
dnber6_med	1.623	1.635	1.616	1.697	1.677	1.620	1.605	1.638	1.648
	(5.66)**	(5.65)**	(5.55)**	(5.80)**	(5.69)**	(5.46)**	(5.40)**	(5.45)**	(5.53)**
dnber6_mech	-0.116	-0.108	-0.099	-0.090	-0.080	-0.086	-0.075	-0.073	-0.089
	(0.45)	(0.42)	(0.38)	(0.35)	(0.31)	(0.33)	(0.29)	(0.28)	(0.34)
dnber6_misc	-0.359	-0.300	-0.303	-0.282	-0.285	-0.313	-0.335	-0.304	-0.339
	(1.02)	(0.85)	(0.86)	(0.80)	(0.81)	(0.88)	(0.94)	(0.85)	(0.95)
FCitations		0.033	0.030	0.033	0.031	0.030	0.031	0.030	0.028
		(3.36)**	(3.14)**	(3.43)**	(3.22)**	(3.14)**	(3.18)**	(3.12)**	(3.00)**
NoClaims			0.013		0.013	0.013	0.013	0.013	0.012
			(2.21)*		(2.14)*	(2.14)*	(2.16)*	(2.08)*	(1.92)+
NoIPC				-0.054	-0.052	-0.051	-0.050	-0.053	-0.048
				(2.01)*	(1.95)+	(1.89)+	(1.86)+	(1.95)+	(1.79)+
NoInv						0.093	0.089	0.098	0.094
						(1.86)+	(1.77)+	(1.96)+	(1.87)+
NoUSPats									0.047
									(1.85)+
nuspatsq									-0.001
									(1.19)
NoRefs								0.047	
								(1.14)	
norefsq								-0.002	
								(1.30)	
WCFirstClaim							-0.004		
							(1.44)		
wcsq							0.000		
							(1.25)		
Constant	-1.851	-1.896	-2.185	-1.741	-2.026	-2.224	-1.875	-2.230	-2.687
	(7.90)**	(8.05)**	(7.98)**	(7.02)**	(7.10)**	(7.29)**	(4.84)**	(7.27)**	(7.04)**
Log Liklihood	-468.40	-461.33	-458.94	-459.14	-456.89	-455.20	-454.16	-453.84	-452.80
LR chi2	64.20	78.35	83.12	82.73	87.22	90.60	92.67	93.32	95.41
Pseudo R2	0.06	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.10

Absolute value of z statistics in parentheses

+ significant at 10%; * significant at 5%; ** significant at 1%

7 Discussions and Conclusions

To summarize the findings, first of all, NASA seems actively engaging in the private sector through licensing its patents. About 25% of patents filed by and assigned to NASA between 1994 and 2002 were licensed to firms. Secondly, chemical, drug, and medical related patents are more likely to be licensed than the most populated technological area – electronics. This observation tells us that licensing decision depends on the technology and demands from the firms. Also, this observation is consistent with the results from the previous studies that firms are more intertwined with the public/basic research in biomedical areas.

Regarding the patent-based indicators, we obtained supporting results for the most of our hypotheses. However, we need to refine and examine further the meaning of some indicators. We found that the more technologically important (as measured by forward citation counts) and the broader in technology areas (as measured by the number of claims), the higher commercial value a patent is likely to have. We found some evidences that the non-obviousness (as measured by the backward citations to the US Patents) and the commercial value of a patent are in a relationship looking like inverted-U shape. We also found a positive association between the number of inventors and the commercial value of a patent.

While we delved into the patent-based indicators in this paper, we have relatively overlooked the processes and implications of licensing itself. For example, which firms license and, if so, which technology? Is it localized and, if so, how? Relative to other mechanisms, how effective in technology transfer is the licensing of federal patents? What is the impact of licensing on the federal lab research and on the industrial innovation? These unanswered questions will hopefully open up new avenues for the future research.

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